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(54) HIGH INTENSITY FOCUSED ULTRASOUND (HIFU) DEVICE AND SYSTEM

(71) Applicant: **Butterfly Network, Inc.**, Guilford, CT (US)

(72) Inventors: **Kailiang Chen**, Branford, CT (US); **Nevada J. Sanchez**, Guilford, CT (US); **Christopher Thomas McNulty**, Guilford, CT (US)

(73) Assignee: **Butterfly Network, Inc.**, Guilford, CT (US)

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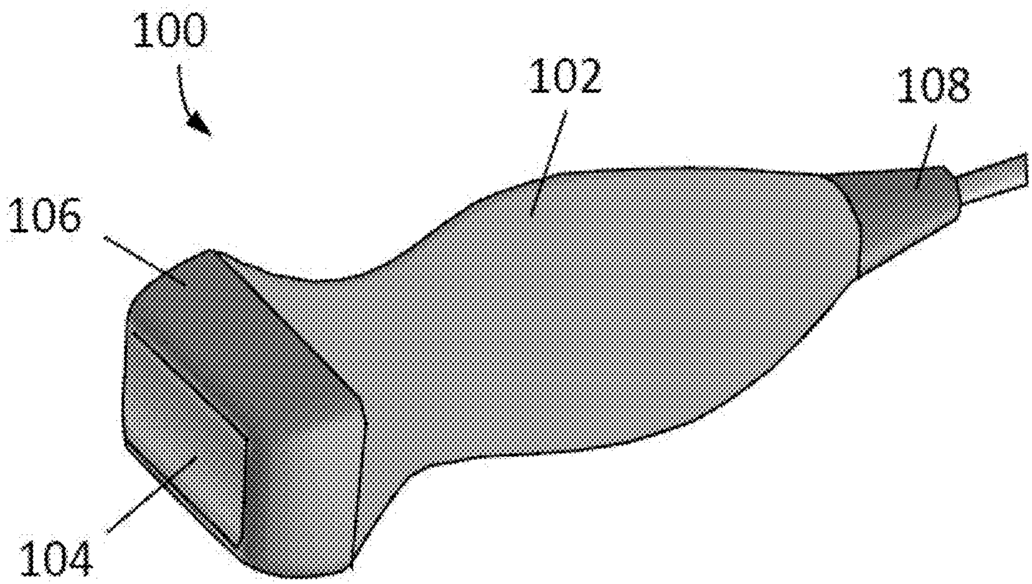
(57) **ABSTRACT**

An exemplary system includes a first ultrasonic transducer assembly configured to deliver high intensity focused ultrasonic (HIFU) energy to a point of interest within a subject, and a second ultrasonic transducer assembly configured to perform imaging of the subject. In another embodiment, a housing is configured to receive an ultrasound probe. The housing may include a cooling circuit and power supply for the ultrasound probe.



