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(54) **ULTRASONIC MEASUREMENT APPARATUS AND ULTRASONIC PROBE**

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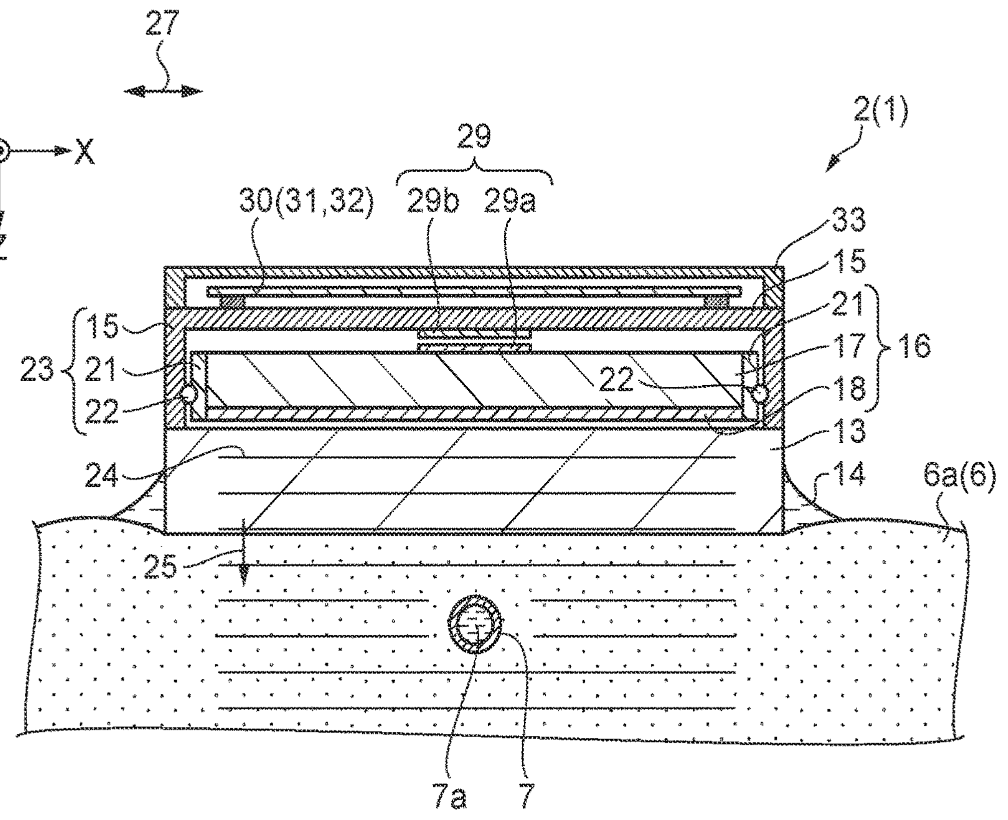
(57) **ABSTRACT**

An ultrasonic measurement apparatus includes: an ultrasonic element array for emitting an ultrasonic wave in a first direction; a columnar acoustic lens for changing the traveling direction of the ultrasonic wave emitted from the ultrasonic element array; and a linear guide for restricting a movement direction so that the acoustic lens and the ultrasonic element array move relatively each other in a second direction crossing the first direction and a column axis direction of the acoustic lens.



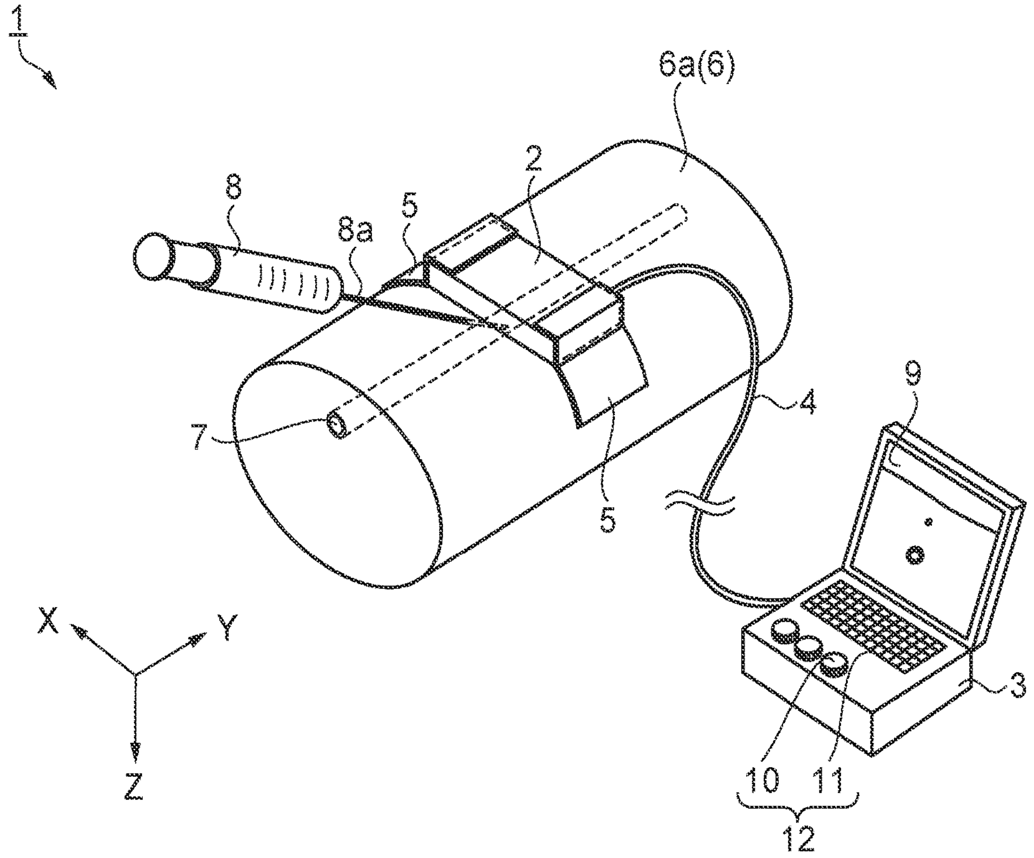
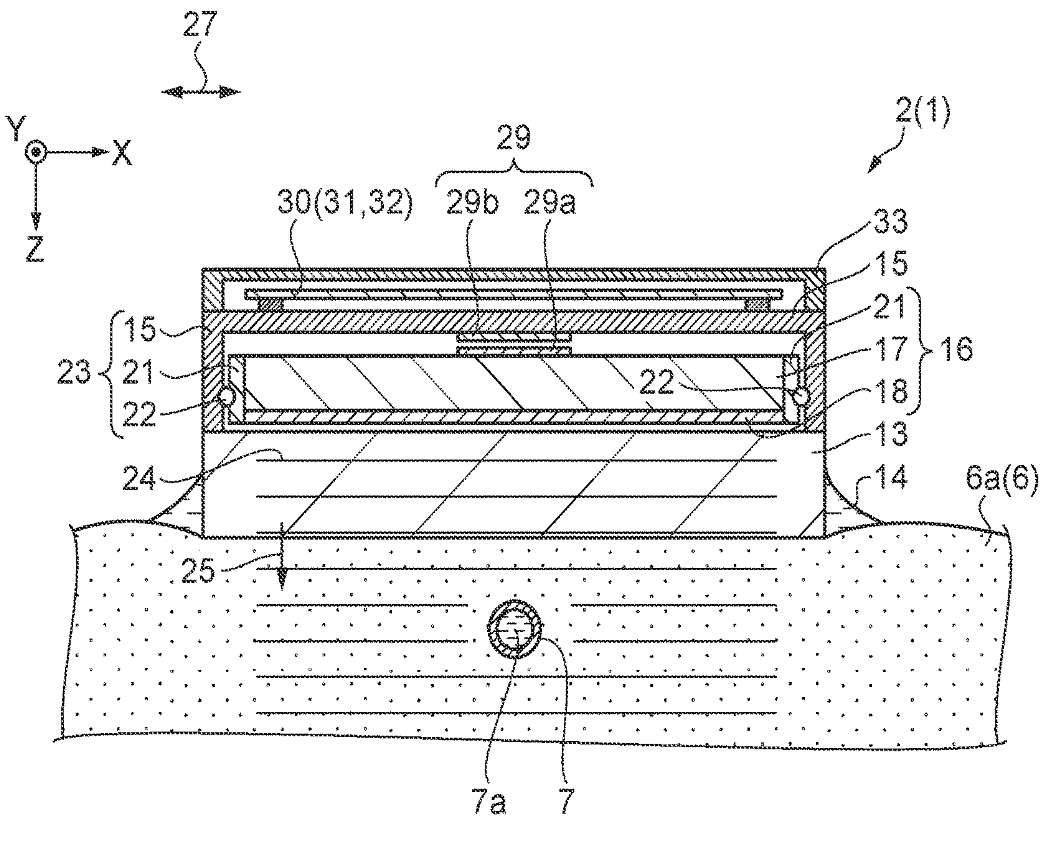


FIG. 1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30(31,32)
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18
13
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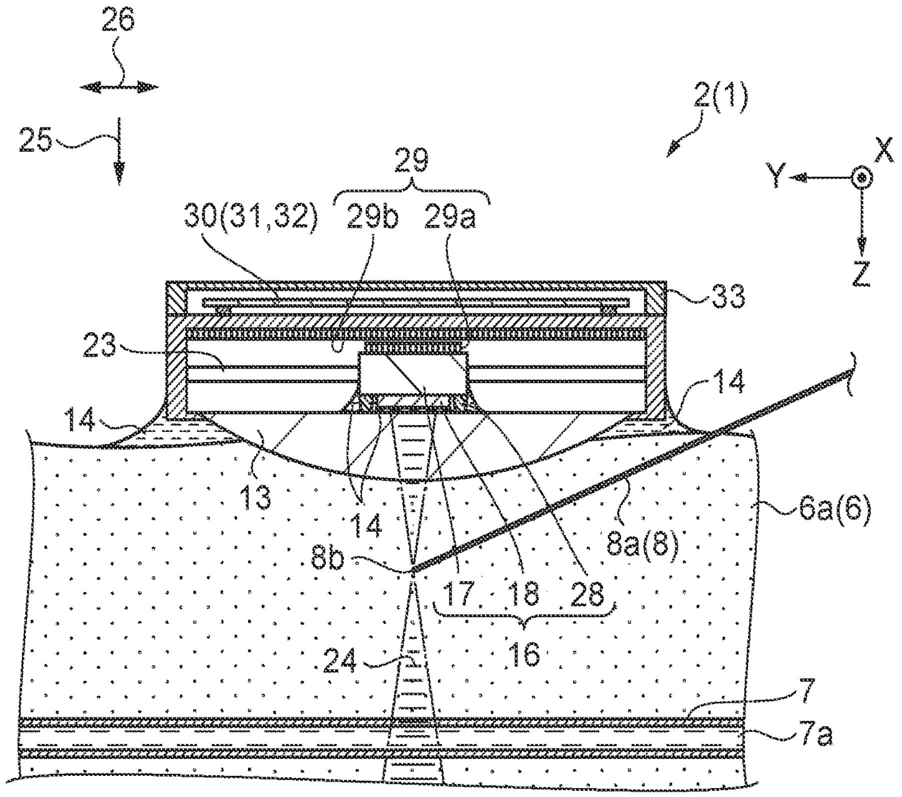
14
6a(6)
25
7a
7

FIG. 2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8a(8)
8b
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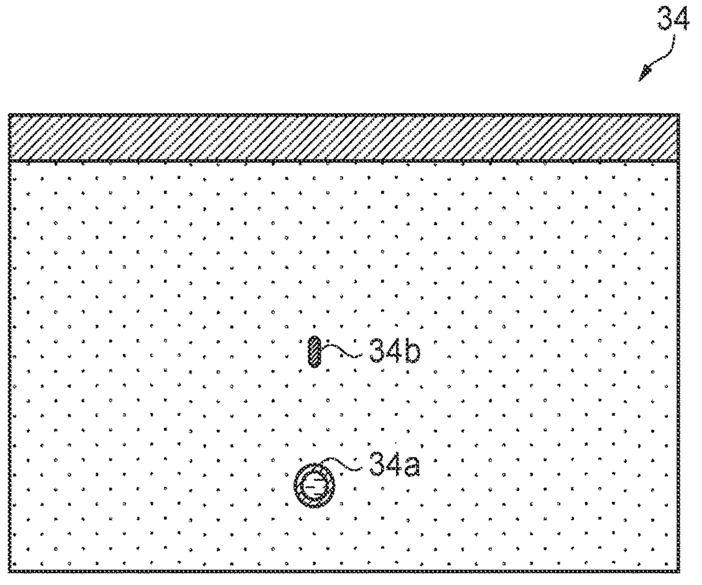
24
7
7a

