



(19) **United States**

(12) **Patent Application Publication**
Meier

(10) **Pub. No.: US 2019/0142377 A1**

(43) **Pub. Date: May 16, 2019**

(54) **HANDHELD IMAGING DEVICES AND RELATED METHODS**

A61B 8/0833 (2013.01); *A61B 8/4477* (2013.01); *A61B 8/462* (2013.01); *A61B 8/0841* (2013.01); *A61B 8/4281* (2013.01); *A61B 8/4422* (2013.01); *A61B 8/54* (2013.01)

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(57) **ABSTRACT**

(21) Appl. No.: **16/243,302**

(22) Filed: **Jan. 9, 2019**

A monitoring device can be configured to facilitate intra-tissue inspection of a probe at a target region, the monitoring device comprising a housing and a transducer coupled to and at least partially located within the housing. The transducer comprises a longitudinal transducer array aligned to scan a longitudinal cross-section of the target region and a transverse transducer array aligned to scan a transverse cross-section of the target region. The longitudinal transducer array is configured to detect a probe point depth of a probe point of the probe along the longitudinal cross-section. The longitudinal transducer array is also configured to send to a processor longitudinal data about the scan of the longitudinal cross-section to track movement of the probe point based upon at least the longitudinal data and determine the probe point depth based upon at least the longitudinal data. The transverse transducer array is configured to send to the processor transverse data about the scan of the transverse cross-section to determine a transverse cross-section view of the transverse cross-section and determine, concurrently with the transverse cross-section view, a location of a probe point highlight of the probe point of the probe at a longitudinal coordinate of the transverse cross-section view, the longitudinal coordinate corresponding to the probe point depth based upon at least the longitudinal data. Other examples, embodiments, and related methods are described herein.

Related U.S. Application Data

(60) Division of application No. 14/703,708, filed on May 4, 2015, now Pat. No. 10,206,657, which is a continuation of application No. 12/837,342, filed on Jul. 15, 2010, now Pat. No. 9,022,940, said application No. 14/703,708 is a continuation-in-part of application No. 12/176,194, filed on Jul. 18, 2008, now abandoned.

(60) Provisional application No. 61/352,350, filed on Jun. 7, 2010.

Publication Classification

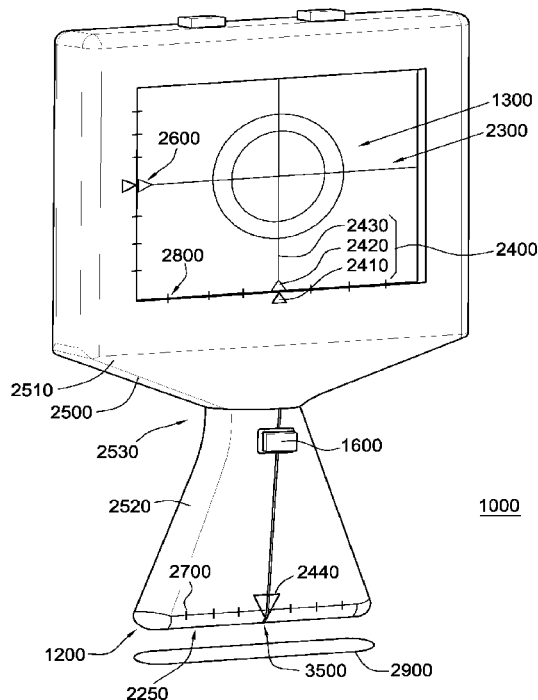
(51) **Int. Cl.**

A61B 8/00 (2006.01)

A61B 8/08 (2006.01)

(52) **U.S. Cl.**

CPC *A61B 8/4427* (2013.01); *A61B 8/56* (2013.01); *A61B 8/5223* (2013.01); *A61B 8/481* (2013.01); *A61B 8/4494* (2013.01); *A61B 8/00* (2013.01); *A61B 8/4472* (2013.01);



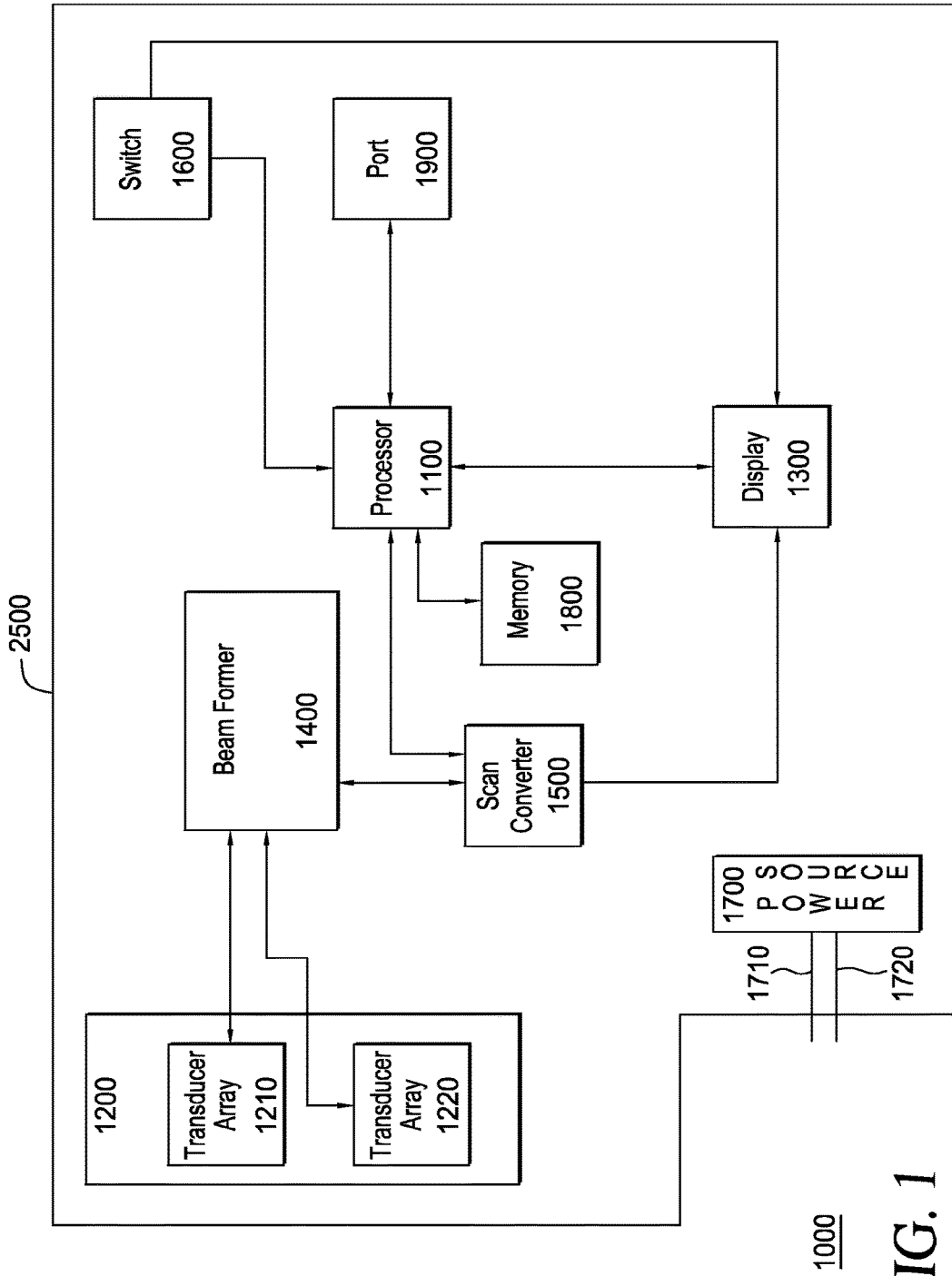
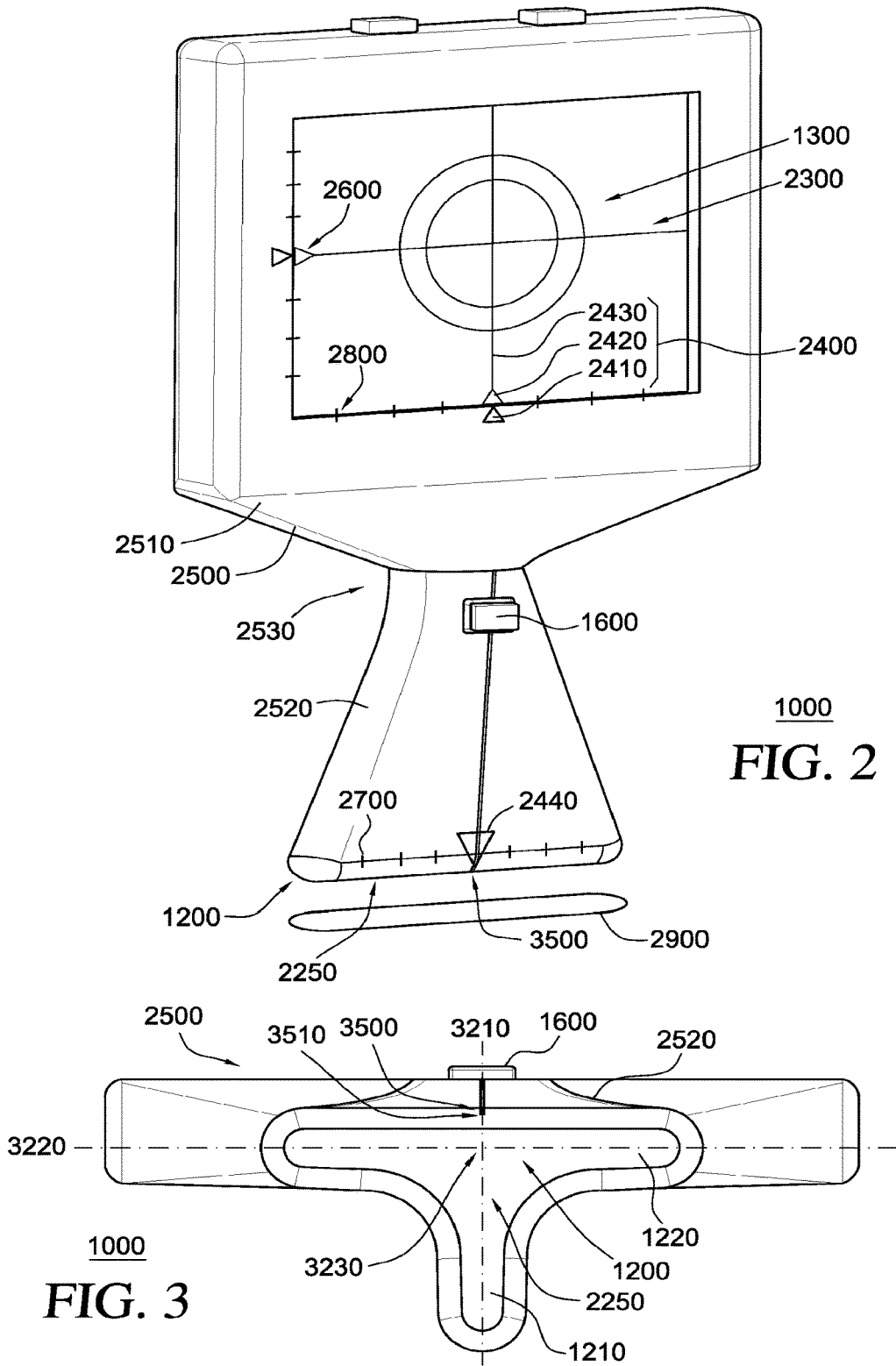