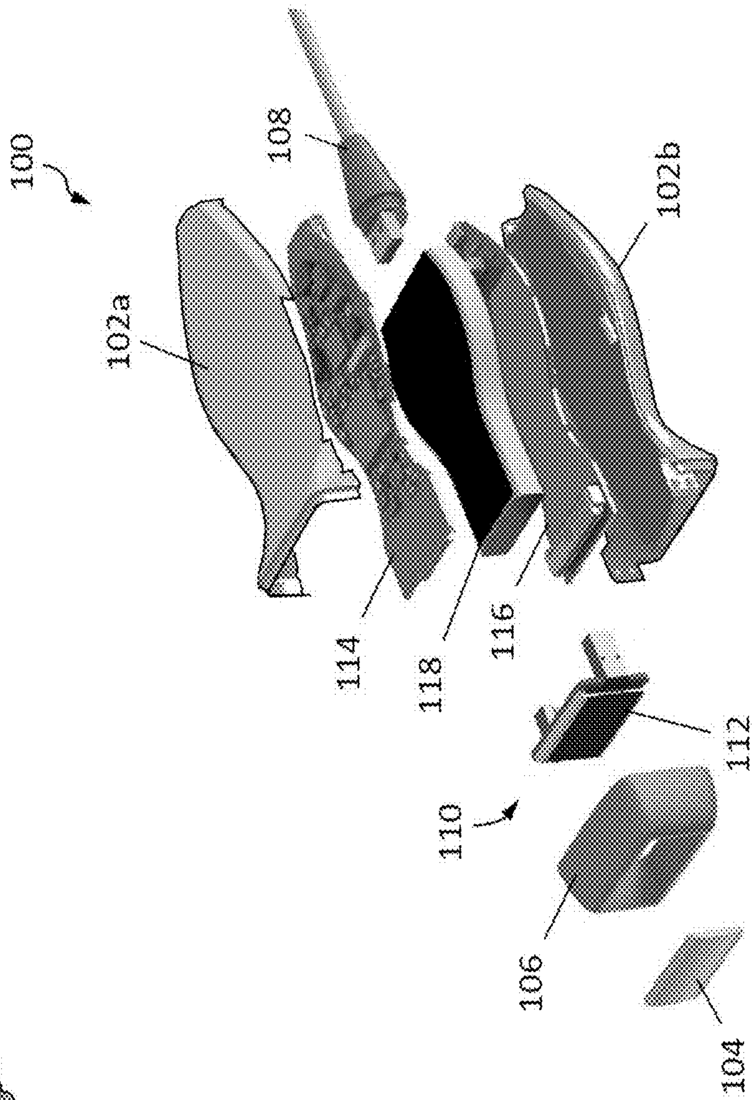

100
108
102a
102b
114
118
116
112
110
106
104

FIG. 2

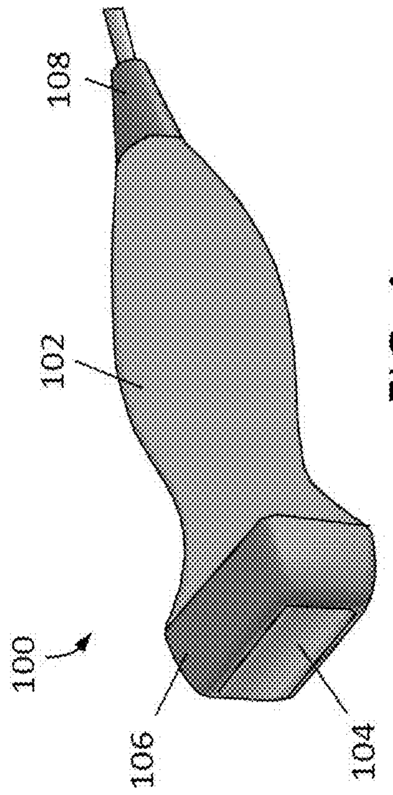

108
102
100
106
104

FIG. 1

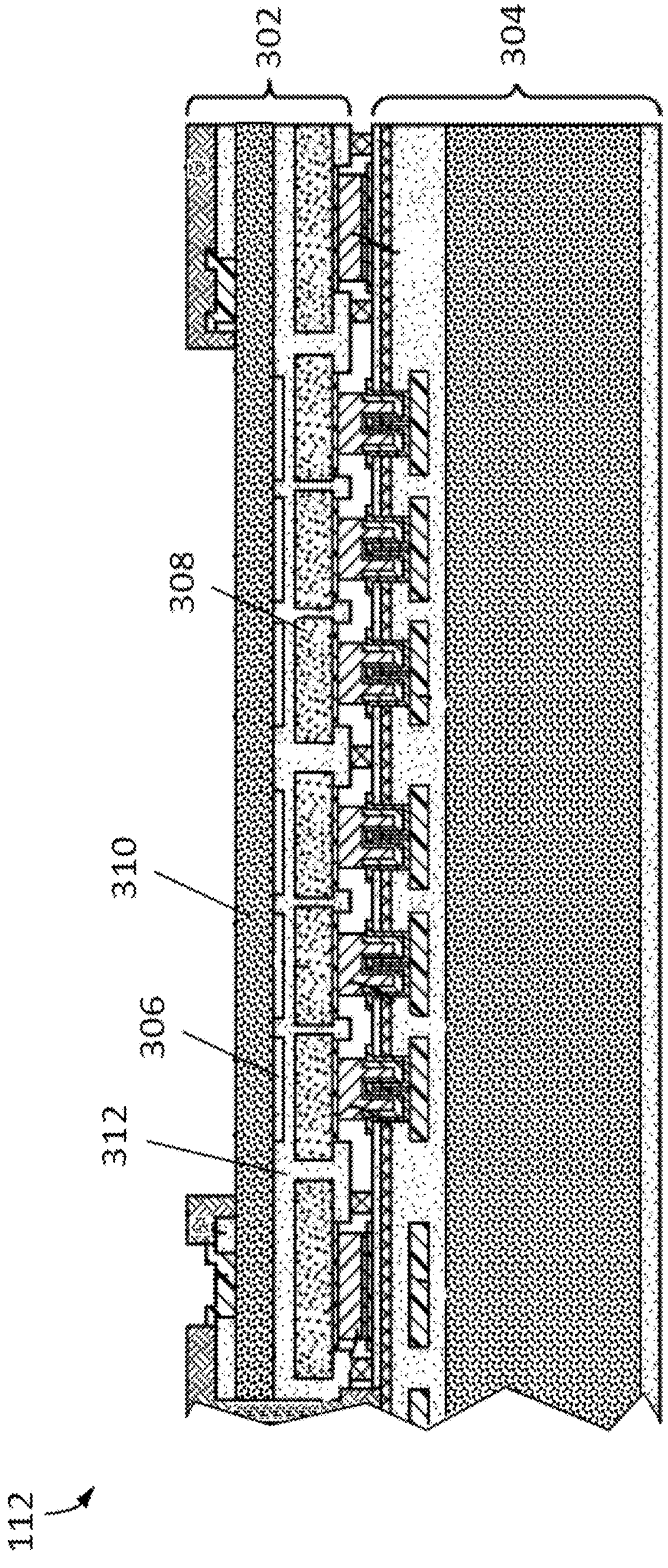


FIG. 3

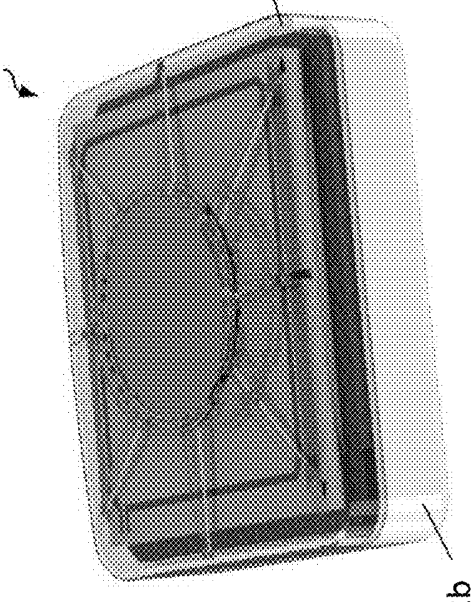


FIG. 4

