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(54) **ULTRASOUND PROBE FOR TREATING SKIN LAXITY**

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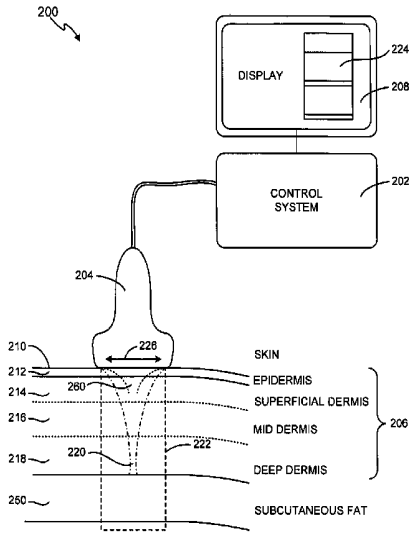
(57) **ABSTRACT**

A probe for ultrasound treatment of skin laxity are provided. Systems and methods can include ultrasound imaging of the region of interest for localization of the treatment area, delivering ultrasound energy at a depth and pattern to achieve the desired therapeutic effects, and/or monitoring the treatment area to assess the results and/or provide feedback. In an embodiment, a treatment system and method can be configured for producing arrays of sub-millimeter and larger zones of thermal ablation to treat the epidermal, superficial dermal, mid-dermal or deep dermal components of tissue.

20 Claims, 22 Drawing Sheets



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(58) **Field of Classification Search**

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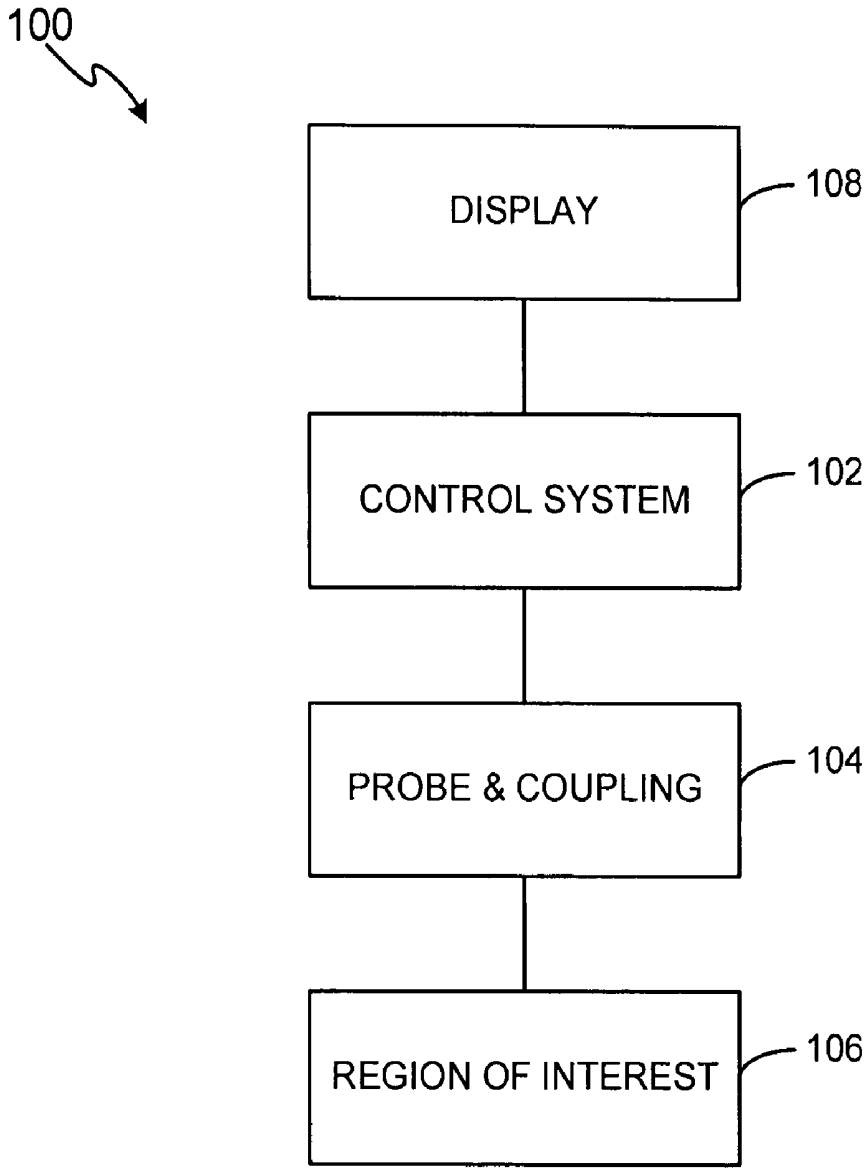
100
DISPLAY
108
CONTROL SYSTEM
102
PROBE & COUPLING
104
REGION OF INTEREST
106

FIG. 1

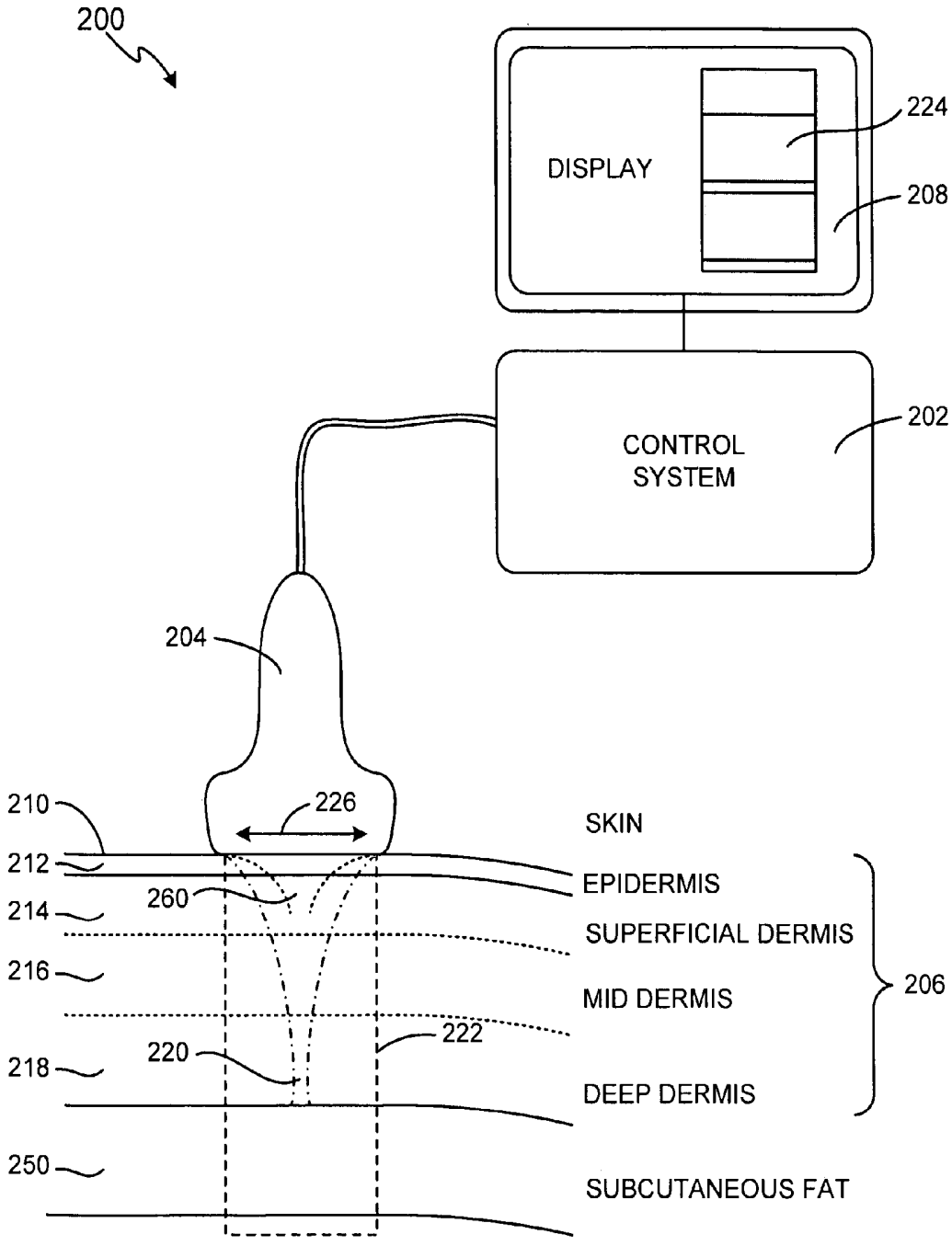
200
DISPLAY
224
208
CONTROL SYSTEM
202
204
210
226
SKIN
212
EPIDERMIS
214
260
SUPERFICIAL DERMIS
216
MID DERMIS
206
222
218
220
DEEP DERMIS
250
SUBCUTANEOUS FAT

FIG. 2A

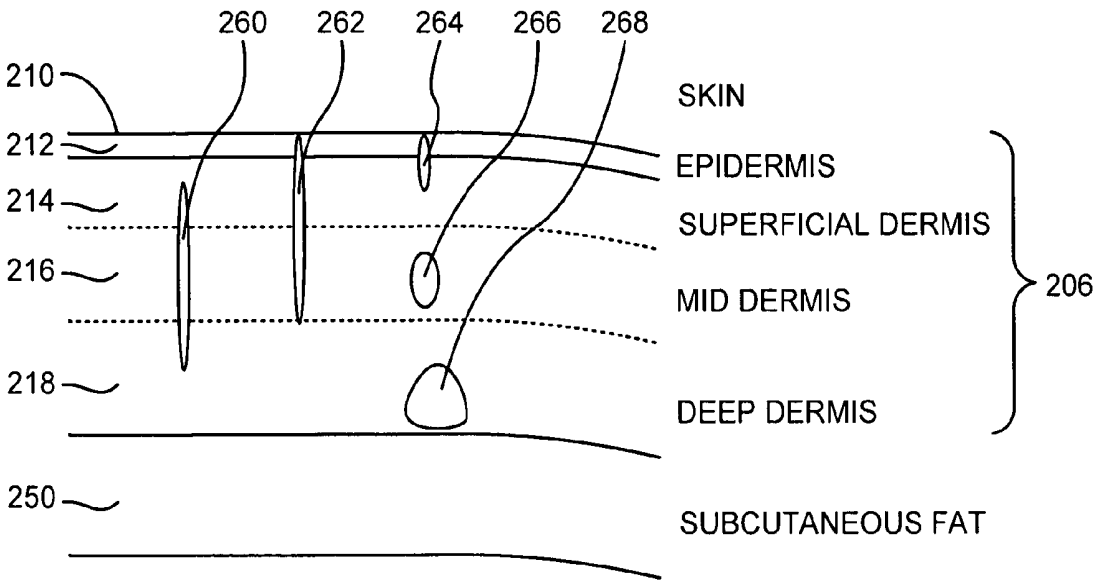
260
262
264
266
268
210
212
214
216
218
250
SKIN
EPIDERMIS
SUPERFICIAL DERMIS
MID DERMIS
DEEP DERMIS
206
SUBCUTANEOUS FAT

FIG. 2B

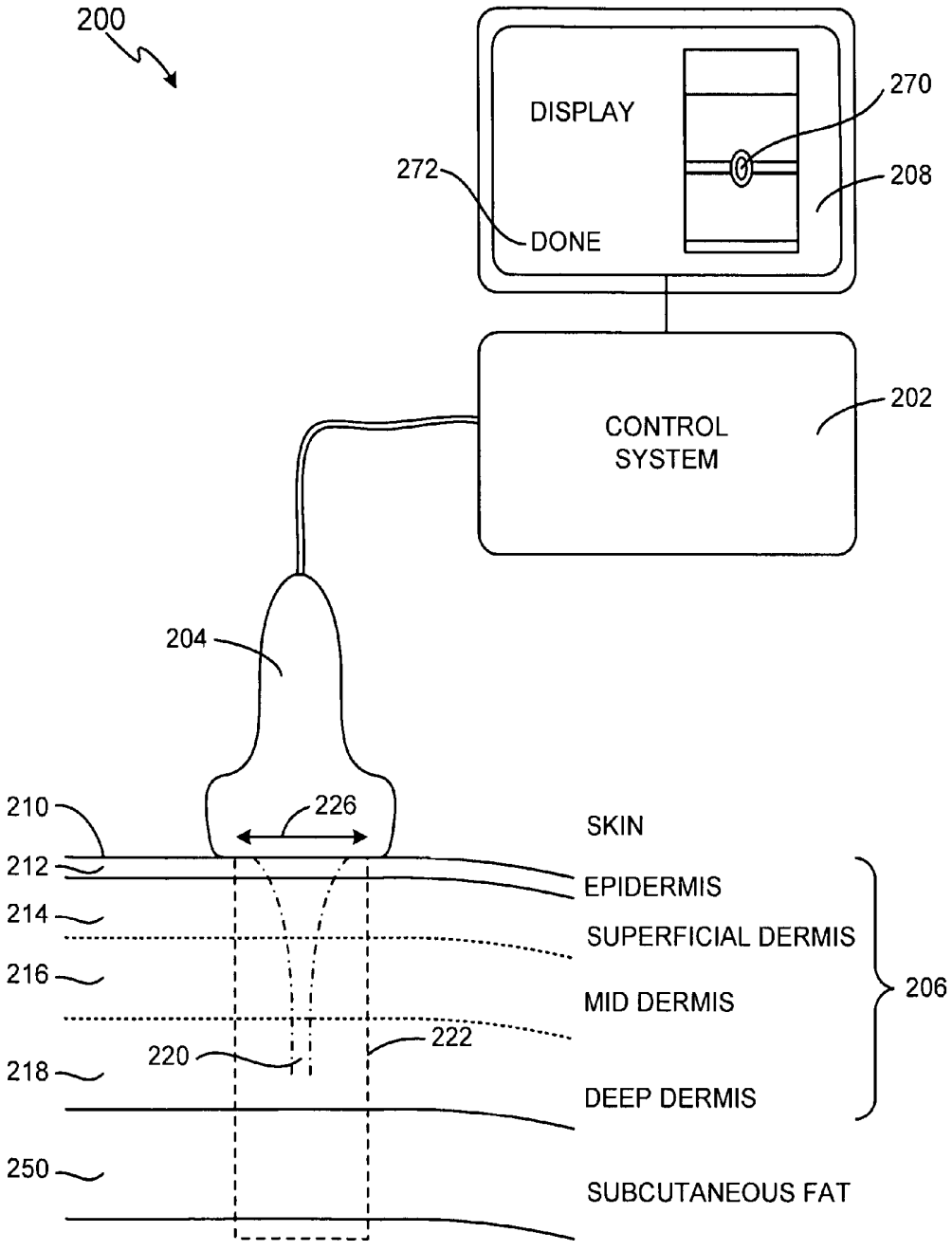
200
DISPLAY
270
272
208
DONE
CONTROL SYSTEM
202
204
210
226
SKIN
212
EPIDERMIS
214
SUPERFICIAL DERMIS
216
MID DERMIS
206
220
222
218
DEEP DERMIS
250
SUBCUTANEOUS FAT