FIG. 1



1000
FIG. 2

1000
FIG. 3

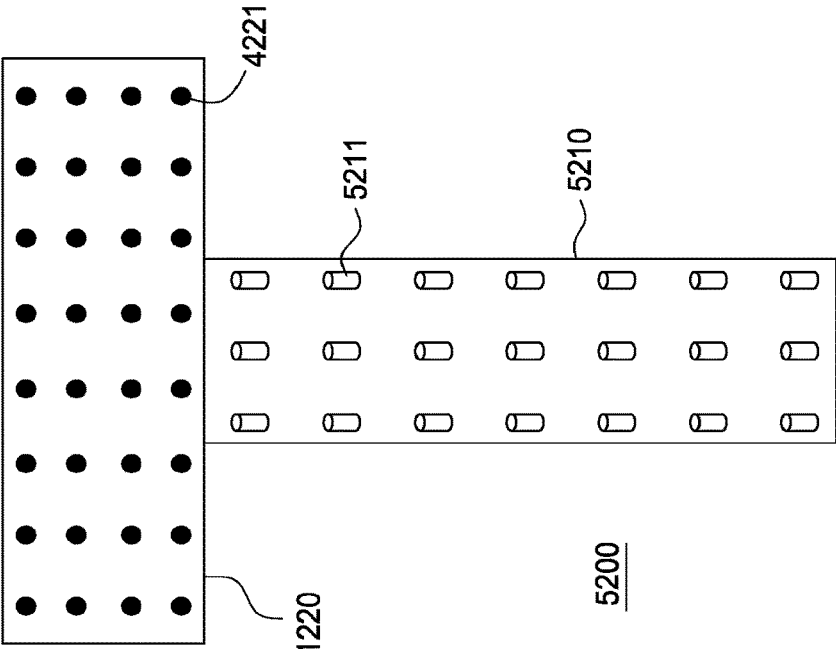


FIG. 5

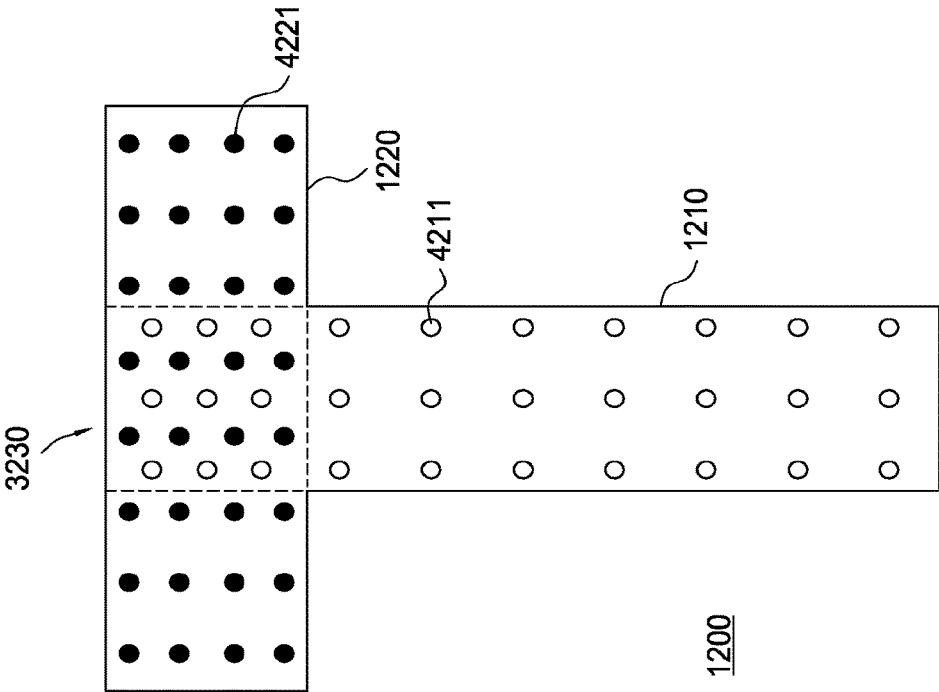
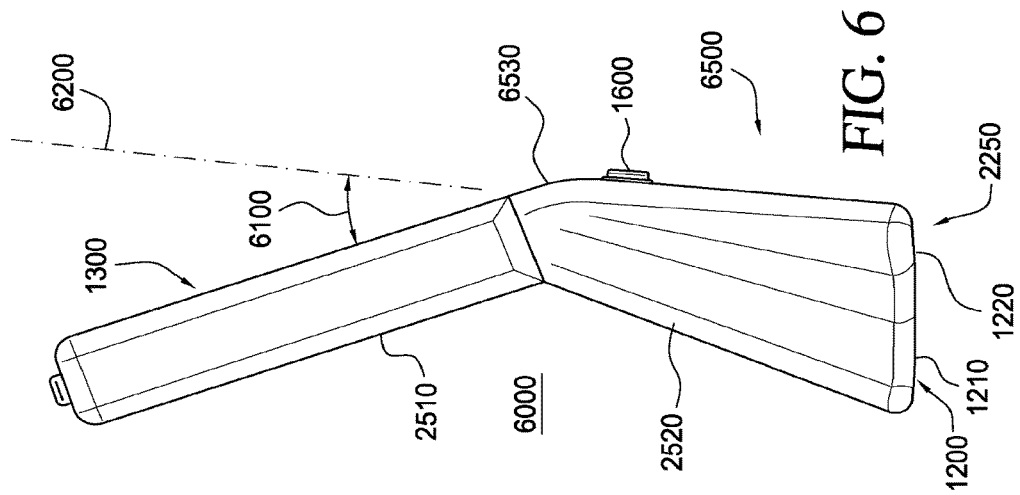
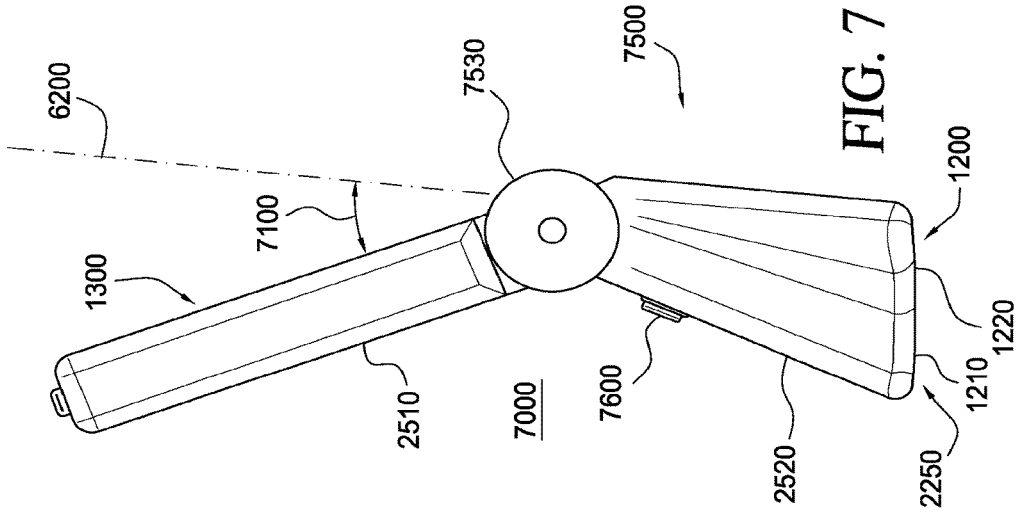