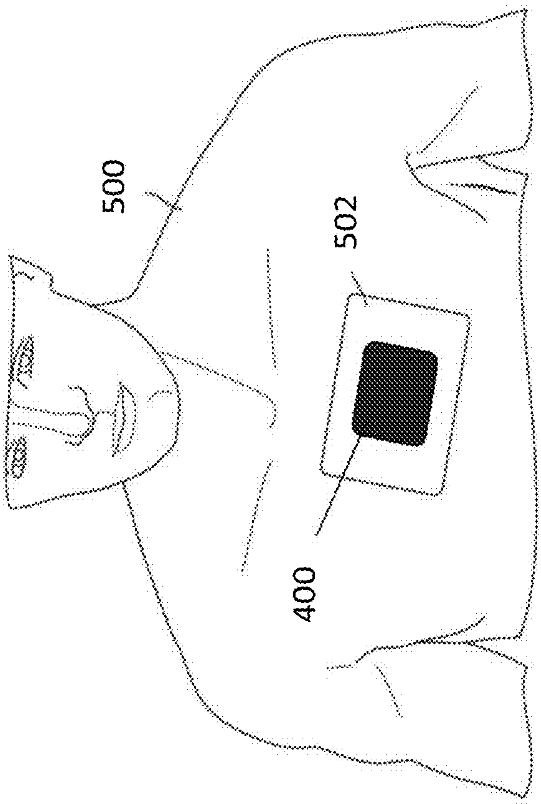


FIG. 5

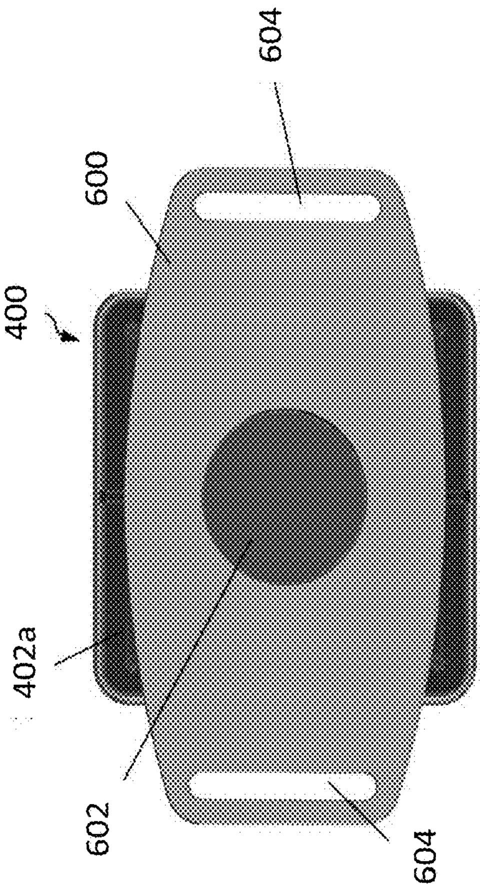


FIG. 6

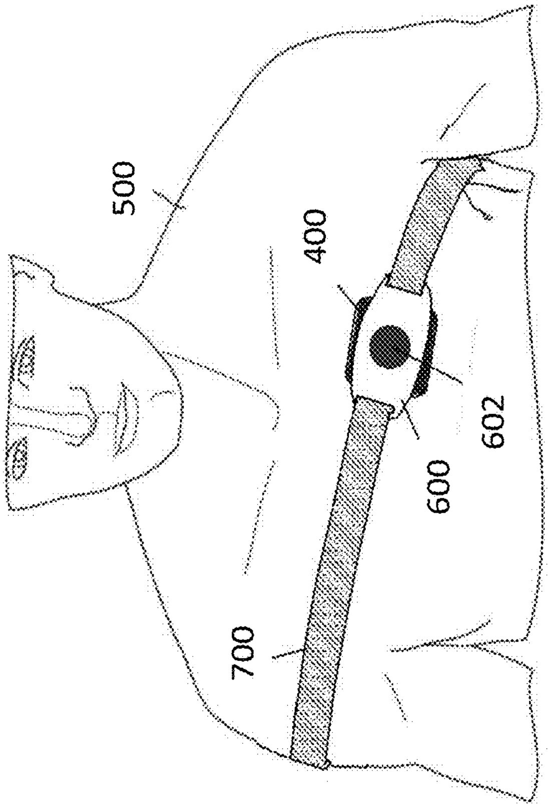


FIG. 7

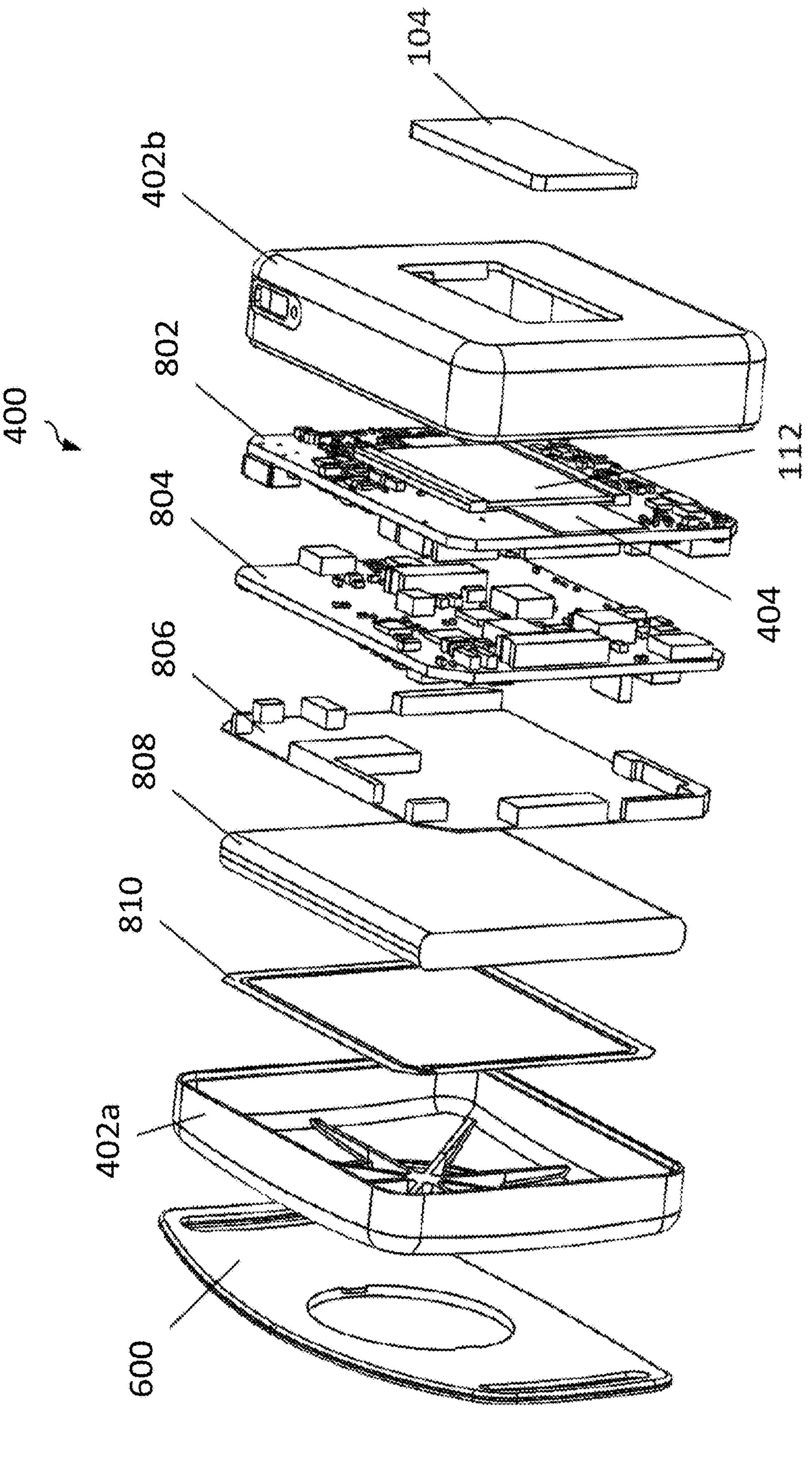


FIG. 8

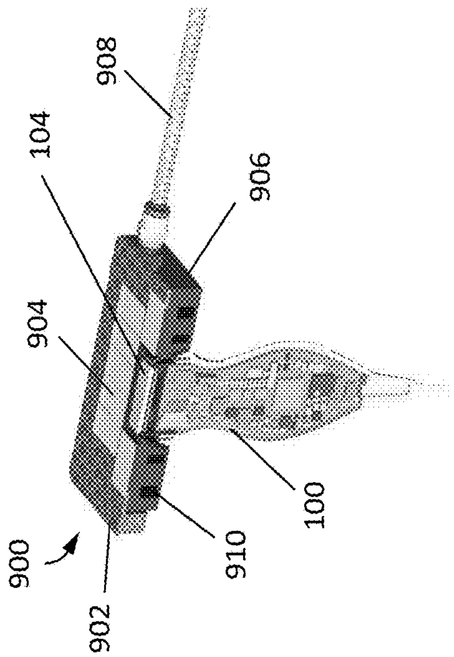


FIG. 10

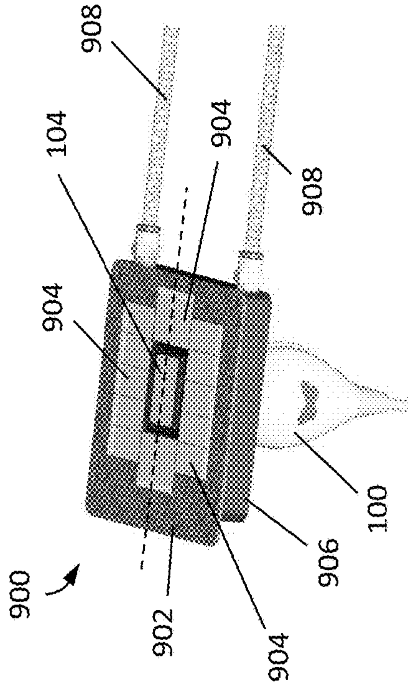


FIG. 9