FIG. 3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34b
34a

FIG. 4

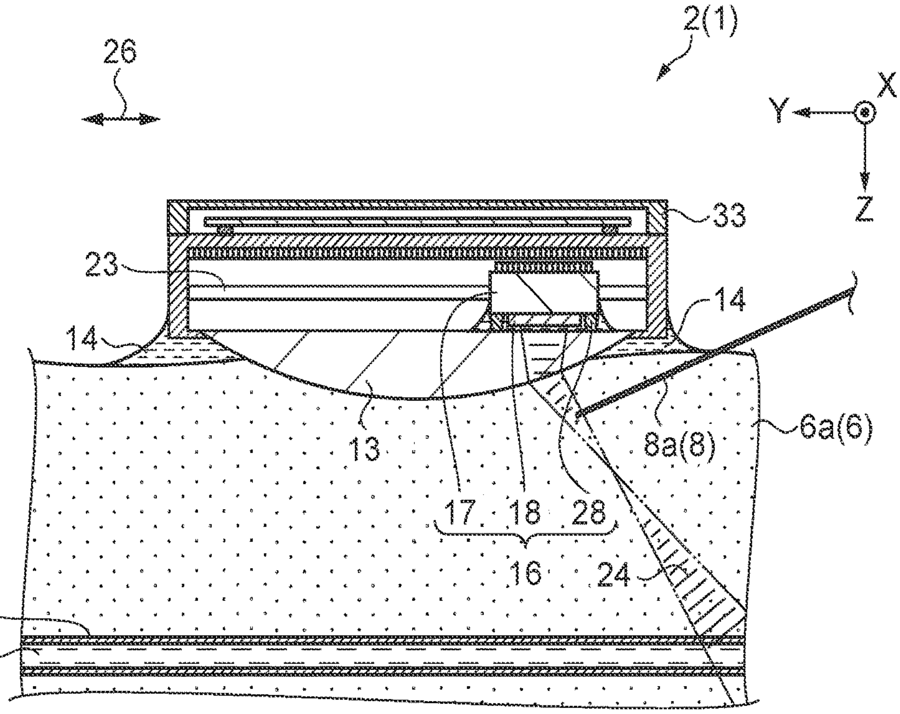


FIG. 5

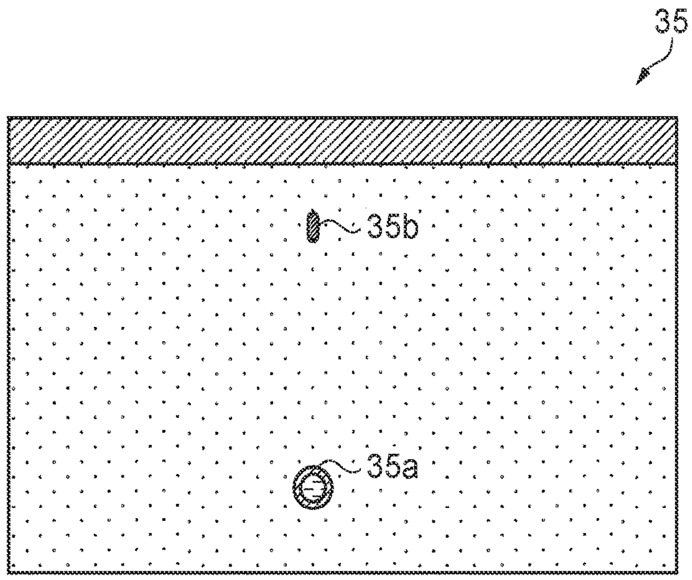


FIG. 6

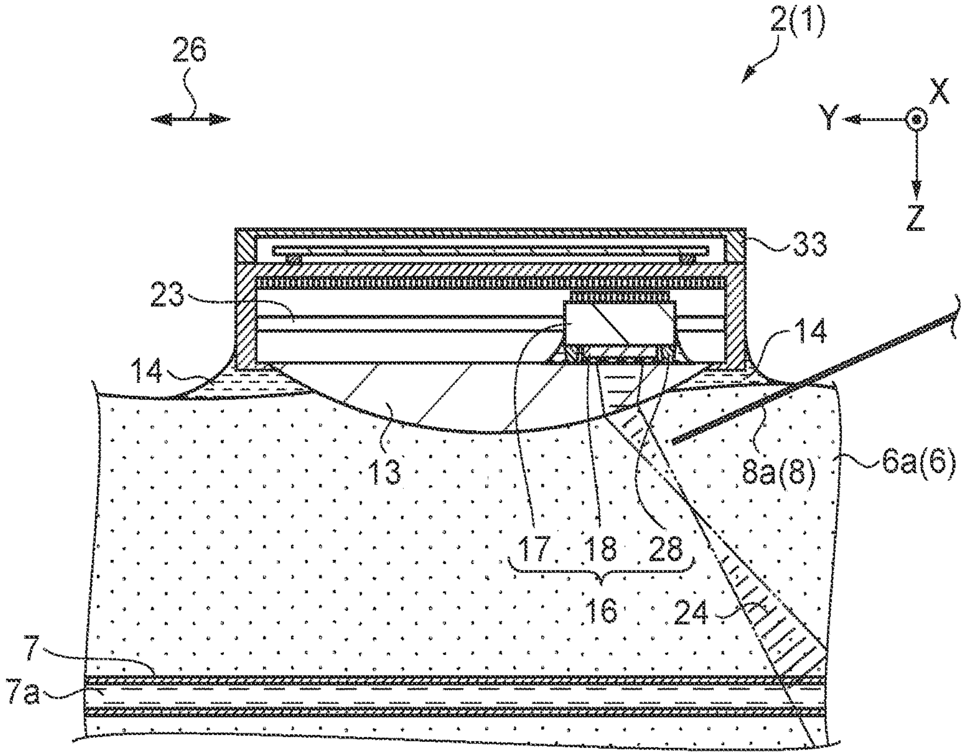


FIG. 7

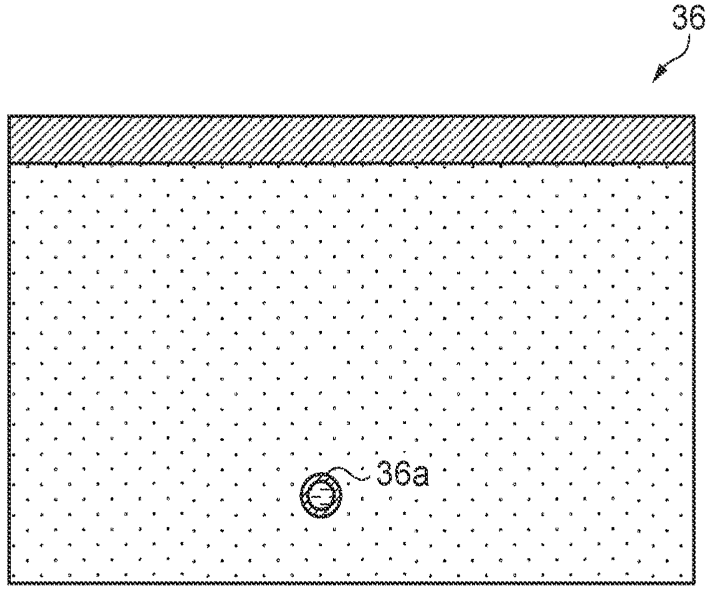


FIG. 8

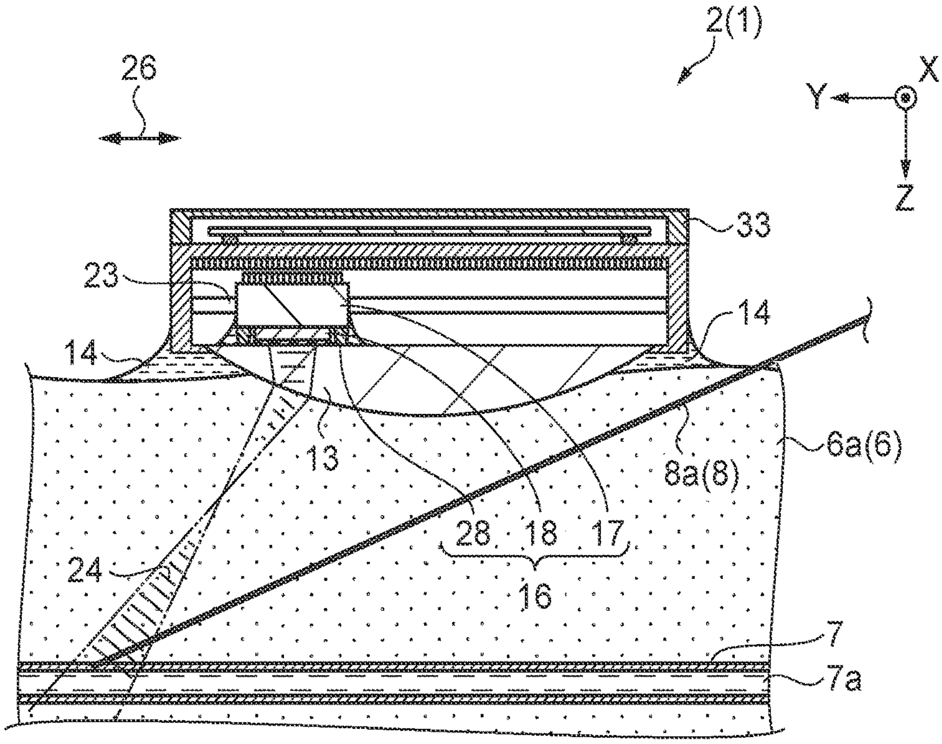


FIG. 9

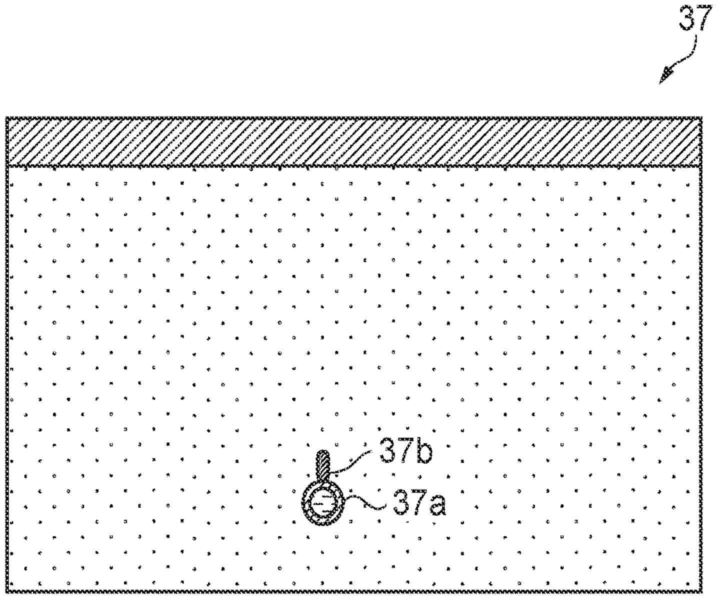
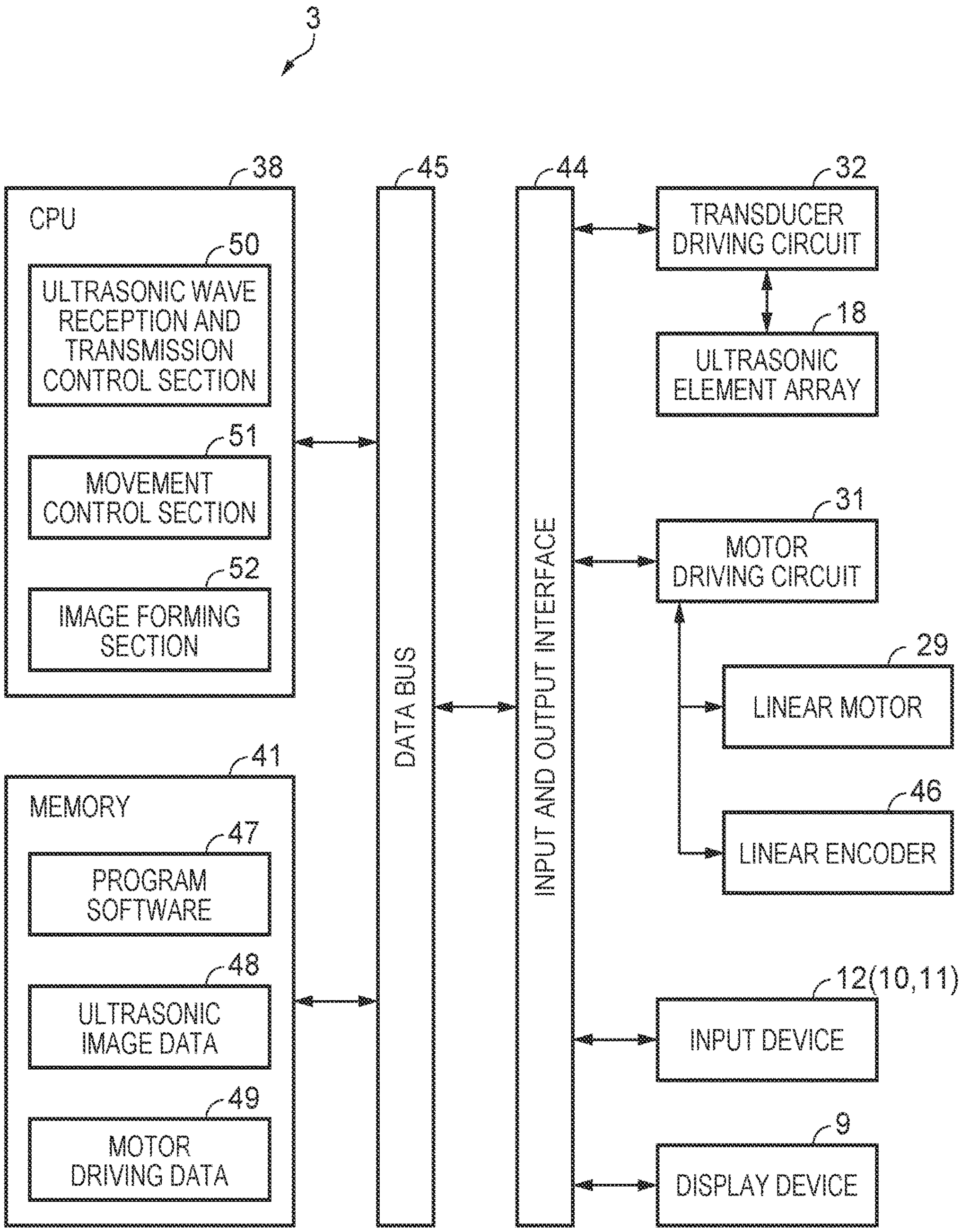


FIG.10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ULTRASONIC WAVE RECEPTION AND TRANSMISSION CONTROL SECTION
51
MOVEMENT CONTROL SECTION
52
IMAGE FORMING SECTION
41
MEMORY
47
PROGRAM SOFTWARE
48
ULTRASONIC IMAGE DATA
49
MOTOR DRIVING DATA
45
DATA BUS
44
INPUT AND OUTPUT INTERFACE
32
TRANSDUCER DRIVING CIRCUIT
18
ULTRASONIC ELEMENT ARRAY
31
MOTOR DRIVING CIRCUIT
29
LINEAR MOTOR
46
LINEAR ENCODER
12(10,11)
INPUT DEVICE
9
DISPLAY DEVICE