FIG. 2C

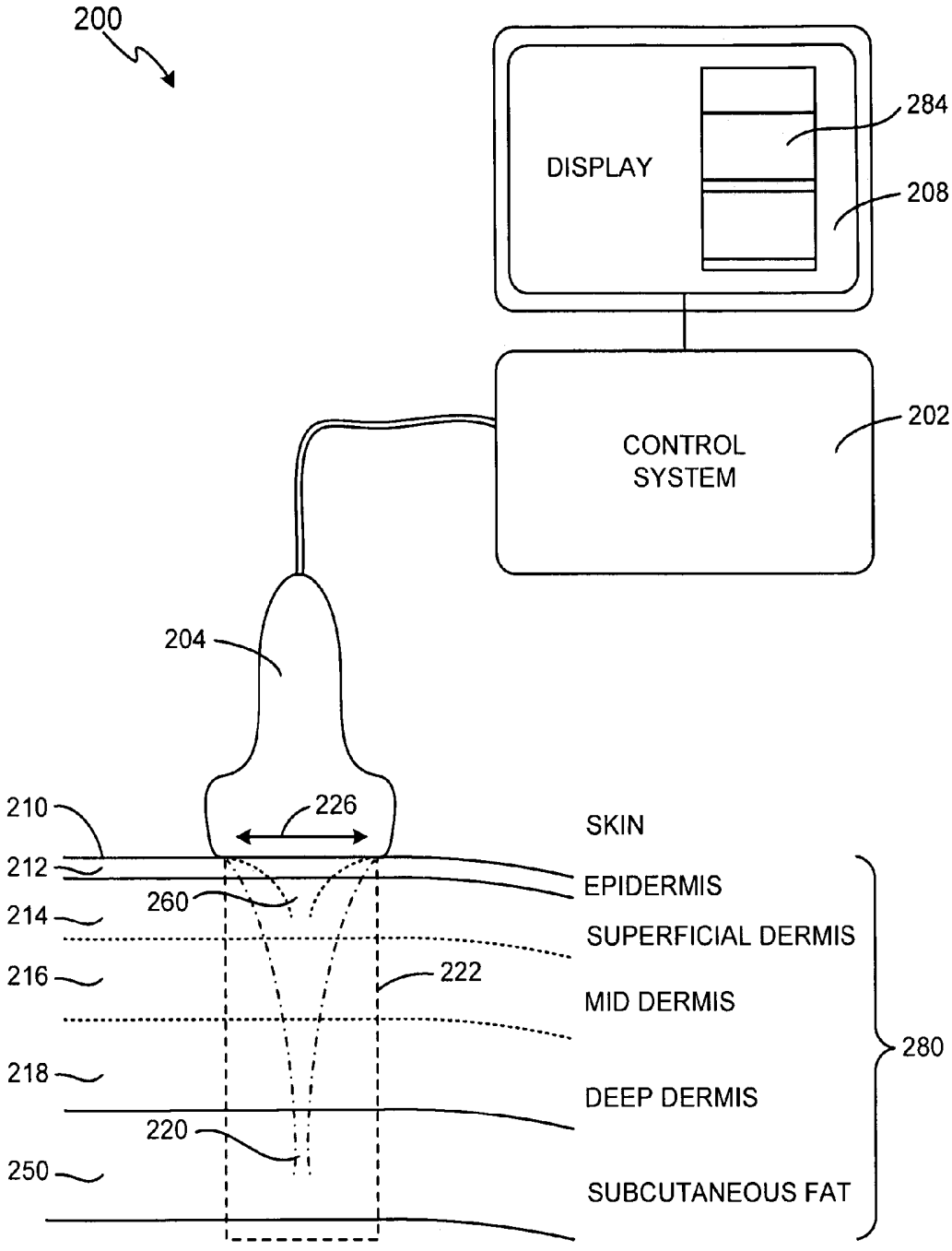
200
DISPLAY
284
208
CONTROL SYSTEM
202
204
210
226
SKIN
212
EPIDERMIS
214
260
SUPERFICIAL DERMIS
216
222
MID DERMIS
280
218
DEEP DERMIS
220
250
SUBCUTANEOUS FAT

FIG. 2D

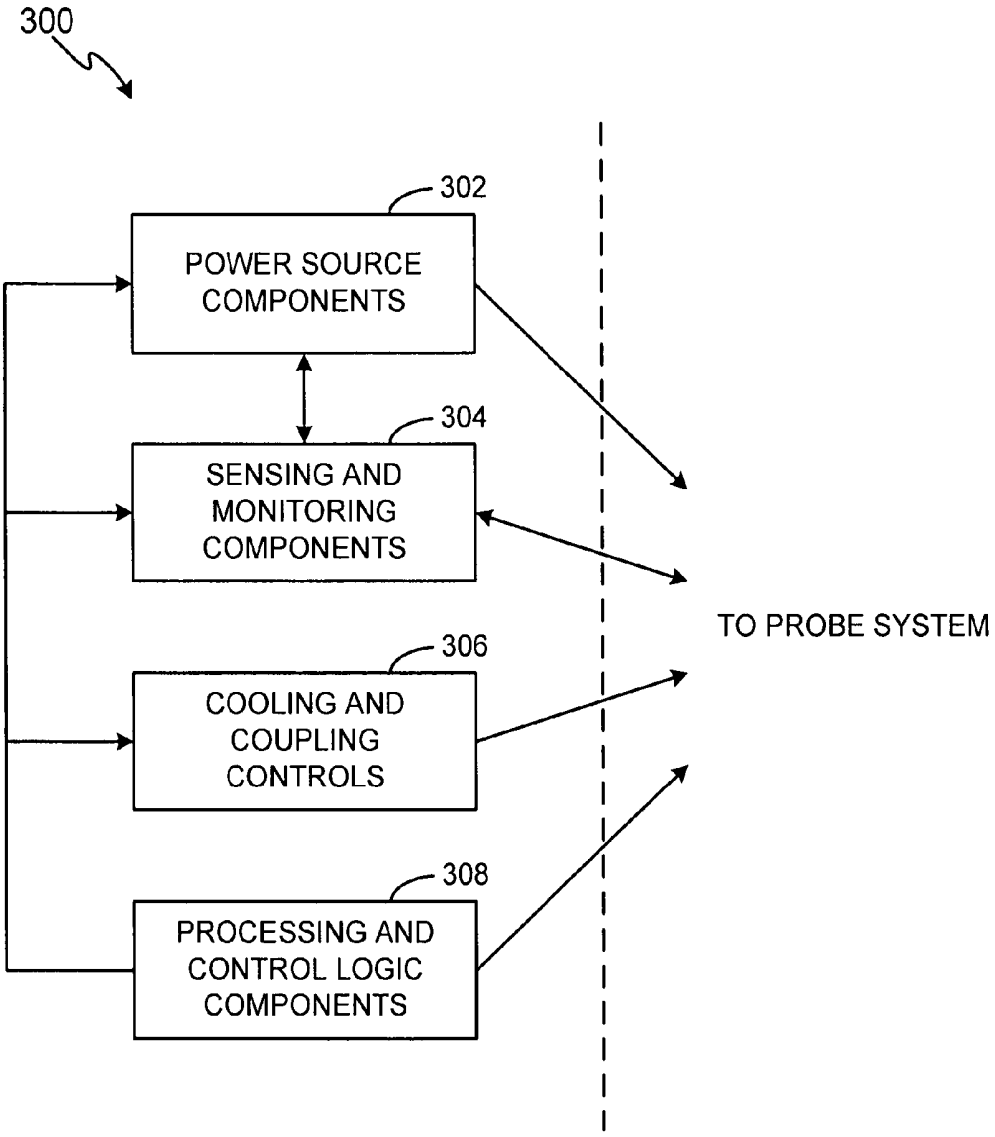
300
302
POWER SOURCE COMPONENTS
304
SENSING AND MONITORING COMPONENTS
306
COOLING AND COUPLING CONTROLS
308
PROCESSING AND CONTROL LOGIC COMPONENTS
TO PROBE SYSTEM

FIG. 3A

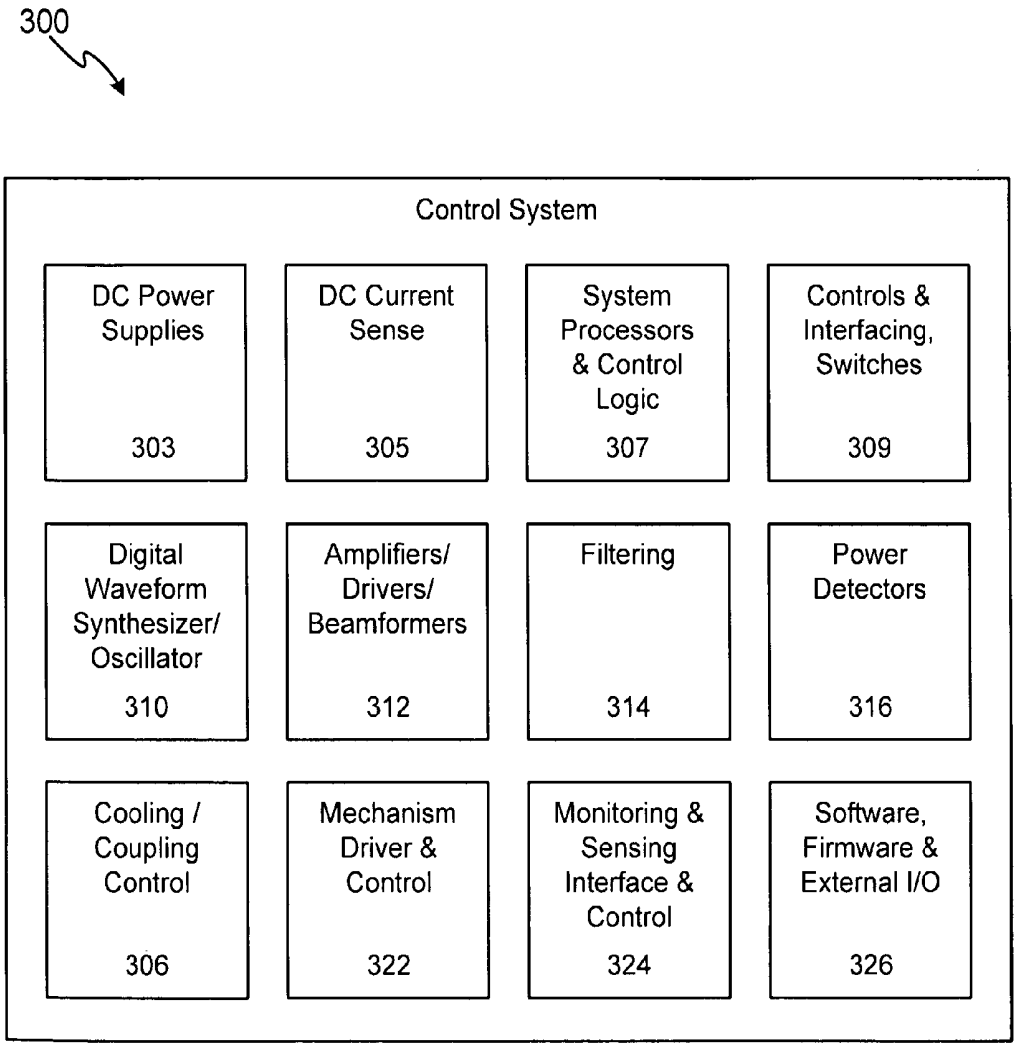
300
Control System
DC Power Supplies
303
DC Current Sense
305
System Processors & Control Logic
307
Controls & Interfacing, Switches
309
Digital Waveform Synthesizer/ Oscillator
310
Amplifiers/ Drivers/ Beamformers
312
Filtering
314
Power Detectors
316
Cooling / Coupling Control
306
Mechanism Driver & Control
322
Monitoring & Sensing Interface & Control
324
Software, Firmware & External I/O
326

FIG. 3B

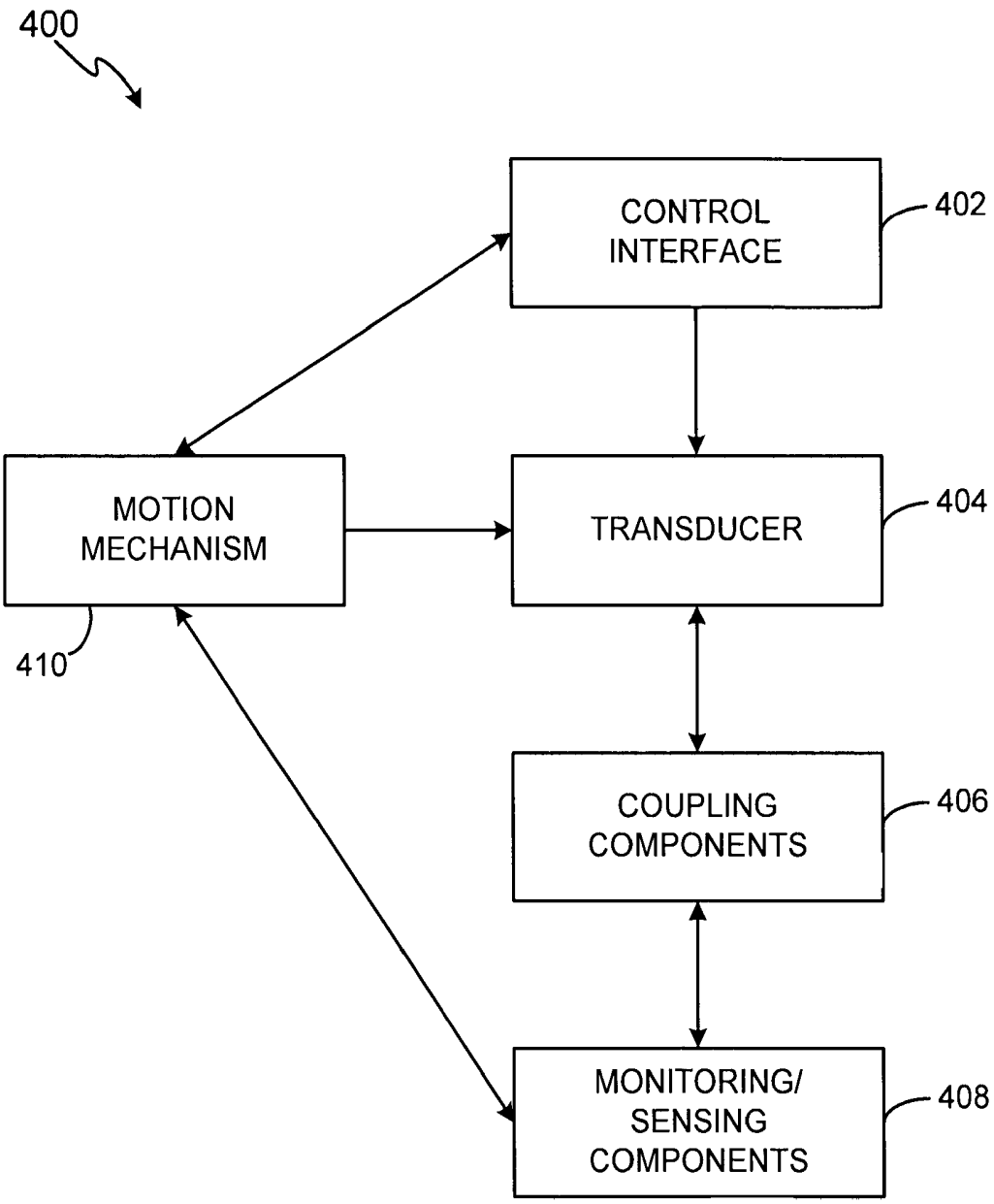
400
CONTROL INTERFACE
402
MOTION MECHANISM
TRANSDUCER
404
410
COUPLING COMPONENTS
406
MONITORING/ SENSING COMPONENTS
408