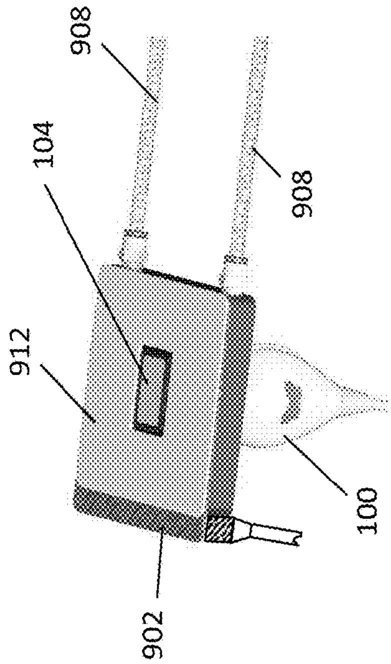


FIG. 11

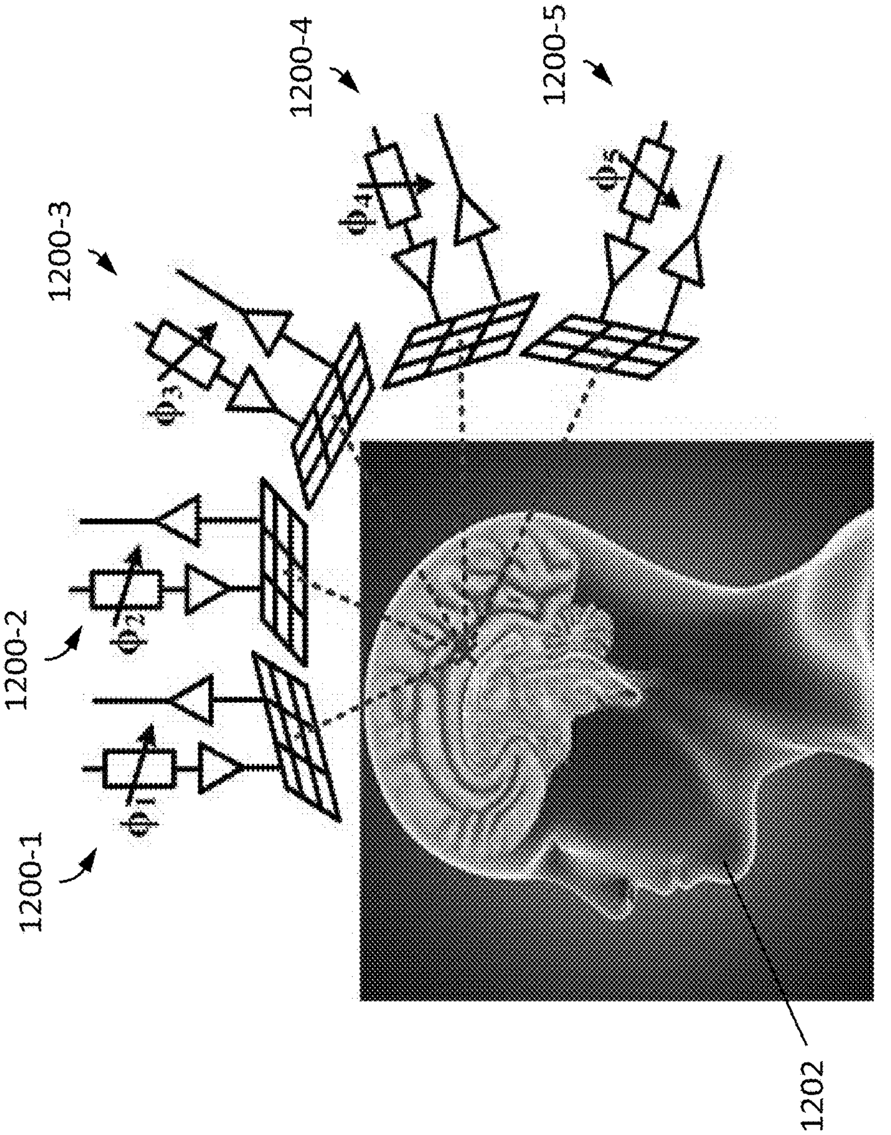


FIG. 12

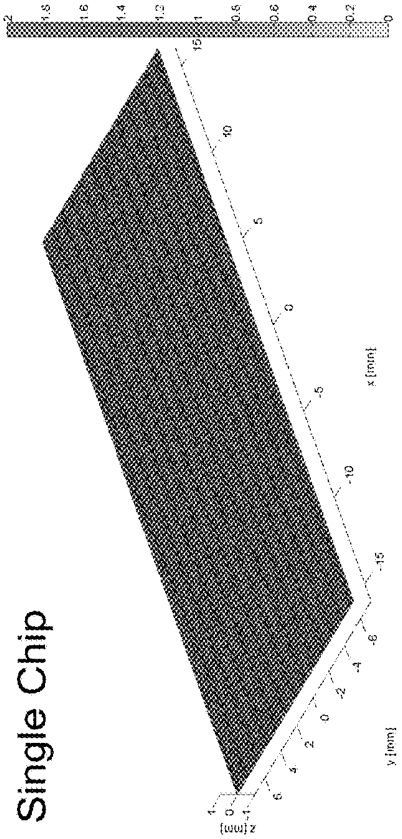

Single Chip
x [mm]
y [mm]
z [mm]

FIG. 13

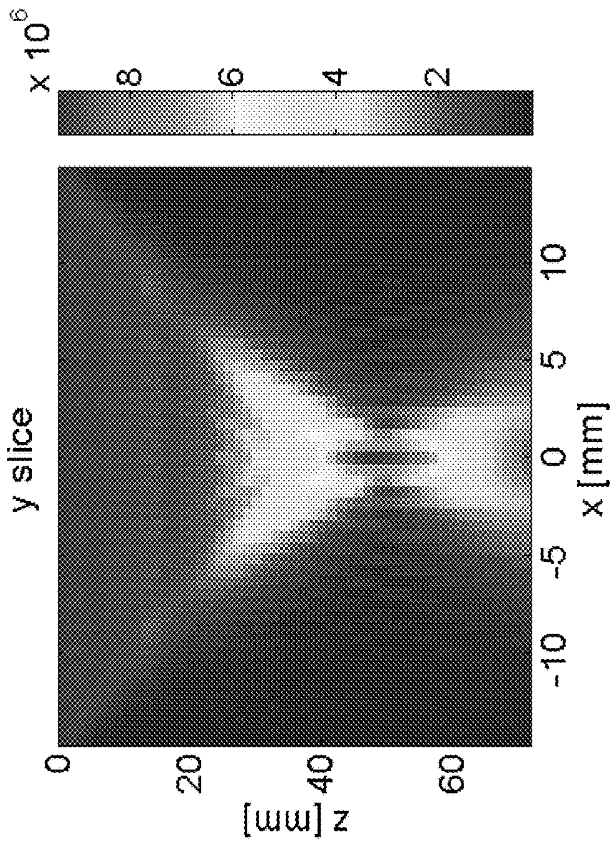

y slice
x 10^6
8
6
4
2
0
20
40
60
z [mm]
-10
-5
0
5
10
x [mm]