FIG.11

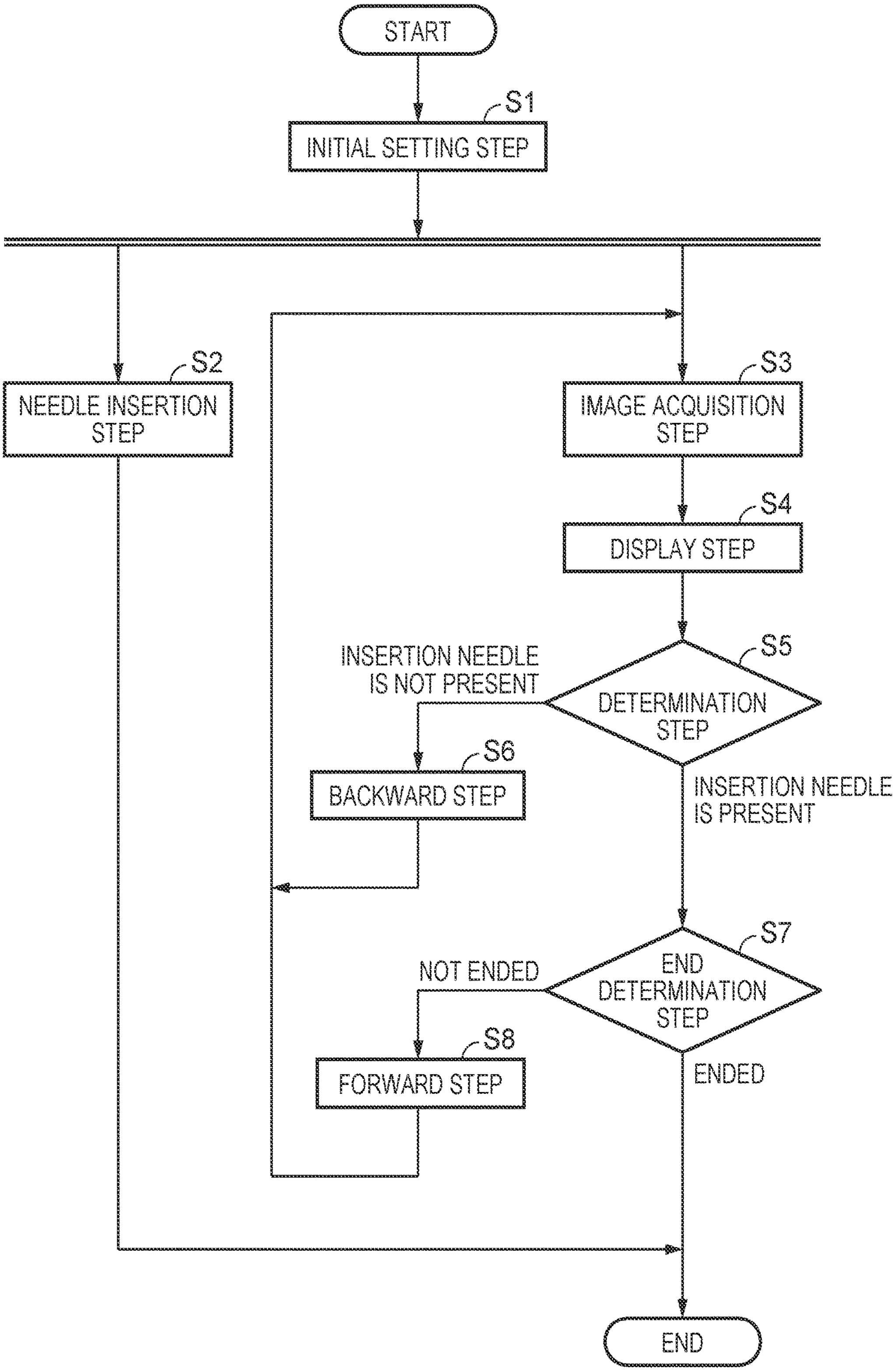
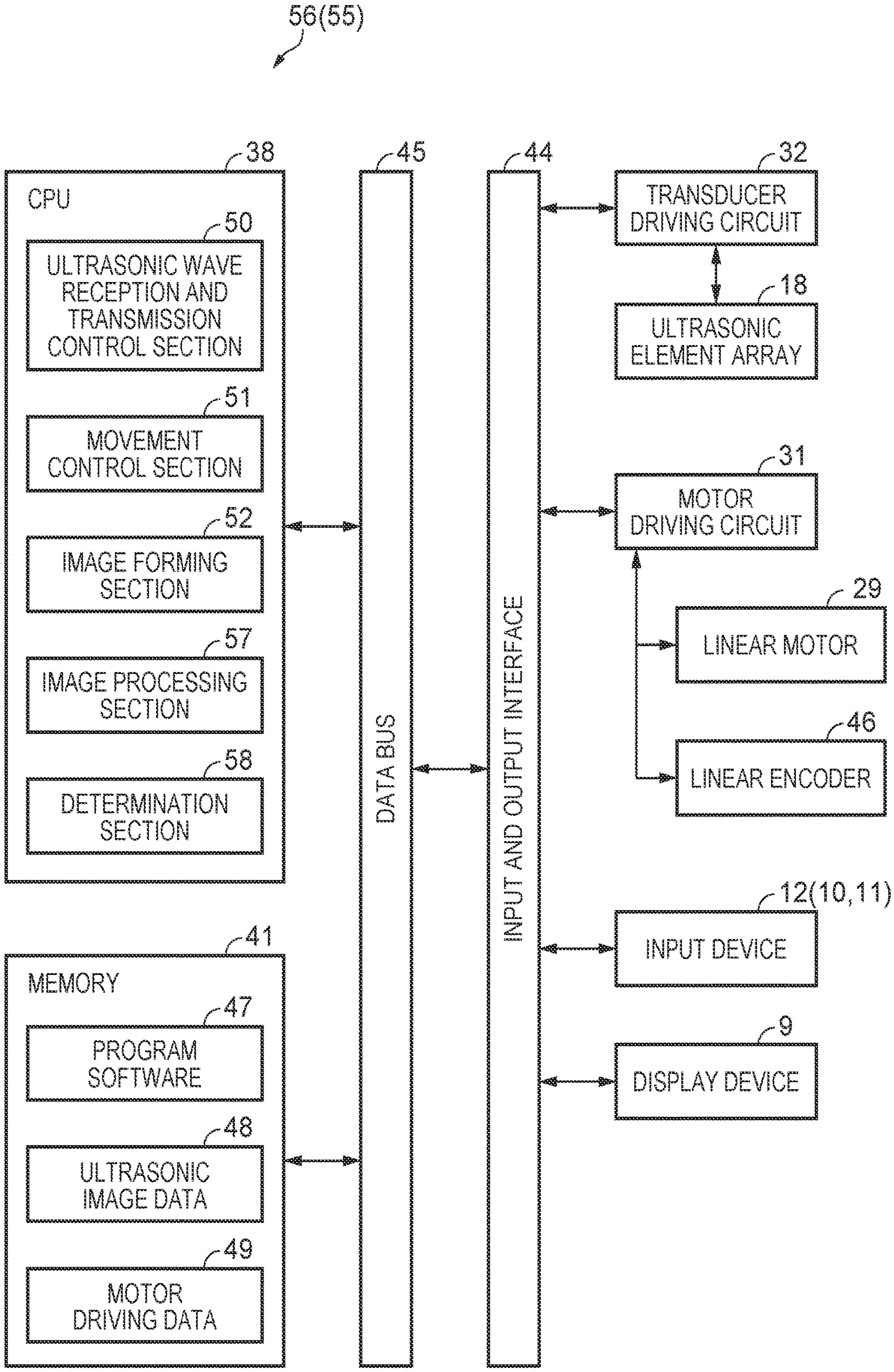

START
S1
INITIAL SETTING STEP
S2
NEEDLE INSERTION STEP
S3
IMAGE ACQUISITION STEP
S4
DISPLAY STEP
S5
DETERMINATION STEP
INSERTION NEEDLE IS NOT PRESENT
S6
BACKWARD STEP
INSERTION NEEDLE IS PRESENT
S7
END DETERMINATION STEP
NOT ENDED
S8
FORWARD STEP
ENDED
END

FIG.12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58
DETERMINATION SECTION
41
MEMORY
47
PROGRAM SOFTWARE
48
ULTRASONIC IMAGE DATA
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MOTOR DRIVING DATA
45
DATA BUS
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INPUT AND OUTPUT INTERFACE
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TRANSDUCER DRIVING CIRCUIT
18
ULTRASONIC ELEMENT ARRAY
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MOTOR DRIVING CIRCUIT
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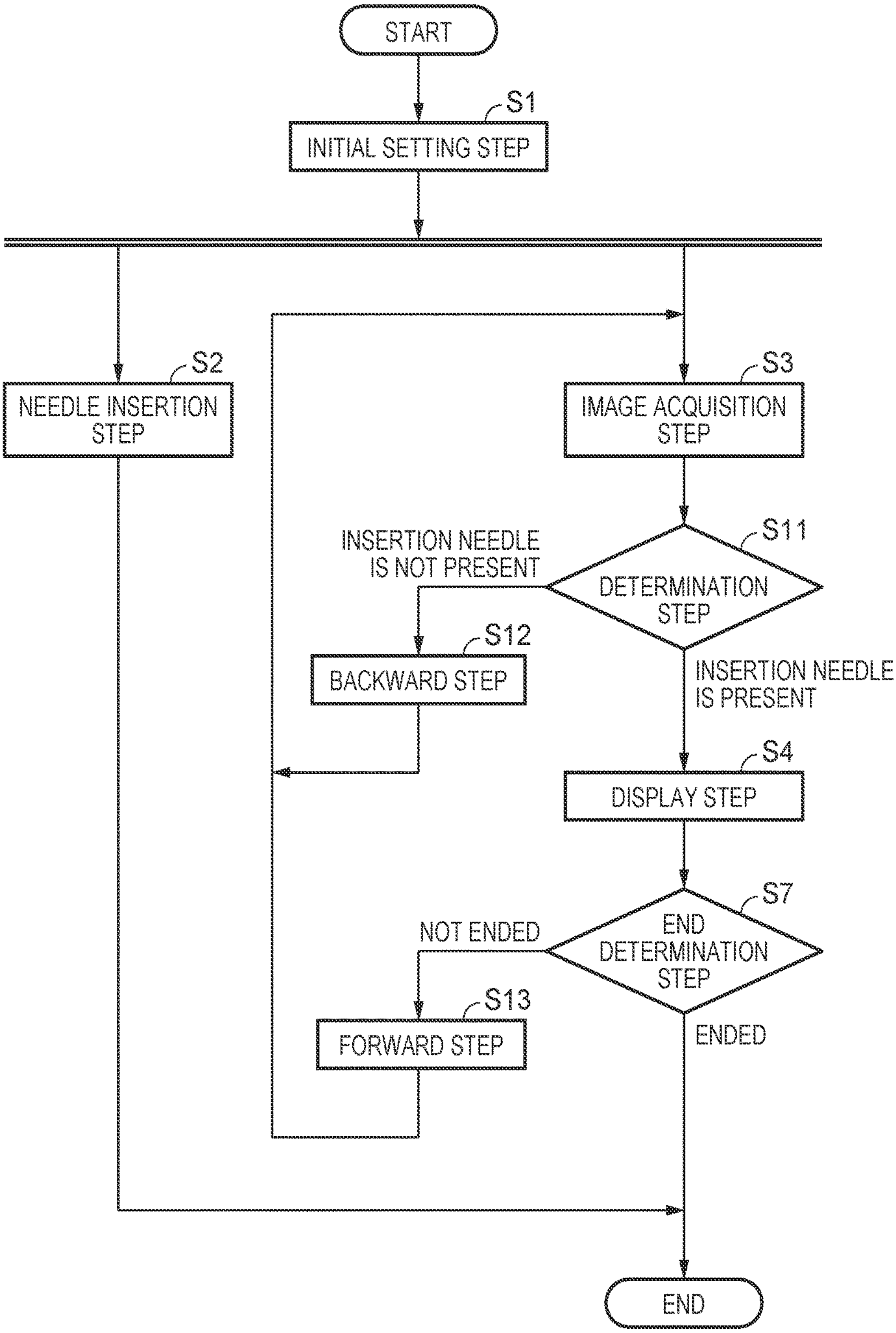
LINEAR MOTOR
46
LINEAR ENCODER
12(10,11)
INPUT DEVICE
9
DISPLAY DEVICE

FIG.13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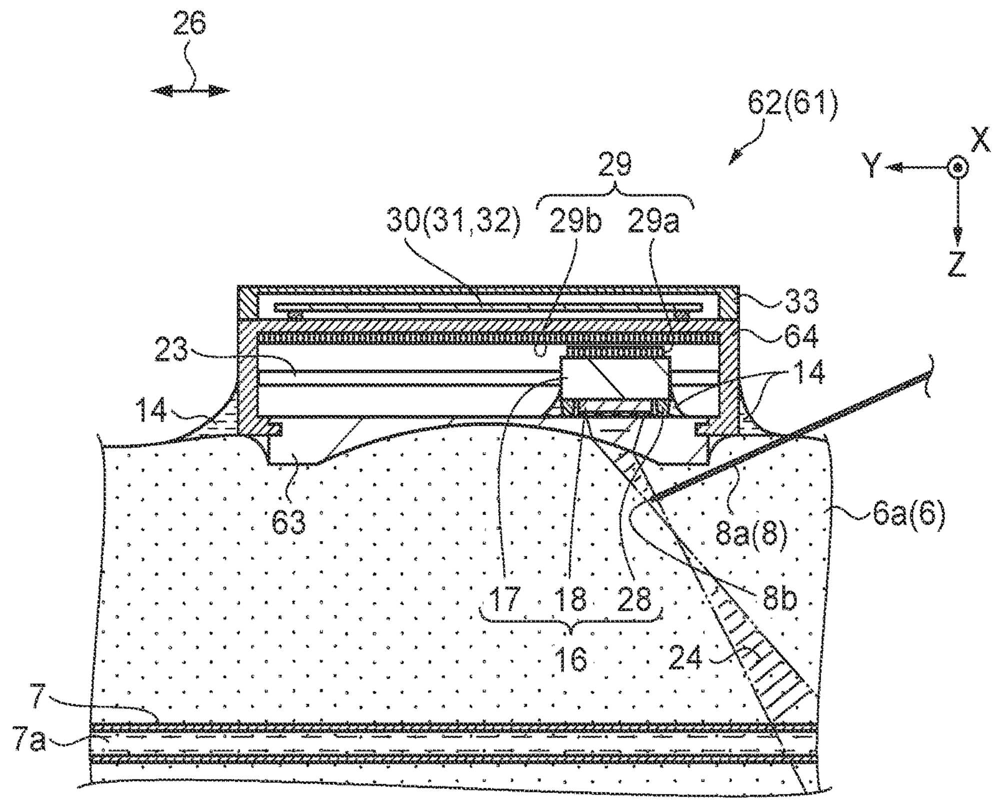
S1
INITIAL SETTING STEP
S2
NEEDLE INSERTION STEP
S3
IMAGE ACQUISITION STEP
S11
DETERMINATION STEP
INSERTION NEEDLE IS NOT PRESENT
S12
BACKWARD STEP
INSERTION NEEDLE IS PRESENT
S4
DISPLAY STEP
S7
END DETERMINATION STEP
NOT ENDED
S13
FORWARD STEP
ENDED
END