FIG. 4



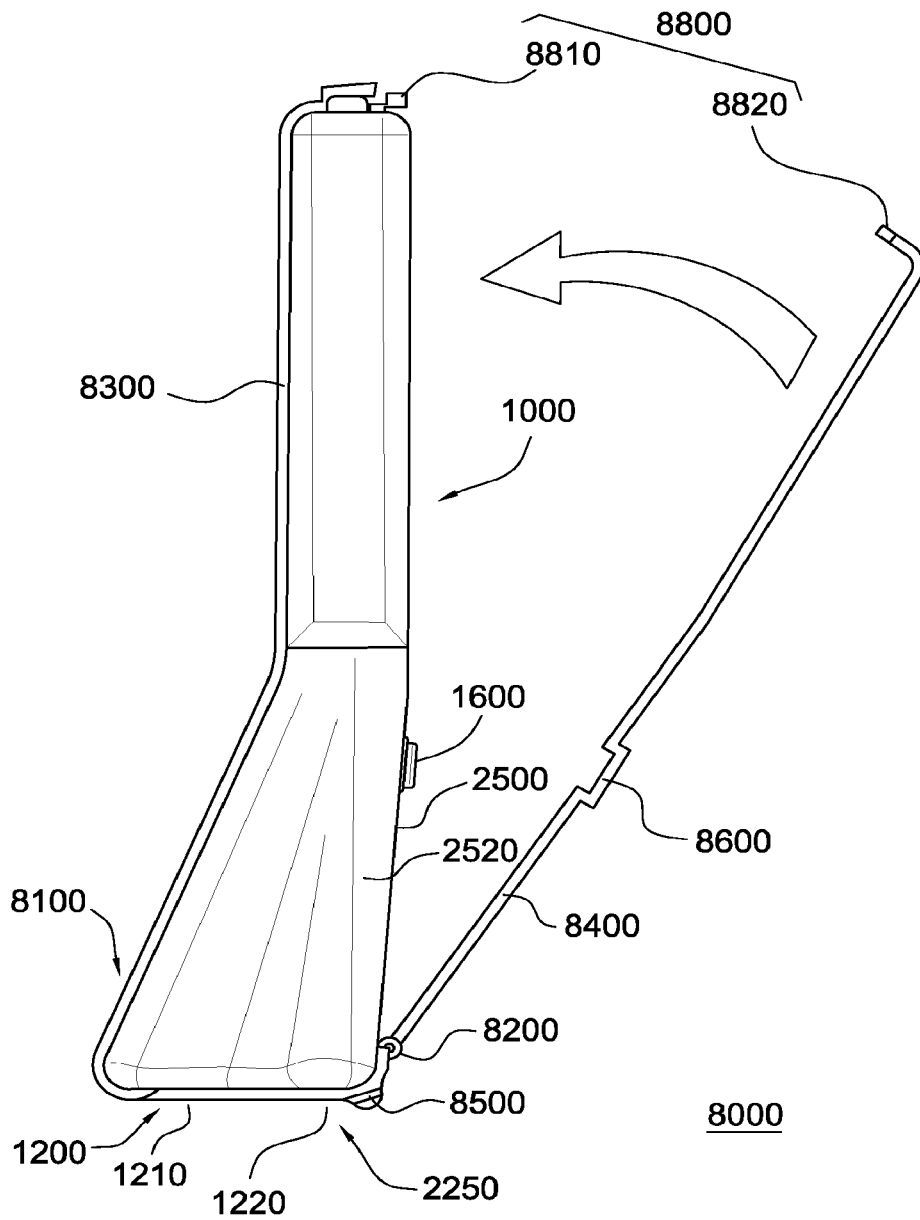


FIG. 8

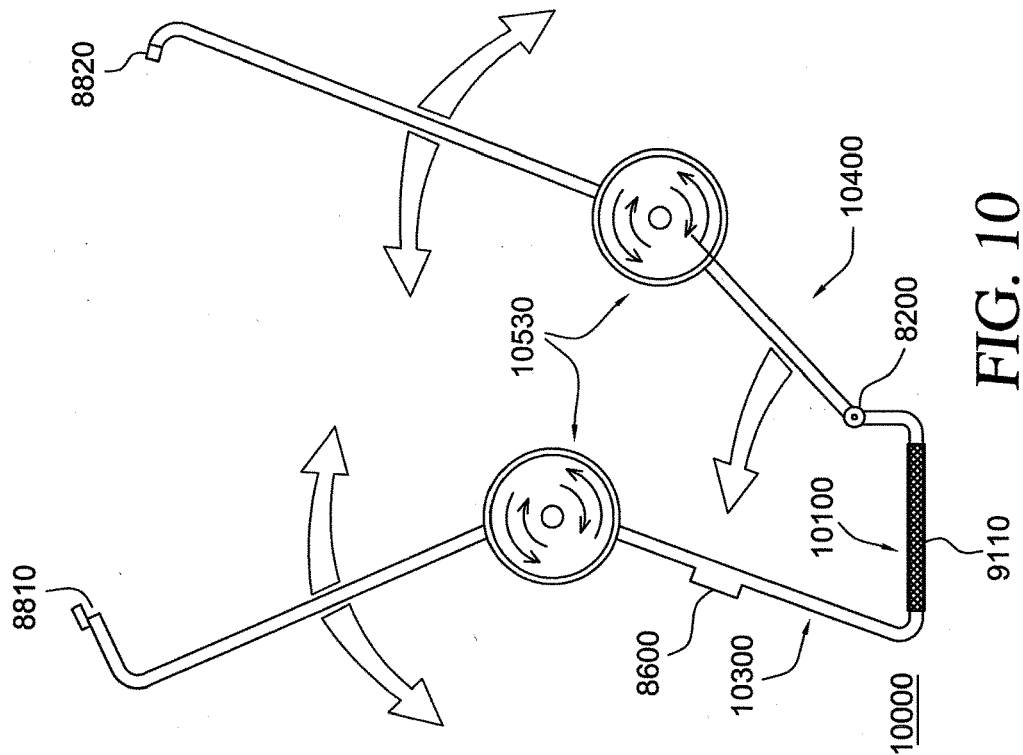


FIG. 10

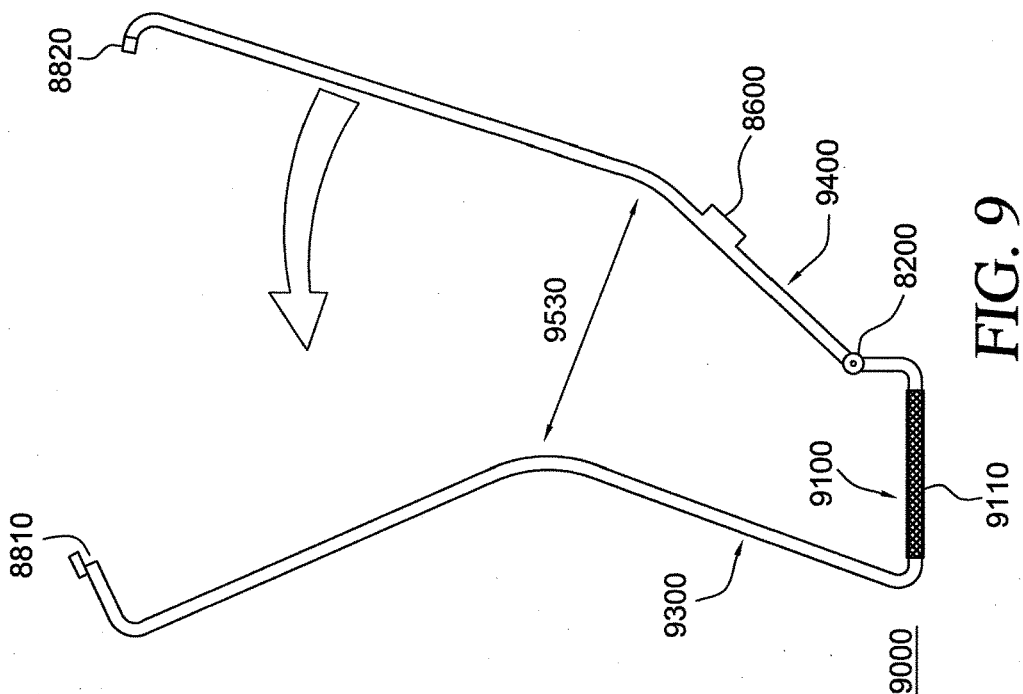


FIG. 9

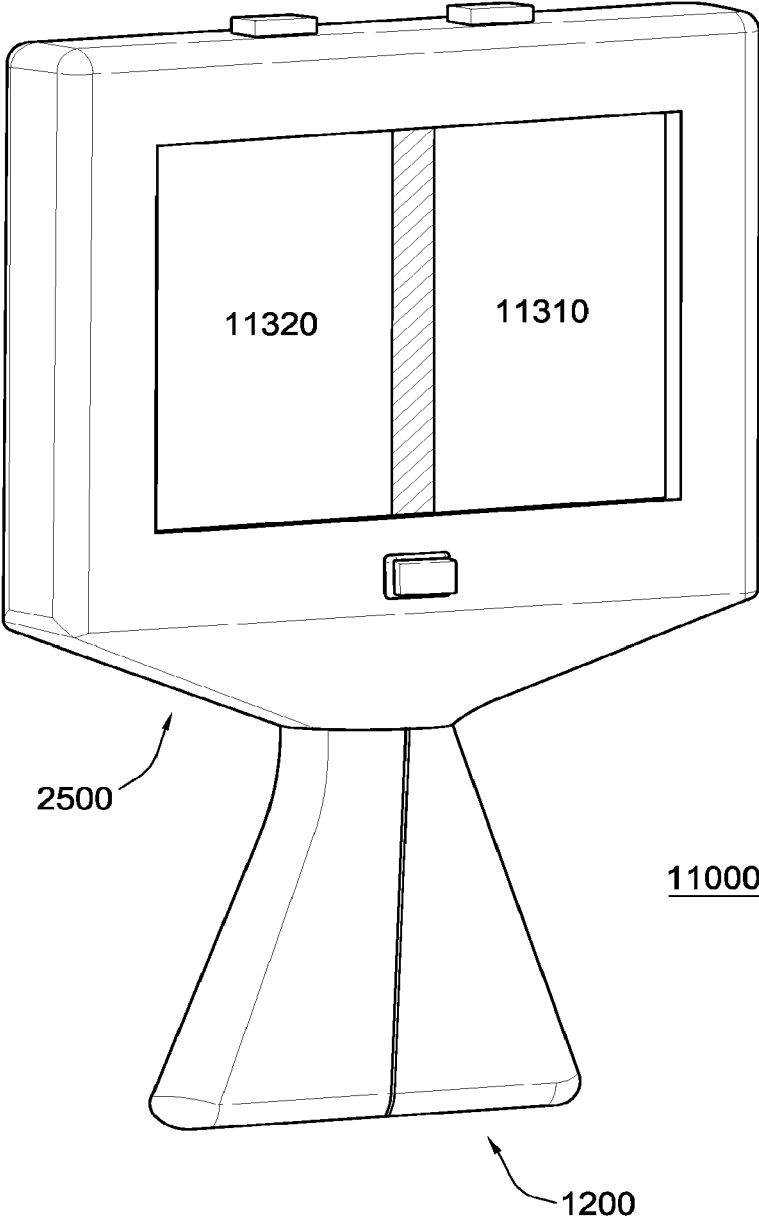
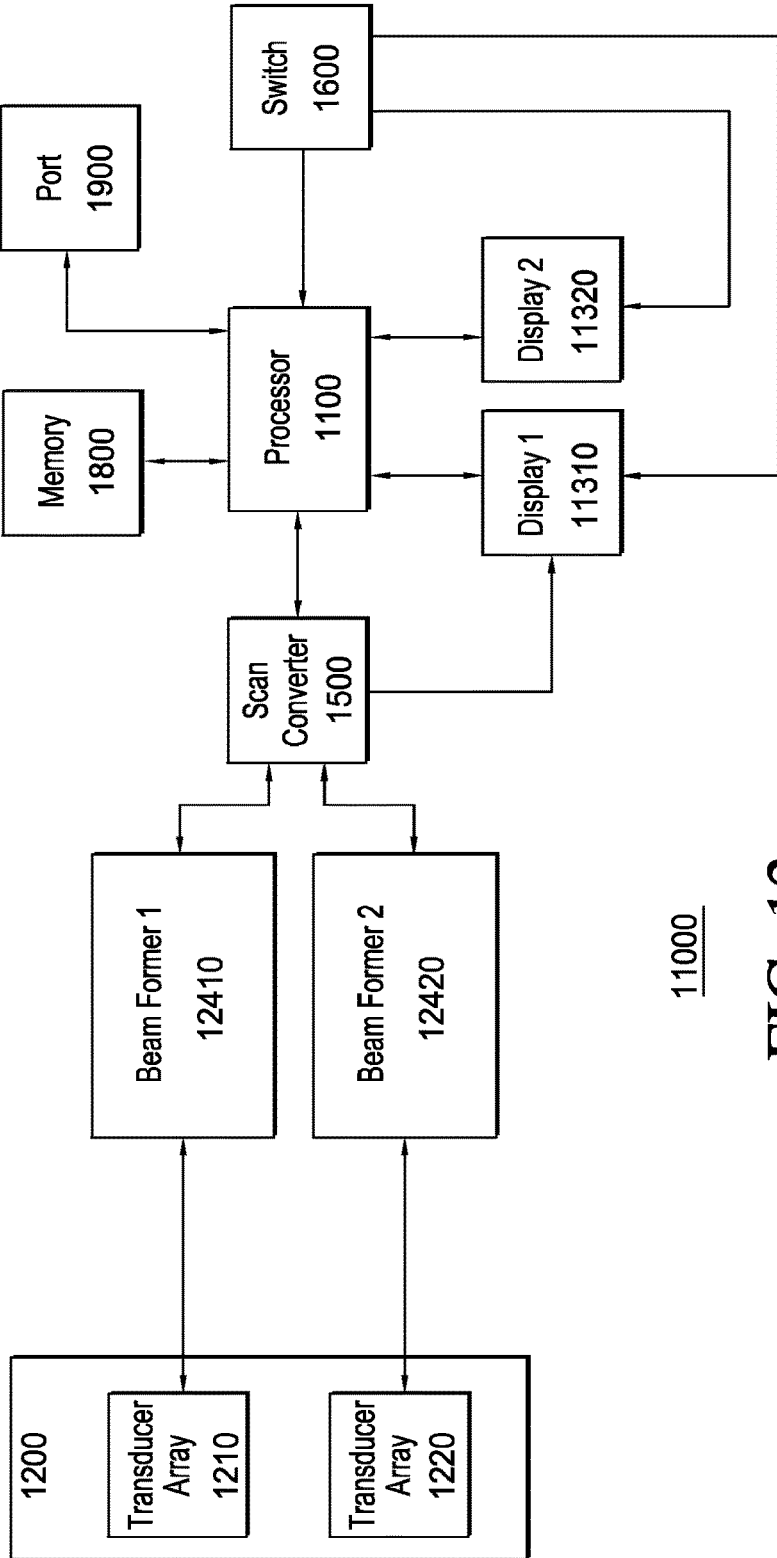