FIG. 14

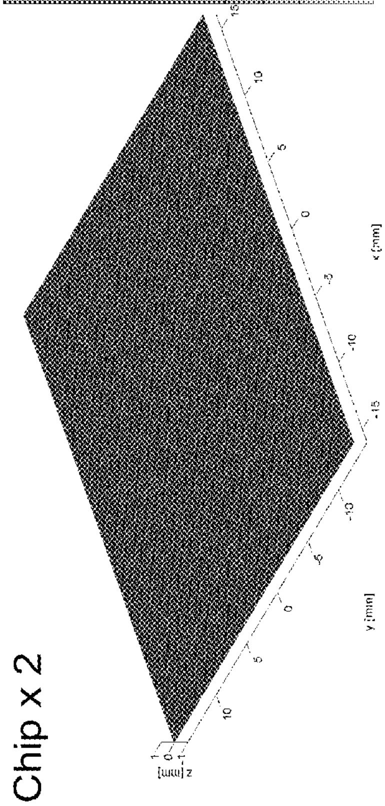


FIG. 15

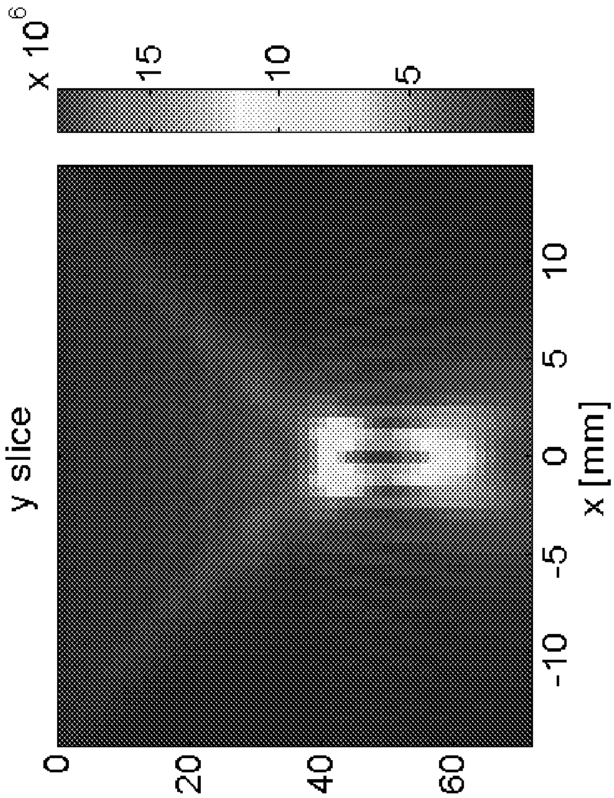
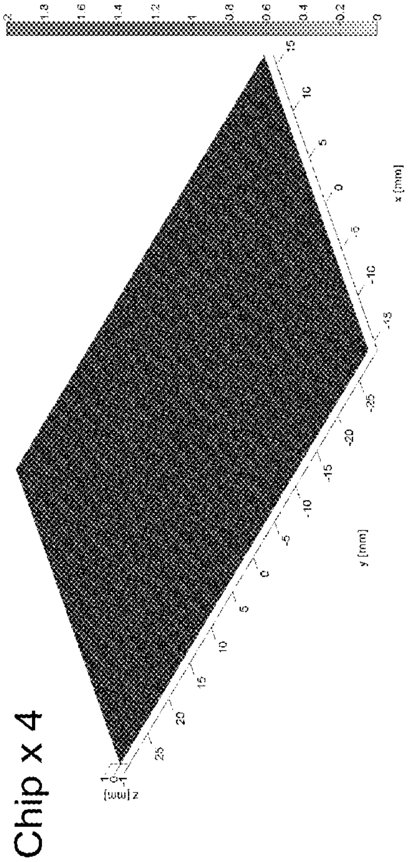
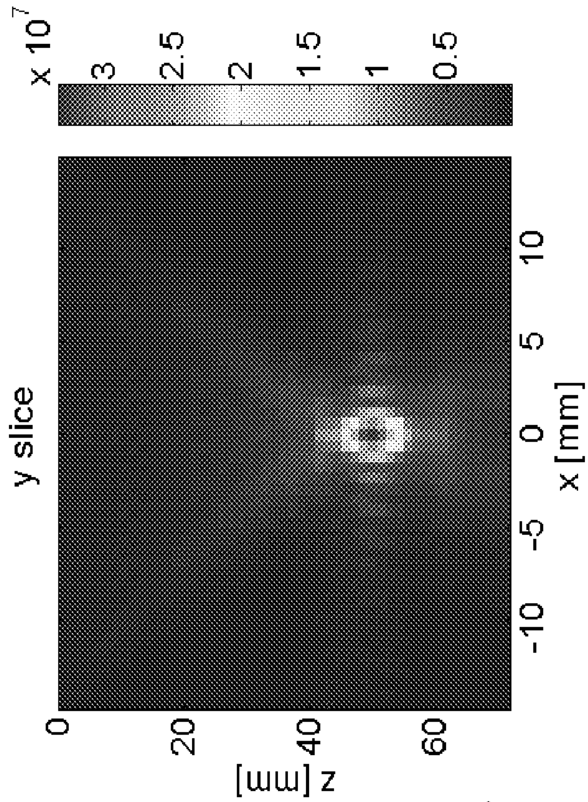


FIG. 16



Chip x 4
y [mm]
x [mm]
z [mm]

FIG. 17



y slice
x [mm]
z [mm]
x 10^7
3
2.5
2
1.5
1
0.5
-10
-5
0
5
10
0
20
40
60

FIG. 18

HIGH INTENSITY FOCUSED ULTRASOUND (HIFU) DEVICE AND SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation of Patent Application Serial No. PCT/US2017/064862, filed Dec. 6, 2017 under Attorney docket No. B1348.70038WO00, and entitled "HIGH INTENSITY FOCUSED ULTRASOUND (HIFU) DEVICE AND SYSTEM," which is hereby incorporated herein by reference in its entirety.

[0002] PCT/US2017/064862 claims the benefit of U.S. Provisional Patent Application Ser. No. 62/431,379, filed Dec. 7, 2016 under Attorney Docket No. B1348.70038US00, and entitled "HIGH INTENSITY FOCUSED ULTRASOUND (HIFU) DEVICE AND SYSTEM," which is hereby incorporated herein by reference in their entirety.

FIELD

[0003] The present disclosure relates generally to ultrasound technology. In particular, the present disclosure relates to a high intensity focused ultrasound (HIFU) device and system.

BACKGROUND

[0004] Ultrasound devices may be used to perform diagnostic imaging and/or treatment, using sound waves with frequencies that are higher with respect to those audible to humans. Ultrasound imaging may be used to see internal soft tissue body structures, for example to find a source of disease or to exclude any pathology. When pulses of ultrasound are transmitted into tissue (e.g., by using a probe), sound waves are reflected off the tissue with different tissues reflecting varying degrees of sound. These reflected sound waves may then be recorded and displayed as an ultrasound image to the operator. The strength (amplitude) of the sound signal and the time it takes for the wave to travel through the body provide information used to produce the ultrasound image. Many different types of images can be formed using ultrasound devices, including real-time images. For example, images can be generated that show two-dimensional cross-sections of tissue, blood flow, motion of tissue over time, the location of blood, the presence of specific molecules, the stiffness of tissue, or the anatomy of a three-dimensional region.

[0005] With respect to treatment, as an alternative to more invasive types of surgical procedures, many physicians are employing the use of high intensity focused ultrasound (HIFU) as a technique to therapeutically treat internal body tissues. With HIFU, an ultrasound signal of sufficient power (e.g., pressure and velocity) and time is focused on a target volume of tissue in order to change a state of the tissue by rapid heating and/or mechanical destruction by cavitation. The treated tissue may form one or more lesions that may be left in the body and thereafter absorbed through normal physiological processes.