FIG.14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6a(6)
8b
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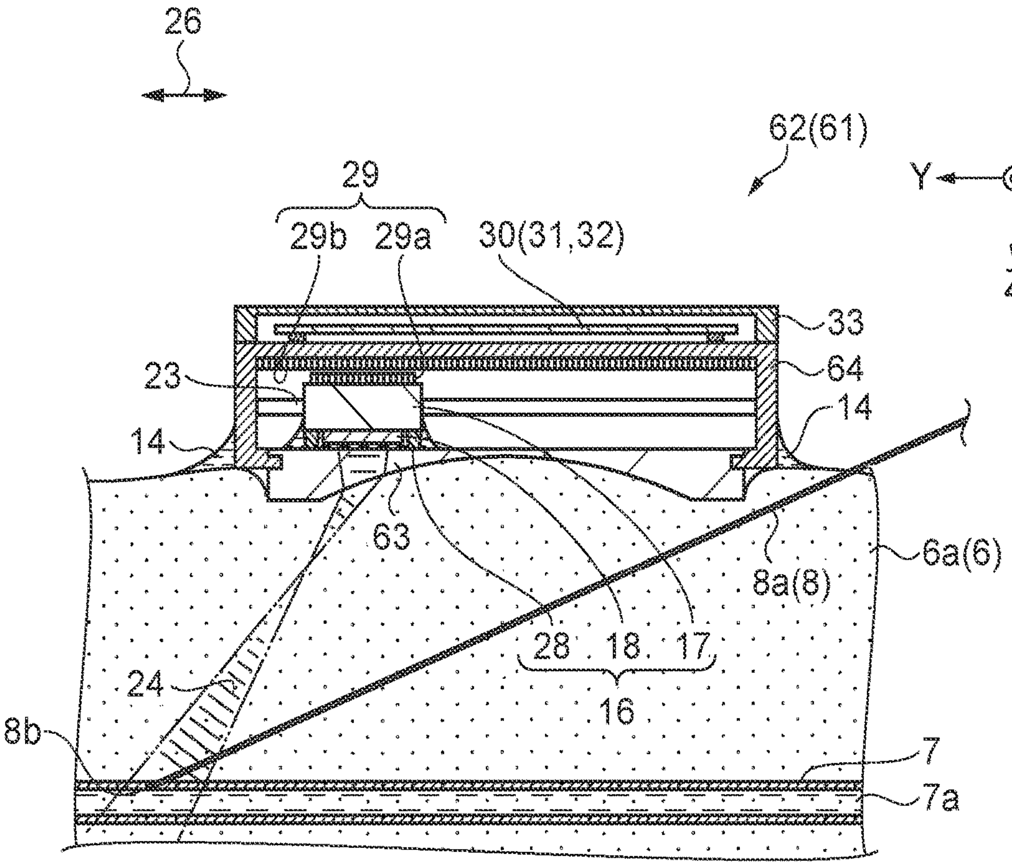
7a

FIG.15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8b
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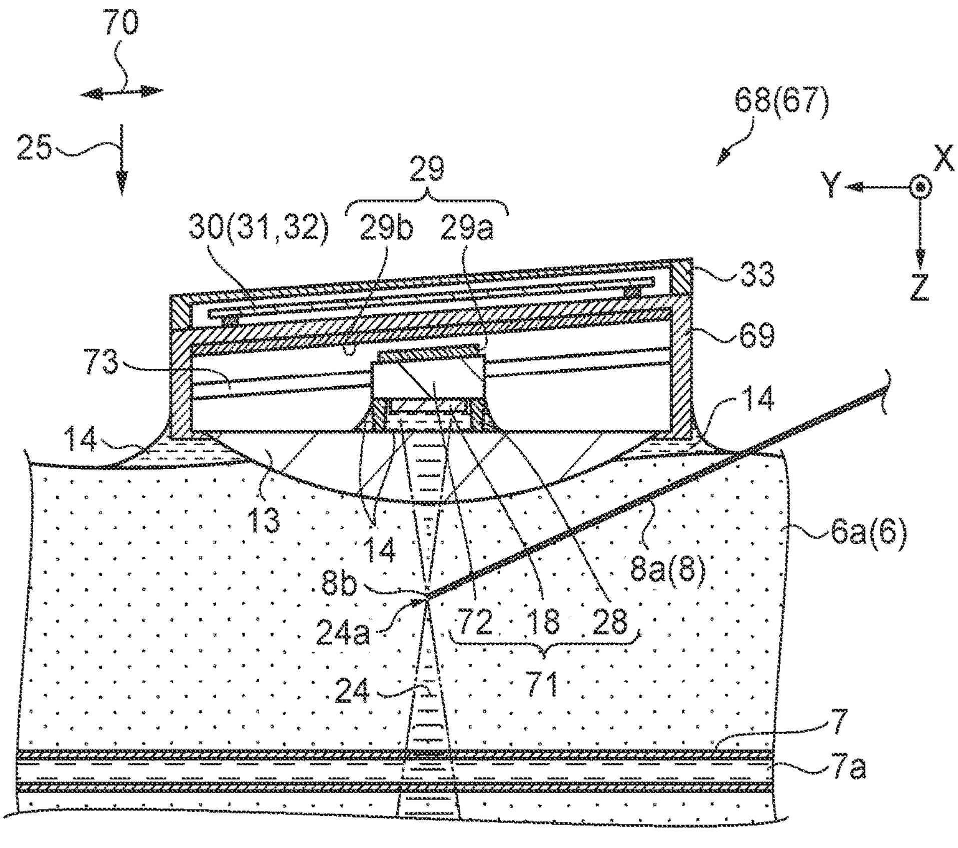
7a

FIG.16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29b
29a
Z
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73
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6a(6)
8a(8)
8b
24a
72
18
28
71
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7
7a

FIG.17

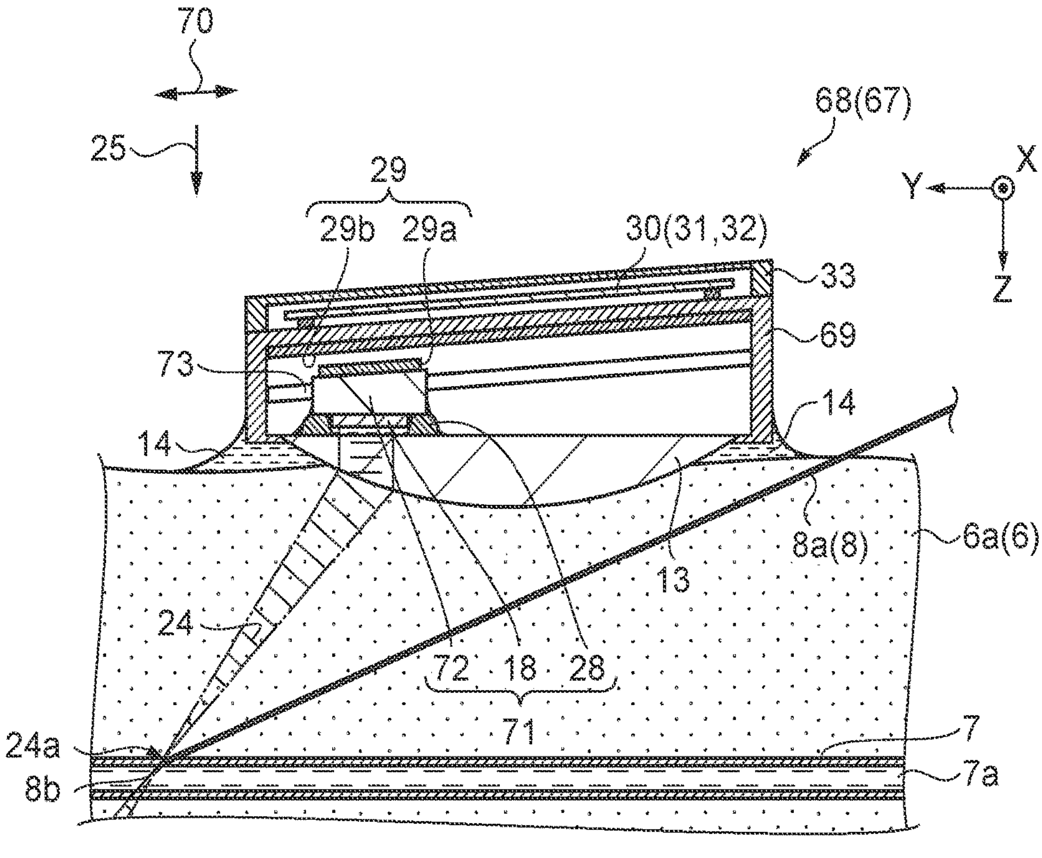
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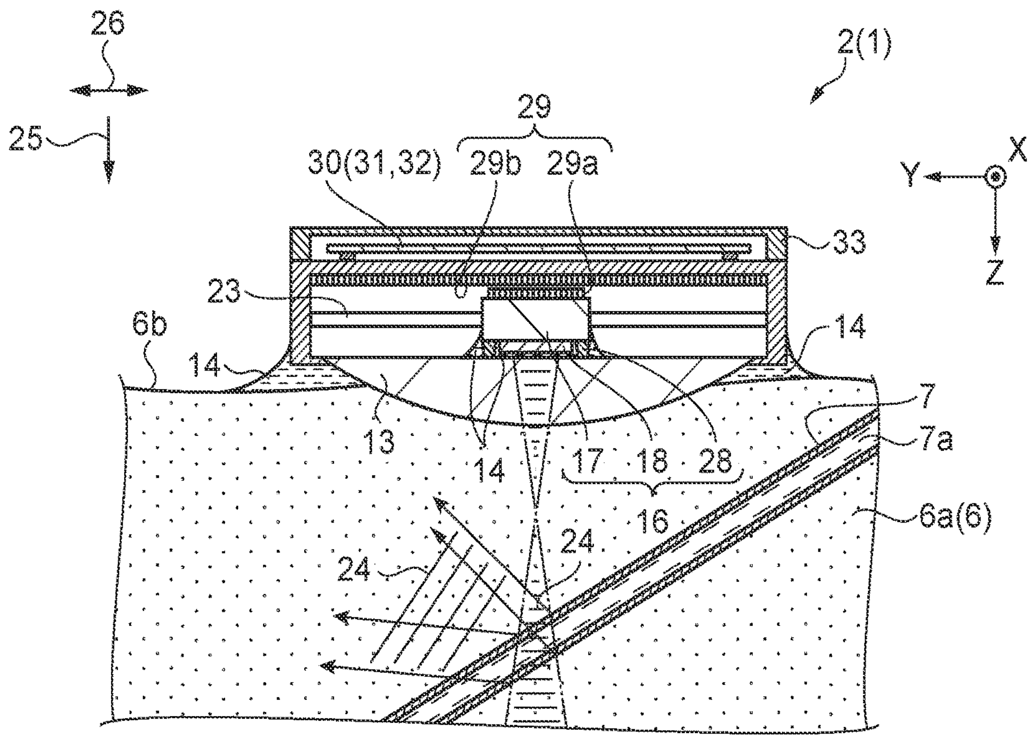
FIG.18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6a(6)
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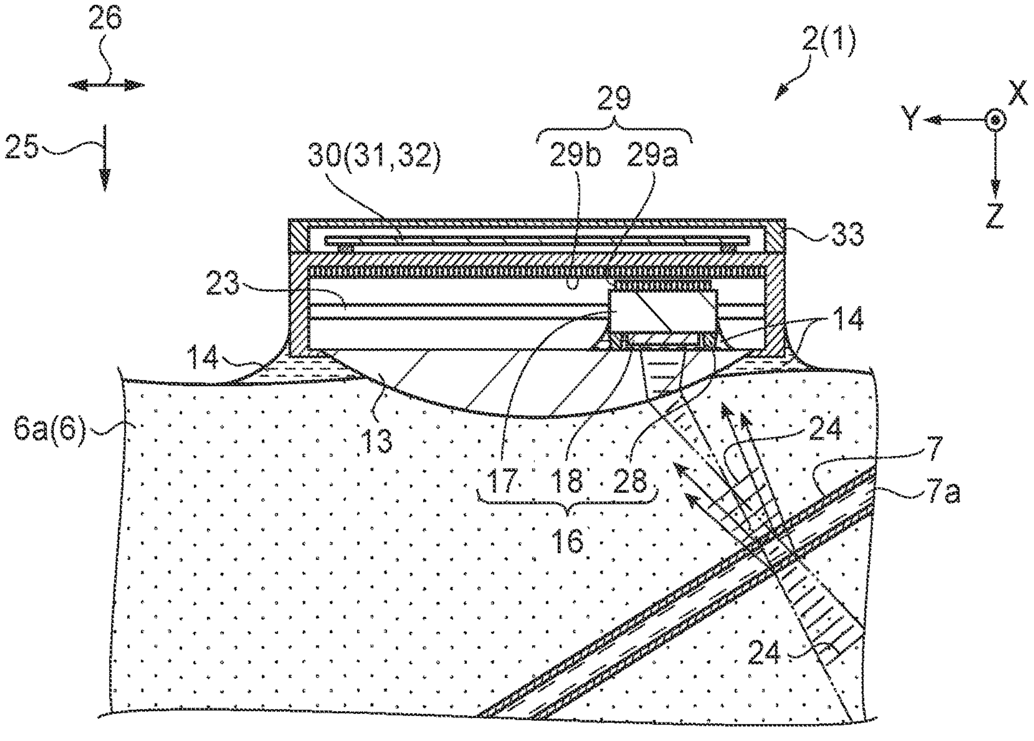
24

FIG.19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7a
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FIG.20

ULTRASONIC MEASUREMENT APPARATUS AND ULTRASONIC PROBE

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention relates to an ultrasonic measurement apparatus and an ultrasonic probe.