FIG. 11



11000

FIG. 12

13000

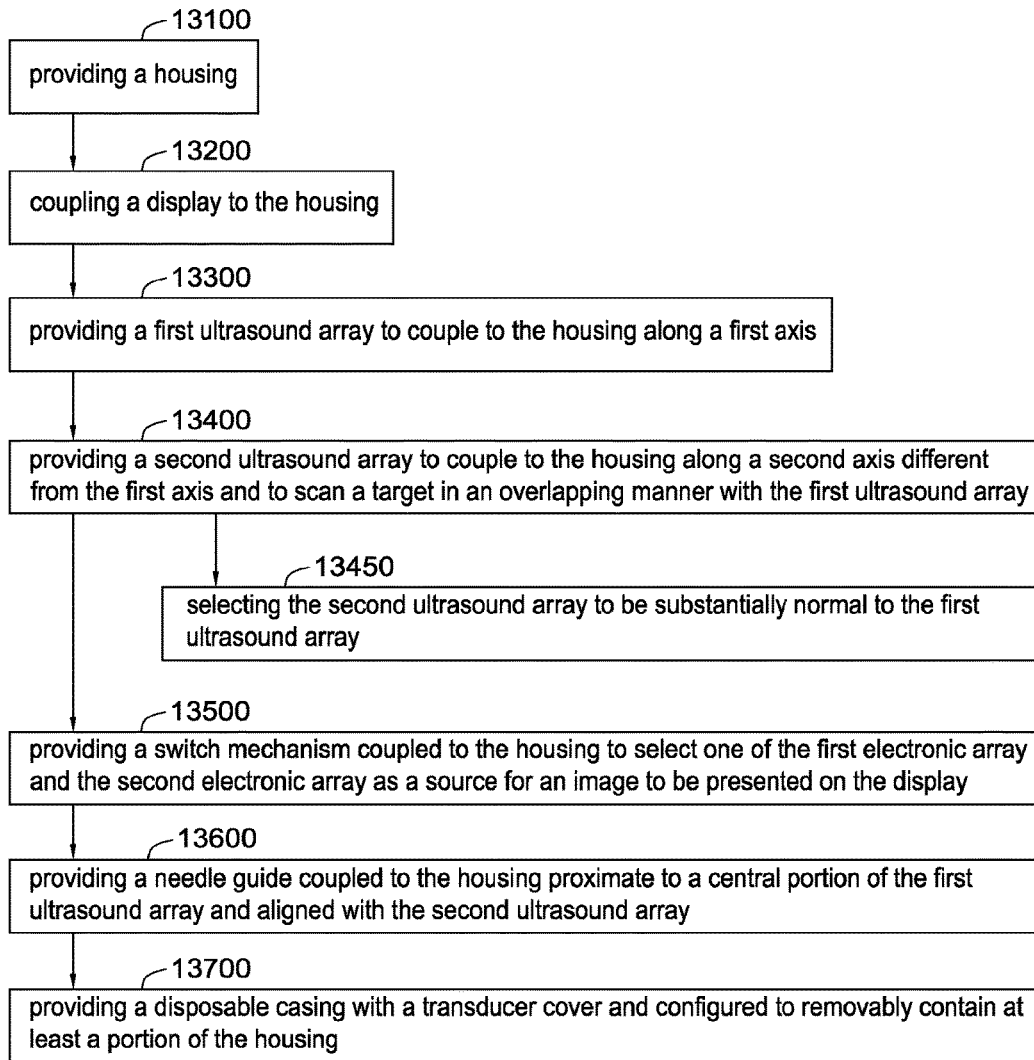


FIG. 13

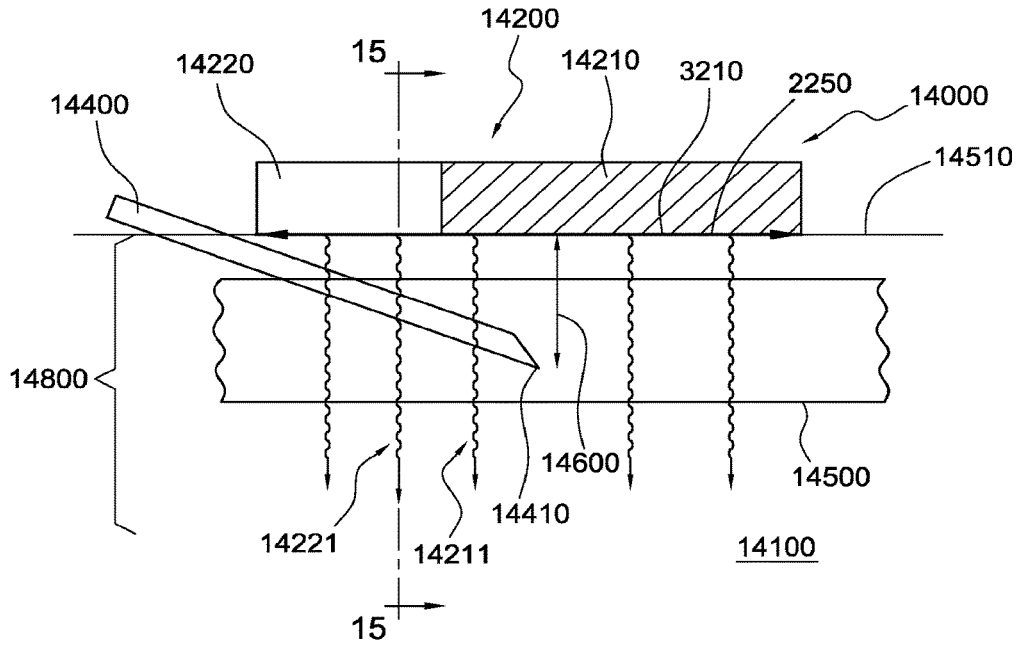


FIG. 14

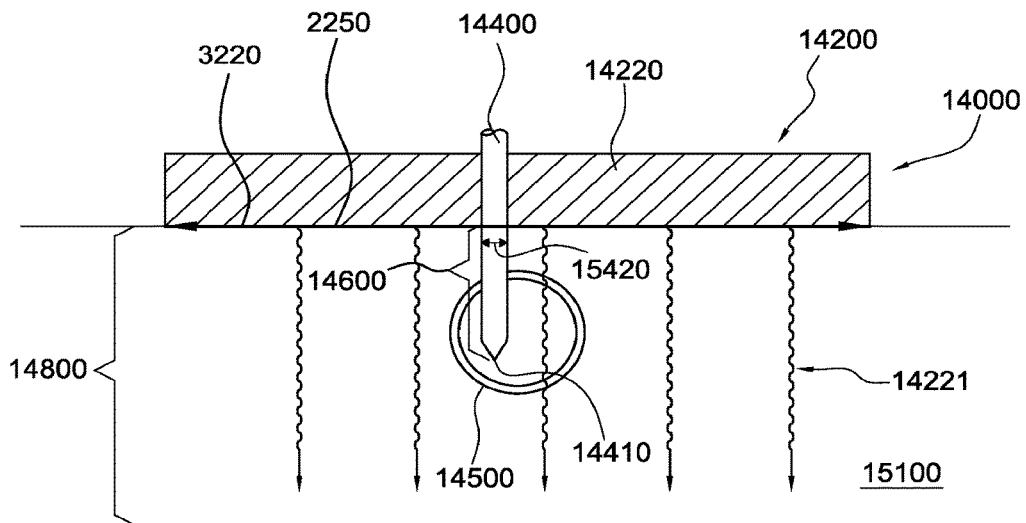


FIG. 15

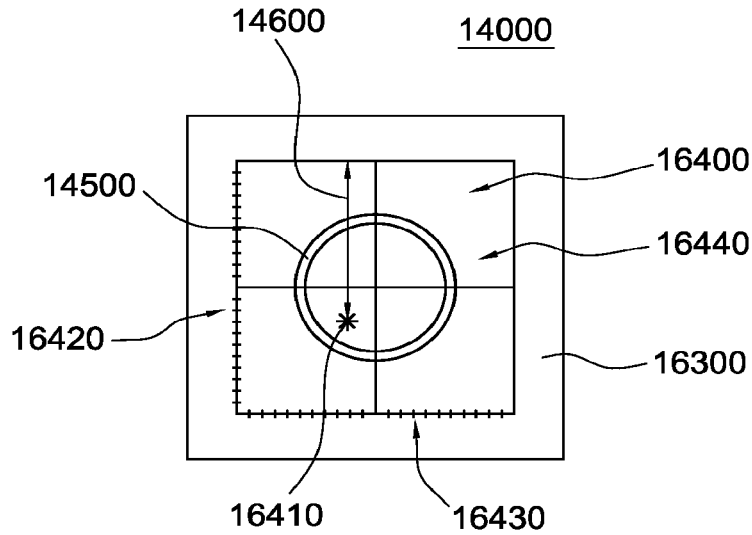


FIG. 16

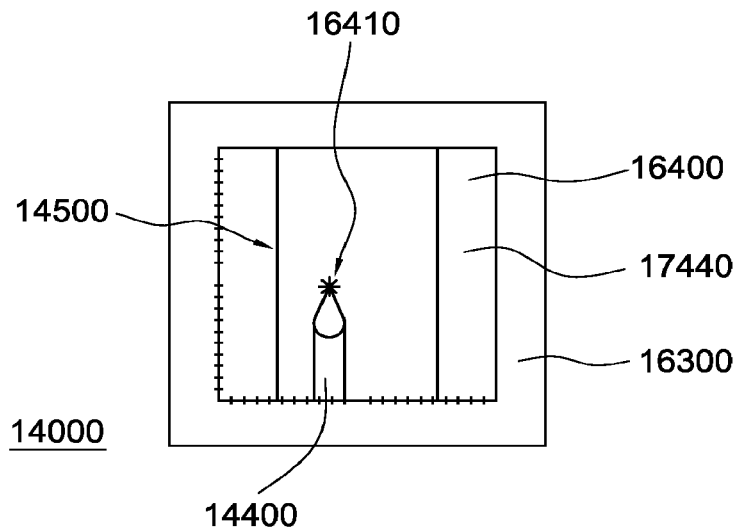


FIG. 17

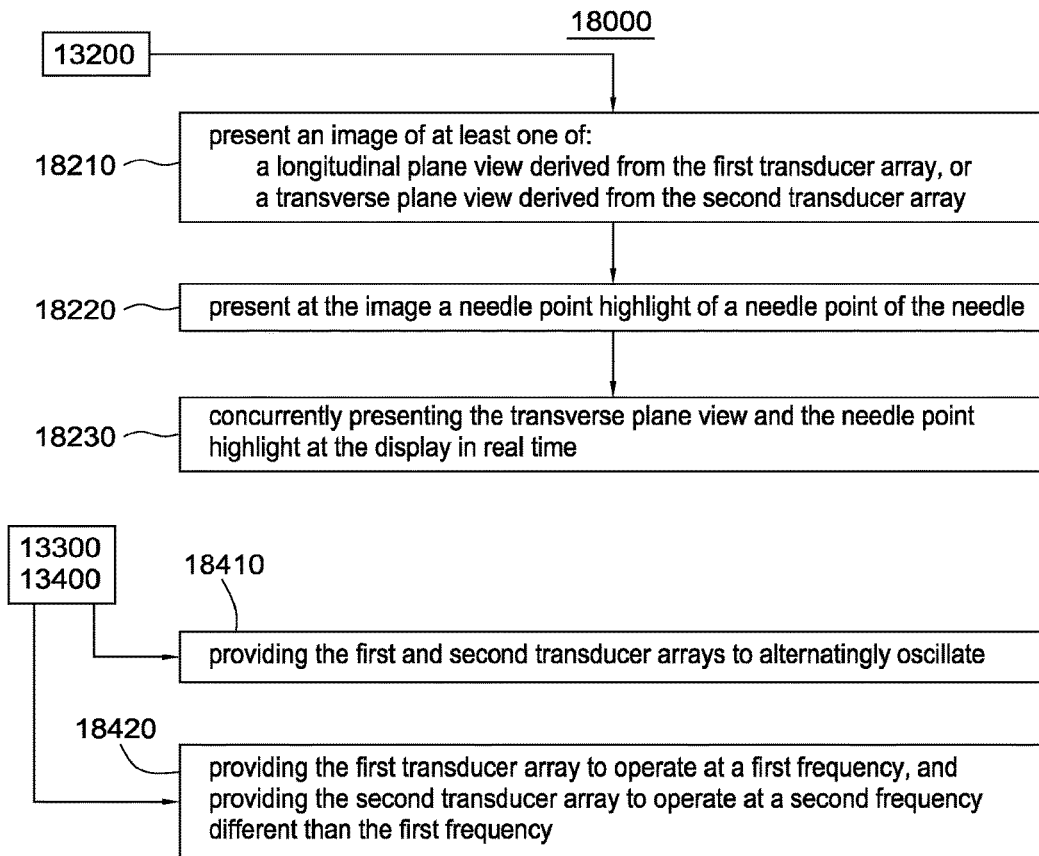


FIG. 18

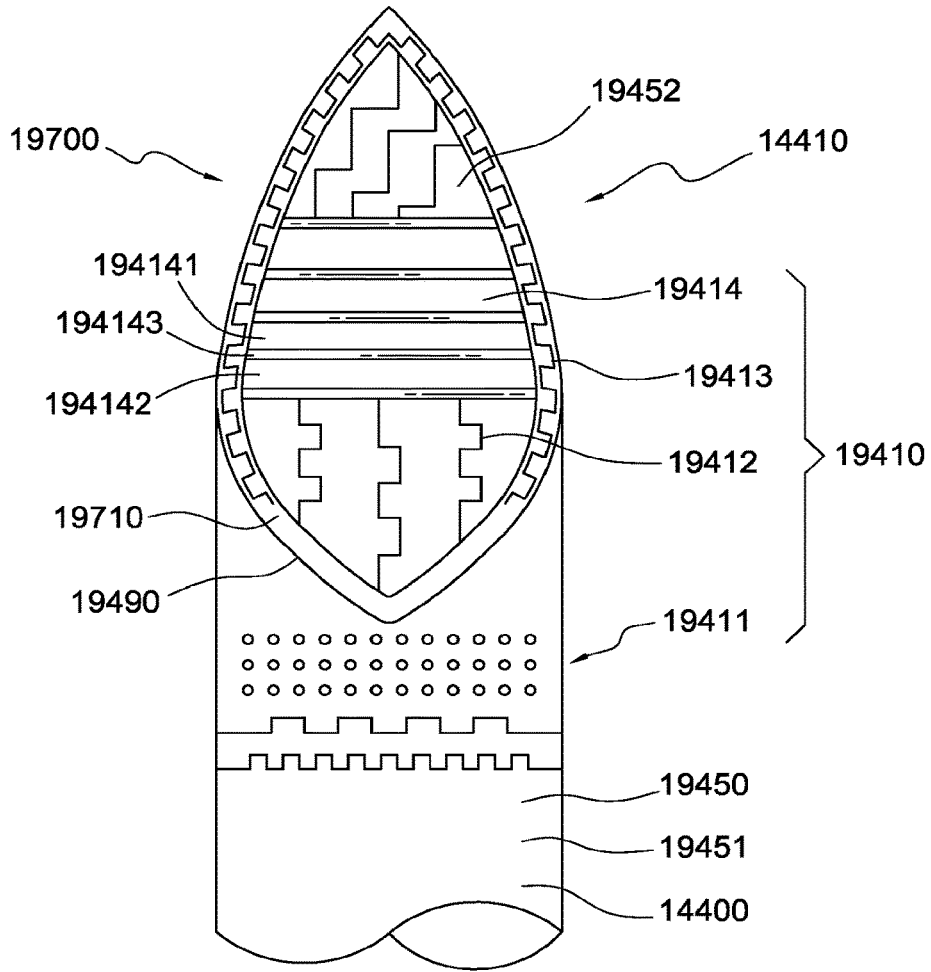


FIG. 19

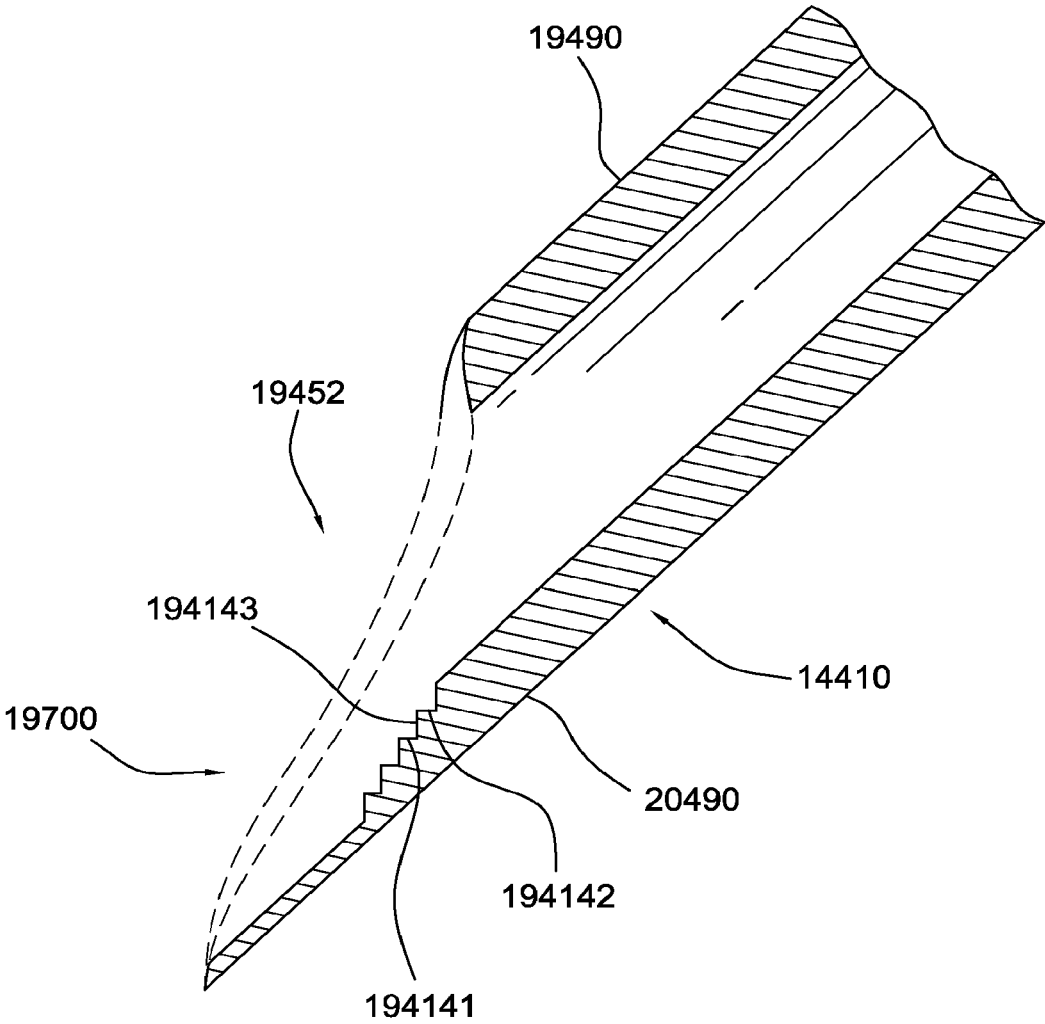


FIG. 20

HANDHELD IMAGING DEVICES AND RELATED METHODS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This patent application is a division of U.S. Patent application Ser. No. 14/703,708, filed May 4, 2015, which is a continuation of U.S. Patent application Ser. No. 12/837,342, filed Jul. 15, 2010, which is a continuation-in-part of U.S. Patent application Ser. No. 12/176,194, filed Jul. 18, 2008, and claims the benefit of U.S. Provisional Patent App. No. 61/352,350, filed Jun. 7, 2010, each of which applications is entirely incorporated herein by reference.

TECHNICAL FIELD

[0002] This disclosure relates generally to imaging devices, and relates more particularly to handheld imaging devices and methods of manufacture for handheld imaging devices.

BACKGROUND

[0003] The use of non-invasive monitoring systems, such as ultrasound devices, to produce real-time images of blood vessels, organs, bones, nerves, tumors, and other target structures under the skin or other layers of tissue in patients has advanced the techniques used for interacting with such target structures. Procedures for epidural placements, lumbar punctures, nerve blockings, and the cannulation of vascular vessels, among other procedures, have been accordingly advanced. For example, prior to the development of such systems, medical practitioners attempting to cannulate a vascular vessel had to rely on approximations of the predicted locations of such target structures, without any internal visual aids to guide the cannulation process through the interior of the patient. This cannulation technique can produce unwanted results, such as the puncturing of wrong vascular vessels or structures, and/or repeated painful attempts to locate and cannulate the correct structure.

[0004] Although technology has advanced the monitoring process, cannulation still requires hand/eye coordination between the images scanned by a monitoring system and a needle or probe as it is inserted by the hand of the medical practitioner into a target area of a patient. Accordingly, a need exists for a monitoring device that can present real-time internal images of the cannulation process proximate to, and aligned with, the target area and internal target structure to, therefore, assist the hand/eye coordination of the medical practitioner during the monitoring and/or cannulation process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The invention will be better understood from a reading of the following detailed description of examples of embodiments, taken in conjunction with the accompanying figures in the drawings in which:

[0006] FIG. 1 illustrates a block diagram of a monitoring device.

[0007] FIG. 2 illustrates a front perspective view of the monitoring device of FIG. 1.

[0008] FIG. 3 illustrates a bottom view of the monitoring device of FIG. 1.

[0009] FIG. 4 illustrates a bottom view of a transducer for the monitoring device of FIG. 1.

[0010] FIG. 5 illustrates a bottom view of another transducer for the monitoring device of FIG. 1.

[0011] FIG. 6 illustrates a side view of another monitoring device.

[0012] FIG. 7 illustrates a side view of a different monitoring device.

[0013] FIG. 8 illustrates a side view of the monitoring device of FIG. 1 partially covered by a casing.

[0014] FIG. 9 illustrates a cross-sectional side view of another casing configured to cover the monitoring device of FIG. 6.

[0015] FIG. 10 illustrates a cross-sectional side view of a different casing configured to cover the monitoring device of FIG. 7.

[0016] FIG. 11 illustrates a perspective view of yet another monitoring device.

[0017] FIG. 12 illustrates a block diagram of the monitoring device of FIG. 11.

[0018] FIG. 13 illustrates a block diagram of a method of manufacturing a handheld

[0019] imaging device similar to the monitoring devices of FIGS. 1-11.

[0020] FIG. 14 illustrates a longitudinal cross-section of a target zone during cannulation of a blood vessel by a needle, as monitored by a monitoring device similar to those of the figures above.

[0021] FIG. 15 illustrates a transverse cross-section of the target zone of FIG. 14.

[0022] FIG. 16 illustrates an image of a transverse view of the cannulation of FIGS. 14-15 as presented on a display of the monitoring device of FIG. 14.

[0023] FIG. 17 illustrates an image of a longitudinal view of the cannulation of FIGS. 14-15 as presented on the display of the monitoring device of FIG. 14.