FIG. 4A

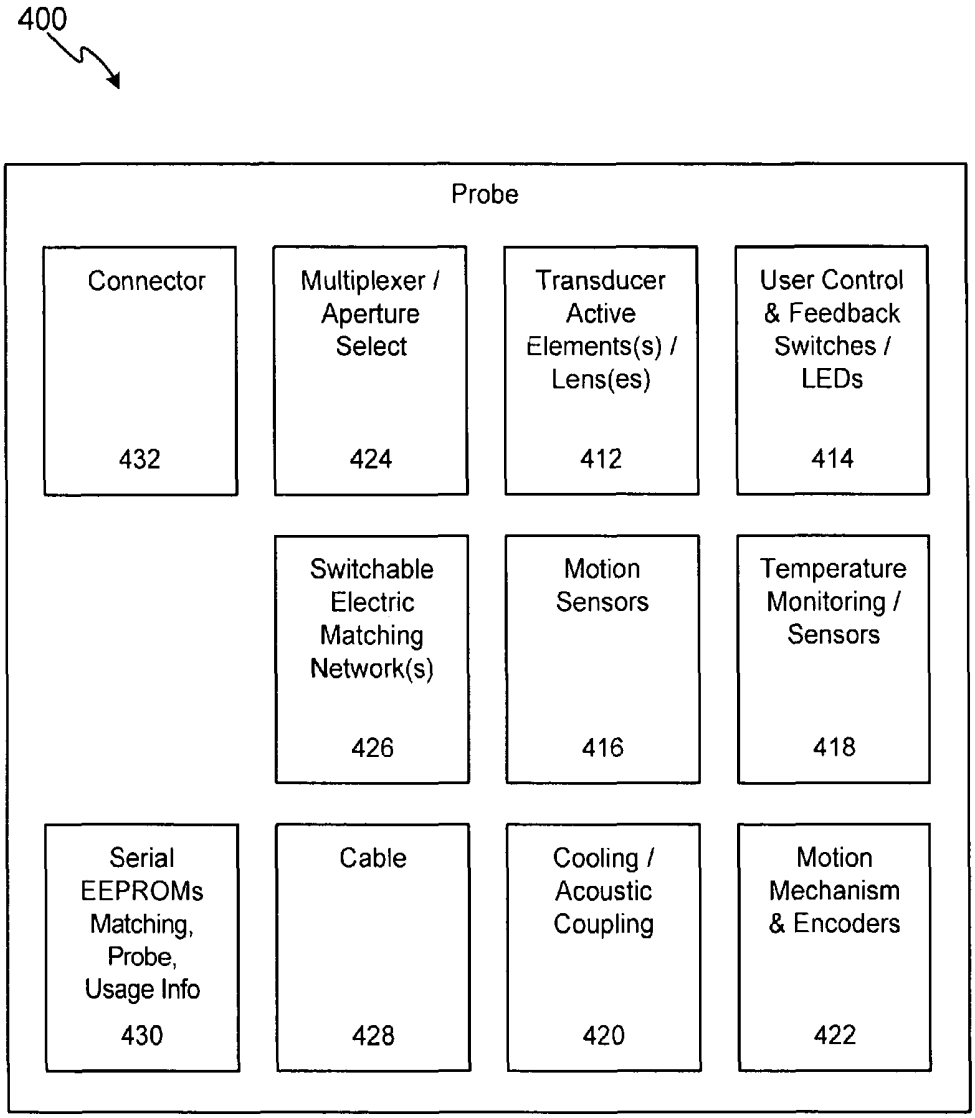
400
Probe
Connector
432
Multiplexer / Aperture Select
424
Transducer Active Elements(s) / Lens(es)
412
User Control & Feedback Switches / LEDs
414
Switchable Electric Matching Network(s)
426
Motion Sensors
416
Temperature Monitoring / Sensors
418
Serial EEPROMs Matching, Probe, Usage Info
430
Cable
428
Cooling / Acoustic Coupling
420
Motion Mechanism & Encoders
422

FIG. 4B

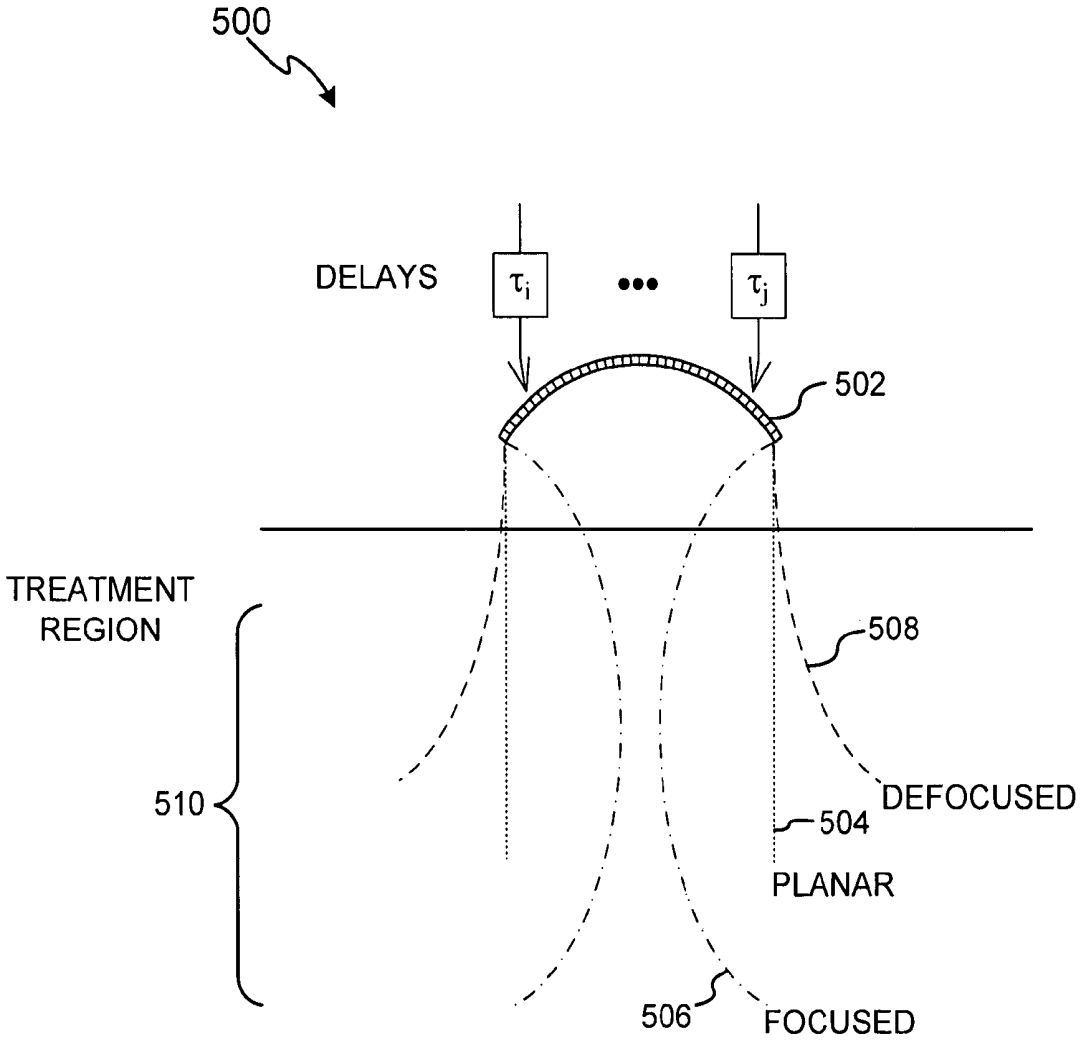
500
DELAYS
τ_i
τ_j
502
TREATMENT REGION
510
508
DEFOCUSED
504
PLANAR
506
FOCUSED

FIG. 5

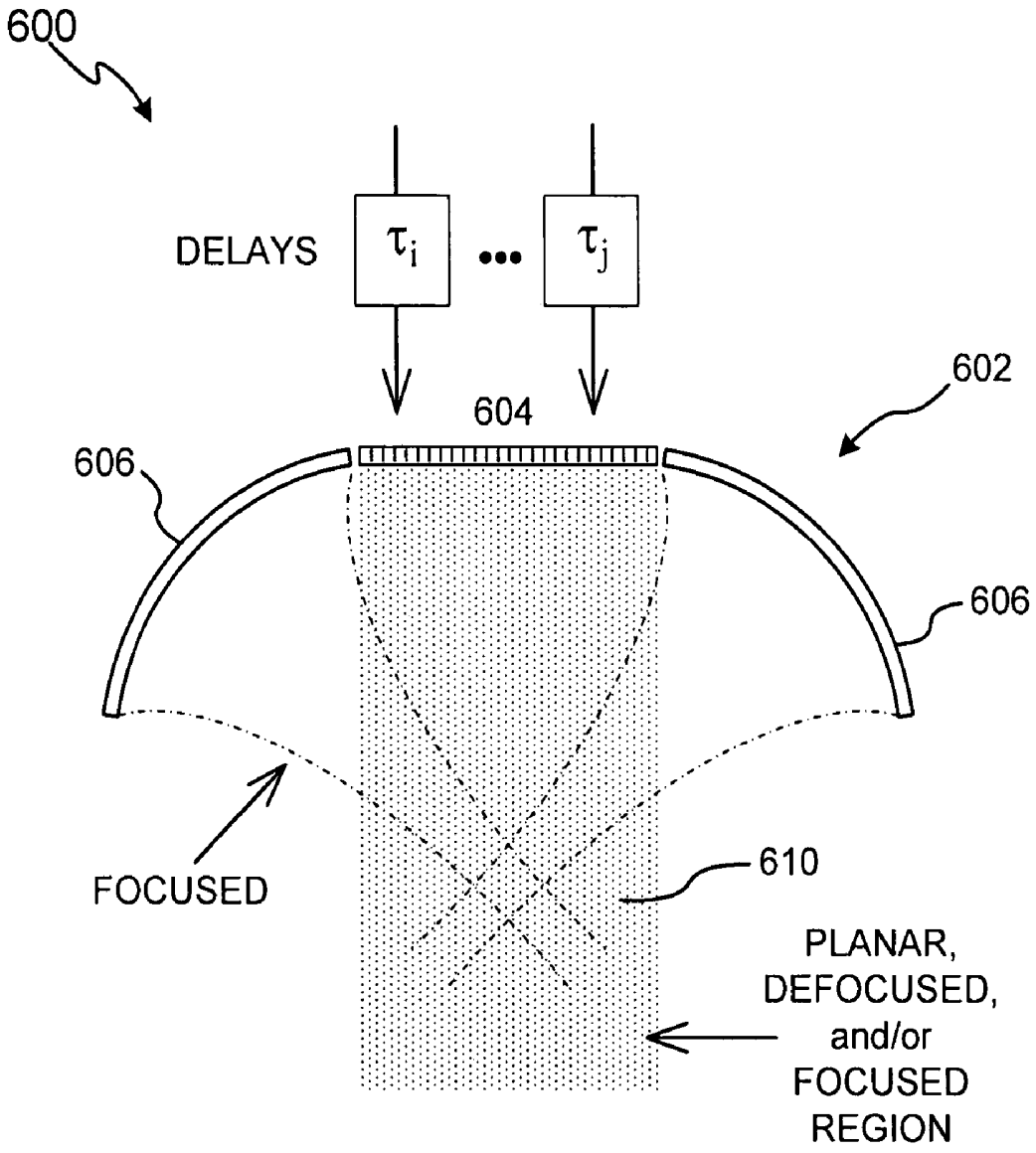
600
DELAYS
τ_i
τ_j
602
604
606
606
FOCUSED
610
PLANAR,
DEFOCUSED,
and/or
FOCUSED
REGION

FIG. 6A

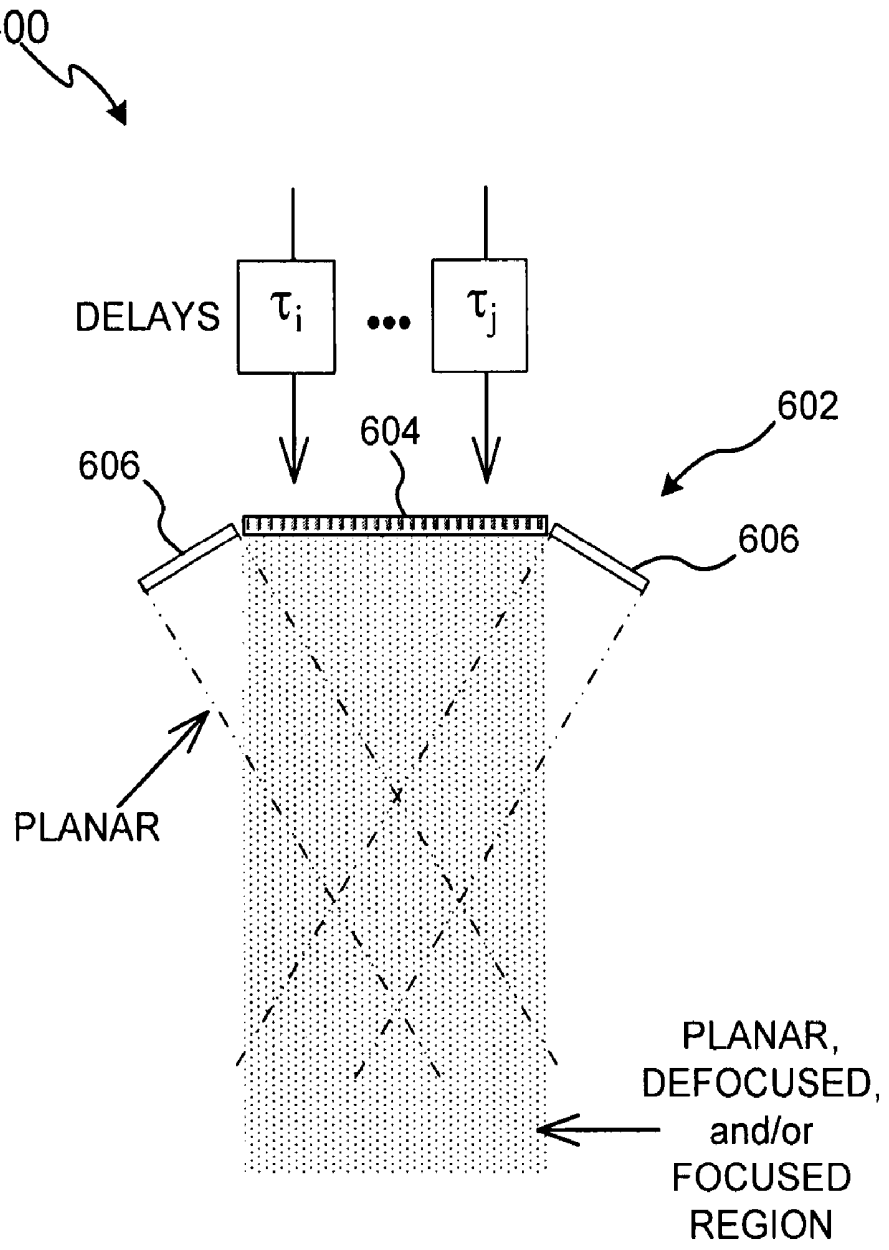
600
DELAYS
τ_i
τ_j
602
604
606
606
PLANAR
PLANAR, DEFOCUSED, and/or FOCUSED REGION

FIG. 6B

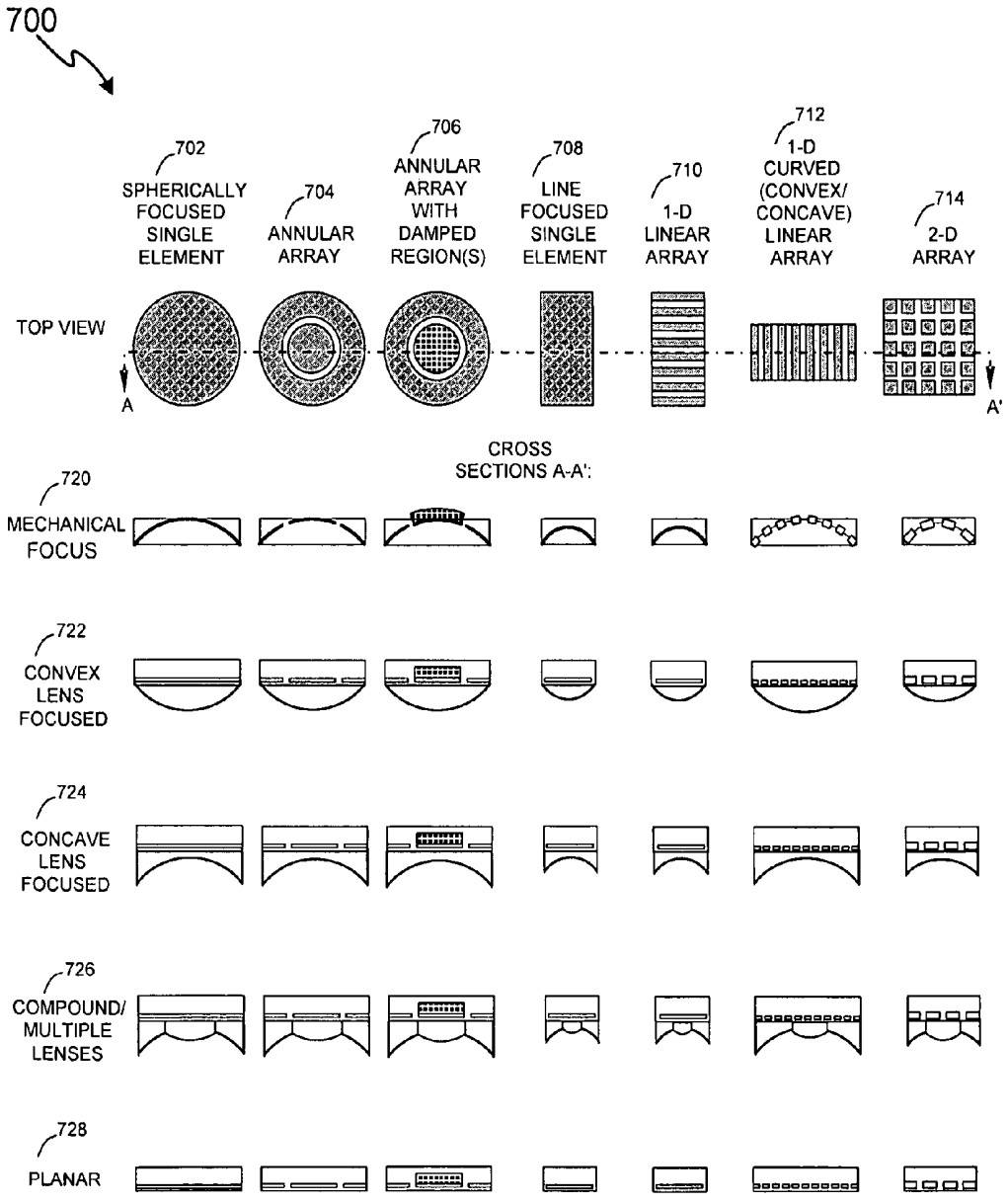
700
702
SPHERICALLY FOCUSED SINGLE ELEMENT
704
ANNULAR ARRAY
706
ANNULAR ARRAY WITH DAMPED REGION(S)
708
LINE FOCUSED SINGLE ELEMENT
710
1-D LINEAR ARRAY
712
1-D CURVED (CONVEX/ CONCAVE) LINEAR ARRAY
714
2-D ARRAY
TOP VIEW
A
A'
CROSS SECTIONS A-A':
720
MECHANICAL FOCUS
722
CONVEX LENS FOCUSED
724
CONCAVE LENS FOCUSED
726
COMPOUND/ MULTIPLE LENSES
728
PLANAR