[0003] 2. Related Art

[0004] An ultrasonic measurement apparatus for displaying ultrasonic waves emitted to a subject under examination using reflected waves, which are obtained by the reflection of the ultrasonic waves from the inside of the subject under examination, has been widely used. An insertion needle may be inserted into an organ, such as a blood vessel located inside the subject under examination using an ultrasonic measurement apparatus. JP-A-2003-334191 discloses an ultrasonic measurement apparatus including a guide unit for guiding an insertion needle. According to this, a hole for guiding the insertion needle is provided in the guide unit.

[0005] When inserting the insertion needle into the subject under examination, the operator performs an operation so that the insertion needle enters an ultrasonic wave emission range. As a result, an image of the insertion needle is displayed on the ultrasonic image. The operator checks whether or not the traveling direction of the insertion needle matches the target location while observing the ultrasonic image. The operator advances the insertion needle to the target location by adjusting the insertion angle of the insertion needle while observing the ultrasonic image.

[0006] The operator checks the insertion needle using an ultrasonic measurement apparatus. At this time, the operator adjusts a probe so that ultrasonic waves are emitted to the distal end of the insertion needle. Since the distal end of the insertion needle moves, the operator adjusts the probe while observing the display screen. When the probe disclosed in JP-A-2003-334191 is used, an operation to move the probe so that the insertion needle is imaged is performed. At this time, since the probe is operated in a state in which the probe is held by hand, the probe shakes. For this reason, the ultrasonic image shakes and the distal end of the insertion needle becomes not clear. As a result, the distal end of the insertion needle may not be able to be checked on the display screen. Therefore, an ultrasonic measurement apparatus capable of changing the traveling direction of ultrasonic waves with good operability has been desired.

SUMMARY

[0007] An advantage of some aspects of the invention is to solve at least a part of the problems described above, and the invention can be implemented as the following forms or application examples.

Application Example 1

[0008] An ultrasonic measurement apparatus according to this application example includes: an ultrasonic wave transmission unit that emits an ultrasonic wave in a first direction; a columnar acoustic lens that changes a traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit; and a movement restriction unit that restricts a movement direction such that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in a second direction crossing the first direction and a column axis direction of the acoustic lens.

[0009] According to this application example, the ultrasonic measurement apparatus includes the ultrasonic wave transmission unit, the acoustic lens, and the movement restriction unit. The ultrasonic wave transmission unit emits an ultrasonic wave in the first direction. The acoustic lens is a columnar lens, and changes the traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit. The acoustic lens is a lens having a predetermined sectional shape extending in a predetermined direction, and the direction in which the predetermined sectional shape extends is referred to as a column axis direction. The second direction is a direction crossing the first direction and the column axis direction of the acoustic lens. In addition, when the acoustic lens and the ultrasonic wave transmission unit move relatively each other, the movement restriction unit restricts the movement direction so that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in the second direction.

[0010] Accordingly, the second direction in which the acoustic lens and the ultrasonic wave transmission unit move relatively each other is a direction crossing the first direction. The second direction is a direction crossing the column axis direction of the acoustic lens. The acoustic lens is a lens whose thickness in the first direction changes corresponding to the position in the second direction. The surface of the acoustic lens on the first direction side has irregularities. In addition, the ultrasonic wave is input to the acoustic lens, and is output from the acoustic lens. The traveling direction of the ultrasonic wave output from the acoustic lens changes corresponding to the angle of the surface of the acoustic lens on the first direction side.

[0011] The acoustic lens and the ultrasonic wave transmission unit move relatively each other in the second direction. Accordingly, since the angle of the surface on the first direction side of the location where the ultrasonic wave is output from the acoustic lens is changed, the traveling direction of the ultrasonic wave output from the acoustic lens is changed. Therefore, the ultrasonic measurement apparatus can change the traveling direction of the ultrasonic wave. The traveling direction of the ultrasonic wave changes only in the second direction, but does not change in the column axis direction. Therefore, the ultrasonic measurement apparatus can change the traveling direction of the ultrasonic wave with good operability.

Application Example 2

[0012] In the ultrasonic measurement apparatus according to the application example, the acoustic lens may be a convex lens, and a material of the acoustic lens may be a material in which a traveling speed of an ultrasonic wave is higher than that of an ultrasonic wave in a subject under examination.

[0013] According to this application example, the acoustic lens is a convex lens. In addition, the acoustic lens is used in contact with the subject under examination. The material of the acoustic lens is a material in which the traveling speed of the ultrasonic wave is higher than the traveling speed of the ultrasonic wave in the subject under examination. Therefore, the traveling speed of the ultrasonic wave is reduced when the ultrasonic wave enters the subject under examination from the acoustic lens. The acoustic lens is a convex lens, and the subject under examination functions as a concave lens. Accordingly, the ultrasonic measurement apparatus can emit the ultrasonic wave to a place wider than the width of the acoustic lens in the second direction.

Application Example 3

[0014] In the ultrasonic measurement apparatus according to the application example, the acoustic lens may be a concave lens, and a material of the acoustic lens may be a material in which a traveling speed of an ultrasonic wave is lower than that of an ultrasonic wave in a subject under examination.

[0015] According to this application example, the acoustic lens is a concave lens. In addition, the acoustic lens is used in contact with the subject under examination. The material of the acoustic lens is a material in which the traveling speed of the ultrasonic wave is lower than the traveling speed of the ultrasonic wave in the subject under examination. Therefore, the traveling speed of the ultrasonic wave is increased when the ultrasonic wave enters the subject under examination from the acoustic lens. In addition, since the acoustic lens is a concave lens, the ultrasonic measurement apparatus can emit the ultrasonic wave to a place wider than the width of the acoustic lens in the second direction.

Application Example 4

[0016] The ultrasonic measurement apparatus according to the application example further includes: a moving unit that moves the acoustic lens and the ultrasonic wave transmission unit relatively each other; a control unit that controls a relative position between the acoustic lens and the ultrasonic wave transmission unit; and an input unit that receives an input of the relative position.

[0017] According to this application example, the ultrasonic measurement apparatus further includes the moving unit, the control unit, and the input unit. The moving unit moves the acoustic lens and the ultrasonic wave transmission unit relatively each other. The control unit controls the relative position. The input unit receives an input of the relative position between the acoustic lens and the ultrasonic wave transmission unit that are moved relatively each other by the moving unit. The operator inputs the relative position through the input unit. The control unit controls the moving unit to move the acoustic lens and the ultrasonic wave transmission unit relatively each other. Therefore, the operator can perform an operation of moving the acoustic lens and the ultrasonic wave transmission unit relatively each other in the second direction.

Application Example 5

[0018] The ultrasonic measurement apparatus according to the application example may further include: a moving unit that moves the acoustic lens and the ultrasonic wave transmission unit relatively each other; a control unit that controls the moving unit; an ultrasonic wave receiving unit that receives a reflected wave reflected by a subject under examination; an image forming unit that forms an ultrasonic image from data of the reflected wave; a determination unit that determines a subject of the ultrasonic image; and a display unit that displays the ultrasonic image. When the ultrasonic image does not include the subject, the control unit controls the moving unit such that the ultrasonic image includes the subject.

[0019] According to this application example, the ultrasonic measurement apparatus includes the moving unit, the control unit, the ultrasonic wave receiving unit, the image forming unit, and the determination unit in addition to the ultrasonic wave transmission unit, the acoustic lens, and the movement restriction unit. The moving unit moves the acoustic lens and the ultrasonic wave transmission unit relatively each other. The control unit controls the moving unit. The ultrasonic wave receiving unit receives a reflected wave reflected by the subject under examination. The image forming unit forms an ultrasonic image from the data of the reflected wave. The determination unit determines a subject of the ultrasonic image. The display unit displays an ultrasonic image.

[0020] The ultrasonic wave transmission unit emits an ultrasonic wave to the subject under examination, and the ultrasonic wave receiving unit receives a reflected wave that is reflected by the subject under examination. Then, the image forming unit forms an ultrasonic image from the data of the reflected wave, and the determination unit determines a subject of the ultrasonic image. At this time, when the ultrasonic image does not include a subject, the control unit controls the moving unit. Then, the ultrasonic image is made to include a subject. As a result, the operator can recognize the position of the subject by observing the ultrasonic image without controlling the moving unit.

Application Example 6

[0021] In the ultrasonic measurement apparatus according to the application example, the subject may be a rod-shaped member having a distal end portion, and the control unit may detect the distal end portion and display the ultrasonic image including the distal end portion on the display unit.

[0022] According to this application example, the subject is a rod-shaped member having a distal end portion. The control unit detects the distal end portion. Then, the ultrasonic measurement apparatus displays an ultrasonic image having a subject in a place close to the distal end portion on the display unit. Accordingly, the operator can check the position of the distal end portion even when the distal end portion of the rod-shaped member moves.

Application Example 7

[0023] In the ultrasonic measurement apparatus according to the application example, a liquid material may be disposed between the ultrasonic wave transmission unit and the acoustic lens.

[0024] According to this application example, the liquid material is disposed between the ultrasonic wave transmission unit and the acoustic lens. A change in the acoustic impedance between the ultrasonic wave transmission unit and the acoustic lens can be reduced by the liquid material. As a result, it is possible to suppress the reflection of the ultrasonic wave between the ultrasonic wave transmission unit and the acoustic lens.

Application Example 8

[0025] According to this application example, an ultrasonic probe includes: an ultrasonic wave transmission unit that emits an ultrasonic wave in a first direction; a columnar acoustic lens that changes a traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit; and a movement restriction unit that restricts a movement direction such that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in a second direction crossing the first direction and a column axis direction of the acoustic lens.

[0026] According to this application example, the ultrasonic probe includes the ultrasonic wave transmission unit, the acoustic lens, and the movement restriction unit. The ultrasonic wave transmission unit emits an ultrasonic wave in the first direction. The acoustic lens is a columnar lens, and changes the traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit. The acoustic lens is a lens having a predetermined sectional shape extending in a predetermined direction, and the direction in which the predetermined sectional shape extends is referred to as a column axis direction. The second direction is a direction crossing the first direction and the column axis direction of the acoustic lens. In addition, when the acoustic lens and the ultrasonic wave transmission unit move relatively each other, the movement restriction unit restricts the movement direction so that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in the second direction.

[0027] Accordingly, the second direction in which the acoustic lens and the ultrasonic wave transmission unit move relatively each other is a direction crossing the first direction. The second direction is a direction crossing the column axis direction of the acoustic lens. The acoustic lens is a lens whose thickness in the first direction changes corresponding to the position in the second direction. The surface of the acoustic lens on the first direction side has irregularities. In addition, the ultrasonic wave is input to the acoustic lens, and is output from the acoustic lens. The traveling direction of the ultrasonic wave output from the acoustic lens changes corresponding to the angle of the surface of the acoustic lens on the first direction side.

[0028] The acoustic lens and the ultrasonic wave transmission unit move relatively each other in the second direction. Accordingly, since the angle of the surface on the first direction side of the location where the ultrasonic wave is output from the acoustic lens is changed, the traveling direction of the ultrasonic wave output from the acoustic lens is changed. Therefore, the ultrasonic probe can change the traveling direction of the ultrasonic wave. The traveling direction of the ultrasonic wave changes only in the second direction, but does not change in the column axis direction. Therefore, the ultrasonic probe can change the traveling direction of the ultrasonic wave with good operability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

[0030] FIG. **1** is a schematic perspective view showing the configuration of an ultrasonic measurement apparatus according to a first embodiment.

[0031] FIG. **2** is a schematic side sectional view showing the structure of an ultrasonic probe.

[0032] FIG. **3** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0033] FIG. **4** is a diagram showing an ultrasonic image.

[0034] FIG. **5** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0035] FIG. **6** is a diagram showing an ultrasonic image.

[0036] FIG. **7** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0037] FIG. **8** is a diagram showing an ultrasonic image.

[0038] FIG. **9** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0039] FIG. **10** is a diagram showing an ultrasonic image.

[0040] FIG. **11** is an electrical control block diagram of an ultrasonic measurement apparatus.

[0041] FIG. **12** is a flowchart of an insertion needle insertion method.

[0042] FIG. **13** is an electrical control block diagram of an ultrasonic measurement apparatus according to a second embodiment.

[0043] FIG. **14** is a flowchart of the insertion needle insertion method.

[0044] FIG. **15** is a schematic side sectional view showing the structure of an ultrasonic probe according to a third embodiment.

[0045] FIG. **16** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0046] FIG. **17** is a schematic side sectional view showing the structure of an ultrasonic probe according to a fourth embodiment.

[0047] FIG. **18** is a schematic side sectional view showing the structure of the ultrasonic probe.

[0048] FIG. **19** is a schematic side sectional view for explaining a method of detecting a blood vessel using ultrasonic waves according to a fifth embodiment.

[0049] FIG. **20** is a schematic side sectional view for explaining a method of detecting a blood vessel using ultrasonic waves.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0050] Hereinafter, embodiments will be described with reference to the accompanying diagram. In each diagram, the scale of each member is adjusted in order to have a recognizable size.

First Embodiment

[0051] In the present embodiment, characteristic examples of an ultrasonic measurement apparatus and a method of inserting an insertion needle into a blood vessel using the ultrasonic measurement apparatus will be described with reference to the diagrams. The ultrasonic measurement apparatus according to the first embodiment will be described with reference to FIGS. **1** to **12**. FIG. **1** is a schematic perspective view showing the configuration of the ultrasonic measurement apparatus. As shown in FIG. **1**, the ultrasonic measurement apparatus **1** includes an ultrasonic probe **2** and a control device **3** as a control unit, and the ultrasonic probe **2** and the control device **3** are connected to each other by a wiring line **4**.

[0052] The ultrasonic probe **2** is fixed to an arm **6***a* as a subject under examination of a human body **6** by a tape **5**. In the arm **6***a*, a blood vessel **7** is present along the arm **6***a*. A direction in which the blood vessel **7** extends along the arm **6***a* is defined as a Y direction, and a direction toward the blood vessel **7** from the surface of the arm **6***a* is defined as a Z direction. A direction perpendicular to the Y and Z directions is defined as an X direction.