[0024] FIG. 18 illustrates a block diagram of an optional flow for blocks 13200, 13300, and 13400 of method 13000.

[0025] FIG. 19 illustrates a top view of a tip of the needle of FIG. 14.

[0026] FIG. 20 illustrates a cross-sectional side view of the tip of FIG. 19.

[0027] For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the invention. Additionally, elements in the drawing figures are not necessarily drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of examples of embodiments. The same reference numerals in different figures denote the same elements.

[0028] The terms "first," "second," "third," "fourth," and the like in the description and in the claims, if any, are used for distinguishing between similar elements and not necessarily for describing a particular sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in sequences other than those illustrated or otherwise described herein. Furthermore, the terms "include," and "have," and any variations thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to those elements, but

may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[0029] The terms “left,” “right,” “front,” “back,” “top,” “bottom,” “over,” “under,” and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein. The term “coupled,” as used herein, is defined as directly or indirectly connected in an electrical, physical, mechanical, or other manner.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0030] In one embodiment, a monitoring device is configured to facilitate intra-tissue inspection of a probe at a target region, the monitoring device comprising a housing and a transducer coupled to and at least partially located within the housing. The transducer comprises a longitudinal transducer array aligned to scan a longitudinal cross-section of the target region and a transverse transducer array aligned to scan a transverse cross-section of the target region. The longitudinal transducer array is configured to detect a probe point depth of a probe point of the probe along the longitudinal cross-section. The longitudinal transducer array is also configured to send to a processor longitudinal data about the scan of the longitudinal cross-section to track movement of the probe point based upon at least the longitudinal data and determine the probe point depth based upon at least the longitudinal data. The transverse transducer array is configured to send to the processor transverse data about the scan of the transverse cross-section to determine a transverse cross-section view of the transverse cross-section and determine, concurrently with the transverse cross-section view, a location of a probe point highlight of the probe point of the probe at a longitudinal coordinate of the transverse cross-section view, the longitudinal coordinate corresponding to the probe point depth based upon at least the longitudinal data.

[0031] In some embodiments, a monitoring device is configured to facilitate intra-tissue inspection of a probe at a target region. The monitoring device comprises a housing and a transducer coupled to the housing. The transducer comprises a longitudinal transducer array aligned to scan a longitudinal cross-section of the target region and a transverse transducer array aligned to scan a transverse cross-section of the target region. The longitudinal transducer array is configured to output longitudinal data about the scan of the longitudinal cross-section, the longitudinal data comprises data to detect a probe point depth of a probe point of the probe along the longitudinal cross-section and output longitudinal data about the scan of the longitudinal cross-section, the longitudinal data comprises data to track movement of the probe point based on at least the longitudinal data and determine the probe point depth based on at least the longitudinal data. The transverse transducer array is configured to output transverse data about the scan of the transverse cross-section, the transverse data comprises data to determine a transverse cross-section view of the transverse cross-section and determine, concurrently with the transverse cross-section view, location of a probe point of

the probe at a longitudinal coordinate of the transverse cross-section view, the longitudinal coordinate corresponding to the probe point depth based on at least the longitudinal data.

[0032] In one embodiment a method for intra-tissue inspection of a probe at a target region comprises scanning, with a longitudinal transducer array, a longitudinal cross-section of the target region and detecting, with the longitudinal transducer array, a probe point depth of a probe point of the probe along the longitudinal cross-section. The method also comprises sending to a processor longitudinal data about the longitudinal cross-section to track movement of the probe point based upon at least the longitudinal data and determine the probe point depth based upon at least the longitudinal data. The method also comprises scanning, with a transverse transducer array, a transverse cross-section of the target region and sending to the processor transverse data about the transverse cross-section to determine a transverse cross-section view of the transverse cross-section and determine, concurrently with the transverse cross-section view, a location of a probe point of the probe at a longitudinal coordinate of the transverse cross-section view, the longitudinal coordinate corresponding to the probe point depth based upon at least the longitudinal data.

[0033] In one embodiment, an ultrasound imaging device is configured to facilitate sub-dermal monitoring. The ultrasound imaging device comprises a handheld housing, a processor within the handheld housing, a beamformer coupled to the processor, a transducer assembly coupled to the handheld housing and to at least one of the beamformer and the processor, a scan converter coupled to the transducer assembly, a display coupled to the handheld housing and coupled to at least one of the scan converter and the processor, a switch mechanism coupled to the processor, a rechargeable power source coupled to the handheld housing, a communications port coupled to the processor, a central pointer aligned with a center of the display, and a needle guide coupled to the handheld housing proximate to the transducer assembly. The transducer assembly comprises a first transducer array coupled to the processor and aligned along a first axis, and a second transducer array coupled to the processor and aligned along a second axis different from the first axis, where the first transducer array and the second transducer array are configured to produce an overlapping scan at a target focus point. The first axis is longitudinal to the target focus point; the second axis is transverse to the target focus point; and the first transducer array and the second transducer array are substantially perpendicular to each other. The first transducer array comprises transducer elements configured to scan images along the first axis, and the second transducer array comprises transducer elements configured to scan images along the second axis. The first and second transducer arrays are capable of concurrently imaging the target focus point. The rechargeable power source is cordless and configured to power the monitoring device uninterrupted for at least approximately a half-hour, and the ultrasound imaging device is configured for single-handed operation.

[0034] In another embodiment, a monitoring device can be configured to facilitate intra-tissue inspection of a needle at a target region, the monitoring device comprising a housing, a transducer coupled to the housing, and a display coupled to the transducer and to the housing. The transducer can comprise a first transducer array aligned to scan a longitu-

dinal plane of the target region, and a second transducer array aligned to scan a transverse plane of the target region. The display can be configured to receive information derived from the first and second transducers to present an image of at least one of the longitudinal plane or the transverse plane, and to present at the image a needle point highlight of a needle point of the needle.

[0035] In one embodiment, an ultrasound imaging device can be configured to facilitate sub-dermal monitoring of a probe inserted into a target zone. The ultrasound imaging device can comprise a handheld housing, a processor within the handheld housing, a transducer assembly coupled to the handheld housing and to the processor, a scan converter coupled to the transducer assembly, a display coupled to the handheld housing and coupled to at least one of the scan converter or the processor, a rechargeable power source coupled to the handheld housing, a central pointer aligned with a center of the display, and a probe guide coupled to the handheld housing proximate to the transducer assembly. The transducer assembly can comprise a first transducer array coupled to the processor and aligned along a first axis, and a second transducer array coupled to the processor and aligned along a second axis different than the first axis, where the first axis is longitudinal to the target zone, and the second axis is transverse to the target zone, and the first transducer array and the second transducer array are substantially perpendicular to each other. The first transducer array can comprise transducer elements configured to scan along the first axis, and the second transducer array can comprise transducer elements configured to scan along the second axis. The rechargeable power source can be cordless and configured to power the monitoring device uninterrupted for at least approximately a half-hour. The ultrasound imaging device is configured for single-handed operation, and the display is configured to present an image comprising a transverse view of a transverse cross-section of the target zone along the second axis, and a probe point highlight of a probe point of the probe.

[0036] In one example, a monitoring device can be configured to facilitate intra-tissue inspection of a probe at a target region. The monitoring device can comprise a housing, a transducer coupled to the housing, and a display coupled to the transducer and to the housing. The transducer can comprise a first transducer array aligned to scan a longitudinal plane of the target region, and a second transducer array aligned to scan a transverse plane of the target region. The display can be configured to receive information derived from the first and second transducers to (1) present an image of at least one of the longitudinal plane or the transverse plane, and (2) present at the image a probe point highlight of a probe point of the probe.

[0037] In one example, a method for providing a monitoring device can comprise providing a housing, providing a transducer coupled to the housing, and providing a display coupled to the transducer and to the housing. Providing the transducer can comprise providing a first transducer array aligned to scan a longitudinal plane of a target region, the target region being subdermal, and providing a second transducer array aligned to scan a transverse plane of the target region. The display can be provided to present an image of at least one of a longitudinal plane view derived from the first transducer array, or a transverse plane view derived from the second transducer array, and to present at the image a probe point highlight of a probe point of a probe.

[0038] In one example, a needle can comprise an interior surface, an exterior surface, a needle tip portion comprising a bevel, and one or more indentations configured to enhance ultrasonic beam reflections off the needle tip portion. A first indentation of the one or more indentations can be located at the interior surface adjacent to the bevel of the tip portion.

[0039] Other examples, embodiments, and related methods are further described below. Such examples, embodiments, and related methods may be found in the figures, in the claims, and/or in the description of the present application.

[0040] Turning over to the figures, FIG. 1 illustrates a block diagram of a monitoring device 1000. FIG. 2 illustrates a front perspective view of monitoring device 1000. FIG. 3 illustrates a bottom view of monitoring device 1000. FIG. 4 illustrates a bottom view of transducer 1200 of monitoring device 1000. FIG. 5 illustrates a bottom view of transducer 5200 of monitoring device 1000.

[0041] In some embodiments, monitoring device 1000 can be used in the medical field for intra-tissue or sub-dermal inspection on a patient. As an example, monitoring device 1000 can be used to facilitate non-invasive imaging of vascular vessels, such as veins and arteries, through skin and/or other tissue. In one example, such imaging can be useful to guide a medical practitioner while cannulating a vascular vessel, allowing the medical practitioner to align, position, and guide a needle into the vascular vessel. In some embodiments, the needle can comprise a probe and/or a catheter.

[0042] In the present embodiment, monitoring device 1000 comprises processor 1100 within housing 2500. Processor 1100 can comprise, for example, a microprocessor such as a general microprocessor for personal computers, and/or a specialized microprocessor for a specific implementation such as analog and mixed signal operations. Monitoring device 1000 can also comprise memory 1800 coupled to processor 1100. Memory 1800 can be used to store software instructions for operating monitoring device 1000, and/or information such as images scanned using monitoring device 1000. In the same or a different embodiment, memory 1800 can comprise non-volatile memory, such as flash memory, and/or magnetic storage such as hard disks. In some embodiments, memory 1800 can comprise removable memory devices, such as SD (Secure Digital) cards. In a different embodiment, processor 1100 and memory 1800 can be combined to form a microcontroller.

[0043] Monitoring device 1000 also comprises display 1300 coupled to processor 1100 and to housing 2500. In some embodiments, display 1300 can comprise a width of approximately 3 to 8 centimeters, and/or a height of approximately 2 to 5 centimeters. In one embodiment, display 1300 can comprise at least one of a Liquid Crystal Display (LCD), a touch-screen display, and a Thin Film Transistor (TFT) display. In the same or a different embodiment, display 1300 can be configured to present a data entry screen, where information such as a patient's name and/or a medical record number can be entered by interacting with the data entry screen. In the same or a different embodiment, the data entry screen can be configured to accept input from a touch-screen coupled to display 1300, a keypad coupled to monitoring device 1000, and/or a point and click mechanism. In the same or a different embodiment, information entered into the

data entry screen can be stored into memory 1800, and/or can be correlated to information or images stored in memory 1800.

[0044] Display 1300 can be configured to be aligned with, and visible through, translucent portion 2300 (FIG. 2) of housing 2500, where translucent portion 2300 can comprise a translucent material, transparent material, or a cutout. In some embodiments, display 1300 can also be coupled to a graphics adapter (not shown). In the same or a different embodiment, the graphics adapter can be part of processor 1100. In a different embodiment, monitoring device 1000 can also comprise additional displays similar to display 1300.

[0045] Monitoring device 1000 also comprises transducer 1200 coupled to processor 1100 and to housing 2500. In the present embodiment, transducer 1200 comprises transducer arrays 1210 and 1220 coupled to processor 1100, where transducer array 1210 is aligned along axis 3210 (FIG. 3), and where transducer array 1220 is aligned along axis 3220 (FIG. 3) of scanning surface 2250 (FIG. 2). In the same or a different embodiment, transducer arrays 1210 and 1220 can be ultrasonic transducer arrays comprising piezoelectric elements configured to emit ultrasonic beams and/or to detect reflections of the ultrasonic beams.

[0046] Transducer arrays 1210 and 1220 are configured to produce different but overlapping scans (not shown), where an image can be presented on display 1300 based on readings from the overlapping scan. In the present embodiment, as more clearly seen in FIG. 4, transducer arrays 1210 and 1220 overlap at transducer junction 3230 of transducer 1200, where respective elements 4211 and 4221 of transducer arrays 1210 and 1220 coincide. In the same or a different embodiment, one or more of elements 4211 and 4221 that are proximate to transducer junction 3230 can be shared by both transducer arrays 1210 and 1220. Portions of transducer arrays 1210 and 1220 overlap substantially perpendicular to each other. In addition, beams emitted by elements 4211 and 4221 are substantially perpendicular to scanning surface 2250. As also seen in FIG. 4, other portions of transducer arrays 1210 and 1220 do not overlap with each other.

[0047] In a different embodiment, as more clearly seen in FIG. 5, monitoring device 1000 can comprise transducer 5200 with transducer arrays 5210 and 1220. Transducer 5200 can also produce different but overlapping scans similar to the overlapping scans produced by transducer 1200, but transducer 5200 differs in that there is no transducer junction because transducer arrays 5210 and 1220 do not physically overlap. Instead, transducer array 5210 comprises elements 5211 that are configured to transmit and/or detect ultrasonic beams at an angle such as to overlap with beams transmitted by elements 4221 of transducer array 1220. In a different embodiment, elements 4221 are modified to transmit and/or detect ultrasonic beams at an angle to overlap with beams transmitted by elements 5211, which are modified to transmit beams substantially perpendicular to scanning surface 2250. In another embodiment, both elements 4221 and 5211 are angled.

[0048] Returning to the embodiment of FIGS. 1-4, transducer 1200 is at least partially enclosed by housing 2500. Similarly, display 1300 is at least partially enclosed by housing 2500. In the same or a different embodiment, transducer 1200 and display 1300 can be integrated with housing 2500 such as to form a single handheld unit out of

monitoring device 1000, with no external cables to interconnect display 1300 and/or transducer 1200 to housing 2500 and/or processor 1100. In the same or a different embodiment, housing 2500 can comprise materials such as metal, acrylics, polycarbonates, and other rigid or semi-rigid plastics. As used herein, the term “integrated” allows for interchangeable portions of monitoring device 1000. For example, in the same or a different embodiment, housing 2500 can be integrated with a different transducer, such as transducer 5200, which is replaceable or interchangeable with transducer 1200.