FIG. 7

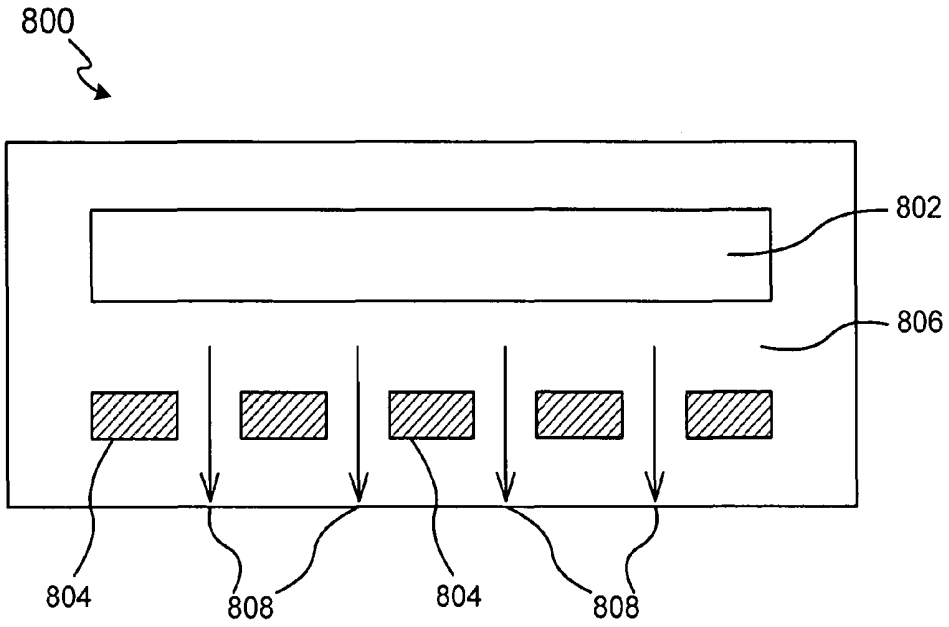

FIG. 8A

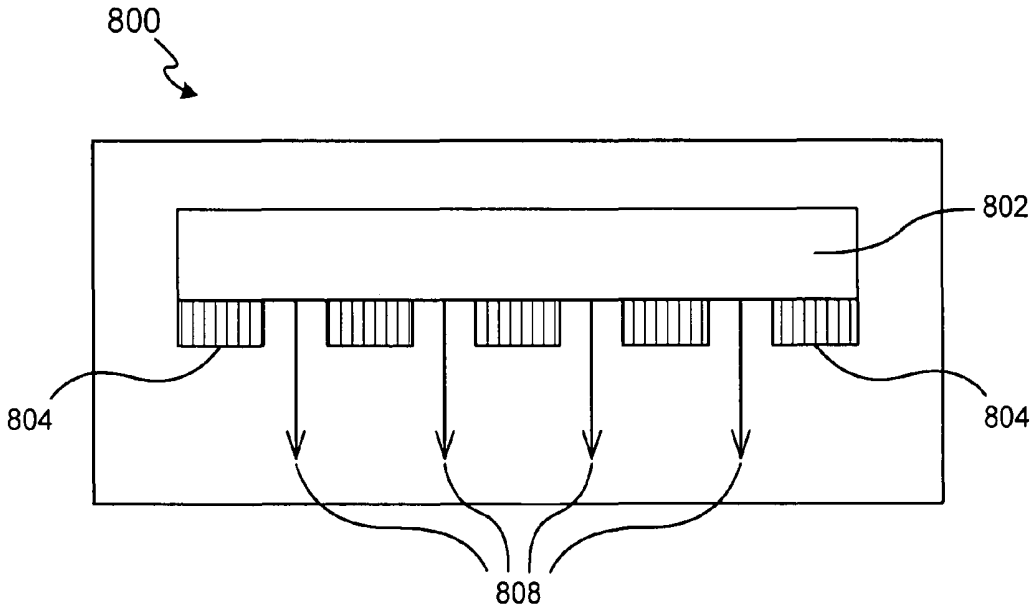

FIG. 8B

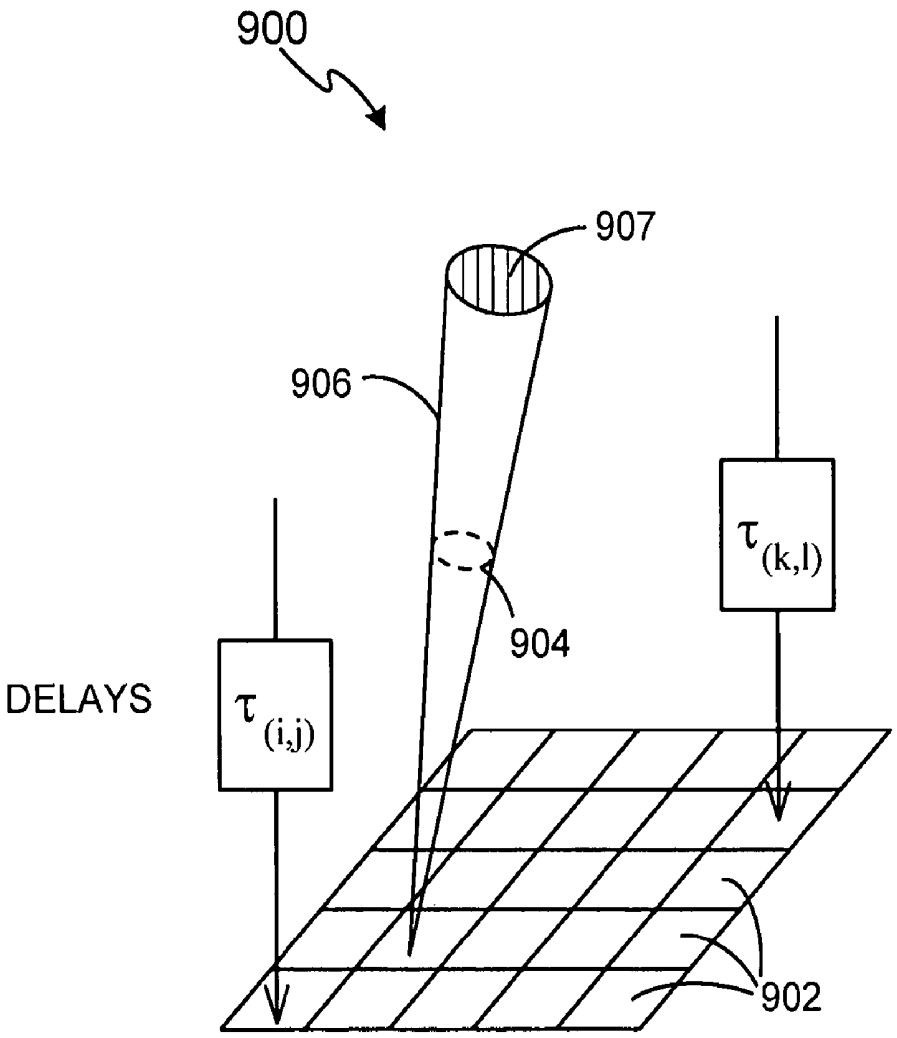

FIG. 9

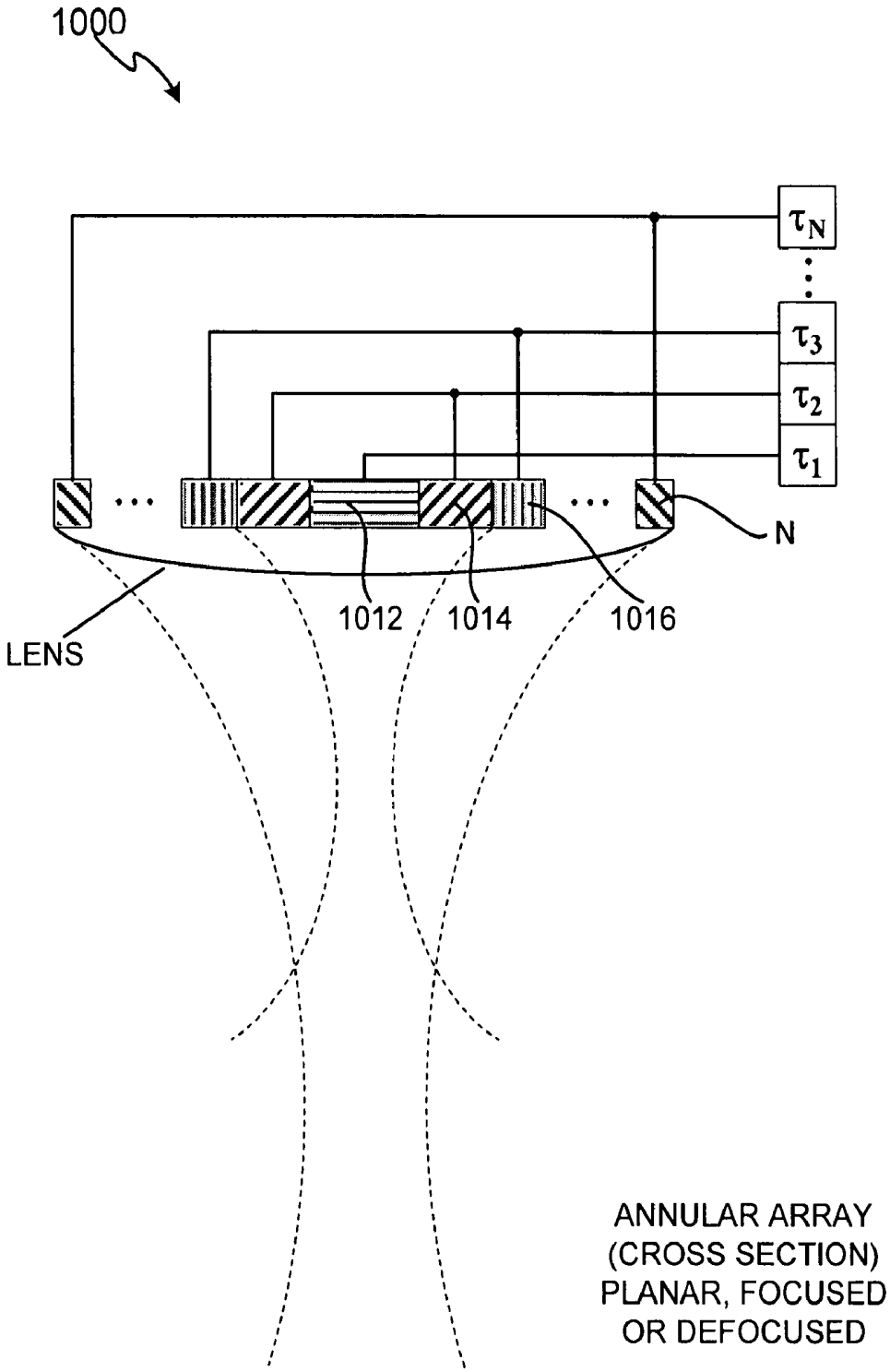
1000
τ_N
τ_3
τ_2
τ_1
N
1012
1014
1016
LENS
ANNULAR ARRAY
(CROSS SECTION)
PLANAR, FOCUSED
OR DEFOCUSED

FIG. 10A

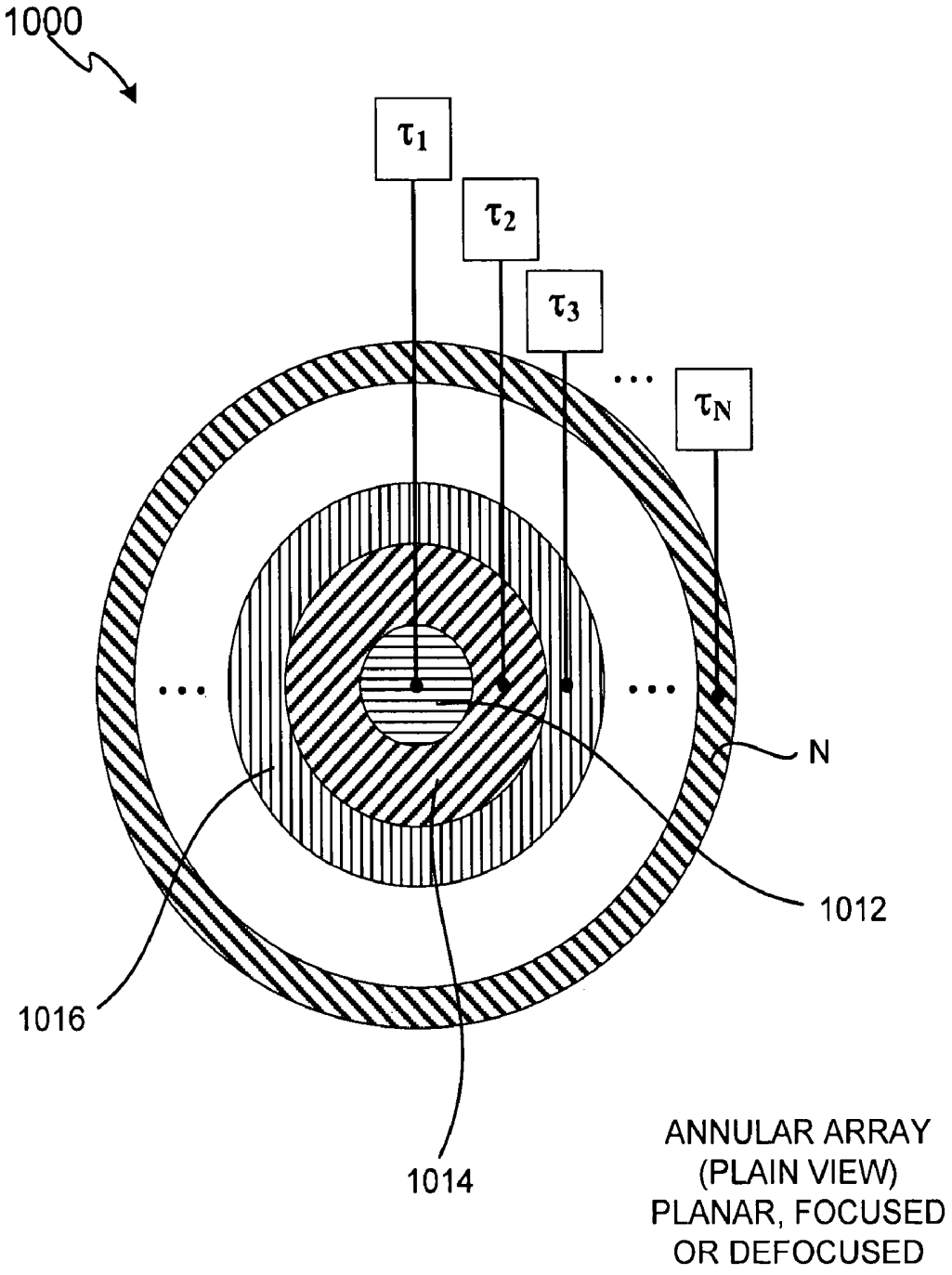
1000
τ_1
τ_2
τ_3
τ_N
N
1012
1016
1014
ANNULAR ARRAY
(PLAIN VIEW)
PLANAR, FOCUSED
OR DEFOCUSED