[0053] An operator inserts the insertion needle **8***a* as a subject of a syringe **8** into the blood vessel **7** of the arm **6***a*. In addition, the blood vessel **7** may be a vein or an artery. Then, the operator stops the movement of the insertion needle **8***a* when the operator inserts the insertion needle **8***a* into the blood vessel **7** and the distal end of the insertion needle **8***a* reaches the blood vessel **7**. In this state, the operator injects medicine into the blood vessel **7**. Alternatively, the operator sucks the blood in the blood vessel **7** into the syringe **8**.

[0054] The ultrasonic probe **2** emits ultrasonic waves towards the distal end of the insertion needle **8***a* and the blood vessel **7**. Then, reflected waves reflected by the distal end of the insertion needle **8***a* and the blood vessel **7** are received, and are converted into an electrical signal. The electrical signal is converted into a digital signal and is transmitted to the control device **3** through the wiring line **4**. A display device **9** as a display unit is provided in the control device **3**, and an ultrasonic image formed by the digital signal is displayed on the display device **9**. The ultrasonic image is a sectional image of the arm **6***a* detected using the reflected waves of the ultrasonic waves.

[0055] An input device **12** as an input unit, such as a rotary knob **10** or a keyboard **11**, is provided in the control device **3**. The operator adjusts the traveling direction or the strength of ultrasonic waves emitted from the ultrasonic probe **2** by operating the input device **12**. Then, the operator checks the position of the distal end of the insertion needle **8***a* with respect to the blood vessel **7** by observing the display device **9**, and inserts the insertion needle **8***a* into the blood vessel **7**. The operator stops the movement of the insertion needle **8***a* when the distal end of the insertion needle **8***a* enters the blood vessel **7**. Then, injection of medicine, collection of blood, and the like are performed.

[0056] It is preferable to perform an operation by two persons. One person operates the input device **12**, and the other person operates the syringe **8**. The person who operates the input device **12** performs an operation so that the distal end of the insertion needle **8***a* is displayed on the display device **9**. The person who operates the syringe **8** inserts the insertion needle **8***a* while observing the display device **9**. Accordingly, the person who operates the syringe **8** can easily insert the insertion needle **8***a* into the blood vessel **7**.

[0057] FIGS. **2** and **3** are schematic side sectional views showing the structure of an ultrasonic probe. FIG. **2** is a diagram viewed from the longitudinal direction of the blood vessel **7**, and FIG. **3** is a diagram viewed from a direction perpendicular to the longitudinal direction of the blood vessel **7**. In FIGS. **2** and **3**, the tape **5** is omitted. As shown in FIGS. **2** and **3**, the blood vessel **7** is located in the arm **6***a*, and blood **7***a* flows in the blood vessel **7**.

[0058] The ultrasonic probe **2** includes an acoustic lens **13**, and the acoustic lens **13** is pressed against the skin of the arm **6***a*. A gel **14** as a liquid material is applied on the surface of the skin. The gel **14** is disposed between the acoustic lens **13** and the arm **6***a*. The gel **14** adjusts the acoustic impedance between the acoustic lens **13** and the arm **6***a*. Due to the gel **14**, it is difficult for an ultrasonic wave **24** to be reflected when entering the arm **6***a* from the acoustic lens **13**. Therefore, the ultrasonic probe **2** can efficiently emit the ultrasonic wave **24** into the arm **6**.

[0059] A bottomed rectangular tubular first support body **15** is provided on the −Z direction side of the acoustic lens **13**. A moving body **16** that moves in the Y direction is provided in the first support body **15**. The moving body **16** includes a substrate **17**, and an ultrasonic element array **18** as an ultrasonic wave transmission unit and an ultrasonic wave receiving unit is provided on the surface of the substrate **17** on the +Z direction side.

[0060] A second support body **21** is provided on both surfaces of the substrate **17** on the +X and −X direction sides, and the substrate **17** is supported by being interposed between the second support bodies **21**. A groove extending in the Y direction is provided on the +X-direction-side surface of the second support body **21** on the X direction side. A groove extending in the Y direction is provided on the −X-direction-side surface on the inner side of the first support body **15**. A plurality of spheres **22** are provided between the grooves of the first support body **15** and the second support body **21**. The −X-direction-side structure of the moving body **16** and the first support body **15** is the same as the +X-direction-side structure of the moving body **16** and the first support body **15**. The first support body **15**, the second support body **21**, and the sphere **22** form a linear guide **23** as a movement restriction unit. In the linear guide **23**, since the sphere **22** rolls, the frictional resistance at the time of movement is small.

[0061] In the ultrasonic element array **18**, diaphragms are provided in a matrix on the silicon substrate. A piezoelectric element is provided on each diaphragm. An AC waveform is applied to the piezoelectric element. As a result, the piezoelectric element vibrates the diaphragm to emit the ultrasonic wave **24**. An ultrasonic element is mainly formed by the diaphragm and the piezoelectric element. The emitted ultrasonic wave **24** travels through the arm **6***a*, and is reflected by the blood vessel **7** or the insertion needle **8***a*. The ultrasonic element array **18** receives the reflected wave of the ultrasonic wave **24**. Some of the reflected ultrasonic waves vibrate the diaphragm to expand or contract the piezoelectric element. As a result, the piezoelectric element outputs a voltage corresponding to the reflected wave. The control device **3** forms an ultrasonic image using the voltage output from each piezoelectric element.

[0062] In the ultrasonic element array **18**, one ultrasonic element may perform both transmission and reception of ultrasonic waves. In addition, an ultrasonic element with good ultrasonic wave transmission characteristics and an ultrasonic element with good ultrasonic wave reception characteristics may be arranged. Although the type of the piezoelectric element is not particularly limited, it is possible to use a piezoelectric element, such as a lead zirconate titanate (PZT) element or a polyvinylidene fluoride (PDVF) element. In the present embodiment, a PZT element is used as a piezoelectric element.

[0063] A direction in which the ultrasonic element array **18** emits the ultrasonic wave **24** is defined as a first direction **25**. The first direction **25** is the Z direction. A direction in which the moving body **16** moves is defined as a second direction **26**. The second direction **26** is the Y direction. The acoustic lens **13** has a shape obtained by cutting a cylinder along a plane parallel to the axial direction. The axial direction of the cylinder is defined as a column axis direction **27**. The column axis direction **27** is the X direction.

[0064] An elastic packing **28** is provided on the surface of the substrate **17** on the +Z direction side. The packing **28** is provided so as to surround the ultrasonic element array **18**. When the moving body **16** moves, the packing **28** slides on the acoustic lens **13**. The gel **14** is provided between the substrate **17** and the acoustic lens **13**, and the gel **14** is also surrounded by the packing **28**. In addition, when the moving body **16** moves, the gel **14** also moves with the moving body

16. Therefore, the gel **14** is always located between the ultrasonic element array **18** and the acoustic lens **13**.

[0065] A change in the acoustic impedance between the ultrasonic element array **18** and the acoustic lens **13** can be reduced by the gel **14**. As a result, it is possible to suppress the reflection of the ultrasonic wave **24** between the ultrasonic element array **18** and the acoustic lens **13**.

[0066] On the surface of the substrate **17** on the −Z direction side, a permanent magnet **29***a* is provided. In the permanent magnet **29***a*, an S pole and an N pole are alternately arranged in the Y direction so as to be magnetized at fine pitches. On the surface of the first support body **15** on the +Z direction side, an electromagnet **29***b* is provided. In the electromagnet **29***b*, coils are arranged side by side in the Y direction. The permanent magnet **29***a* and the electromagnet **29***b* form a linear motor **29** as a moving unit. By switching a current flowing through the coil in the linear motor **29**, the S pole and the N pole are switched. In addition, the linear motor **29** moves the moving body **16** by applying a Lorentz force between the permanent magnet **29***a* and the electromagnet **29***b*.

[0067] In addition to the electromagnetic linear motor **29**, it is possible to use a linear piezoelectric motor driven by a piezoelectric element, a linear resonance actuator that is moved by vibration, and the like.

[0068] A circuit board **30** is provided on the −Z direction side of the first support body **15**. A motor driving circuit **31** for driving the linear motor **29** and a transducer driving circuit **32** for driving the ultrasonic element array **18** are mounted on the circuit board **30**. The circuit board **30** is connected to the control device **3** by the wiring line **4**. On the −Z direction side of the first support body **15**, a housing **33** is provided so as to cover the circuit board **30**. The housing **33** prevents the circuit board **30** from being short-circuited or from becoming dirty.

[0069] As shown in FIG. **2**, the ultrasonic element array **18** has a shape that is long in the column axis direction **27**. In addition, an ultrasonic image displayed on the display device **9** is an image of a plane passing through the column axis direction **27** and the first direction **25**.

[0070] As shown in FIG. **3**, the linear motor **29** moves the moving body **16** in the second direction **26**. In other words, the linear motor **29** moves the acoustic lens **13** and the ultrasonic element array **18** relatively each other. When the moving body **16** and the ultrasonic element array **18** are located at the center in the second direction **26**, the ultrasonic wave **24** travels in the first direction **25**. Then, when the insertion needle **8***a* is located in the first direction **25** of the ultrasonic element array **18**, some of the reflected waves of the ultrasonic waves **24** are input to the ultrasonic element array **18** from the insertion needle **8***a*.

[0071] FIG. **4** is a diagram showing an ultrasonic image. An ultrasonic image **34** is an image formed by the reflected wave of the ultrasonic wave **24** shown in FIG. **3**. As shown in FIG. **4**, a blood vessel image **34***a* showing the blood vessel **7** and an insertion needle image **34***b* showing the insertion needle **8***a* are displayed on the ultrasonic image **34**. At this time, since the insertion needle **8***a* is a rod-shaped member and a distal end portion **8***b*, which is the distal end of the insertion needle **8***a*, is away from the blood vessel **7**, an image is obtained in which the blood vessel image **34***a* and the insertion needle image **34***b* are separated from each other.

[0072] FIG. **5** is a schematic side sectional view showing the structure of the ultrasonic probe, and is a diagram when viewed from a direction perpendicular to the longitudinal direction of the blood vessel **7**. As shown in FIG. **5**, when the moving body **16** moves to the −Y direction side along the second direction **26**, the ultrasonic wave **24** travels to the −Y direction side due to the acoustic lens **13**.

[0073] The material of the acoustic lens **13** is a material in which the traveling speed of the ultrasonic wave **24** is higher than the traveling speed of the ultrasonic wave **24** in the arm **6***a*. The traveling speed of the ultrasonic wave **24** in the arm **6***a* is 1530 m/s. Nylon, polystyrene, and polyethylene can be used as materials of the acoustic lens **13**. The traveling speed of the ultrasonic wave **24** in nylon is 2600 m/s, the traveling speed of the ultrasonic wave **24** in polystyrene is 2350 m/s, and the traveling speed of the ultrasonic wave **24** in polyethylene is 1900 m/s. In the present embodiment, for example, nylon is used as the material of the acoustic lens **13**.

[0074] At this time, the traveling speed of the ultrasonic wave **24** is reduced when the ultrasonic wave **24** enters the arm **6***a* from the acoustic lens **13**. The acoustic lens **13** is a convex lens, and the subject under examination functions as a concave lens. Accordingly, the ultrasonic probe **2** can emit the ultrasonic wave **24** to a place wider than the width of the acoustic lens **13** in the second direction **26**. By moving the moving body **16** to the −Y direction side, the ultrasonic wave **24** is made to travel to the −Y direction side. Therefore, it is possible to detect the insertion needle **8***a* inserted from the −Y direction side.

[0075] FIG. **6** is a diagram showing an ultrasonic image. An ultrasonic image **35** is an image formed by the reflected wave of the ultrasonic wave **24** shown in FIG. **5**. As shown in FIG. **6**, a blood vessel image **35***a* showing the blood vessel **7** and an insertion needle image **35***b* showing the insertion needle **8***a* are displayed on the ultrasonic image **35**. At this time, since the distal end portion **8***b* of the insertion needle **8***a* is away from the blood vessel **7**, an image is obtained in which the blood vessel image **35***a* and the insertion needle image **35***b* are separated from each other. Then, it is possible to check that the insertion needle image **35***b* is located in a shallow place of the arm **6***a*.

[0076] FIG. **7** is a schematic side sectional view showing the structure of the ultrasonic probe, and is a diagram when viewed from a direction perpendicular to the longitudinal direction of the blood vessel **7**. As shown in FIG. **7**, when the moving body **16** moves to the +Y direction side by a short distance along the second direction **26**, the ultrasonic wave **24** passes the +Y direction side from the distal end portion **8***b* of the insertion needle **8***a*. Accordingly, there is no reflected wave from the insertion needle **8***a*.

[0077] FIG. **8** is a diagram showing an ultrasonic image. An ultrasonic image **36** is an image formed by the reflected wave of the ultrasonic wave **24** shown in FIG. **7**. As shown in FIG. **8**, a blood vessel image **36***a* showing the blood vessel **7** is displayed on the ultrasonic image **36**. At this time, it is not possible to check an image corresponding to the insertion needle **8***a*. Since it is not possible to check the image corresponding to the insertion needle **8***a* even if the distance of the movement of the moving body **16** is short, it can be seen that the ultrasonic wave **24** has passed the vicinity of the distal end portion **8***b* of the insertion needle **8***a*. Therefore, the operator can recognize that the position of the insertion needle image **35***b* of the ultrasonic image **35** is close to the position of the distal end portion **8***b* of the insertion needle **8***a*.

[0078] FIG. **9** is a schematic side sectional view showing the structure of the ultrasonic probe, and is a diagram when viewed from a direction perpendicular to the longitudinal direction of the blood vessel **7**. As shown in FIG. **9**, the insertion needle **8***a* is inserted in the +Y direction. At this time, the control device **3** moves the moving body **16** to the +Y direction side along the second direction **26**. Then, since the ultrasonic wave **24** passes through the distal end portion **8***b* of the insertion needle **8***a*, the ultrasonic element array **18** detects reflected waves from the distal end portion **8***b* of the insertion needle **8***a*.

[0079] FIG. **10** is a diagram showing an ultrasonic image. An ultrasonic image **37** is an image formed by the reflected wave of the ultrasonic wave **24** shown in FIG. **9**. As shown in FIG. **10**, a blood vessel image **37***a* showing the blood vessel **7** and an insertion needle image **37***b* showing the insertion needle **8***a* are displayed on the ultrasonic image **37**. At this time, since the distal end portion **8***b* of the insertion needle **8***a* is in contact with the blood vessel **7**, an image is obtained in which the blood vessel image **37***a* and the insertion needle image **37***b* are in contact with each other. Then, the operator can check that the insertion needle **8***a* has reached the blood vessel **7**.