[0049] In the present embodiment, as shown in FIG. 1, monitoring device 1000 comprises beamformer 1400 coupled to transducer 1200. In addition, processor 1100 couples to transducer 1200 through beamformer 1400. In the present example, beamformer 1400 is configured to control the timing, strength, angle, amplitude, and/or phase of ultrasound signals transmitted by transducer arrays 1210 and 1220. In the same or a different example, beamformer 1400 can be configured to control transducer arrays 1210 and 1220 to receive signals predominantly from a chosen angular direction.

[0050] Continuing with the present embodiment, monitoring device 1000 also comprises scan converter 1500 coupled to beamformer 1400 and to display 1300. In some embodiments, scan converter 1500 can be coupled to display 1300 via processor 1100. Scan converter 1500 can be used to convert information from ultrasound signals received by transducer arrays 1210 and 1220 into an image format that can be displayed on, for example, display 1300. In the present embodiment, beamformer 1400 can comprise at least one of a B-mode, F-mode, and a D-mode acquisition mode.

[0051] As described above, monitoring device 1000 can be used to image through target location 2900 (FIG. 2), where target location 2900 can be under the skin surface of a patient or person. In the present embodiment, axis 3210 (FIG. 3) is longitudinal to target location 2900, while axis 3220 is transverse to target location 2900. In addition, display 1300 is substantially parallel to axis 3220. Transducer 1200 is configured to scan a set of readings of target location 2900 using at least a portion of transducer array 1210, while simultaneously scanning a different set of readings of target location 2900 using at least a portion of transducer array 1220. In the current embodiment, at least one of transducer arrays 1210 and 1220 is configured to scan a depth of field of up to approximately 10 centimeters.

[0052] In the same or a different embodiment, at least one of transducer arrays 1210 and 1220 is configured to scan a span of up to approximately 4 to 5 cm. In the same or a different embodiment, at least one of transducer arrays 1210 and 1220 can be configured to scan at a transducer frequency of approximately between 2 and 50 MHz.

[0053] In the present embodiment, monitoring device 1000 also comprises a switch mechanism 1600 coupled to processor 1100. Switch Mechanism 1600 is configured to deactivate transducer array 1220 and activate transducer array 1210 in response to a first setting of switch mechanism 1600. In addition, switch mechanism 1600 is configured to deactivate transducer array 1210 and activate transducer array 1220 in response to a second setting of switch mechanism 1600. In the present embodiment, the settings of switch mechanism 1600 are recognized by processor 1000, which causes transducer arrays 1210 and/or 1220 to activate or

deactivate accordingly and which changes the image(s) shown on display 1300. In a different embodiment, switch mechanism 1600 can communicate more directly with transducer arrays 1210 and/or 1220, such as through beamformer 1400, to activate or deactivate transducer arrays 1210 and/or 1220 accordingly.

[0054] In the same or a different embodiment, monitoring device 1000 is configured for one-handed operation. For example, monitoring device 1000 can be configured to allow a hand to grab around portion 2520 (FIG. 2) of housing 2500, such that switch mechanism 1600 can be still operable by a finger (e.g., a thumb) of the same hand without releasing portion 2520. In addition, monitoring device 1000 can be configured for non-dominant handed operation. Such non-dominant handed configuration can be advantageous, for example, to free-up a user's dominant hand to cannulate a vascular vessel monitored through monitoring device 1000. In some embodiments, a weight of monitoring device 1000 is between approximately 0.3 and 0.7 kilograms.

[0055] In some embodiments, monitoring device 1000 can comprise other switches or buttons to control other operations or features of monitoring device 1000. Such other switches can comprise one or more of an on/off control, a gain control, a depth control, a focus control, a brightness control, and/or a contrast control.

[0056] Display 1300, in the current embodiment of monitoring device 1000, is configured to present images correlated to readings from transducer array 1210 in response to one setting of switch mechanism 1600. Display 1300 is also configured to present images correlated to a set of readings from transducer array 1220 in response to a different setting of switch mechanism 1600. In the present embodiment, because display 1300 is sized to allow monitoring device 1000 to be handheld, it can be clearer for display 1300 to present images from only one of transducer arrays 1210 and 1220 at a time. Switch mechanism 1600 can therefore be used to toggle the source of images on display 1300 from array 1210 to 1220, and vice-versa. In a different embodiment, however, monitoring device 1000 can be configured to simultaneously present images correlated to readings from transducer array 1210 on one portion of display 1300, and images correlated to readings from transducer array 1220 on another portion of display 1300.

[0057] In the same or a different embodiment, display 1300 can also present other information, such as menu screens and/or other images. In the same or a different embodiment, switch mechanism 1600 can also be used to toggle display 1300 to and from presenting such other information. In a different embodiment, switch mechanism 1600 can comprise more than one switch, where different switches can be correlated to additional displays similar to display 1300, and/or to individual transducer arrays similar to transducer arrays 1210 and 1220.

[0058] FIG. 1. illustrates power source 1700. In the present embodiment, power source 1700 comprises a portable battery, which can be rechargeable. Power source 1700 is coupled to housing 2500, and is configured to power electrical systems of monitoring device 1000, such as processor 1100 and transducer 1200, among others. In the present embodiment, power source 1700 is located within housing 2500. In a different embodiment, power source 1700 can be attached to an exterior surface of housing 2500. In a different embodiment, power source 1700 can comprise a power cord

to recharge power source 1700, where the power cord can be detachable in some examples.

[0059] In some embodiments, power source 1700 can be configured to be charged via a docking station (not shown), where the docking station can be tailored accommodate and/or support a portion of the surface of housing 2500. In one embodiment, power source 1700 comprises charging leads 1711-1712 accessible through the exterior of housing 2500, and the docking station comprises contact leads (not shown) complementary with charging leads 1711-1712. The contact leads in the same embodiment can be configured to contact charging leads 1711-1712 to charge power source 1700 when monitoring device 1000 is docked with the docking station. In a different embodiment, the docking station can be configured to charge power source 1700 via one of a capacitive coupling or an inductive coupling, where direct contact between charging and/or contact leads may not be needed.

[0060] As shown in FIG. 1, the present embodiment also comprises port 1900 coupled to processor 1100. Port 1900 can be used to place monitoring device 1000 in communication with other electronic devices. For example, port 1900 can be used to interface monitoring device 1000 with a personal computer or a database to transmit information such as scanned images. In one example, port 1900 can comprise a wired port, such as a USB or Firewire® port. In the same or a different example, port 1900 can also comprise a wireless port. In some examples, the docking station described above for power source 1700 can also be configured to couple with port 1900 to facilitate the communication with other electronic devices when monitoring device 1000 is docked with the docking station.

[0061] As more clearly illustrated in FIG. 2, monitoring device 1000 comprises a central pointer 2400 configured to indicate a center of an image shown on display 1300. In some embodiments, central pointer 2400 comprises one or more of pointer 2410 on housing 2500, pointer 2420 presented on display 1300, pointer line 2430 presented also on display 1300, and/or pointer 2440 proximate to scanning surface 2250. In the present example, central pointer 2400 indicates a midpoint of display 1300. Central pointer 2400 is correlated to a centerline of transducer array 1210 (FIGS. 1, 3, and 4) in the current example. In the present or a different example, monitoring device 1000 can comprise central pointer 2600, similar to central pointer 2400, but correlated instead to a centerline of transducer array 1220 (FIGS. 1, 3, and 4). In the present embodiment, the centerlines of transducer arrays 1210 and 1220 can correspond to axes 3210 and 3220, respectively, in FIG. 3.

[0062] In the present embodiment, housing 2500 comprises gridmarks 2700 aligned along an axis substantially parallel to axis 3220. In addition, monitoring device 1000 comprises grid pointers 2800 configured to demarcate on display 1300 subdivisions correlated to gridmarks 2700. Grid pointers 2800 can comprise physical and/or electronic grid pointers.

[0063] As seen in FIG. 3, monitoring device 1000 comprises needle guide 3500 aligned with transducer array 1210 and proximate to a central portion of transducer array 1220. In the present example, needle guide 3500 is coupled to housing 2500 proximate to scanning surface 2250. Needle guide 3500 is substantially in-line with axis 3210 in the present example, and comprises needle alignment groove 3510. In one embodiment, needle guide 3500 can be used to

assist a user in aligning a needle with central pointer 2400 prior to and during cannulation of a vascular vessel presented on display 1300.

[0064] Continuing with the figures, FIG. 6 illustrates a side view of monitoring device 6000. FIG. 7 illustrates a side view of monitoring device 7000.

[0065] Monitoring devices 6000 and 7000 are similar to monitoring device 1000 (FIGS. 1-6), but differ by comprising housings 6500 and 7500, respectively, similar to housing 2500 (FIG. 2). Housing 6500 in FIG. 6 comprises joint 6530 between portions 2510 and 2520 of housing 6500. Similarly, housing 7500 in FIG. 7 comprises joint 7530 between portions 2510 and 2520 of housing 7500. In contrast with joint 2530 of housing 2500 (FIG. 2), where portions 2510 and 2520 of housing 2500 are substantially planar relative to each other, joints 6530 and 7530 permit their respective portions 2510 and 2520 to be angled relative to each other to facilitate viewing of display 1300.

[0066] FIG. 6 shows portion 2510 is fixedly angled towards a rear of monitoring device 6000 at angle 6100. In the present example, angle 6100 comprises approximately 25 degrees. In some examples, angle 6100 can be fixed at approximately between 10 to 45 degrees. In the example of FIG. 7, joint 7530 permits portion 2510 to be variably angled and adjustable relative to portion 2520 of housing 7500. In some embodiments, angle 7100 can be varied between approximately 0 and 90 degrees. In some examples, display 1300 can also be rotated about axis 6200.

[0067] In the example of FIG. 7, monitoring device 7000 comprises switch mechanism 7600, similar to switch mechanism 1600 of FIGS. 1-3 and 6. Switch mechanism 7600 differs by being located towards the rear of monitoring device 7000 such as to be operable in a pistol-trigger fashion. This arrangement could facilitate the single-handed operation of monitoring device 7000 when portion 2520 of housing 7500 is grabbed by a hand.

[0068] Moving on, FIG. 8 illustrates a side view of monitoring device 1000 (FIGS. 1-5) partially covered by casing 8000. FIG. 9 illustrates a cross-sectional side view of casing 9000 configured to cover monitoring device 6000 (FIG. 6). FIG. 10 illustrates a cross-sectional side view of casing 10000 configured to cover monitoring device 7000 (FIG. 7). In some embodiments, at least one of casings 8000, 9000, and/or 10000 can be referred to as a cover.

[0069] Casing 8000 comprises transducer cover portion 8100, configured to removably envelop at least a portion of housing 2500. In the present embodiment, transducer arrays 1210 and 1220 are arranged in a T-shape, as shown in FIG. 4, and portion 8100 is configured to accommodate the T-shape. Casing 8000 comprises hinge 8200 to permit portions 8300 and 8400 to envelop monitoring device 1000 in a clamshell fashion. Transducer cover portion 8100 is transparent proximate to scanning surface 2250 with respect to transducer arrays 1210 and 1220 such as to minimize interference with the transmission and reception of signals from transducer 1200.

[0070] In the present example, transducer cover portion 8100 also comprises needle guide 8500, similar to needle guide 3500 as described above for FIG. 3. Casing 8000 is configured to be disposable and/or sterilizable, such that monitoring device 1000 can be brought into and used at a clean room or sterile environment.

[0071] Casings 9000 and 10000 are similar to casing 8000, but differ by allowing for an angle between portions 2510

and 2520 of monitoring devices 6000 and 7000. Similar to casing 8000, casings 9000 and 10000 also comprise hinge 8200 to permit portions 9300 and 9400, and portions 10300 and 10400, respectively, to envelop monitoring devices 6000 and 7000 in a clamshell fashion. In the embodiments of FIGS. 8-10, locks 8810 and 8820 of locking mechanism 8800 can be brought together to secure casings 8000, 9000, and 10000 when closed.

[0072] In some embodiments, one or more portions of casings 8000, 9000, and/or 10000 can comprise materials such as rigid plastic, semi-rigid plastic, and/or flexible materials such as silicone. In the same or a different embodiment, at least a portion of casings 8000, 9000, and/or 10000 can conform to a shape of a portion of monitoring device 1000, 6000, and/or 7000. As an example, portion 9530 of casing 9000 in FIG. 9 and portion 10530 of casing 10000 in FIG. 10 can comprise a semi-rigid or flexible material to accommodate the envelopment of joint 6530 (FIG. 6) or joint 7530 (FIG. 7). In the same or a different embodiment, portion 9530 of casing 9000 and portion 10530 of casing 10000 can be configured in an accordion manner to allow for the angle between portions 2510 and 2520. In some embodiments, switch mechanisms 1600 (FIGS. 1, 6, 8) and 7600 (FIG. 7) of respective monitoring devices 1000, 6000, and 7000 can be covered by pliable portions 8600 of casings 8000, 9000, and 10000, respectively. In some examples, pliable portions 8600 can comprise materials similar to those materials described above for portion 9530, and can permit a user to operate switch mechanisms 1600 and 6600 while covered by casings 8000, 9000, and 10000.

[0073] The embodiments shown in FIGS. 9-10 show transducer casings 9100 and 10100 comprising gel-pack 9110 positioned proximate to transducer arrays 1210 and 1220 (FIGS. 6-7). In some embodiments, gel-pack 9110 can comprise a bladder filled with an aqueous, flexible gel material suitable for the transmission of ultrasound signals. In the same or a different embodiment, gel-pack 9110 can be similar to an Aquaflex® gel pad from Parker Laboratories, Inc. In a different embodiment, casing 8000 can also comprise gel-pack 9110.

[0074] In some embodiments, part of transducer cover portion 8100 can comprise a non-stick material proximate to scanning surface 2250 to facilitate sliding monitoring device 1000 over a target surface. In the same or a different embodiment, one or more of transducer cover portions 8100, 9100, and/or 10100 can comprise a T-shape tailored to dimensions of transducer arrays 1210 and 1220 on portion 2520 (FIGS. 3-4). In the some examples, a thickness of a portion of one or more of casings 8000, 9000, and/or 10000 comprises approximately between 0.5 to 5 millimeters. In a embodiment different than as illustrated in FIGS. 8-10, a cover similar to casing 8000 can be configured to leave display 1300 exposed so as to cover only, for example, portion 2520 of monitoring device 1000.