FIG. 10B

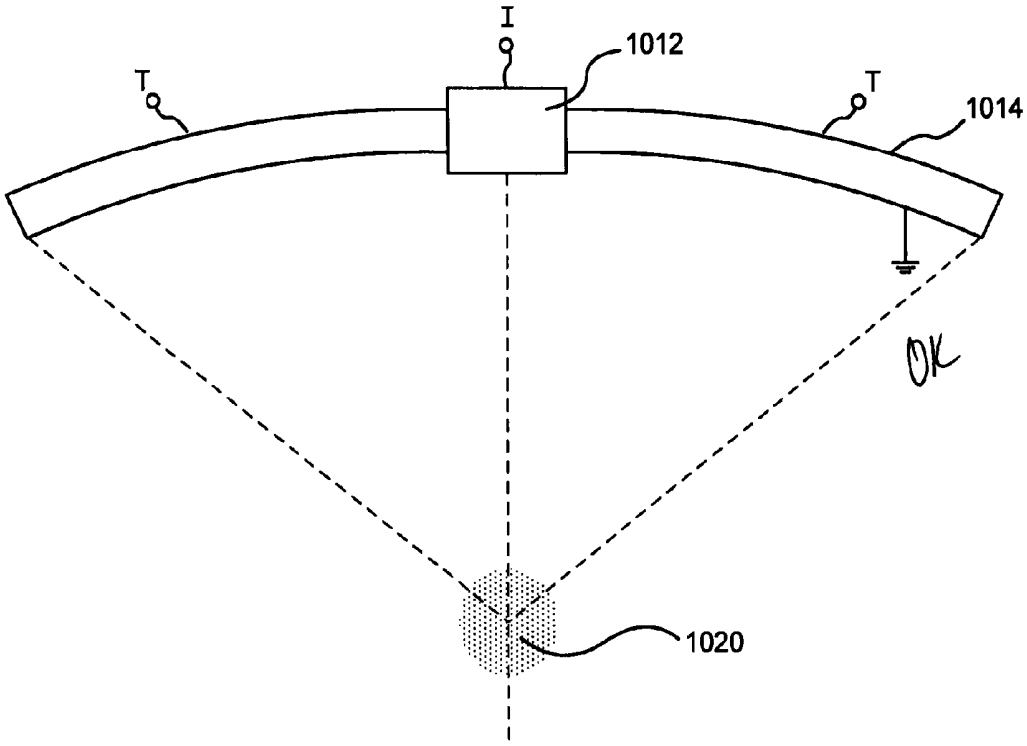

FIG. 10C

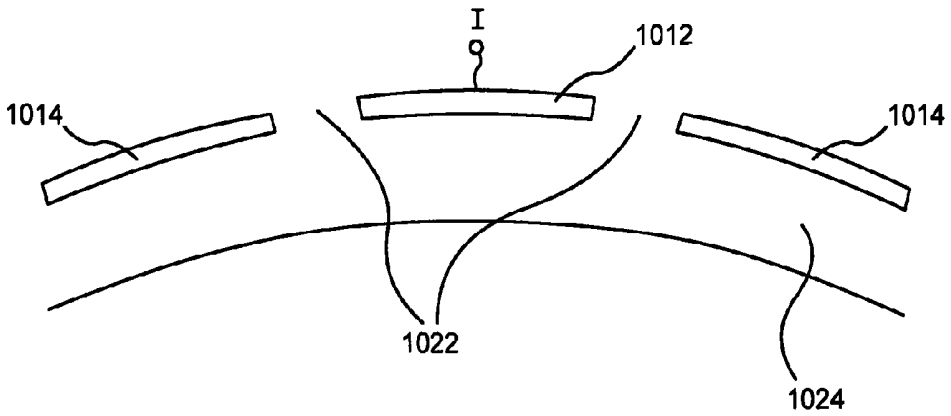

FIG. 10D

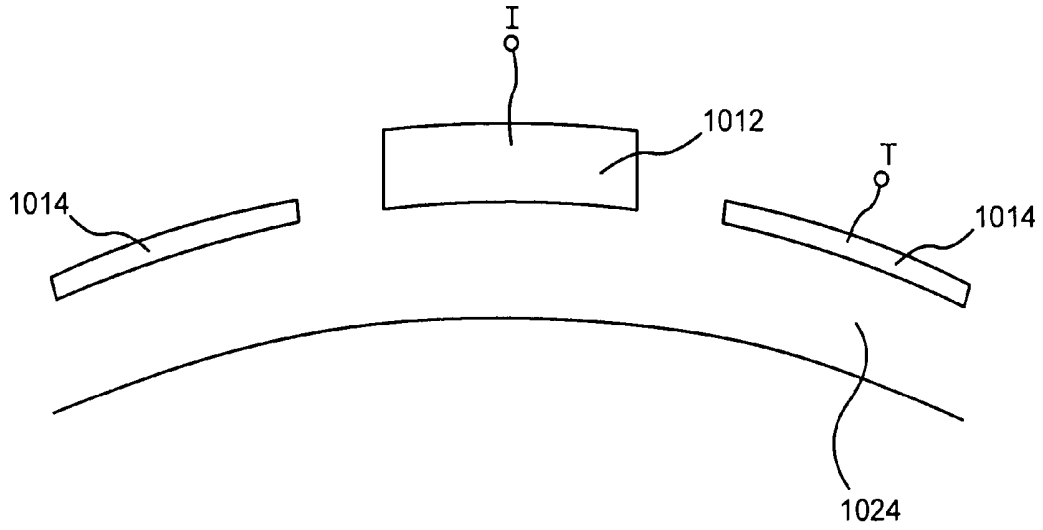

FIG. 10E

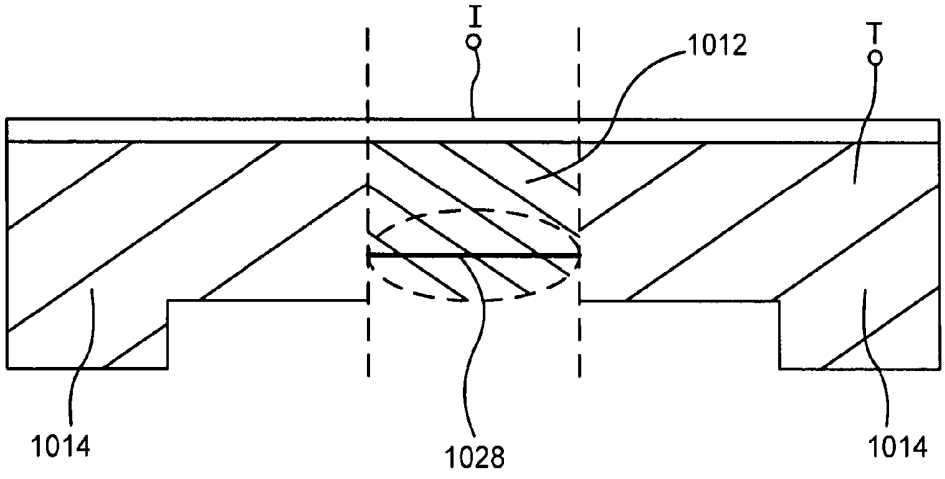

FIG. 10F

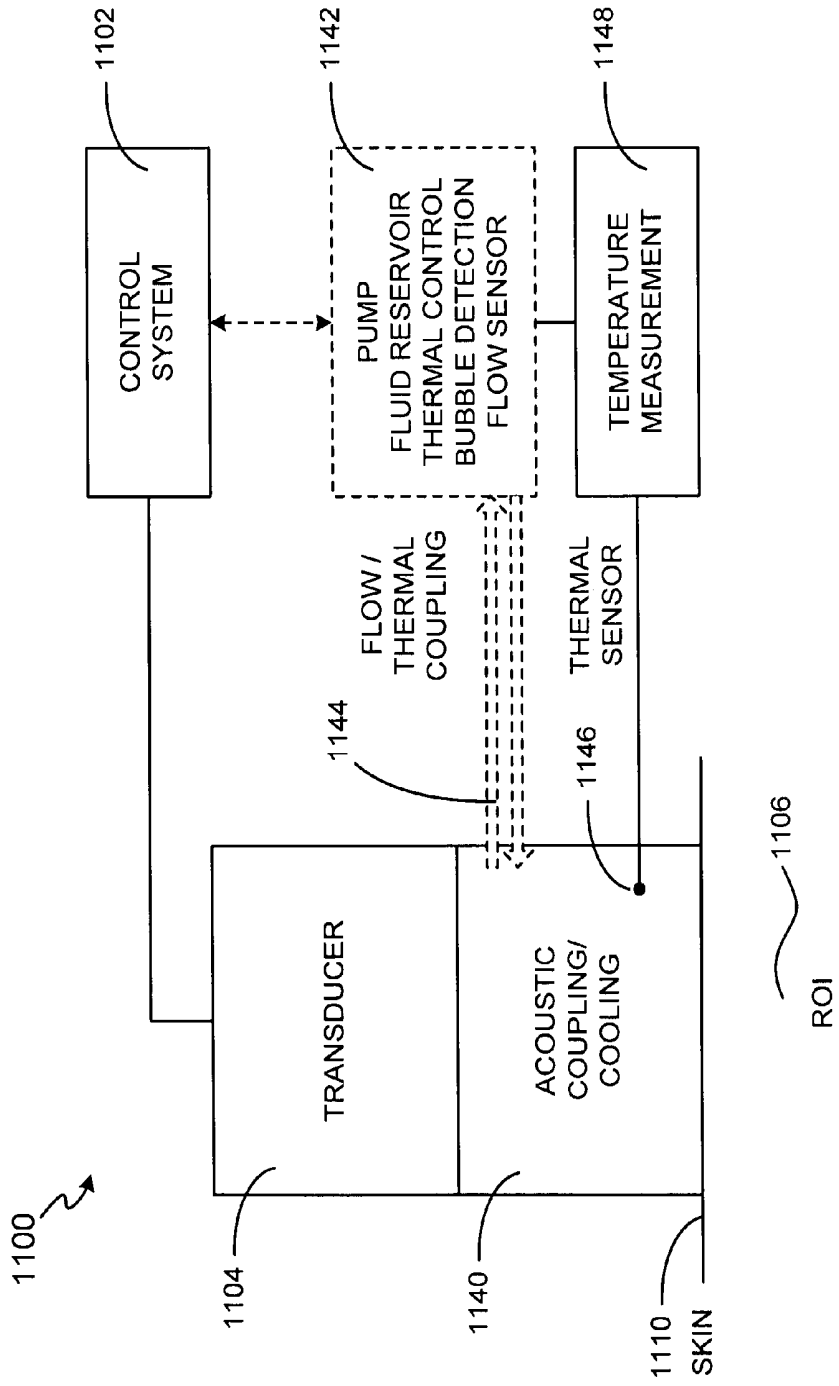
1100
1102
CONTROL SYSTEM
1142
PUMP
FLUID RESERVOIR
THERMAL CONTROL
BUBBLE DETECTION
FLOW SENSOR
1148
TEMPERATURE MEASUREMENT
1144
FLOW / THERMAL COUPLING
1146
THERMAL SENSOR
1106
ROI
TRANSDUCER
ACOUSTIC COUPLING/ COOLING
1104
1140
1110
SKIN

FIG. 11

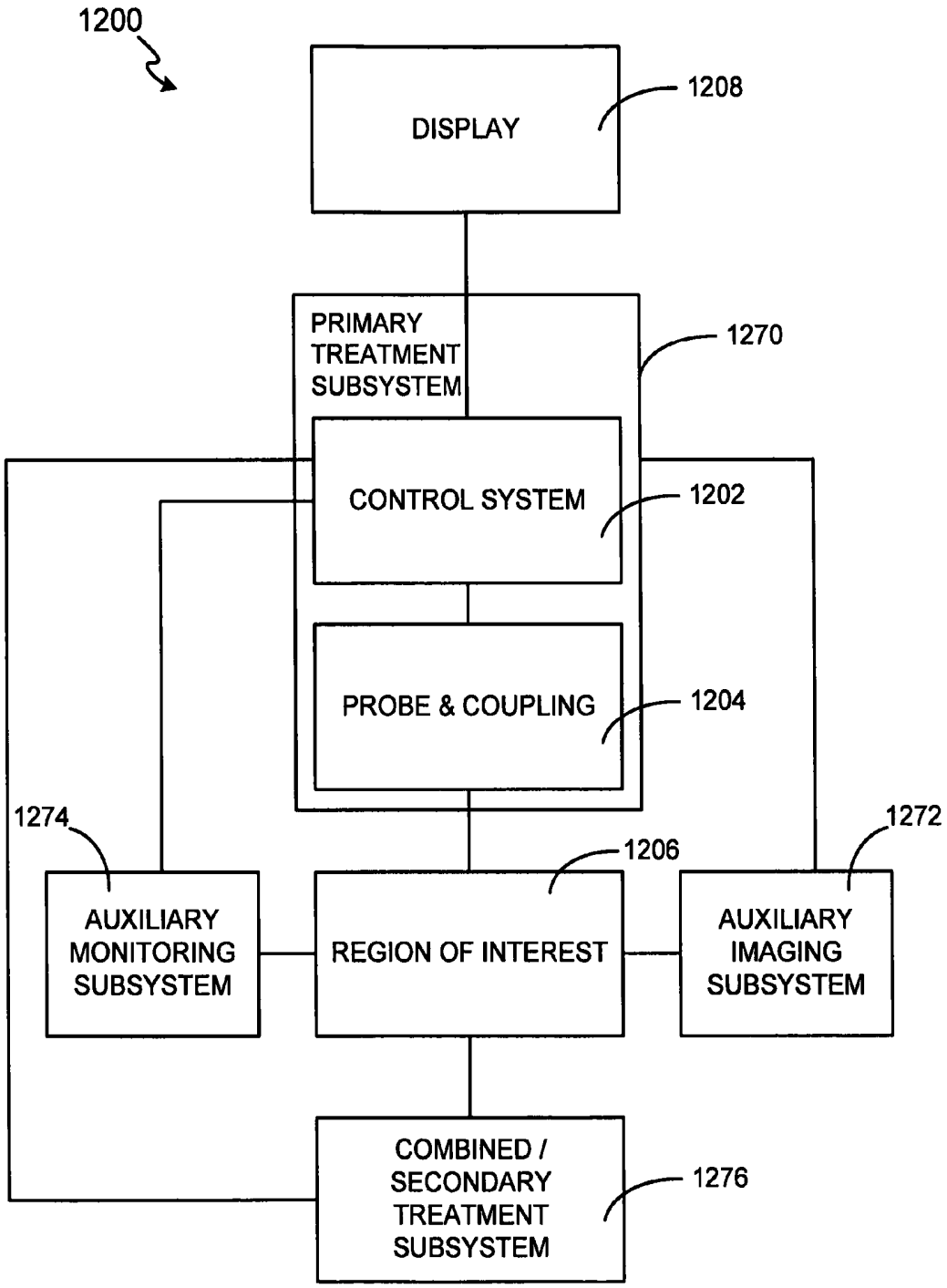
1200
DISPLAY
1208
PRIMARY TREATMENT SUBSYSTEM
1270
CONTROL SYSTEM
1202
PROBE & COUPLING
1204
1274
1272
1206
AUXILIARY MONITORING SUBSYSTEM
REGION OF INTEREST
AUXILIARY IMAGING SUBSYSTEM
COMBINED / SECONDARY TREATMENT SUBSYSTEM
1276