[0080] Thus, the ultrasonic element array **18** emits the ultrasonic wave **24** in the first direction **25**. The acoustic lens **13** is a columnar lens, and changes the traveling direction of the ultrasonic wave **24** emitted from the ultrasonic element array **18**. The acoustic lens **13** is a lens having a predetermined semicircular sectional shape extending in the column axis direction **27**. The second direction **26** is a direction crossing the first direction **25** and the column axis direction **27**. The linear guide **23** restricts the movement direction so that the acoustic lens **13** and the ultrasonic element array **18** move relatively each other in the second direction **26**.

[0081] The acoustic lens **13** is a lens whose thickness in the first direction **25** changes corresponding to the position of the second direction **26**. The ultrasonic wave **24** is input to the acoustic lens **13**, and is output from the acoustic lens **13**. The traveling direction of the ultrasonic wave **24** output from the acoustic lens **13** changes corresponding to the angle of the surface of the acoustic lens on the +Z direction side.

[0082] The acoustic lens **13** and the ultrasonic element array **18** move relatively each other in the second direction **26**. Then, when the ultrasonic wave **24** is output from the acoustic lens **13**, the traveling direction of the ultrasonic wave **24** is changed. Therefore, the ultrasonic probe **2** can change the traveling direction of the ultrasonic wave **24**. The traveling direction of the ultrasonic wave **24** changes only in the second direction **26**, but does not change in the column axis direction **27**. When the traveling direction of the ultrasonic wave **24** changes in the column axis direction **27**, images of the ultrasonic images **34** to **37** shake in the horizontal direction. Accordingly, it is difficult to check the images. The ultrasonic measurement apparatus **1** can change the traveling direction of the ultrasonic wave **24** only in the second direction **26** with good operability. Accordingly, since the traveling direction of the ultrasonic wave **24** does not change in the column axis direction **27**, it becomes easy to check the image by suppressing the shaking of the images of the ultrasonic images **34** to **37** in the horizontal direction.

[0083] FIG. **11** is an electric control block diagram of the ultrasonic measurement apparatus. In FIG. **11**, the ultrasonic measurement apparatus **1** includes the control device **3** that controls the operation of the ultrasonic measurement apparatus **1**. In addition, the control device **3** includes a central processing unit (CPU **38**) that performs various kinds of arithmetic processing as a processor and a memory **41** that stores various kinds of information. The transducer driving circuit **32**, the motor driving circuit **31**, the input device **12**, and the display device **9** are also connected to the CPU **38** through an input and output interface **44** and a data bus **45**.

[0084] The transducer driving circuit **32** is a device for driving the ultrasonic element array **18**. The transducer driving circuit **32** receives an instruction signal from the CPU **38**. Transducers are provided in the ultrasonic element array **18**. The transducer driving circuit **32** sequentially vibrates the transducers at predetermined locations. The ultrasonic waves **24** are emitted at the locations where the transducers vibrate. The emitted ultrasonic waves **24** are reflected by the blood vessel **7** or the insertion needle **8***a*, and some of the ultrasonic waves **24** reach the ultrasonic element array **18**. In the ultrasonic element array **18**, transducers are vibrated by the received ultrasonic wave **24**, and a voltage signal is output to the transducer driving circuit **32**. The transducer driving circuit **32** receives the voltage signal, converts the voltage signal into a digital signal, and outputs the digital signal to the CPU **38**.

[0085] The motor driving circuit **31** is a device for driving the linear motor **29** and a linear encoder **46**. The linear encoder **46** is provided in the first support body **15**, and the linear encoder **46** detects the position of the moving body **16**. The motor driving circuit **31** receives an instruction signal from the CPU **38**. Then, the position and the traveling speed of the moving body **16** are detected using the linear encoder **46**. Then, the motor driving circuit **31** drives the linear motor **29** so that the moving body **16** is located at a position indicated by the instruction signal.

[0086] In addition to the rotary knob **10** or the keyboard **11**, a device for performing cable communication and wireless communication with an external computer is included in the input device **12**. Various kinds of data are input to the CPU **38** and the memory **41** through the input device **12**. The operator inputs an instruction of the relative position of the moving body **16** with respect to the acoustic lens **13** by operating the input device **12**.

[0087] The display device **9** is a display device, such as a liquid crystal display (LCD) or an organic light-emitting diode (OLED). Measurement conditions, the ultrasonic images to **37** that are measurement results, and the like are displayed on the display device **9**.

[0088] The memory **41** is a concept including a semiconductor memory, such as a RAM or a ROM, or an external storage device, such as a hard disk or a DVD-ROM. Functionally, a storage region for storing program software **47**, in which the control procedure of the operation of the ultrasonic measurement apparatus **1** is described, or a storage region for storing ultrasonic image data **48** detected by the ultrasonic element array **18** is set. In addition, a storage region for storing motor driving data **49**, which is the data of conditions for driving the linear motor **29**, is set. In addition, a storage region functioning as a temporary file or a work area for the CPU **38** or other various kinds of storage regions are set.

[0089] The CPU **38** moves the moving body **16** according to the program software **47** stored in the memory **41**. Then, the CPU **38** performs control to detect the reflected wave by emitting the ultrasonic wave **24** from the ultrasonic element array **18**. As a specific function realizing section, the CPU **38** has an ultrasonic wave reception and transmission control section **50**. The ultrasonic wave reception and transmission control section **50** performs control to acquire the data of the ultrasonic wave **24** by making the transducer driving circuit **32** drive the ultrasonic element array **18**.

[0090] In addition, the CPU **38** has a movement control section **51**. The movement control section **51** receives information of the detection position input from the input device **12**. The information of the detection position is information that the operator sets by operating the input device **12**. Then, the movement control section **51** receives the position data of the moving body **16** detected by the linear encoder **46**. Then, the movement control section **51** performs control to move the moving body **16** so that the moving body **16** is located at the position input by the operator. That is, the input device **12** receives an input of the relative position between the acoustic lens **13** and the ultrasonic element array **18** that are moved relatively each other by the linear motor **29**. The movement control section **51** controls the relative position between the acoustic lens **13** and the ultrasonic element array **18**.

[0091] In addition, the CPU **38** has an image forming section **52**. The image forming section **52** receives digital data of the reflected waves output from the transducer driving circuit **32**. Then, an ultrasonic image is formed by the data of reflected waves. In the present embodiment, each of the functions described above is realized by program software using the CPU **38**. However, in a case where each of the functions described above can be realized by a single electronic circuit (hardware) in which the CPU **38** is not used, it is also possible to use such an electronic circuit.

[0092] Next, an insertion needle insertion method for inserting the insertion needle **8***a* into the blood vessel **7** using the ultrasonic measurement apparatus **1** will be described with reference to FIG. **12**. FIG. **12** is a flowchart of the insertion needle insertion method. The operation of the ultrasonic measurement apparatus **1** is performed by two operators of first and second operators.

[0093] In the flowchart shown in FIG. **12**, step S1 is an initial setting step. This step is a step in which the movement control section **51** moves the moving body **16** to the end on the −Y direction side by making the motor driving circuit **31** drive the linear motor **29**. Since the insertion needle **8***a* is inserted from the −Y direction side, the ultrasonic element array **18** emits the ultrasonic wave **24** to the −Y direction side and stands by. Then, the process proceeds to steps S2 and S3. Step S2 corresponds to a needle insertion step. This step is a step in which the first operator inserts the insertion needle **8***a* into the arm **6***a*. At this time, the first operator inserts the insertion needle **8***a* while observing the ultrasonic image displayed on the display device **9**. Steps S2 and S3 to S6 are performed in parallel.

[0094] Step S3 is an image acquisition step. This step is a step of acquiring an ultrasonic image. First, the ultrasonic wave reception and transmission control section **50** emits the ultrasonic wave **24** into the arm **6***a* by making the transducer driving circuit **32** drive the ultrasonic element array **18**. Some of the ultrasonic waves **24** are reflected by the blood vessel **7**, the insertion needle **8***a*, or the like. Some of the reflected ultrasonic waves **24** reach the ultrasonic element array **18**. In the ultrasonic element array **18**, transducers are vibrated by the ultrasonic waves **24** that have reached the ultrasonic element array **18**, thereby outputting a voltage proportional to the strength of the ultrasonic wave **24** to the transducer driving circuit **32**. The transducer driving circuit **32** converts the voltage proportional to the strength of the ultrasonic wave **24** into digital data, and outputs the digital data to the image forming section **52** of the CPU **38**. The image forming section **52** forms the ultrasonic image data **48** by combining the digital data, and stores the ultrasonic image data **48** in the memory **41**. Then, the process proceeds to step S4.

[0095] Step S4 is a display step. This step is a step in which the display device **9** displays the ultrasonic image data **48**. Then, the process proceeds to step S5. Step S5 is a determination step. This step is a step in which the second operator determines whether or not the ultrasonic image includes an insertion needle image while observing the display device **9**. When the second operator determines that the ultrasonic image does not include an insertion needle image, the process proceeds to step S6. When the second operator determines that the ultrasonic image includes an insertion needle image, the process proceeds to step S7.

[0096] Step S6 is a backward step. This step is a step of moving the moving body **16** in the −Y direction. The second operator operates the input device **12** to input an instruction to move the moving body **16** by a predetermined distance in the −Y direction. The movement control section **51** receives a movement instruction signal, thereby receiving the position of the moving body **16** indicated by the linear encoder **46**. When the moving body **16** is located at the end in the −Y direction, the position of the moving body **16** is maintained. Then, a message indicating that the ultrasonic wave **24** has reached the end in the −Y direction is displayed on the display device **9**. When the moving body **16** is not located at the end in the −Y direction, the motor driving circuit **31** is made to drive the linear motor **29** so that the moving body **16** is moved by a predetermined distance in the −Y direction. Then, the process proceeds to step S3.

[0097] Step S7 is an end determination step. This step is a step of determining whether or not to end the measurement of the position of the insertion needle **8***a*. In this step, the second operator checks an ultrasonic image displayed on the display device **9**. When the insertion needle **8***a* reaches the blood vessel **7** and the distal end portion **8***b* of the insertion needle **8***a* is not inserted into the blood vessel **7**, it is determined that the measurement of the position of the insertion needle **8***a* is not ended. Then, the process proceeds to step S8. When the insertion needle **8***a* reaches the blood vessel **7** and the distal end portion **8***b* of the insertion needle **8***a* is inserted into the blood vessel **7**, it is determined that the measurement of the position of the insertion needle **8***a* is ended. Then, the step of inserting the insertion needle **8***a* into the blood vessel **7** is ended.

[0098] Step S8 is a forward step. This step is a step of moving the moving body **16** in the +Y direction. The second operator operates the input device **12** to input an instruction to move the moving body **16** by a predetermined distance in the +Y direction. The movement control section **51** receives a movement instruction signal, thereby receiving the position of the moving body **16** indicated by the linear encoder **46**. When the moving body **16** is located at the end in the +Y direction, the position of the moving body **16** is maintained.

Then, a message indicating that the ultrasonic wave **24** has reached the end in the +Y direction is displayed on the display device **9**. When the moving body **16** is not located at the end in the +Y direction, the motor driving circuit **31** is made to drive the linear motor **29** so that the moving body **16** is moved by a predetermined distance in the +Y direction. Then, the process proceeds to step S3.

[0099] Next, an insertion needle insertion method corresponding to steps S4 to S8 shown in FIG. **12** will be described in detail with reference to FIGS. **5** to **8**. In the image acquisition step of step S3, as shown in FIG. **7**, the insertion needle **8***a* is located on the −Y direction side with respect to the ultrasonic wave **24**. At this time, the ultrasonic image **36** shown in FIG. **8** is displayed on the display device **9** in the display step of step S4. In the determination step of step S5, the second operator determines that the ultrasonic image **36** does not include an insertion needle image. Then, in the backward step of step S6, the second operator moves the moving body **16** in the −Y direction by operating the input device **12**. The amount of movement of the moving body **16** is a predetermined short distance.

[0100] As a result, in step S3, as shown in FIG. **5**, the ultrasonic wave **24** is emitted to the insertion needle **8***a*. Then, in step S4, the ultrasonic image **35** shown in FIG. **6** is displayed on the display device **9**. The blood vessel image **35***a* and the insertion needle image **35***b* are displayed on the ultrasonic image **35**. Since the amount of movement of the moving body **16** is short, the insertion needle image **35***b* of the location of the distal end portion **8***b* of the insertion needle **8***a* is displayed on the ultrasonic image **35**. Through the ultrasonic image **35**, the first operator can recognize that the blood vessel image **35***a* and the insertion needle image **35***b* are away from each other. Then, in step S2, the first operator further inserts the insertion needle **8***a*. As a result, the distal end portion **8***b* of the insertion needle **8***a* is located on the +Y direction side with respect to the location where the ultrasonic wave **24** passes.

[0101] In the determination step of step S5, the second operator determines that the ultrasonic image **35** includes the insertion needle image **35***b*. Then, in the forward step of step S8, the second operator moves the moving body **16** by a predetermined distance in the +Y direction by operating the input device **12**. Thus, steps S2 to S8 are repeated. The first operator can advance the insertion needle **8***a* while checking the position of the distal end portion **8***b* of the insertion needle **8***a* according to this procedure. Then, as shown in FIG. **9**, the insertion needle **8***a* reaches the blood vessel **7**. In step S4, the first operator checks that the insertion needle **8***a* has reached the blood vessel **7**, and further inserts the insertion needle **8***a* into the blood vessel **7**. Then, the first and second operators check that the insertion needle **8***a* has been inserted into the blood vessel **7** by checking the display device **9**. In the end determination step of step S7, determination to end a step of acquiring an ultrasonic image is made, and a step of inserting the insertion needle **8***a* into the blood vessel **7** is ended.

[0102] As described above, according to the present embodiment, the following effect is obtained.