[0075] In some embodiments, monitoring devices 6000 and 7000 can be charged via a docking station (not shown), similar to as described above for monitoring device 1000. In the same or a different example, the docking station can also be configured to charge power source 1700 while monitoring devices 1000, 6000, and/or 7000 are covered by casings 8000, 9000, and 10000, respectively.

[0076] Continuing with the figures, FIG. 11 illustrates a perspective view of a monitoring device 11000. FIG. 12 illustrates a block diagram of monitoring device 11000.

Monitoring device **11000** is similar to monitoring device **1000**, but comprises displays **11310** and **11320** rather than a single display. In the same or other examples, displays **11310** and **11320** can comprise different portions of a common screen. Monitoring device **11000** comprises transducer **1200** like monitoring device **1000**, and is configured to simultaneously present images correlated to readings from transducer array **1210** on display **11310**, and images correlated to readings from transducer array **1220** on display **11320**. As seen in

[0077] FIG. 12, monitoring device **11000** comprises beamformers **12410** and **12420** configured to control and couple to transducer arrays **1210** and **1220**, respectively. In the present embodiment, beamformers **12410** and **12420** connect to scan converter **1500**, although in a different embodiment beamformers **12410** and **12420** can connect to their own dedicated scan converters.

[0078] Skipping ahead in the figures, FIG. 14 illustrates a longitudinal cross-section of target zone **14800** during cannulation of blood vessel **14500** by needle **14400**, as monitored by monitoring device **14000**. FIG. 15 illustrates a transverse cross-section of target zone **14800** during the cannulation of blood vessel **14500**. FIGS. 14-15 are related in that FIG. 15 presents transverse plane **15100** of target zone **14800** along line **15-15** of FIG. 14, while FIG. 14 presents longitudinal plane **14100** of target zone **14800**. For simplicity, only transducer **14200** of monitoring device **14000** is shown in FIGS. 14-15, but monitoring device **14000** can be similar to one of monitoring devices **1000** (FIGS. 1-3, 8), **6000** (FIG. 6), **7000** (FIG. 7), or **11000** (FIG. 11).

[0079] In the present example transducer **14200** is located over target zone **14800**, and comprises transducer array **14210** aligned longitudinally with respect to blood vessel **14500** for longitudinal scan **14211** of the longitudinal cross-section of FIG. 14 along axis **3210** (FIG. 14) of scanning surface **2250**. Similarly, transducer array **14220** can be aligned transversely with respect to blood vessel **14500** for transverse scan **14221** of the transverse cross-section of FIG. 15 along axis **3220** (FIG. 15) of scanning surface **2250**. In some examples, transducer array **14210** can be similar to transducer array **1210** of transducer **1200** (FIG. 4), and/or to transducer array **5210** of transducer **5200** (FIG. 5). In the same or other examples, transducer array **14220** can be similar to transducer array **1220** of transducer **1200** (FIG. 4), and/or of transducer **5200** (FIG. 5). FIG. 16 illustrates image **16400** of transverse view **16440** of the cannulation of blood vessel **14500** of FIGS. 14-15. FIG. 17 illustrates image **16400** of longitudinal view **17440** of the cannulation of blood vessel **14500** of FIGS. 14-15. Image **16400** is presented on display **16300**, which can be similar to display **1300** of monitoring device **1000** (FIG. 1) and/or to one or both of displays **11310** and **11320** of monitoring device **11000** (FIG. 11).

[0080] In the present example, needle **14400** is introduced into skin surface **14510** and routed until needle **14400** cannulates blood vessel **14500**. The routing of needle **14400** is monitored by monitoring device **14000**, which is placed over skin surface **14510** above blood vessel **14500**, so that transducer **14200** can subdermally scan the progress of needle **14400** towards blood vessel **14400**. Display **16300** is configured to present image **16400**, where image **16400** can comprise transverse view **16440** of the transverse cross-section of FIG. 15 along axis **3220** to illustrate the progress

of needle **14400**. In FIG. 16, display **16300** is also configured to present, at image **16400**, needle point highlight **16410** of needle point **14410** (FIG. 14). Needle point highlight **16410** can be used to represent needle point depth **14600** (FIGS. 14 & 16), comprising a distance from transducer **14200** at skin surface **14510** to needle point **14410**, as measured by transducer array **14210** along the longitudinal cross-section of FIG. 14.

[0081] Although image **16400** is based primarily on transverse scan **14221** of target zone **14800** by transducer array **14220** (FIG. 15), display **16300** also can be configured to locate needle point highlight **16410** at image **16400**, based on needle point depth **14600**, as detected by transducer **14210** (FIG. 14) via longitudinal scan **14211** of target zone **14800**. As a result, even though needle point **14410** is past the range of transverse scan **14221**, data from longitudinal scan **14211** can be used to present needle point highlight **16410** at image **16400** in FIG. 17. In the present example, needle point **14410** is located at a tip or end of needle **14400**, but there may be other examples where needle point **14410** may represent another point along a length of needle **14400**. In some examples, needle point highlight **16410** can comprise a graphic of a dot, where the dot may be white or colored, solid or hollow, and/or constant or blinking. The dot also may comprise one or more geometric shapes, such as oval, triangle, or square, among others.

[0082] Monitoring device **14000** of FIGS. 14-16 can comprise architectures similar to those presented in FIGS. 1 and/or 12. In the present example, processor **1100** (FIG. 1) of monitoring device **14000** is configured to receive and process data from transducer **14210** about longitudinal scan **14211** to determine needle point depth **14600**. Processor **1100** also is configured to instruct display **16300** to locate needle point highlight **16410** at a longitudinal coordinate **16420** (FIG. 16) of display **16300**, where longitudinal coordinate **16420** corresponds to a position in display **16300** representative of the needle point depth. In the example of FIG. 16, longitudinal coordinate **16420** corresponds to a coordinate of a y-axis of display **16300**.

[0083] In some examples, at least one of transducers **14210** or **14220** can be configured to detect a location of needle width **15420** along the transverse cross-section of FIG. 15. There can be examples where needle width **15420** is detected by transducer array **14220** via transverse scan **14221**. Needle width **15420** may also be detected by transducer array **14210** via longitudinal scan **14211** in the same or other examples. Data concerning the detection of needle width **15420** can be received and processed by processor **1100**, which can instruct display **16300** to locate needle point highlight **16410** at transverse coordinate **16430** corresponding to a position in display **16300** representative of the location of needle width **15420**. In the example of FIG. 16, longitudinal coordinate **16430** corresponds to a coordinate of an x-axis of display **16300**. In the same or other examples, longitudinal coordinate **16420** and/or transverse coordinate **16430** may correspond to coordinates of one or more pixels of display **16300**.

[0084] As described above, monitoring device **14000** can be similar to the other monitoring devices described herein, and can share similar features. For example, monitoring device **14000** can comprise switch **1600**. In the present example, display **16300** can be configured such that, when switch **1600** (FIG. 1) is at the first setting, image **16400** presents a longitudinal view of the longitudinal cross-section

of target zone **14800**, as derived from longitudinal scan **14211** by transducer array **14210** and as shown in FIG. **17**. Similarly, display **16300** can be configured such that, when switch **1600** is at the second setting, image **16400** presents transverse view **16440** of the transverse cross-section of target zone **14800**, as shown in FIG. **16** and as derived from transverse scan **14221** by transducer array **14220** with needle point highlight **16410**, as derived from longitudinal scan **14211** by transducer array **14210**.

[0085] In some embodiments, monitoring device **14000** can be configured such that transducer array **14210** is operable at a first frequency, while transducer array **14220** is operable at a second frequency. In the same or other examples, the first and second frequencies can be configured to be substantially non-interfering with each other, such that transducer arrays **14210** and **14220** may be operated simultaneously to concurrently present and update transverse view **16440** and needle point highlight **16410** without disturbing longitudinal scan **14211** and/or transverse scan **14221**. Although the first and second frequencies can be different from each other, there can be examples where the first and second frequencies can be the same if they are substantially non-interfering with each other during operation of transducer arrays **14210** and **14220**.

[0086] There also can be embodiments where monitoring device **14000** can be configured such that transducer arrays **14210** and **14220** are alternately oscillatable relative to each other to permit concurrent presentation of transverse view **16440** and needle point highlight **16410** at image **16400**. As an example, transducer arrays **14210** and **14220** can be alternately oscillated at a high rate such that, when transducer array **14210** is activated to perform longitudinal scan **14211**, transducer array **14220** is deactivated to cease transverse scan **14221**. Similarly, when transducer array **14220** is activated for transverse scan **14221**, transducer array **14210** is deactivated to cease longitudinal scan **14211**.

[0087] In some embodiments, a monitoring device similar to one or more of monitoring devices **1000** (FIGS. **1-3**, **8**), **6000** (FIG. **6**), **7000** (FIG. **7**), **11000** (FIG. **11**), or **14000** (FIGS. **14-17**) may be configured to track and/or direct a probe or catheter as the probe is routed along a vessel such as blood vessel **14500** (FIGS. **14-15**). In some examples, the probe may comprise a needle and/or a catheter such as a peripherally inserted central catheter (PICC catheter). The probe may be monitored and inserted into the vessel as described in FIGS. **14-17** for needle **14400**, and may be then routed to a desired location along the vessel with further aid from the monitoring device. For example, the monitoring device may be moved over the skin surface and along the vessel to monitor the progress of the probe as it makes its way through the vessel. In the same or other examples, the probe may comprise a sensor, and the monitoring device may be configured to process signals received from the sensor of the probe. The sensor of the probe can be located at one or more locations, such as at a tip of the probe, and/or along a length of the probe. In the same or other examples, the sensor may comprise a wire lead, and/or a column of saline. For instance, the sensor of the probe may be configured to detect a proximity signal, such as a change in P-waves of an electrocardiogram (EKG) as the tip of the probe approaches a desired location along the vessel proximate to the atria of the heart. In this example, the monitoring device can be configured to recognize when the sensor of the probe detects the proximity signal to indicate that the probe

has reached the desired location. In some examples, the monitoring device can react to the signals from the sensor of the probe by actuating a proximity indicator to indicate that the probe is at or proximate to the desired location. In some examples, the proximity indicator may emit a visual indication and/or an auditory indication. The visual indication may be presented at a display of the monitoring device, such as display **16300** (FIG. **16**), and/or by blinking a light such as a light emitting diode (LED).

[0088] Other sensors may be placed elsewhere on a patient's body to monitor the probe's approach to the desired location together with the sensor of the probe. There can be examples where the sensor of the probe and/or the other sensors described above may couple to an accessory box configured to process information from such sensors and to communicate with the monitoring device to actuate the proximity indicator. In the same or other embodiments, the monitoring device may communicate wirelessly to receive information from the sensor of the probe, from the other sensors, and/or from the accessory box.

[0089] Continuing with the figures, FIG. **19** illustrates a top view of tip **14410** of needle **14400**. FIG. **20** illustrates a cross-sectional side view of tip **14410** of needle **14400**.

[0090] Needle **14400** comprises shaft **19450** with interior surface **19452** and exterior surface **19451**. Needle **14400** also comprises bevel **19700** of needle tip **14410**, where bevel **19700** is shaped to ease the insertion of needle **14400** during cannulation of target zone **14800** (FIG. **14**). In the present example, needle **14400** also comprises one or more indentations **19410**, such as indentations **19411-19414**, configured to enhance ultrasonic beam reflections proximate to needle tip **14410**. As can be seen in FIG. **14**, needle **14400** is inserted "bevel-up" into target zone **14800** so that bevel edge thickness **19710**, interior surface **19452**, and/or indentations **19410** can enhance reflection and echotexture proximate to bevel **19700** for transducer **14200**. There also can be examples where one or more or more portions proximate to needle tip **14410**, such as bevel edge thickness **19710**, can be flared for further enhanced reflection.

[0091] In the present example, indentation **19412** comprises a groove located on interior surface **19452** at bevel **19700**. Indentation **19413** comprises a groove located at bevel edge thickness **19710** of bevel **19700**, where bevel edge thickness **19710** extends between interior surface **19452** and exterior surface **19451** of shaft **19450**. Indentations **19411** are located proximate to needle tip **14410** on exterior surface **19451**. In some examples, indentations **19411** can be located on exterior surface **19451** along a needle spine region, where the needle spine region is located along an apex of the needle when the needle is "bevel-up." Several patterns can be seen for indentations **19410** in FIG. **19**, including stairstep groove patterns, square function groove patterns, and geometric figured patterns, among others.

[0092] The present example also encompasses indentation **19414**, comprising a stair structure at interior surface **19452**, with ledge **194141** at a lower level of interior surface **19452**, ledge **194142** at an upper level of interior surface **19452**, and riser **194143** coupled between ledges **194141-194142**. As can be seen in FIG. **20**, interior surface **19452** at bevel **19700** is visible from top side **19490** of needle **14400**, and bottom side **20490** of needle **14400** is opposite top side **19490**.

Ledges **194141-194142** are configured such that the lower level of ledge **194141** is closer to bottom side **20490** than the upper level of ledge **194142**.

[0093] The location of indentations **19410** as described above can be beneficial, for example, to enhance ultrasonic beam reflections as close as possible to the end of needle tip **14410** for better localization thereof by monitoring device **14000** (FIG. 14), and/or by other ultrasound monitoring devices. In some examples, interior surface **19452** at bevel **19700** may be at least partially flattened to better direct ultrasonic beam reflections therefrom. For example, ledges **194141-194142** can be substantially flat, and can be set at an angle to reflect ultrasonic beams more directly towards a monitoring device, such as monitoring device **14000** (FIGS. 14-17). With respect to the illustration of FIG. 14, ledges **194141-194142** can be angled, relative to a length of needle **14400**, to be substantially parallel to transducer **14200** when needle **14400** is inserted into target zone **14800**. There also can be examples where a stair structure similar to that of indentation **19414** can be located elsewhere, such as at bevel edge thickness **19710** and/or at the needle spine of needle **14400**. Although FIG. 19 illustrates several different kinds of indentations **19410**, other examples may comprise only one type of indentation pattern rather than the combination shown for FIGS. 19-20.