FIG. 12

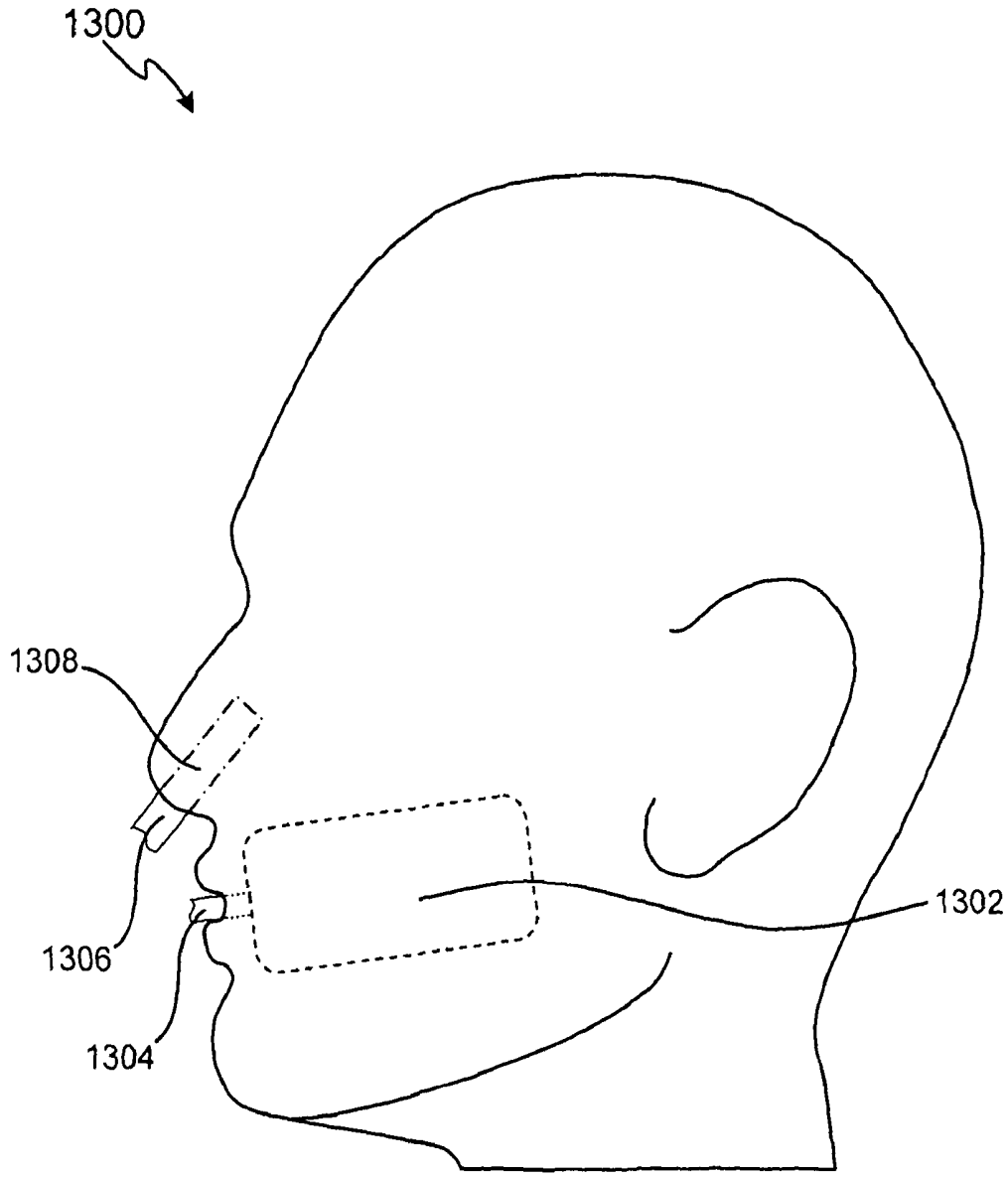

FIG. 13

ULTRASOUND PROBE FOR TREATING SKIN LAXITY

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/996,255, issued as U.S. Pat. No. 10,265,550, which is a continuation of U.S. patent application Ser. No. 15/821,070, issued as U.S. Pat. No. 10,010,724, which is a continuation of U.S. patent application Ser. No. 15/625,700, issued at U.S. Pat. No. 9,827,449, which is a continuation of U.S. patent application Ser. No. 15/248,407, issued as U.S. Pat. No. 9,694,211, which is a continuation of U.S. patent application Ser. No. 14/692,114, issued as U.S. Pat. No. 9,427,600, which is a continuation of U.S. patent application Ser. No. 14/169,709, issued as U.S. Pat. No. 9,039,619, which is a continuation of U.S. patent application Ser. No. 13/230,498, issued as U.S. Pat. No. 8,641,622, which is a continuation of U.S. patent application Ser. No. 11/163,150, issued as U.S. Pat. No. 8,066,641, which claims the benefit of priority to U.S. Provisional Application No. 60/617,295, each of which is incorporated in its entirety by reference herein. Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.

BACKGROUND

The present invention relates to ultrasound therapy and imaging systems, and in particular to a method and system for treating photoaged tissue.

Photoaging of human skin is a complex response due to inflammation, oxidative injury, cellular and extracellular changes induced by decades of sunlight exposure. UV wavelengths are thought to be mainly responsible. Both of the primary skin layers, epidermis and dermis, are affected. Epidermal photoaging includes pigmentary lesions called ephelides (freckles) and solar lentigines (larger pigmented spots), plus precancerous clonal lesions of keratinocytes called actinic keratoses. Thermal destruction of part or all of the epidermis, the outermost cellular layer of skin about 0.1 mm thick, is an effective treatment for epidermal photoaging. For example, lasers that vaporize epidermis are highly effective in a treatment called laser resurfacing. However laser resurfacing creates a significant skin wound with risk of infection, and prolonged healing. Dermal changes of photoaging include solar elastosis (an accumulation of abnormally-formed elastin fibers in the upper reticular layer of the dermis), laxity, loss of elasticity, fine and coarse wrinkles. Laser resurfacing to a depth below the dermoepidermal junction can be highly effective for improving dermal photoaging, through a process of stimulated wound healing. Deep chemical peels, dermabrasion and other methods of destruction of epidermis and/or dermis are also effective, and also produce a significant open skin wound with risk of infection and delayed healing.

Patterns of stimulated thermal damage to epidermis and/or dermis are also effective for treatment of photoaging. Recently, "fractional photothermolysis" using mid-infrared lasers to produce a microscopic array of thermal injury zones that include both epidermis and dermis was reported to be effective and well-tolerated for treatment of photoaging (D. Manstein et al. "Fractional Photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal injury." Lasers Surg Med 34:426-438, 2004). A primary advantage of fractional photothermolysis is that each zone of thermal injury is smaller than can be easily seen with the unaided eye, and surrounded by a zone of healthy tissue that initiates a rapid healing response. As described Manstein, the epidermis is stimulated to heal rapidly and without creating an open wound. The microscopic zones of thermally injured epidermis slough harmlessly from the skin surface after several days to several weeks, leaving a rejuvenated epidermis with less photoaging changes. Repeat treatments, which are well tolerated, can be performed until a desired result is obtained. The microscopic zones of thermal injury with fractional photothermolysis extend well into the dermis, as well. Dermis does not heal as rapidly as epidermis, in general. Over weeks to months following treatment, some of the abnormal dermis due to photoaging is remodeled, however, leading to improvement in laxity, wrinkles and skin texture.

Fractional photothermolysis (FP) is intrinsically limited to regions of approximately the upper 1-millimeter of skin. The basic concept of producing well-controlled arrays of thermal injury is therefore limited with fractional photothermolysis, to superficial aspects of photoaging. Aging, which also causes laxity of the skin, and photoaging involve deeper layers of the dermis. Solar elastosis can extend throughout the dermis, to approximately 3 mm deep or more. Laxity and loss of elasticity due to aging are bulk problems of the dermis.

A fundamental requirement for producing arrays of small thermal injury zones using a source of radiant energy that propagates and is absorbed within tissue, is that the source of radiant energy be capable of being adequately delivered to the tissue depth for which the array is desired. Near the skin surface, light can be used, as in fractional photothermolysis. However, light that propagates more than about 1 mm through skin has been multiplied scattered, and can no longer be focused or delivered.

SUMMARY

A method and system for ultrasound treatment of photoaged tissue are provided. An exemplary method and system are configured for first, ultrasound imaging of the region of interest for localization of the treatment area, second, delivery of ultrasound energy at a depth and pattern to achieve the desired therapeutic effects, and third to monitor the treatment area during and after therapy to assess the results and/or provide feedback. The exemplary treatment method and system can be configured for producing arrays of sub-millimeter and larger zones of thermal ablation to treat the epidermal, superficial dermal, mid-dermal and deep dermal components of photoaged tissue.

In accordance with an exemplary embodiment, the treatment method and system use focused, unfocused, and/or defocused ultrasound for treatment of epidermal, superficial dermal, dermal, mid-dermal, and/or deep dermal components of photoaged tissue by adjusting the strength, depth, and/or type of focusing, energy levels and timing cadence. For example, focused ultrasound can be used to create precise arrays of microscopic thermal damage much deeper into the skin or even into subcutaneous structures. Detection of changes in the reflection of ultrasound can be used for feedback control to detect a desired effect on the tissue and used to control the exposure intensity, time, and/or position.

In accordance with an exemplary embodiment, an exemplary treatment system comprises an imaging/therapy probe, a control system and display system. The imaging/therapy probe can comprise various probe and/or transducer con-

figurations. For example, the probe can be configured for a combined dual-mode imaging/therapy transducer, coupled or co-housed imaging/therapy transducers, a separate therapy probe and imaging probe, or a single therapy probe. The control system and display system can also comprise various configurations for controlling probe and system functionality, including for example a microprocessor with software and a plurality of input/output and communication devices, a system for controlling electronic and/or mechanical scanning and/or multiplexing of transducers, a system for power delivery, systems for monitoring, systems for sensing the spatial position of the probe and/or temporal parameters of the transducers, and systems for handling user input and recording treatment input and results, among others.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the invention is particularly pointed out in the concluding portion of the specification. The invention, however, both as to organization and method of operation, may best be understood by reference to the following description taken in conjunction with the accompanying drawing figures, in which like parts may be referred to by like numerals:

FIG. **1** illustrates a block diagram of a treatment system in accordance with an exemplary embodiment of the present invention;

FIGS. **2**A-**2**D illustrates a schematic diagram of an ultrasound treatment system including therapy, imaging and/or monitoring and treating photoaged tissue in accordance with various exemplary embodiments of the present invention;

FIGS. **3**A and **3**B illustrate block diagrams of an exemplary control system in accordance with exemplary embodiments of the present invention;

FIGS. **4**A and **4**B illustrate block diagrams of an exemplary probe system in accordance with exemplary embodiments of the present invention;

FIG. **5** illustrates a cross-sectional diagram of an exemplary transducer in accordance with an exemplary embodiment of the present invention;

FIGS. **6**A and **6**B illustrate cross-sectional diagrams of an exemplary transducer in accordance with exemplary embodiments of the present invention;

FIG. **7** illustrates exemplary transducer configurations for ultrasound treatment in accordance with various exemplary embodiments of the present invention;

FIGS. **8**A and **8**B illustrate cross-sectional diagrams of an exemplary transducer in accordance with another exemplary embodiment of the present invention;

FIG. **9** illustrates an exemplary transducer configured as a two-dimensional, array for ultrasound treatment in accordance with an exemplary embodiment of the present invention;

FIGS. **10**A-**10**F illustrate cross-sectional diagrams of exemplary transducers in accordance with other exemplary embodiments of the present invention;

FIG. **11** illustrates a schematic diagram of an acoustic coupling and cooling system in accordance with an exemplary embodiment of the present invention;

FIG. **12** illustrates a block diagram of an ultrasound treatment system combined with additional subsystems and methods of treatment monitoring and/or treatment imaging as well as a secondary treatment subsystem in accordance with an exemplary embodiment of the present invention; and

FIG. **13** illustrates a schematic diagram with imaging, therapy, or monitoring being provided with one or more active or passive oral inserts in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

The present invention may be described herein in terms of various functional components and processing steps. It should be appreciated that such components and steps may be realized by any number of hardware components configured to perform the specified functions. For example, the present invention may employ various medical treatment devices, visual imaging and display devices, input terminals and the like, which may carry out a variety of functions under the control of one or more control systems or other control devices. In addition, the present invention may be practiced in any number of medical contexts and that the exemplary embodiments relating to a method and system for treating photoaged tissue as described herein are merely indicative of exemplary applications for the invention. For example, the principles, features and methods discussed may be applied to any medical application. Further, various aspects of the present invention may be suitably applied to other applications.

In accordance with various aspects of the present invention, a method and system for treating photoaged tissue are provided. For example, in accordance with an exemplary embodiment, with reference to FIG. **1**, an exemplary treatment system **100** configured to treat a region of interest (ROI) **106** comprises a control system **102**, an imaging/therapy probe with acoustic coupling **104**, and a display system **108**. Control system **102** and display **108** can comprise various configurations for controlling functionality of probe **104** and system **100**, including for example a microprocessor with software and a plurality of input/output and communication devices, a system for controlling electronic and/or mechanical scanning and/or multiplexing of transducers, a system for power delivery, systems for monitoring, systems for sensing the spatial position of the probe and/or temporal parameters of the transducers, and/or systems for handling user input and recording treatment input and results, among others. Imaging/therapy probe **104** can comprise various probe and/or transducer configurations. For example, probe **104** can be configured for a combined dual-mode imaging/therapy transducer, coupled or co-housed imaging/therapy transducers, a separate therapy probe and separate imaging probe, or a single therapy probe. In accordance with exemplary embodiments, imaging transducers may operate at frequencies from approximately 2 to 75 MHz or more, while therapy energy can be delivered at frequencies from approximately 2 to 50 MHz, with 2 MHz to 25 MHz being typical.

For the treatment of photoaged tissue, it is desirable to be able to produce well controlled arrays of microscopic zones of thermal injury not only near the surface of skin, but in the mid-dermis, and/or in the deep dermis. Thermal ablation of dermis at temperatures greater than about 60° C., capable of producing denaturation of tissue, is also desirable in such arrays of thermal lesions. Shrinkage of dermis due to thermal action results from tightening of the skin.

In contrast to optical or RF approaches, ultrasound energy propagates as a wave with relatively little scattering, over depths up to many centimeters in tissue depending on the ultrasound frequency. The focal spot size achievable with any propagating wave energy, depends on wavelength.

Ultrasound wavelength is equal to the acoustic velocity divided by the ultrasound frequency. Attenuation (absorption, mainly) of ultrasound by tissue also depends on frequency.

In accordance with an exemplary embodiment, the use of focused, unfocused, or defocused ultrasound for treatment of epidermal, superficial dermal, dermal, mid-dermal, and deep dermal components of photoaged tissue through adjustment of the strength, depth, and type of focusing, energy levels and timing cadence. For example, focused ultrasound can be used to create precise arrays of microscopic thermal ablation zones which have several advantages over fractional photothermolysis (FP). At high frequency and with superficial focusing or diffraction pattern, ultrasound ablation can mimic FP but utilize a simpler ablation device. Unlike fractional photothermolysis, ultrasound can produce an array of ablation zones much deeper into the skin or even into subcutaneous structures. Detection of changes in the reflection of ultrasound can be used for feedback control to detect a desired effect on the tissue and used to control the exposure intensity, time, and/or position.

To further illustrate the use of ultrasound for the treatment of photoaged tissue, with reference to FIG. **2**A, an exemplary method and system are configured for initially imaging a region **222** of a region of interest **206** and displaying that region **224** during the localization of the treatment area and surrounding structures. After localization, delivery of ultrasound energy **220** at a depth, distribution, timing, and energy level to achieve the desired therapeutic effect of thermal ablation to treat an epidermis layer **212**, superficial dermis layer **214**, mid-dermis layer **216**, and/or deep dermis layer **218** can be provided. Before, during, and after therapy, i.e., before, during, and after the delivery of ultrasound energy **220**, exemplary method and system **200** can suitably monitor the treatment area and surrounding structures to plan and assess the results and/or provide feedback to control system **202** and/or a system user.

While an imaging function may be configured within control system **202** to facilitate imaging a region of interest, in accordance with another exemplary embodiment, an exemplary treatment system **200** may also be configured for therapy only or therapy and monitoring, without imaging functions. In such a case prior known depth of the region of interest, approximately 0 to 5 mm or less, is employed to achieve treatment zones in photoaged skin.

Probe **204** and/or transducers within can be mechanically and/or electronically scanned in a direction **226** to place treatment zones **260** over an extended area, such as a line to generate a matrix of closely spaced treatment spots. Treatment depth **220** can be adjusted between a range of approximately 0 to 5 mm, or otherwise until the depth of the deep dermis. Treatment may be confined to a fixed depth or a few discrete depths, or can be adjustment limited to a fine range, e.g. from approximately between 0 to 5 mm or the greatest depth of the deep dermis, or can be dynamically adjusted during treatment, to the treat region of interest **206** that lies above subcutaneous fat region **250**.