[0006] In order to effectively treat tissue, the energy of the delivered HIFU signal must be sufficient to cause the desired physical effect(s). On the other hand, the delivered energy should not be too large or uncontrolled so as to cause unintended collateral damage to healthy tissues surrounding the target volume. The non-homogenous nature of tissue(s) in the body creates variations in attenuation, propagation velocity, and acoustic impedance that modify the expected acoustic wave propagation and deposition of HIFU energy delivered to a target tissue volume when compared to homogeneous material. Thus, certain treatment regimens that are solely based on applying a predetermined dose of HIFU energy may therefore achieve inconsistent results due to such variations.

SUMMARY

[0007] In one embodiment, a system includes a first ultrasonic transducer assembly configured to deliver high intensity focused ultrasonic (HIFU) energy to a point of interest within a subject, and a second ultrasonic transducer assembly configured to perform imaging of the subject.

[0008] In another embodiment, a system includes a plurality of high intensity focused ultrasonic (HIFU) units, each configured to deliver high energy focused ultrasound energy to a point of focus; and receive circuitry configured to determine a relative alignment between individual HIFU units so as to implement a self-calibration with respect to a transmit phase of the individual HIFU units.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Various aspects and embodiments of the disclosed technology will be described with reference to the following Figures. It should be appreciated that the figures are not necessarily drawn to scale. Items appearing in multiple figures are indicated by the same reference number in all the figures in which they appear.

[0010] FIG. **1** is a perspective view of a handheld ultrasound probe suitable for use with exemplary embodiments;

[0011] FIG. **2** is an exploded perspective view of the ultrasound probe of FIG. **1**;

[0012] FIG. **3** is a partial cross-sectional view of an exemplary ultrasound-on-chip device suitable for use with exemplary embodiments;

[0013] FIG. **4** is a perspective view of another type of ultrasound probe suitable for use with exemplary embodiments;

[0014] FIG. **5** illustrates the ultrasound probe of FIG. **4** affixed to a patient;

[0015] FIG. **6** is a top view illustrating an alternative fastening mechanism for the ultrasound probe of FIG. **4**;

[0016] FIG. **7** illustrates the ultrasound probe of FIG. **4** affixed to the patient;

[0017] FIG. **8** is an exploded perspective view of the ultrasound probe of FIG. **6**;

[0018] FIGS. **9**-**11** are perspective views of a HIFU apparatus in accordance with exemplary embodiments;

[0019] FIG. **12** is a schematic diagram illustrating an exemplary application of a HIFU apparatus, in accordance with embodiments; and

[0020] FIGS. **13**-**18** illustrate various power and acoustic pressure field simulations using different numbers of HIFU transducer chips.

DETAILED DESCRIPTION

[0021] Disclosed herein are embodiments of a fully integrated HIFU Array, device and system. Among several advantages of the disclosed embodiments are, for example: the observation and tracking of targets from ultrasonic imaging; the use of an electronic array with flexible focusing of targets; and a multi-chip assembly that may be adapted to different clinical applications. For example, several HIFU chips may be tiled into a large aperture to produce higher delivered energy and better focusing. In one specific example, a curved aperture may be configured for use in brain related therapy, in which phase adjustment techniques may be applied to address any chip-to-chip misalignment.

[0022] Still another advantage that may be gained with respect to conventional ultrasonic transducers formed from piezoelectric materials is the use of capacitive micromachined ultrasonic transducers (CMUTs) formed from a semiconductor substrate. In the case of a CMUT device, a flexible membrane is suspended above a conductive electrode by a small gap. When a voltage is applied between the membrane and the electrode, Coulombic forces attract the flexible membrane to the electrode. As the applied voltage varies over time, so does the membrane position, thereby generating acoustic energy that radiates from the face of the transducer as the membrane moves. More specifically, one advantage arising from the use of CMUTs is a smaller degree of self-heating, as silicon has less of impedance mismatch to a medium, and better thermal conductivity with respect, to PZT. Furthermore, capacitive sensors have lower electrical losses/heating with respect to piezo counterparts.

[0023] From a manufacturing standpoint, CMUTs have the further benefit of low-cost, scalable semiconductor fabrication, as well as the ability to implement 2D arrays and flexible interconnection(s) with electronics. In contrast, with PZT technology, manual dicing is required, and it is difficult to interconnect for 2D arrays. In addition, PZT devices have a relatively large kerf between elements and less active area.

[0024] Embodiments of the present disclosure are described more fully hereinafter with reference to the accompanying drawings, in which some, but not all, embodiments of the present disclosure are shown. Indeed, the present disclosure can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure clearly satisfies applicable legal requirements. Like numbers refer to like elements throughout.

[0025] Referring initially to FIG. **1** and FIG. **2**, an exemplary ultrasound probe **100** is depicted in a perspective view and an exploded perspective view, respectively. It should be understood, however, that the ultrasound probe **100** depicted in FIG. **1** and FIG. **2** represents one exemplary application for the acoustic attenuation features described herein, and other form factors, applications and devices are also contemplated. As shown in FIG. **1**, the exemplary ultrasound probe **100** is a handheld probe that includes a probe housing **102** having an acoustic lens **104** and shroud **106** disposed at a first end thereof, and a cable assembly **108** disposed at a second end thereof. The shroud **106** prevents direct contact between an ultrasonic transducer assembly **110** (FIG. **2**) and a patient (not shown) when the ultrasound probe **100** is used to image and/or provide therapy to the patient.

[0026] In addition to imaging, the acoustic lens **104** may also be configured to focus acoustic energy to spots having areas of the size required for high-intensity focused ultrasound (HIFU) procedures. Furthermore, the acoustic lens **104** may acoustically couple the ultrasonic transducer assembly **110** to the patient (not shown) to minimize acoustic reflections and attenuation. In some embodiments, the acoustic lens **104** may be fabricated with materials providing impedance matching between ultrasonic transducer assembly **110** and the patient. In still other embodiments, the acoustic lens **104** may provide electric insulation and may include shielding to prevent electromagnetic interference (EMI). Additionally, the shroud **106** and acoustic lens **104** may provide a protective interface to absorb or reject stress between the ultrasonic transducer assembly **110** and the acoustic lens **104**.

[0027] As also shown in FIG. **2**, the ultrasonic transducer assembly **110** includes an ultrasound-on-chip device **112** having an ultrasonic transducer array that is covered by the acoustic lens **104** when the ultrasound probe **100** is assembled. An interior region of the ultrasound probe **100**, encapsulated by upper probe housing section **102*a*** and lower probe housing section **102*b***, may also include components such as a first circuit board **114**, a second circuit board **116** and a battery **118**. The circuit boards **114** and **116** may include circuitry configured to operate the ultrasonic transducer arrangement **110** in a transmit mode to transmit ultrasound signals, or receive mode, to convert received ultrasound signals into electrical signals. Additionally, such circuitry may provide power to the ultrasonic transducer assembly **110**, generate drive signals for the ultrasonic transducer assembly **110**, process electrical signals produced by the ultrasonic transducer assembly **110**, or perform any combination of such functions. The cable assembly **108** may carry any suitable analog and/or digital signals to and from circuit boards **114** and **116**.