[0094] Backtracking through the figures, FIG. 13 illustrates a block diagram of method **13000** for manufacturing a handheld imaging device. In some embodiments, the handheld imaging device can be one of monitoring devices **1000** (FIGS. 1-3, 8), **6000** (FIG. 6), **7000** (FIG. 7), **11000** (FIGS. 11-12), and **14000** (FIGS. 14-16).

[0095] Block **13100** of method **13000** comprises providing a housing. In one example, the housing can be one of housings **2500** (FIGS. 2, 3, 8, 11), **6500** (FIG. 6), **7500** (FIG. 7), or the housing for monitoring device **14000** (FIGS. 14-17).

[0096] Block **13200** of method **13000** comprises coupling a display to the housing of block **13100**. In some examples, the display can be similar to the display described above for display **1300** (FIGS. 1-2), **11310**, **11320** (FIGS. 11-12), and/or **16300** (FIG. 16).

[0097] Block **13300** of method **13000** comprises providing a first ultrasound array to couple to the housing of block **13100** along a first axis. In some examples, the first ultrasound array can be similar to the array described above for transducer arrays **1210** (FIGS. 1, 3, 4), **5210** (FIG. 5), and/or **14210** (FIG. 14). For example, the first transducer array can be aligned to scan a longitudinal plane of a target subdermal region, as illustrated in FIG. 14 for transducer array **14210** with respect to longitudinal plane **14100** and target zone **14800**. Similarly, the first axis can be similar to axis **3210** in FIGS. 3 and 14.

[0098] Block **13400** of method **13000** comprises providing a second ultrasound array to couple to the housing of block **13100** along a second axis different from the first axis of block **13300**, and to scan a target in an overlapping manner with the first ultrasound array of block **13300**. In one embodiment, the second ultrasound array can be similar to the array described above for transducer array **1220** (FIGS. 1, 3, 4, 5), and/or **14220** (FIGS. 14-15). For example, the second transducer array can be aligned to scan a transverse plane of a target subdermal region, as illustrated in FIG. 15 for transducer array **14220** with respect to transverse plane

15100 and target zone **14800**. Similarly, the second axis can be similar to axis **3220** in FIGS. 3 and 15.

[0099] In one embodiment, the first and second ultrasound arrays of blocks **13300** and **13400** can scan the target in an overlapping manner by overlapping as shown and described for transducer arrays **1210** and **1220** in FIG. 4. In a different embodiment, the first and second ultrasound arrays can scan the target in overlapping manner as shown and described for transducer arrays **5210** and **1220** in FIG. 5. There can also be other embodiments where blocks **13300** and/or **13400** may be modified such that the first and second arrays need not scan in an overlapping manner.

[0100] Skipping ahead in the figures, FIG. 18 illustrates a block diagram **18000** of an optional flow for blocks **13200**, **13300**, and **13400** of method **13000** in FIG. 13. In the example of FIG. 18, sub-block **18210** of block **13200** involves providing the display to present an image of at least one of a longitudinal plane view derived from the first transducer array, or of a transverse plane view derived from the second transducer array. In some examples, the longitudinal plane view may be similar to that described above for display **11310** (FIG. 11) as derived from transducer array **1210** (FIG. 4) or transducer array **5210** (FIG. 5), and the transverse plane view may be similar to that described above for display **11320** as derived from transducer array **1220** (FIGS. 4-5). In the same or other examples, the longitudinal plane view may be similar to that described above for display **16300** in FIG. 17, as derived from transducer array **14210** (FIG. 14), and the transverse plane view can be similar to that described above for display **16300** in FIG. 16, as derived from transducer array **14220** (FIGS. 14-15). Sub-block **18220** involves providing the display to present at the image a needle point highlight of a needle point of a needle during cannulation. In some examples, the needle can be similar to one of the needles described above used for subdermal cannulation of, for example, blood vessel **14500** (FIGS. 14-17). The needle point highlight can be similar to needle point highlight **16410** for needle point **14410**, as shown with respect to needle **14400** of FIGS. 14-17.

[0101] In some embodiments comprising sub-block **18220**, providing the display in block **13200** can comprise providing the display to locate the needle at a coordinate of the transverse plane view, the coordinate corresponding to a needle point depth detected by the array of block **13300**. In such embodiments, block **13300** can comprise providing the first transducer array to detect the needle point depth measured between the transducer and the needle point along the longitudinal plane. As an example, the coordinate of the transverse plane view can be similar to longitudinal coordinate **16420** of transverse view **16440** in FIG. 16, and the needle point depth can be similar to needle point depth **14600** (FIGS. 14-16) as detected by transducer array **14210** (FIG. 14).

[0102] Sub-block **18230** of block **18230** comprises concurrently presenting the transverse plane view and the needle point highlight at the display in real time. In some examples, sub-block **18230** can be enabled by sub-block **18410**, comprising providing the first and second transducer arrays in blocks **13300** and **13400** to alternately oscillate, such as to prevent or limit interference between respective transverse and longitudinal scans, as described above with respect to transducer arrays **14210** and **14220** for FIGS. 14-17.

[0103] There also can be examples where sub-block **18230** can be enabled by sub-block **18420**, comprising providing the first transducer array to operate at a first frequency, and providing the second transducer array to operate at a second frequency different than the first frequency, such as to prevent or limit interference between respective transverse and longitudinal scans, as described above with respect to transducer arrays **14210** and **14220** for FIGS. **14-17**.

[0104] Backtracking to FIG. **13**, Block **13450** of method **13000** comprises selecting the second ultrasound array of block **13400** to be substantially normal to the first ultrasound array of block **13300**. Block **13450** can be a sub-part of block **13400**. In some examples, the second ultrasound array of block **13400** can be substantially normal to the first ultrasound array of block **13300** as shown in FIG. **4** for transducer arrays **1210** and **1220**, or as shown in FIG. **5** for transducer arrays **5210** and **1220**.

[0105] Block **13500** of method **13000** comprises providing a switch mechanism coupled to the housing of block **13100** to select one of the first electronic array of block **13300** and the second electronic array of block **13400** as a source for an image to be presented on the display of block **13200**. In one embodiment, the switch mechanism can be similar to switch mechanism **1600** (FIGS. **1-3**). In the same or a different example, the switch mechanism can be configured to deactivate the second ultrasound array of block **13400** and activate the first ultrasound array of block **13300** in response to a first setting of the switch mechanism, and to deactivate the first ultrasound array of block **13300** and activate the second ultrasound array of block **13400** in response to a second setting of the switch mechanism. In the same or a different example, the display of block **13200** is configured to present images scanned from the first ultrasound array of block **13300** in response to the first setting of the switch mechanism, and to present images scanned from the second ultrasound array of block **13400** in response to the second setting of the switch mechanism.

[0106] Block **13600** of method **13000** comprises providing a needle guide aligned with the first transducer array of block **13300** and proximate to a central portion of the second transducer array of block **13400**. In some examples, the needle guide can be similar to the guide described for needle guide **3500** (FIG. **3**).

[0107] Block **13700** of method **13000** comprises providing a disposable casing with a transducer cover and configured to removably contain at least a portion of the housing of block **13100**. In some examples, the disposable casing can be as described above for casings **8000**, **9000**, and/or **10000** (FIGS. **8-10**).

[0108] In some embodiments, the sequence of blocks **13100**, **13200**, **13300**, **13400**, **13450**, **13500**, **13600**, and/or **13700** of method **13000** can be changed or otherwise altered. For example, sub-blocks **18220** and **18210** of block **13200** can be swapped in sequence. In the same or a different embodiment, one or more of blocks **13100**, **13200**, **13300**, **13400**, **13450**, **13500**, **13600**, and/or **13700** of method **13000** can comprise parts of a single block. For example, sub-blocks **18210** and/or **18220** can be sub-parts of sub-block **18230**.

[0109] Although the disclosure herein has been described with reference to specific embodiments, it will be understood by those skilled in the art that various changes may be made without departing from the spirit or scope of the invention. For example, method **13000** of FIG. **13** can be

expanded with further blocks. In one example, method **13000** could further comprise coupling a beamformer, such as beamformer **1400** (FIG. **1**), with the first and second ultrasound arrays. In the same or a different example, method **13000** can further comprise coupling a scan converter, such as scan converter **1500** (FIG. **1**), with the display of block **13200**. In the same or a different example, method **13000** can further comprise incorporating the display of block **13200**, and the first and second ultrasound arrays of blocks **13300** and **13400**, with the housing of block **13100**. In the same or a different example, method **13000** can further comprise providing a portable and/or rechargeable power source, such as power source **1700** (FIG. **1**), coupled to the housing of block **13100**. In the same or a different example, method **13000** can further comprise configuring the housing of block **13100** for single-handed and/or non-dominant-handed operation of the handheld imaging device, as described above for monitoring device **1000**. Such alternate configurations would not depart from the inventive concepts herein disclosed. Additional examples have been given in the foregoing description.

[0110] Accordingly, the disclosure of embodiments in the disclosure is intended to be illustrative of the scope of the invention and is not intended to be limiting. It is intended that the scope of the invention shall be limited only to the extent required by the appended claims. To one of ordinary skill in the art, it will be readily apparent that the handheld imaging devices and related methods discussed herein may be implemented in a variety of embodiments, and that the foregoing discussion of certain of these embodiments does not necessarily represent a complete description of all possible embodiments. Rather, the detailed description of the drawings, and the drawings themselves, disclose at least one preferred embodiment of the invention, and may disclose alternative embodiments of the invention. All elements claimed in any particular claim are essential to the invention claimed in that particular claim. Consequently, replacement of one or more claimed elements constitutes reconstruction and not repair. Additionally, benefits, other advantages, and solutions to problems have been described with regard to specific embodiments. The benefits, advantages, solutions to problems, and any element or elements that may cause any benefit, advantage, or solution to occur or become more pronounced, however, are not to be construed as critical, required, or essential features or elements of any or all of the claims, unless such benefit, advantage, solution, or element is stated in such claims.

[0111] Moreover, embodiments and limitations disclosed herein are not dedicated to the public under the doctrine of dedication if the embodiments and/or limitations: (1) are not expressly claimed in the claims; and (2) are or are potentially equivalents of express elements and/or limitations in the claims under the doctrine of equivalents.

What is claimed is:

1. An apparatus for facilitating intra-tissue inspection of a probe at a target region, the apparatus comprising:
 - a processor configured to,
 - receive, from a longitudinal transducer array, data comprising a longitudinal scan of a longitudinal cross-section of the target region,
 - receive, from a transverse transducer array, data comprising a transverse scan of a transverse cross-section of the target region,

track movement of a probe point of the probe based on the longitudinal scan,
 determine a probe point depth of the probe point based on the longitudinal scan,
 generate a transverse cross-section view of the target region based on the transverse scan, the transverse cross-section view having depth coordinates and transverse coordinates, the probe point depth having a corresponding depth coordinate in the transverse cross-section view, and
 display the transverse cross-section view with a probe point highlight at the depth coordinate of the transverse cross-section view corresponding to the probe point depth of the probe point.

2. The apparatus of claim 1, wherein the transverse transducer array is arranged to provide the transverse cross-section view of the target region transverse to a direction of travel of the probe.

3. The apparatus of claim 1, wherein the longitudinal transducer array is arranged such that an axis of the longitudinal array is aligned with a direction of travel of the probe.

4. The apparatus of claim 1, wherein the processor is configured to display the probe point highlight in the transverse cross-section view when the probe point is located within a range of the transverse scan.

5. The apparatus of claim 1, wherein the processor is configured to display the probe point highlight in the transverse cross-section view when the probe point is located outside a range of the transverse scan.

6. The apparatus of claim 1, wherein the processor is further configured to control operation of the longitudinal transducer array and the transverse transducer array.

7. The apparatus of claim 6, wherein the processor is configured to simultaneously operate the longitudinal transducer array at a first frequency and the transverse transducer array at a second frequency substantially non-interfering with the first frequency.

8. The apparatus of claim 6, wherein the processor is configured to operate the longitudinal transducer array in response to a first user input and operate the transverse transducer array in response to a second user input subsequent to the first user input.

9. The apparatus of claim 1, wherein the processor is configured to receive data from the transverse transducer array and data from the longitudinal transducer array with high frequency oscillation between the transverse transducer array and the longitudinal transducer array.

10. The apparatus of claim 1, wherein the processor is further configured to present on a display the transverse cross-section view of the target region concurrently with the probe point highlight at the depth coordinate of the transverse cross-section view.

11. The apparatus of claim 1, wherein the probe point highlight comprises a graphic of a dot, oval, triangle, or square.

12. The apparatus of claim 1, wherein the processor is further configured to determine a probe width location based on at least one of the longitudinal scan and the transverse scan, the probe width location having a corresponding transverse coordinate in the transverse cross-section view, and display the probe point highlight at the transverse coordinate of the transverse cross-section view corresponding to the probe width location.

13. The apparatus of claim 1, further comprising a transducer in communication with the processor, wherein the transducer comprises a plurality of transducer elements, and wherein a first portion of the plurality of transducer elements comprises the longitudinal transducer array, and wherein a second portion of the plurality of transducer elements comprises the transverse transducer array.

14. The apparatus of claim 13, wherein the first portion or the second portion of the plurality of transducer elements is aligned along an axis.

15. The apparatus of claim 13, wherein the first portion of the plurality of transducer elements and the second portion of the plurality of transducer elements are non-overlapping or at least partially overlapping.

16. The apparatus of claim 13, wherein a portion of the plurality of transducer elements is shared between the longitudinal transducer array and the transverse transducer array.

17. The apparatus of claim 1, further comprising a first transducer and a second transducer in communication with the processor, wherein the first transducer comprises the longitudinal transducer array, and the second transducer comprises the transverse transducer array.

18. The apparatus of claim 1, wherein the longitudinal transducer array is aligned along a first axis and the transverse transducer array is aligned along a second axis, and wherein the longitudinal and transverse transducer arrays are arranged such that the first axis and the second axis are transverse to each other.

19. The apparatus of claim 18, wherein the longitudinal and transverse transducer arrays are arranged such that the first axis and the second axis are perpendicular.

20. The apparatus of claim 1, further comprising the probe, the probe comprising a needle having an interior surface, an exterior surface, a needle tip comprising a bevel, and one or more indentations configured to enhance ultrasonic beam reflections off the needle tip, wherein a first indentation of the one or more indentations is located at the interior surface adjacent to the bevel of the needle tip.

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