In accordance with another exemplary embodiment of the present invention, with reference to FIG. **2**B, a treated zone **260** may extend throughout regions of the dermis, and may even extend to the epidermis, **262**. In addition, as a treated zone increases in depth its cross section may increase from small size **264** (sub millimeter) in a shallow region near or at the epidermis, to medium size **266** (sub millimeter to millimeter sized) in a middle zone near or at the mid dermis, to large size **268** (millimeter sized) in deep zones near or at the deep dermis. Furthermore a. single treated zone can have a shape expanding in cross section with depth, and/or be composed of the fusion of several smaller treatment zones. Spacing of treatment zones can be on the order of the treatment zone size. The ultrasound beam can be spatially and/or temporally controlled by changing the position of the transducer, its frequency, treatment depth, drive amplitude, and timing via the control system. For example, the ultrasound beam can be controlled as set forth in U.S. patent application Ser. No. 11/163,148, filed Oct. 6, 2005, and entitled METHOD AND SYSTEM FOR CONTROLLED THERMAL INJURY OF HUMAN SUPERFICIAL TISSUE, and hereby incorporated by reference.

In accordance with another exemplary embodiment of the present invention, with reference to FIG. **2**C, an exemplary treatment method and system **200** may be configured to monitor the temperature profile or other tissue parameters of region of interest **206**, such as attenuation or speed of sound of the treatment region and suitably adjust the spatial and/or temporal characteristics and energy levels of the ultrasound therapy transducer. The results of such monitoring techniques may be indicated on display **208**, such as through display of one-, two-, or three-dimensional images of monitoring results **270**, or may comprise an indicator **272**, such as a success, fail and/or completed/done type of indication, or combinations thereof. Additional treatment monitoring methods may be based on one or more of temperature, video, profilometry, strain imaging and/or gauges or any other suitable sensing method.

In accordance with another exemplary embodiment, with reference to FIG. **2**D, an expanded region of interest **280** can suitably include a combination of tissues, such as subcutaneous fat/adipose tissue **250**. A combination of such tissues includes at least one of epidermis **212**, superficial dermis **214**, mid dermis **216**, or deep dermis **218**, in combination with at least one of muscle tissue, adipose tissue, or other tissues useful for treatment. For example, treatment **260** of superficial dermis may be performed in combination with treatment **220** of subcutaneous fat **250** by suitable adjustment of the spatial and temporal parameters of transducers in probe **204**.

An exemplary control system **202** and display system **208** may be configured in various manners for controlling probe and system functionality for providing the various exemplary treatment methods illustrated above. For example, with reference to FIGS. **3**A and **3**B, in accordance with exemplary embodiments, an exemplary control system **300** can be configured for coordination and control of the entire therapeutic treatment process for producing arrays of submillimeter and larger zones of thermal ablation to treat the epidermal, superficial dermal, mid-dermal and deep dermal components of photoaged tissue. For example, control system **300** can suitably comprise power source components **302**, sensing and monitoring components **304**, cooling and coupling controls **306**, and/or processing and control logic components **308**. Control system **300** can be configured and optimized in a variety of ways with more or less subsystems and components to implement the therapeutic system for controlled thermal injury of photoaged tissue, and the embodiments in FIGS. **3**A and **3**B are merely for illustration purposes.

For example, for power sourcing components **302**, control system **300** can comprise one or more direct current (DC) power supplies **303** configured to provide electrical energy for entire control system **300**, including power required by a transducer electronic amplifier/driver **312**. A DC current

sense device **305** can also be provided to confirm the level of power going into amplifiers/drivers **312** for safety and monitoring purposes.

Amplifiers/drivers **312** can comprise multi-channel or single channel power amplifiers and/or drivers. In accordance with an exemplary embodiment for transducer array configurations, amplifiers/drivers **312** can also be configured with a beamformer to facilitate array focusing. An exemplary beamformer can be electrically excited by an oscillator/digitally controlled waveform synthesizer **310** with related switching logic.

The power sourcing components can also include various filtering configurations **314**. For example, switchable harmonic filters and/or matching may be used at the output of amplifier/driver **312** to increase the drive efficiency and effectiveness. Power detection components **316** may also be included to confirm appropriate operation and calibration. For example, electric power and other energy detection components **316** may be used to monitor the amount of power going to an exemplary probe system.

Various sensing and monitoring components **304** may also be suitably implemented within control system **300**. For example, in accordance with an exemplary embodiment, monitoring, sensing and interface control components **324** may be configured to operate with various motion detection systems implemented within transducer probe **204** to receive and process information such as acoustic or other spatial and temporal information from a region of interest. Sensing and monitoring components can also include various controls, interfacing and switches **309** and/or power detectors **316**. Such sensing and monitoring components **304** can facilitate open-loop and/or closed-loop feedback systems within treatment system **200**.

Cooling/coupling control systems **306** may be provided to remove waste heat from an exemplary probe **204**, provide a controlled temperature at the superficial tissue interface and deeper into tissue, and/or provide acoustic coupling from transducer probe **204** to region-of-interest **206**. Such cooling/coupling control systems **306** can also be configured to operate in both open-loop and/or closed-loop feedback arrangements with various coupling and feedback components.

Processing and control logic components **308** can comprise various system processors and digital control logic **307**, such as one or more of microcontrollers, microprocessors, field-programmable gate arrays (FPGAs), computer boards, and associated components, including firmware and control software **326**, which interfaces to user controls and interfacing circuits as well as input/output circuits and systems for communications, displays, interfacing, storage, documentation, and other useful functions. System software and firmware **326** controls all initialization, timing, level setting, monitoring, safety monitoring, and all other system functions required to accomplish user-defined treatment objectives. Further, various control switches **308** can also be suitably configured to control operation.

An exemplary transducer probe **204** can also be configured in various manners and comprise a number of reusable and/or disposable components and parts in various embodiments to facilitate its operation. For example, transducer probe **204** can be configured within any type of transducer probe housing or arrangement for facilitating the coupling of transducer to a tissue interface, with such housing comprising various shapes, contours and configurations. Transducer probe **204** can comprise any type of matching, such as for example, electric matching, which may be electrically switchable; multiplexer circuits and/or aperture/element selection circuits; and/or probe identification devices, to certify probe handle, electric matching, transducer usage history and calibration, such as one or more serial EEPROM (memories). Transducer probe **204** may also comprise cables and connectors; motion mechanisms, motion sensors and encoders; thermal monitoring sensors; and/or user control and status related switches, and indicators such as LEDs. For example, a motion mechanism in probe **204** may be used to controllably create multiple lesions, or sensing of probe motion itself may be used to controllably create multiple lesions and/or stop creation of lesions, e.g. for safety reasons if probe **204** is suddenly jerked or is dropped. In addition, an external motion encoder arm may be used to hold the probe during use, whereby the spatial position and attitude of probe **104** is sent to the control system to help controllably create lesions. Furthermore, other sensing functionality such as profilometers or other imaging modalities may be integrated into the probe in accordance with various exemplary embodiments.

With reference to FIGS. **4**A and **4**B, in accordance with an exemplary embodiment, a transducer probe **400** can comprise a control interface **402**, a transducer **404**, coupling components **406**, and monitoring/sensing components **408**, and/or motion mechanism **410**. However, transducer probe **400** can be configured and optimized in a variety of ways with more or less parts and components to provide ultrasound energy for controlled thermal injury of photoaged tissue, and the embodiments in FIGS. **4**A and **4**B are merely for illustration purposes.

Control interface **402** is configured for interfacing with control system **300** to facilitate control of transducer probe **400**. Control interface components **402** can comprise multiplexer/aperture select **424**, switchable electric matching networks **426**, serial EEPROMs and/or other processing components and matching and probe usage information **430** and interface connectors **432**.

Coupling components **406** can comprise various devices to facilitate coupling of transducer probe **400** to a region of interest. For example, coupling components **406** can comprise cooling and acoustic coupling system **420** configured for acoustic coupling of ultrasound energy and signals. Acoustic cooling/coupling system **420** with possible connections such as manifolds may be utilized to couple sound into the region-of-interest, control temperature at the interface and deeper into tissue, provide liquid-filled lens focusing, and/or to remove transducer waste heat. Coupling system **420** may facilitate such coupling through use of various coupling mediums, including air and other gases, water and other fluids, gels, solids, and/or any combination thereof, or any other medium that allows for signals to be transmitted between transducer active elements **412** and a region of interest. In addition to providing a coupling function, in accordance with an exemplary embodiment, coupling system **420** can also be configured for providing temperature control during the treatment application. For example, coupling system **420** can be configured for controlled cooling of an interface surface or deeper region between transducer probe **400** and a region of interest and beyond by suitably controlling the temperature of the coupling medium. The suitable temperature for such coupling medium can be achieved in various manners, and utilize various feedback systems, such as thermocouples, thermistors or any other device or system configured for temperature measurement of a coupling medium. Such controlled cooling can be configured to further facilitate spatial and/or thermal energy delivery control of transducer probe **400**.

In accordance with an exemplary embodiment, with additional reference to FIG. **11**, acoustic coupling and cooling **1140** can be provided to acoustically couple energy and imaging signals from transducer probe **1104** to and from the region of interest **1102**, to provide thermal control at the probe to region-of-interest interface **1110** and deeper into tissue, and to remove potential waste heat from the transducer probe at region **1144**. Temperature monitoring can be provided at the coupling interface via a thermal sensor **1146** to provide a mechanism of temperature measurement **1148** and control via control system **1106** and a thermal control system **1142**. Thermal control may consist of passive cooling such as via heat sinks or natural conduction and convection or via active cooling such as with peltier thermoelectric coolers, refrigerants, or fluid-based systems comprised of pump, fluid reservoir, bubble detection, flow sensor, flow channels/tubing **1144** and thermal control **1142**.

With continued reference to FIG. **4**, monitoring and sensing components **408** can comprise various motion and/or position sensors **416**, temperature monitoring sensors **418**, user control and feedback switches **414** and other like components for facilitating control by control system **300**, e.g., to facilitate spatial and/or temporal control through open-loop and closed-loop feedback arrangements that monitor various spatial and temporal characteristics.

Motion mechanism **410** can comprise manual operation, mechanical arrangements, or some combination thereof. For example, a motion mechanism **422** can be suitably controlled by control system **300**, such as through the use of accelerometers, encoders or other position/orientation devices **416** to determine and enable movement and positions of transducer probe **400**. Linear, rotational or variable movement can be facilitated, e.g., those depending on the treatment application and tissue contour surface.

Transducer **404** can comprise one or more transducers configured for treating of SMAS layers and targeted regions. Transducer **404** can also comprise one or more transduction elements and/or lenses **412**. The transduction elements can comprise a piezoelectrically active material, such as lead zirconate titanate (PZT), or any other piezoelectrically active material, such as a piezoelectric ceramic, crystal, plastic, and/or composite materials, as well as lithium niobate, lead titanate, barium titanate, and/or lead metaniobate. In addition to, or instead of, a piezoelectrically active material, transducer **404** can comprise any other materials configured for generating radiation and/or acoustical energy. Transducer **404** can also comprise one or more matching layers configured along with the transduction element such as coupled to the piezoelectrically active material. Acoustic matching layers and/or damping may be employed as necessary to achieve the desired electroacoustic response.

In accordance with an exemplary embodiment, the thickness of the transduction element of transducer **404** can be configured to be uniform. That is, a transduction element **412** can be configured to have a thickness that is substantially the same throughout. In accordance with another exemplary embodiment, the thickness of a transduction element **412** can also be configured to be variable. For example, transduction element(s) **412** of transducer **404** can be configured to have a first thickness selected to provide a center operating frequency of approximately 2 kHz to 75 MHz, such as for imaging applications. Transduction element **412** can also be configured with a second thickness selected to provide a center operating frequency of approximately 2 to 50 MHz, and typically between 2 MHz and 25 MHz for therapy application. Transducer **404** can be configured as a single broadband transducer excited with at least two or more frequencies to provide an adequate output for generating a desired response. Transducer **404** can also be configured as two or more individual transducers, wherein each transducer comprises one or more transduction element. The thickness of the transduction elements can be configured to provide center-operating frequencies in a desired treatment range.

Transducer **404** may be composed of one or more individual transducers in any combination of focused, planar, or unfocused single-element, multi-element, or array transducers, including 1-D, 2-D, and annular arrays; linear, curvilinear, sector, or spherical arrays; spherically, cylindrically, and/or electronically focused, defocused, and/or lensed sources. For example, with reference to an exemplary embodiment depicted in FIG. **5**, transducer **500** can be configured as an acoustic array **502** to facilitate phase focusing. That is, transducer **500** can be configured as an array of electronic apertures that may be operated by a variety of phases via variable electronic time delays. By the term "operated," the electronic apertures of transducer **500** may be manipulated, driven, used, and/or configured to produce and/or deliver an energy beam corresponding to the phase variation caused by the electronic time delay. For example, these phase variations can be used to deliver defocused beams **508**, planar beams **504**, and/or focused beams **506**, each of which may be used in combination to achieve different physiological effects in a region of interest **510**. Transducer **500** may additionally comprise any software and/or other hardware for generating, producing and/or driving a phased aperture array with one or more electronic time delays.

Transducer **500** can also be configured to provide focused treatment to one or more regions of interest using various frequencies. In order to provide focused treatment, transducer **500** can be configured with one or more variable depth devices to facilitate treatment. For example, transducer **500** may be configured with variable depth devices disclosed in U.S. patent application Ser. No. 10/944,500, entitled "System and Method for Variable Depth Ultrasound", filed on Sep. 16, 2004, having at least one common inventor and a common Assignee as the present application, and incorporated herein by reference. In addition, transducer **500** can also be configured to treat one or more additional ROI **510** through the enabling of sub-harmonics or pulse echo imaging, as disclosed in U.S. patent application Ser. No. 10/944,499, entitled "Method and System for Ultrasound Treatment with a Multi-directional Transducer," filed on Sep. 16, 2004, having at least one common inventor and a common Assignee as the present application, and also incorporated herein by reference.

Moreover, any variety of mechanical lenses or variable focus lenses, e.g. liquid-filled lenses, may also be used to focus and/or defocus the sound field. For example, with reference to exemplary embodiments depicted in FIGS. **6**A and **6**B, transducer **600** may also be configured with an electronic focusing array **604** in combination with one or more transduction elements **606** to facilitate increased flexibility in treating ROI **610**. Array **604** may be configured in a manner similar to transducer **502**. That is, array **604** can be configured as an array of electronic apertures that may be operated by a variety of phases via variable electronic time delays, for example, T**1**, T**2** . . . Tj. By the term "operated," the electronic apertures of array **604** may be manipulated, driven, used, and/or configured to produce and/or deliver energy in a manner corresponding to the phase variation caused by the electronic time delay. For example, these phase variations can be used to deliver defocused beams,

planar beams, and/or focused beams, each of which may be used in combination to achieve different physiological effects in ROI **610**.

Transduction elements **606** may be configured to be concave, convex, and/or planar. For example, in an exemplary embodiment depicted in FIG. **6**A, transduction elements **606** are configured to be concave in order to provide focused energy for treatment of ROI **610**. Additional embodiments are disclosed in U.S. patent application Ser. No. 10/944,500, entitled "Variable Depth Transducer System and Method", and again incorporated herein by reference.

In another exemplary embodiment, depicted in FIG. **6**B, transduction elements **606** can be configured to be substantially flat in order to provide substantially uniform energy to ROI **610**. While FIGS. **6**A and **6**B depict exemplary embodiments with transduction elements **604** configured as concave and substantially flat, respectively, transduction elements **604** can be configured to be concave, convex, and/or substantially flat. In addition, transduction elements **604** can be configured to be any combination of concave, convex, and/or substantially flat structures. For example, a first transduction element can be configured to be concave, while a second transduction element can be configured to be substantially flat.

With reference to FIGS. **8**A and **8**B, transducer **404** can be configured as single-element arrays, wherein a single-element **802**, e.g., a transduction element of various structures and materials, can be configured with a plurality of masks **804**, such masks comprising ceramic, metal or any other material or structure for masking or altering energy distribution from element **802**, creating an array of energy distributions **808**. Masks **804** can be coupled directly to element **802** or separated by a standoff **806**, such as any suitably solid or liquid material.