[0028] One possible configuration for the ultrasound-on-chip device **112** is illustrated in the partial cross-sectional view of FIG. **3**. In the embodiment depicted, the ultrasound-on-chip device **112** includes an ultrasonic transducer substrate **302** that is bonded to an integrated circuit substrate **304**, such as a complementary metal oxide semiconductor (CMOS) substrate for example. The ultrasonic transducer substrate **302** has a plurality of cavities **306** formed therein, and is an example of a CMUT device as described above. The cavities **306** are formed between a first silicon device layer **308** and a second silicon device layer **310**. A silicon oxide layer **312** (e.g., a thermal silicon oxide such as a silicon oxide formed by thermal oxidation of silicon) may be formed between the first and second silicon device layers **308** and **310**, with the cavities **306** being formed therein. In this non-limiting example, the first silicon device layer **308** may be configured as a bottom electrode and the second silicon device layer **310** may be configured as a membrane. Thus, the combination of the first silicon device layer **308**, second silicon device layer **310**, and cavities **306** may form an ultrasonic transducer (e.g., a CMUT), of which six are illustrated in this non-limiting cross-sectional view. To facilitate operation as a bottom electrode or membrane, one or both of the first silicon device layer **308** and second silicon device layer **310** may be doped to act as conductors, and in some cases are highly doped (e.g., having a doping concentration greater than 10^{15} dopants/cm^3 or greater).

[0029] In terms of the aforementioned forward direction toward a subject being imaged and/or having therapy applied thereto, this would be in the upward direction with respect to the view in FIG. **3**, whereas the backward direction away from the subject being imaged and/or having therapy applied thereto would be in the downward direction with respect to the view in FIG. **3**. Additional information regarding the fabrication and integration of CMUTs with CMOS wafers may be found in U.S. Pat. No. 9,067,779, assigned to the assignee of the present application, the contents of which are incorporated by reference herein in their entirety. Again however, it should be appreciated that the ultrasonic transducer substrate **302**/CMOS substrate **304** embodiment represents just one possible configuration for the ultrasound-on-chip device **112**. Other configurations are also possible including, but not limited to, a side-by-side arrangement where transducers and CMOS circuitry are formed on a same substrate, as well as arrays formed from piezoelectric micromachined ultrasonic transducers (PMUTs), or other suitable types of ultrasonic transducers. In still other embodiments, the ultrasound-on-chip device **112** may include an ultrasonic transducer array by itself (i.e., an ultrasonic transducer chip), where CMOS circuitry is located on a different substrate or circuit board altogether.

[0030] Other examples of suitable ultrasound on a chip systems for use in HIFU are described in U.S. Pat. No. 9,521,991, which is assigned to the Assignee of the current application and which is incorporated herein by reference in its entirety. U.S. Pat. No. 8,852,103 also describes HIFU, is assigned to the Assignee of the present application, and is incorporated herein by reference in its entirety.

[0031] In addition to handheld probe embodiments such as depicted in FIG. **1** and FIG. **2**, it is further contemplated that other ultrasound probe form factors may incorporate HIFU functionality as described hereinafter. For example, FIG. **4** is a perspective view illustrating an ultrasound probe **400** that is embodied in a patch configuration, and having an upper housing **402***a* and a lower housing **402***b*. The probe **400** is shown coupled to a patient **500** in FIG. **5**, and may be configured to wirelessly communicate with one or more external devices. In the example depicted, the probe **400** may also be provided with dressing **502** that provides an adhesive surface for both the probe housing as well as to the skin of the patient. One non-limiting example of such a dressing **502** is Tegaderm™, a transparent medical dressing available from 3M Corporation. Although not specifically shown in FIG. **5**, the lower housing **402***b* may include an opening that aligns with a corresponding opening in the dressing **502** so that transducer elements of the ultrasound probe **400** may be acoustically coupled to the patient **500**.

[0032] Referring to FIG. **6**, an alternative fastening mechanism for the ultrasound probe **400** is illustrated. In the embodiment shown, the ultrasound probe **400** further includes a buckle **600** affixed to the upper housing **402***a* via a post **602** using, for example, a threaded engagement between the buckle **600** and the post **602**. Other attachment configurations are also contemplated, however. As further shown in FIG. **16**, the buckle **600** includes a pair of slots **604** that in turn accommodate a strap **700** (FIG. **7**). In this example, the strap **700** is wrapped around the patient **500** and appropriately tightened in order to secure the ultrasound probe **400** to a desired location on the patient **1500** for acquisition of desired ultrasound data and/or delivery of desired ultrasound energy.

[0033] FIG. **8** illustrates an exploded perspective view of the ultrasound probe **400** of FIG. **6**. For ease of illustration and comparison, similar components with respect to the embodiment of FIG. **1** and FIG. **2** are designated with similar reference numerals. For example, in addition to the upper housing **402***a*, lower housing **402***b* and buckle, the ultrasound probe **400** further includes an acoustic lens **104** to cover the ultrasound-on-chip device **112**, which in turn is attached to a heat sink device **404**. In contrast to the handheld probe embodiment of FIGS. **1-2** in which the ultrasonic transducer assembly **110** includes an interposer circuit board **402**, the ultrasound-on-chip device **112** and heat sink device **404** are attached directly to a first circuit board **1802**. In addition, the ultrasound probe **400** further includes, by way of example, a second circuit board **804** (e.g., for power supply components), an insulator board **806**, battery **808** and antenna (e.g., to enable wireless communication to and from the ultrasound probe **400**).

[0034] Referring now to FIG. **9** and FIG. **10**, there is shown a perspective view of a HIFU apparatus **900** in accordance with exemplary embodiments. In the embodiment depicted, the apparatus **900** includes a circuit board **902** having one or more HIFU transducer chips **904** mounted thereon. The HIFU transducer chips **904** are also in thermal contact with a cooling block **906** (e.g., copper or other thermally conductive material(s)). Cooling lines **908** may be used to circulate a coolant material (not shown) through one or more channels **910** of the cooling block **906**, as best seen in FIG. **10**. The number of HIFU transducer chips provided with the apparatus **900** is not necessarily limited to any specific number as depicted in the illustrated embodiments, and may be selected based on the desired application(s). As further illustrated in FIG. **9** and FIG. **10**, an ultrasound probe (e.g., probe **100**) may be inserted through an opening in the cooling block **906** and circuit board **902** such that the acoustic lens **104** of the probe **100** is substantially co-planar with the plurality of HIFU transducer chips **904**. In this manner, the HIFU apparatus **900** may provide both imaging functionality (via the probe **100**) and HIFU therapy functionality (via the HIFU transducer chips **904**). In other embodiments, the HIFU transducer chips **904** need not necessarily be co-planar with one another or co-planar with the acoustic lens **104** of the probe **100**. As shown in FIG. **11**, an acoustic lens **912** or other capping material may be formed over the HIFU transducer chips **904**, optionally with an opening therein to allow the acoustic lens **104** of the probe **100** to protrude therethrough. FIG. **11** also illustrates an connector **914** and cable **916** that may attach to the circuit board **902** to deliver power and signals to/from the HIFU transducer chips **904**.