An exemplary transducer **404** can also be configured as an annular array to provide planar, focused and/or defocused acoustical energy. For example, with reference to FIGS. **10**A and **10**B, in accordance with an exemplary embodiment, an annular array **1000** can comprise a plurality of rings **1012**, **1014**, **1016** to N. Rings **1012**, **1014**, **1016** to N can be mechanically and electrically isolated into a set of individual elements, and can create planar, focused, or defocused waves. For example, such waves can be centered on-axis, such as by methods of adjusting corresponding transmit and/or receive delays, T**1**, T**2**, T**3** . . . TN. An electronic focus can be suitably moved along various depth positions, and can enable variable strength or beam tightness, while an electronic defocus can have varying amounts of defocusing. In accordance with an exemplary embodiment, a lens and/or convex or concave shaped annular array **1000** can also be provided to aid focusing or defocusing such that any time differential delays can be reduced. Movement of annular array **800** in one, two or three-dimensions, or along any path, such as through use of probes and/or any conventional robotic arm mechanisms, may be implemented to scan and/or treat a volume or any corresponding space within a region of interest.

Transducer **404** can also be configured in other annular or non-array configurations for imaging/therapy functions. For example, with reference to FIGS. **10**C-**10**F, a transducer can comprise an imaging element **1012** configured with therapy element(s) **1014**. Elements **1012** and **1014** can comprise a single-transduction element, e.g., a combined imaging/transducer element, or separate elements, can be electrically isolated **1022** within the same transduction element or between separate imaging and therapy elements, and/or can comprise standoff **1024** or other matching layers, or any combination thereof. For example, with particular reference to FIG. **10**F, a transducer can comprise an imaging element **1012** having a surface **1028** configured for focusing, defocusing or planar energy distribution, with therapy elements **1014** including a stepped-configuration lens configured for focusing, defocusing, or planar energy distribution.

In accordance with various exemplary embodiments of the present invention, transducer **404** may be configured to provide one, two and/or three-dimensional treatment applications for focusing acoustic energy to one or more regions of interest. For example, as discussed above, transducer **404** can be suitably diced to form a one-dimensional array, e.g., transducer **602** comprising a single array of sub-transduction elements.

In accordance with another exemplary embodiment, transducer **404** may be suitably diced in two-dimensions to form a two-dimensional array. For example, with reference to FIG. **9**, an exemplary two-dimensional array **900** can be suitably diced into a plurality of two-dimensional portions **902**. Two-dimensional portions **902** can be suitably configured to focus on the treatment region at a certain depth, and thus provide respective slices **904**, **907** of the treatment region. As a result, the two-dimensional array **900** can provide a two-dimensional slicing of the image place of a treatment region, thus providing two-dimensional treatment.

In accordance with another exemplary embodiment, transducer **404** may be suitably configured to provide three-dimensional treatment. For example, to provide three-dimensional treatment of a region of interest, with reference again to FIG. **1**, a three-dimensional system can comprise a transducer within probe **104** configured with an adaptive algorithm, such as, for example, one utilizing three-dimensional graphic software, contained in a control system, such as control system **102**. The adaptive algorithm is suitably configured to receive two-dimensional imaging, temperature and/or treatment or other tissue parameter information relating to the region of interest, process the received information, and then provide corresponding three-dimensional imaging, temperature and/or treatment information.

In accordance with an exemplary embodiment, with reference again to FIG. **9**, an exemplary three-dimensional system can comprise a two-dimensional array **900** configured with an adaptive algorithm to suitably receive **904** slices from different image planes of the treatment region, process the received information, and then provide volumetric information **906**, e.g., three-dimensional imaging, temperature and/or treatment information. Moreover, after processing the received information with the adaptive algorithm, the two-dimensional array **900** may suitably provide therapeutic heating to the volumetric region **906** as desired.

In accordance with other exemplary embodiments, rather than utilizing an adaptive algorithm, such as three-dimensional software, to provide three-dimensional imaging and/or temperature information, an exemplary three-dimensional system can comprise a single transducer **404** configured within a probe arrangement to operate from various rotational and/or translational positions relative to a target region.

To further illustrate the various structures for transducer **404**, with reference to FIG. **7**, ultrasound therapy transducer **700** can be configured for a single focus, an array of foci, a locus of foci, a line focus, and/or diffraction patterns. Transducer **700** can also comprise single elements, multiple elements, annular arrays, one-, two-, or three-dimensional arrays, broadband transducers, and/or combinations thereof, with or without lenses, acoustic components, and mechani-

cal and/or electronic focusing. Transducers configured as spherically focused single elements **702**, annular arrays **704**, annular arrays with damped regions **706**, line focused single elements **708**, 1-D linear arrays **710**, 1-D curvilinear arrays in concave or convex form, with or without elevation focusing, 2-D arrays, and 3-D spatial arrangements of transducers may be used to perform therapy and/or imaging and acoustic monitoring functions. For any transducer configuration, focusing and/or defocusing may be in one plane or two planes via mechanical focus **720**, convex lens **722**, concave lens **724**, compound or multiple lenses **726**, planar form **728**, or stepped form, such as illustrated in FIG. **10**F. Any transducer or combination of transducers may be utilized for treatment. For example, an annular transducer may be used with an outer portion dedicated to therapy and the inner disk dedicated to broadband imaging wherein such imaging transducer and therapy transducer have different acoustic lenses and design, such as illustrated in FIG. **10**C-**10**F.

Moreover, such transduction elements **700** may comprise a piezoelectrically active material, such as lead zirconate titanate (PZT), or any other piezoelectrically active material, such as a piezoelectric ceramic, crystal, plastic, and/or composite materials, as well as lithium niobate, lead titanate, barium titanate, and/or lead metaniobate. Transduction elements **700** may also comprise one or more matching layers configured along with the piezoelectrically active material. In addition to or instead of piezoelectrically active material, transduction elements **700** can comprise any other materials configured for generating radiation and/or acoustical energy. A means of transferring energy to and from the transducer to the region of interest is provided.

In accordance with another exemplary embodiment, with reference to FIG. **12**, an exemplary treatment system **200** can be configured with and/or combined with various auxiliary systems to provide additional functions. For example, an exemplary treatment system **1200** for treating a region of interest **1202** can comprise a control system **1206**, a probe **1204**, and a display **1208**. Treatment system **1200** further comprises an auxiliary imaging modality **1272** and/or auxiliary monitoring modality **1274** may be based upon at least one of photography and other visual optical methods, magnetic resonance imaging (MRI), computed tomography (CT), optical coherence tomography (OCT), electromagnetic, microwave, or radio frequency (RF) methods, positron emission tomography (PET), infrared, ultrasound, acoustic, or any other suitable method of visualization, localization, or monitoring of epidermal, superficial dermal, mid-dermal and deep dermal components within the region-of-interest **1202**, including imaging/monitoring enhancements. Such imaging/monitoring enhancement for ultrasound imaging via probe **1204** and control system **1206** could comprise M-mode, persistence, filtering, color, Doppler, and harmonic imaging among others; furthermore an ultrasound treatment system **1270**, as a primary source of treatment, may be combined with a secondary source of treatment **1276**, including radio frequency (RF), intense pulsed light (IPL), laser, infrared laser, microwave, or any other suitable energy source.

In accordance with another exemplary embodiment, with reference to FIG. **13**, treatment composed of imaging, monitoring, and/or therapy to a region of interest **1302** and/or **1308** may be aided, augmented, and/or delivered with passive or active devices **1304** and/or **1306** within the oral and/or nasal cavity, respectively. For example, if passive or active device **1304** and/or **1306** are second transducers or acoustic reflectors acoustically coupled to the mucous membranes it is possible to obtain through transmission, tomographic, or round-trip acoustic waves which are useful for treatment monitoring, such as in measuring acoustic speed of sound and attenuation, which are temperature dependent; furthermore such transducers could be used to treat and/or image. In addition an active, passive, or active/passive object **1304** and/or **1306** may be used to flatten the skin, and/or may be used as an imaging grid, marker, or beacon, to aid determination of position. A passive or active device **1304** and/or **1306** may also be used to aid cooling or temperature control. Natural air in the oral cavity and/or nasal cavity may also be used as passive device **1304** and/or **1306** whereby it may be utilized to as an acoustic reflector to aid thickness measurement and monitoring function.

The present invention has been described above with reference to various exemplary embodiments. However, those skilled in the art will recognize that changes and modifications may be made to the exemplary embodiments without departing from the scope of the present invention. For example, the various operational steps, as well as the components for carrying out the operational steps, may be implemented in alternate ways depending upon the particular application or in consideration of any number of cost functions associated with the operation of the system, e.g., various of the steps may be deleted, modified, or combined with other steps. These and other changes or modifications are intended to be included within the scope of the present invention, as set forth in the following claims.

What is claimed is:

1. An ultrasound probe, comprising:

a housing comprising a motion mechanism and a piezoelectric focused ultrasound transducer,

wherein the piezoelectric focused ultrasound transducer is configured to provide a focus,

wherein the focus is configured to provide ultrasound therapy energy in a form of a thermal focus in a tissue at a depth below a skin surface,

wherein the depth is at a fixed depth below the skin surface to treat the tissue,

wherein the tissue comprises a muscle tissue and any of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, and an adipose tissue,

wherein the thermal focus is formed without a lens,

wherein a portion of the housing is configured for acoustic coupling to the skin surface;

wherein the piezoelectric focused ultrasound transducer is configured for delivery of the ultrasound therapy energy at a temperature sufficient to tighten at least a portion of the tissue at the depth under the skin surface,

wherein the piezoelectric focused ultrasound transducer is connected to the motion mechanism,

wherein the motion mechanism is configured to operate with an encoder, wherein the motion mechanism is configured to move the piezoelectric focused ultrasound transducer to form a plurality of thermal lesions at the depth for tightening at least a portion of the tissue for reducing skin laxity.

2. The ultrasound probe of claim **1**, wherein the ultrasound probe is disposable,

wherein the piezoelectric focused ultrasound transducer is configured to increase the temperature of the tissue to greater than 60° C.,

wherein the piezoelectric focused ultrasound transducer delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz.

3. The ultrasound probe of claim 1, further comprising a piezoelectric ultrasound imaging element co-housed with the piezoelectric focused ultrasound transducer.

4. The ultrasound probe of claim 1, wherein the ultrasound probe is reusable, wherein the housing is configured for connection to a control system,

wherein the control system comprises a microprocessor and a communication device,

wherein the ultrasound transducer is electrically connected to the control system via a cable.

5. The ultrasound probe of claim 1, further comprising an EEPROM to store and record probe identification and usage history,

wherein the ultrasound therapy energy is configured to deliver an energy level for causing at least one of shrinking collagen and denaturing the tissue proximate a wrinkle,

wherein the piezoelectric focused ultrasound transducer delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz.

6. The ultrasound probe of claim 1, wherein the piezoelectric focused ultrasound transducer is configured to connect to a control system and a power supply,

wherein the control system is connected to the motion mechanism, the piezoelectric focused ultrasound transducer, and a power supply,

wherein the power supply is connected to the control system,

wherein the control system comprises a spatial control and a temporal control,

wherein the spatial control and the temporal control are configured for controlling the delivery of the ultrasound therapy energy at a temperature sufficient to cause denaturation of at least the portion of the tissue at the depth under the skin surface,

wherein the spatial control and the temporal control are configured for controlling the delivery of the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz.

7. An ultrasound probe, comprising:

an ultrasound transducer in a housing, the ultrasound transducer being piezoelectric and configured for delivery of a focused ultrasound therapy energy at a temperature sufficient to heat at least a portion of a tissue at a depth in a region of interest under a skin surface,

wherein the tissue comprises a muscle tissue and any one or more of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, and an adipose tissue;

wherein the ultrasound transducer is configured to provide at least one focus,

wherein the at least one focus is configured to provide ultrasound therapy energy in a form of a thermal focus in the tissue at the depth below a skin surface,

wherein the thermal focus is formed without a lens,

wherein the ultrasound transducer is configured for delivery of the ultrasound therapy energy at the temperature sufficient to heat the at least a portion of the tissue at the depth under the skin surface,

wherein the ultrasound transducer forms a plurality of thermal lesions at the depth for reducing an appearance of skin laxity.

8. The ultrasound probe of claim 7, further comprising a storage system comprising probe identification and probe usage history, wherein the region of interest comprises the tissue, wherein the skin surface comprises a wrinkle, and wherein the plurality of thermal lesions tightens the tissue.

9. The ultrasound probe of claim 7, further comprising a piezoelectric ultrasound imaging element co-housed with the ultrasound transducer, wherein the ultrasound transducer delivers the ultrasound therapy energy at a frequency of between 2 MHz to 50 MHz.

10. The ultrasound probe of claim 7, wherein the ultrasound probe is reusable, wherein the ultrasound transducer is configured for communication with a control system, wherein the ultrasound transducer is connected to the control system via a cable, and wherein the control system comprises:

a communication device;

a processor, software, an input device, and a power supply.

11. The ultrasound probe of claim 7,

wherein the ultrasound transducer delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz,

wherein the ultrasound transducer is configured to increase the temperature of the tissue in the region of interest to greater than 60° C.,

wherein the ultrasound probe is disposable,

and wherein the ultrasound probe comprises a storage system for transducer usage history and calibration.

12. An ultrasound probe, comprising:

a housing and a piezoelectric ultrasound transducer, wherein the piezoelectric ultrasound transducer is inside the housing,

wherein the piezoelectric ultrasound transducer is configured to provide a focus,

wherein the focus is configured to provide ultrasound therapy energy in a form of a thermal focus in a tissue at a depth below a skin surface,

wherein the depth is up to 5 mm below the skin surface,

wherein the tissue comprises a muscle tissue and any of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, and an adipose tissue,

wherein the thermal focus is formed without a lens,

wherein the piezoelectric ultrasound transducer is configured for delivery of the ultrasound therapy energy at a temperature sufficient to denature at least a portion of the tissue under the skin surface,

wherein the piezoelectric ultrasound transducer forms a plurality of thermal lesions at the depth for tightening the tissue for reducing skin laxity.

13. The ultrasound probe of claim 12, further comprising a control system and a power supply;

wherein the piezoelectric ultrasound transducer is in communication with the control system,

wherein the ultrasound transducer is connected to the control system via a cable,

wherein the skin surface comprises a wrinkle.

14. The ultrasound probe of claim 12, further comprising an acoustic coupler between the ultrasound transducer and the skin surface, wherein the piezoelectric ultrasound transducer delivers ultrasound energy at a frequency of between 2 MHz to 25 MHz.

15. The ultrasound probe of claim 12, wherein the ultrasound probe is disposable, wherein the piezoelectric ultrasound transducer is configured to increase the temperature of the tissue to greater than 60° C.

16. The ultrasound probe of claim 12, further comprising a storage system and a piezoelectric ultrasound imaging element, wherein the storage system records probe usage

history, and wherein the piezoelectric ultrasound imaging element is co-housed with the piezoelectric ultrasound transducer in the housing.

17. The ultrasound probe of claim **12**, further comprising a monitoring system,

wherein the monitoring system is configured to monitor a treatment parameter,

wherein the treatment parameter measured comprises the temperature of the tissue below the skin surface.

18. The ultrasound probe of claim **12**, further comprising a motion mechanism configured to operate with an encoder, wherein the motion mechanism is configured for movement of the piezoelectric ultrasound transducer to form a plurality of thermal lesions at the depth in the tissue.

19. The ultrasound probe of claim **12**, further comprising a motion mechanism configured to operate with an encoder, wherein the motion mechanism is configured for any one of the group consisting of linear, rotational, and variable movement of the piezoelectric ultrasound transducer.

20. The ultrasound probe of claim **12**, further comprising a motion mechanism configured to operate with an encoder for monitoring a position of the piezoelectric ultrasound transducer,

wherein the piezoelectric ultrasound transducer comprises a single element that delivers the ultrasound therapy energy at a frequency between 2 MHz to 25 MHz,

wherein the piezoelectric ultrasound therapy element is configured to focus the ultrasound therapy energy at the depth below the skin surface.

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专利名称(译)	超声波探头治疗皮肤松弛		
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当前申请(专利权)人(译)	引导治疗系统，L.L.C.		
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摘要(译)

提供了一种用于皮肤松弛的超声治疗的探针。 系统和方法可以包括对感兴趣区域进行超声成像以定位治疗区域，以一定深度和模式传递超声能量以实现所需的治疗效果，和/或监视治疗区域以评估结果和/或提供反馈。 在一个实施例中，治疗系统和方法可以被配置用于产生亚毫米和更大的热消融区域的阵列，以治疗组织的表皮，表皮，中层或深层皮肤成分。