[0035] FIG. **12** is a schematic diagram illustrating an exemplary application of a HIFU apparatus, in accordance with embodiments. The example depicted is illustrative of various capabilities, including (but not limited to): the ability to flexibly focus with a 2D array probe to provide treatment monitoring; the use of multiple HIFU chips collaborating to deliver acoustic energy at a common focus; and multi-chip adaptive phase adjustment. As shown in FIG. **12**, a plurality of HIFU units **1200-1**, **1200-2**, **1200-3**, **1200-4**, **1200-5** is configured to direct HIFU energy at a single point of focus within a patient **1202**. In the example illustrated, the point **1204** of focus is within the brain of the patient **1202**. It should be appreciated that each HIFU unit may have one or more individual HIFU transducer chips associated therewith, and that the specific number of HIFU units depicted in FIG. **12** is exemplary only.

[0036] It may further be appreciated that in the application of HIFU energy to the brain of the patient, the apparatus may be configured such that individual HIFU chips or HIFU units may not be arranged in a planar manner, but instead arranged in a manner to conform to an anatomical structure of the patient **1202** (e.g., a rounded anatomical structure such as a patient's head). Here, the relative location of chips affect the relative phase relationship between the chips/units. Accordingly, embodiments herein provide the capability the self-calibration of phase (e.g., between transmit circuits ϕ_1, ϕ_2, ϕ_3, ϕ_4, ϕ_5). Regardless of whether the HIFU transducer chips or units are co-planar, it is contemplated that any misalignment of the chips/units may utilize an adaptive, auto-correcting phase adjustment. Such a feature may be realized through the receiving capability of the HIFU apparatus.

[0037] FIGS. **13-18** illustrate various power and acoustic pressure field simulations using different numbers of HIFU transducer chips. From a finite element model (FEM) simulation, transducer surface pressure may currently reach about 1.0 MPa (peak-to-peak) with 100 Vpp (peak-to-peak) pulsing, assuming ideal focusing and discarding medium attenuation. Field simulations were based on physical acoustic wave propagation and beamforming predictions of the pressure and intensity (I_SPPA, spatial-peak, pulse-average) at the focal point.

[0038] FIGS. **13** and **14** illustrate pressure and intensity simulations for a single HIFU transducer chip defining a 140×64 array of transducer elements with a 208 μm pitch. The array size is 2.9×1.3 cm^2. Using a focus depth of 5 cm, the simulated pressure=9.4 MPa (pp), with intensity I_SPPA=0.72 kW/cm^2.

[0039] FIGS. **15** and **16** illustrate pressure and intensity simulations for a 2-chip HIFU transducer assembly defining a 140×128 array of transducer elements with a 208 μm pitch. The array size is 2.9×2.7 cm^2. Using a focus depth of 5 cm, the simulated pressure=18.6 MPa (pp), with intensity I_SPPA=2.80 kW/cm^2.

[0040] FIGS. **17** and **18** illustrate pressure and intensity simulations for a 4-chip HIFU transducer assembly defining a 140×256 array of transducer elements with a 208 μm pitch. The array size is 2.9×5.3 cm^2. Using a focus depth of 5 cm, the simulated pressure=33.4 MPa (pp), with intensity I_SPPA=9.07 kW/cm^2.

[0041] One exemplary embodiment of a HIFU apparatus may provide advantageous pressures by employing at least 4 full-reticle chips tiled together with coherent delays between the chips. Non-limiting examples of tiling ultrasound chips are described in U.S. Pat. No. 9,351,706, which is assigned to the Assignee of the present application and is incorporated herein by reference in its entirety. From a power perspective, a 100-200V multi-level, charge recycling pulser may be used. In one specific example, a 5-level pulser design fits a 400 μm×400 μm element size. A peak power consumption estimate per chip corresponds to 2 $pF*140*64*(100V)^2*2\ MHz/4=90\ W$.

[0042] The techniques described herein are exemplary, and should not be construed as implying any particular limitation on the present disclosure. It should be understood that various alternatives, combinations and modifications could be devised by those skilled in the art from the present disclosure. For example, steps associated with the processes described herein can be performed in any order, unless otherwise specified or dictated by the steps themselves.

What is claimed is:

1. An ultrasound imaging system, comprising:
a first ultrasonic transducer assembly configured to deliver high intensity focused ultrasonic (HIFU) energy to a point of interest within a subject; and
a second ultrasonic transducer assembly configured to perform imaging of the subject.

2. The system of claim **1**, further comprising a circuit board to which the first ultrasonic transducer assembly is mounted.

3. The system of claim **2**, wherein the second ultrasonic transducer assembly is coupled to the circuit board.

4. The system of claim **3**, wherein the first ultrasonic transducer assembly comprises a plurality of HIFU transducer chips.

5. The system of claim **4**, wherein the plurality of HIFU transducer chips is arranged on the circuit board so as to surround the second ultrasonic transducer assembly.

6. The system of claim **1**, further comprising a cooling block in thermal contact with the first ultrasonic transducer assembly.

7. A system, comprising:
a plurality of high intensity focused ultrasonic (HIFU) units, each configured to deliver high energy focused ultrasound energy to a point of focus; and
receive circuitry configured to determine a relative alignment between individual HIFU units so as to implement a self-calibration with respect to a transmit phase of the individual HIFU units.

8. The system of claim **7**, wherein the plurality of HIFU units are arranged such that the point of focus is within a brain of a subject.

9. The system of claim **7**, wherein the plurality of HIFU units are arranged in a non-coplanar fashion.

10. The system of claim **7**, wherein the plurality of HIFU units are arranged to accommodate a rounded anatomical structure.

11. An ultrasound imaging system, comprising:
an ultrasound probe having an acoustic lens; and
a housing configured to receive at least the acoustic lens of an ultrasound probe.

12. The ultrasound imaging system of claim **11**, wherein the housing further comprises an aperture configured to receive at least a portion of the ultrasound probe.

13. The ultrasound imaging system of claim **12**, wherein the housing is further configured to receive the acoustic lens to thereby form a co-planar surface of a surface of the housing and the acoustic lens.

14. The ultrasound imaging system of claim **11**, wherein the housing further comprises at least one cooling line to deliver a coolant to the housing.

15. The ultrasound imaging system of claim **11**, wherein the housing further comprises a connector to deliver power to at least one of the housing and the ultrasound probe.

16. The ultrasound imaging system of claim **11**, wherein the housing further comprises a transducer chip array.

17. The ultrasound imaging system of claim **16**, wherein the transducer chip array comprises a plurality of capacitive micromachined ultrasonic transducers (CMUTs) formed from a semiconductor substrate.

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当前申请(专利权)人(译)	蝶形网络，INC.		
[标]发明人	CHEN KAILIANG SANCHEZ NEVADA J		
发明人	CHEN, KAILIANG SANCHEZ, NEVADA J. MCNULTY, CHRISTOPHER THOMAS		
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摘要(译)

示例性系统包括第一超声换能器组件和第二超声换能器组件，第一超声换能器组件配置成将高强度聚焦超声（HIFU）能量传递到受试者体内的感兴趣点，第二超声换能器组件配置成执行受试者的成像。在另一个实施例中，壳体配置成接收超声探头。壳体可包括冷却回路和用于超声探头的电源。