[0103] (1) According to the present embodiment, the ultrasonic measurement apparatus **1** includes the ultrasonic element array **18**, the acoustic lens **13**, and the linear guide **23**. The ultrasonic element array **18** emits the ultrasonic wave **24** in the first direction **25**. The acoustic lens **13** is a columnar lens, and changes the traveling direction of the ultrasonic wave **24** emitted from the ultrasonic element array **18**. The acoustic lens **13** has a shape in which a predetermined sectional shape extends in the column axis direction **27**. When the acoustic lens **13** and the ultrasonic element array **18** move relatively each other, the linear guide **23** restricts the movement direction so that the acoustic lens **13** and the ultrasonic element array **18** move relatively each other in the second direction **26**.

[0104] Accordingly, the second direction **26** in which the acoustic lens **13** and the ultrasonic element array **18** move relatively each other is a direction crossing the first direction **25**. The second direction **26** is a direction crossing the column axis direction **27** of the acoustic lens **13**. The acoustic lens **13** is a lens whose thickness in the first direction **25** changes corresponding to the position of the second direction **26**. That is, the surface of the acoustic lens **13** in the first direction **25** is a convex shape. The ultrasonic wave **24** is input to the acoustic lens **13**, and is output from the acoustic lens **13**. The traveling direction of the ultrasonic wave **24** output from the acoustic lens **13** changes corresponding to the angle of the surface of the acoustic lens **13** on the first direction **25** side.

[0105] The acoustic lens **13** and the ultrasonic element array **18** move relatively each other in the second direction **26**. Accordingly, since the angle of the surface on the first direction **25** side of the location where the ultrasonic wave **24** is output from the acoustic lens **13** is changed, the traveling direction of the ultrasonic wave **24** is changed when the ultrasonic wave **24** is output from the acoustic lens **13**. Therefore, the ultrasonic measurement apparatus **1** can change the traveling direction of the ultrasonic wave **24**. The traveling direction of the ultrasonic wave **24** changes only in the second direction **26**, but does not change in the column axis direction **27**. Since the traveling direction of the ultrasonic wave **24** does not change in the column axis direction **27**, it is possible to suppress the shaking of the ultrasonic image displayed on the display device **9** in the horizontal direction. Therefore, the ultrasonic measurement apparatus **1** can change the traveling direction of the ultrasonic wave **24** with good operability.

[0106] (2) According to the present embodiment, the acoustic lens **13** is a convex lens. In addition, the acoustic lens **13** is used in contact with the arm **6***a*. The material of the acoustic lens **13** is a material in which the traveling speed of the ultrasonic wave **24** is higher than the traveling speed of the ultrasonic wave **24** in the arm **6***a*. For this reason, the traveling speed of the ultrasonic wave **24** is reduced when the ultrasonic wave **24** enters the subject under examination from the acoustic lens **13**. In addition, since the acoustic lens **13** is a convex lens and the arm **6***a* functions as a concave lens, the ultrasonic measurement apparatus **1** can emit the ultrasonic wave **24** to a place wider than the width of the acoustic lens in the second direction **26**.

[0107] (3) According to the present embodiment, the ultrasonic measurement apparatus **1** further includes the linear motor **29**, the movement control section **51**, and the input device **12**. The linear motor **29** moves the acoustic lens **13** and the ultrasonic element array **18** relatively each other. The movement control section **51** controls the relative position between the acoustic lens **13** and the ultrasonic element array **18**. The second operator inputs the relative position using the input device **12**. Then, the input device **12** receives an input of the relative position between the acoustic lens **13** and the ultrasonic element array **18** that are moved relatively each other by the linear motor **29**. The movement control section **51** controls the linear motor **29** to move the acoustic lens **13** and the ultrasonic element array **18** relatively each other. Therefore, the second operator can perform an operation of moving the acoustic lens **13** and the ultrasonic element array **18** in the second direction **26**. As a result, the distal end portion **8***b* of the insertion needle **8***a* can be displayed on the display device **9**.

[0108] (4) According to the present embodiment, the gel **14** is disposed between the ultrasonic element array **18** and the acoustic lens **13**. A change in the acoustic impedance between the ultrasonic element array **18** and the acoustic lens **13** can be reduced by the gel **14**. As a result, it is possible to suppress the reflection of the ultrasonic wave **24** between the ultrasonic element array **18** and the acoustic lens **13**.

[0109] (5) According to the present embodiment, since the first operator can observe the distal end portion **8***b* of the insertion needle **8***a* in a clear ultrasonic image, it is possible to reduce the failure of insertion. In addition, it is possible to reduce complications caused by blood leakage due to the failure of insertion.

Second Embodiment

[0110] Next, an embodiment of the ultrasonic measurement apparatus will be described with reference to FIGS. **13** and **14**. The present embodiment is different from the first embodiment in that the CPU **38** has functions of an image processing section and a determination section. In addition, the explanation of the same points as in the first embodiment will be omitted.

[0111] FIG. **13** is an electric control block diagram of the ultrasonic measurement apparatus. That is, in the present embodiment, as shown in FIG. **13**, in a control device **56** as a control unit of the ultrasonic measurement apparatus **55**, the CPU **38** has an image processing section **57** as a specific function realizing section. The image processing section **57** performs image processing on the ultrasonic image formed by the image forming section **52**. First, the image processing section **57** removes noise from the ultrasonic image. This makes the brightness of a portion having a minute area the same as the surrounding brightness. Then, division into a bright portion and a dark portion is performed using a predetermined brightness setting value. Usually, this step is called binarization. Then, the respective bright and dark regions are divided into separate islands, and the number of pixels of each island is measured. This island indicates a portion when a bright portion and a dark portion are separated from each other and each region of a region of a bright portion and a region of a dark portion. The number of pixels is a feature quantity corresponding to the area of the ultrasonic image. In addition, the image processing section **57** calculates the feature quantity of each island by calculating the circumference and the width of each island and performing classification as to whether or not the island has a ring shape.

[0112] The CPU **38** has a determination section **58**. The determination section **58** performs classification into an island corresponding to a blood vessel image and an island corresponding to an insertion needle image from the feature quantity, such as the area measured by the image processing section **57**. Then, the determination section **58** checks an insertion needle image in the ultrasonic image to determine whether or not the ultrasonic image includes an insertion needle image. The motor driving data **49** of the memory **41** includes data of the amount of movement for moving the moving body **16** in the forward step and the backward step. The determination section **58** has a function of outputting an instruction signal, which indicates whether to advance the moving body **16** in the +Y direction or to retreat the moving body **16** in the −Y direction according to a determination result regarding whether or not the ultrasonic image includes an insertion needle image, to the movement control section **51**. The movement control section **51** receives the instruction signal of the determination section **58**, and performs control to move the moving body **16** based on the instruction signal.

[0113] FIG. **14** is a flowchart of the insertion needle insertion method. The operation of the ultrasonic measurement apparatus **55** is performed by one first operator. Since steps S1 to S3 are the same as in the first embodiment, the explanation thereof will be omitted. After step S3, a determination step of step S11 is performed. In step S11, the CPU **38** determines whether or not the ultrasonic image **36** includes an insertion needle image. Specifically, the image processing section **57** calculates a feature quantity, such as the area of each island of an image included in the ultrasonic image. The insertion needle image has a vertically long shape, and the blood vessel image has a circular shape. Such determination can be made based on the ratio of the horizontal width and the vertical length. Since the area of the insertion needle image is smaller than the area of the blood vessel image, such determination can be made by comparison with a predetermined determination value. In addition, respective islands are classified into an island corresponding to the blood vessel image and an island corresponding to the insertion needle image. Then, the determination section **58** checks an insertion needle image in the ultrasonic image to determine whether or not the ultrasonic image includes an insertion needle image.

[0114] When the determination section **58** determines that the ultrasonic image does not include an insertion needle image in the determination step of step S11, the process proceeds to the backward step of step S12. Then, in the backward step of step S12, the movement control section **51** controls the motor driving circuit **31** to drive the linear motor **29** so that the moving body **16** is moved in the −Y direction. Data of the amount of movement as the amount of relative movement by which the moving body **16** moves is stored in the motor driving data **49**, and is a predetermined length. Then, the process proceeds to step S3. When the ultrasonic image does not include an insertion needle image, steps S3, S11, and S12 are repeated so that the ultrasonic image includes an insertion needle image. Then, the control device **56** controls the moving body **16** so that the ultrasonic image includes an insertion needle image.

[0115] When the determination section **58** determines that the ultrasonic image includes an insertion needle image in the determination step of step S11, the process proceeds to the display step of step S4. In step S4, the ultrasonic image is displayed on the display device **9**. The insertion needle **8***a* is a rod-shaped member having the distal end portion **8***b*, and the determination section **58** proceeds to step S4 only when an insertion needle image is detected in the ultrasonic image. Then, in step S4, an ultrasonic image including the insertion needle image of the distal end portion is displayed on the display device **9**. Since the ultrasonic image includes the insertion needle image, the operator can check the position of the insertion needle. Then, the process proceeds to the end determination step of step S7. When the first operator determines "not ended", the process proceeds to the forward step of step S13. In step S13, the movement control section **51** controls the motor driving circuit **31** to drive the linear motor **29** so that the moving body **16** is moved in the +Y direction. Data of the amount of movement as the amount of relative movement by which the moving body **16** moves is stored in the motor driving data **49**, and is a predetermined length. Then, the process proceeds to step S3.

[0116] When the first operator determines "ended" in the end determination step of step S7, the step of inserting the insertion needle **8***a* into the blood vessel **7** is ended.

[0117] An ultrasonic image is displayed on the display device **9** only when the moving body **16** is moved in the +Y direction in the forward step of step S13 and the ultrasonic image includes an insertion needle image in the determination step of step S11. When the ultrasonic wave **24** is emitted to the +Y direction side from the distal end portion **8***b* of the insertion needle **8***a*, no ultrasonic image is displayed on the display device **9** since the ultrasonic image does not include an insertion needle image. Therefore, an ultrasonic image including the image of the distal end portion **8***b* of the insertion needle **8***a* is displayed on the display device **9**.

[0118] As described above, according to the present embodiment, the following effect is obtained.

[0119] (1) According to the present embodiment, the image forming section **52** forms an ultrasonic image from the data of reflected waves, and the determination section **58** determines an insertion needle image of the ultrasonic image. At this time, when the ultrasonic image does not include an insertion needle image, the movement control section **51** controls the linear motor **29**. Then, the ultrasonic image is made to include an insertion needle image. As a result, the first operator can recognize the position of the distal end portion **8***b* of the insertion needle **8***a* by observing the ultrasonic image.

[0120] (2) According to the present embodiment, the insertion needle **8***a* is a rod-shaped member having the distal end portion **8***b*. The determination section **58** detects the distal end portion **8***b* depending on whether or not the distal end portion **8***b* is reflected on the ultrasonic image. Then, the ultrasonic measurement apparatus **55** displays the ultrasonic image including the distal end portion **8***b* on the display device **9**. Therefore, the first operator can check the position of the distal end portion **8***b* even when the distal end portion **8***b* of the insertion needle **8***a* moves.

Third Embodiment

[0121] Next, an embodiment of the ultrasonic measurement apparatus will be described with reference to FIGS. **15** and **16**. The present embodiment is different from the first embodiment in that the acoustic lens is a concave lens. In addition, the explanation of the same points as in the first embodiment will be omitted.

[0122] FIGS. **15** and **16** are schematic side sectional views showing the structure of an ultrasonic probe. FIG. **15** is a diagram when the moving body **16** has moved in the −Y direction, and FIG. **16** is a diagram when the moving body **16** has moved in the +Y direction. That is, in the present embodiment, as shown in FIG. **15**, an ultrasonic probe **62** provided in an ultrasonic measurement apparatus **61** includes an acoustic lens **63**. The acoustic lens **63** is a concave lens. The acoustic lens **63** is pressed against the skin of the arm **6***a*, and is used in contact with the skin of the arm **6***a*.

[0123] A bottomed rectangular tubular first support body **64** is provided on the -Z direction side of the acoustic lens **63**. A moving body **16** that moves in the Y direction is provided in the first support body **64**. The moving body **16** includes a substrate **17**, and an ultrasonic element array **18** as an ultrasonic wave transmission unit and an ultrasonic wave receiving unit is provided on the surface of the substrate **17** on the +Z direction side.

[0124] When the moving body **16** moves to the −Y direction side along the second direction **26**, the ultrasonic wave **24** travels to the −Y direction side due to the acoustic lens **63**. The material of the acoustic lens **63** is a material in which the traveling speed of the ultrasonic wave **24** is lower than the traveling speed of the ultrasonic wave **24** in the arm **6***a*. The traveling speed of the ultrasonic wave **24** in the arm **6***a* is 1530 m/s. Silicone rubber and PDMS can be used as materials of the acoustic lens **63**. The traveling speed of the ultrasonic wave **24** in silicone rubber is 1000 m/s, and the traveling speed of the ultrasonic wave **24** in polydimethylsiloxane (PDMS) is 900 to 10000 m/s. In the present embodiment, for example, silicone rubber is used as a material of the acoustic lens **63**.

[0125] At this time, the traveling speed of the ultrasonic wave **24** is increased when the ultrasonic wave **24** enters the arm **6***a* from the acoustic lens **63**. The acoustic lens **63** is a concave lens, and the subject under examination functions as a convex lens. Accordingly, the ultrasonic probe **62** can emit the ultrasonic wave **24** to a place wider than the width of the acoustic lens **63** in the second direction **26**. By moving the moving body **16** to the −Y direction side, the ultrasonic wave **24** is made to travel to the −Y direction side. Therefore, it is possible to detect the insertion needle **8***a* inserted from the −Y direction side.

[0126] As shown in FIG. **16**, the insertion needle **8***a* is inserted in the +Y direction. At this time, the control device **3** moves the moving body **16** to the +Y direction side along the second direction **26**. The ultrasonic wave **24** travels to bend in the +Y direction due to the acoustic lens **63**. Then, since the ultrasonic wave **24** passes through the distal end portion **8***b* of the insertion needle **8***a*, the ultrasonic element array **18** detects reflected waves from the distal end portion **8***b* of the insertion needle **8***a*.

[0127] As described above, according to the present embodiment, the following effect is obtained.

[0128] (1) According to the present embodiment, the acoustic lens **63** is a concave lens. In addition, the acoustic lens **63** is used in contact with the arm **6***a*. The material of the acoustic lens **63** is a material in which the traveling speed of the ultrasonic wave **24** is lower than the traveling speed of the ultrasonic wave **24** in the arm **6***a*. Accordingly, the traveling speed of the ultrasonic wave **24** is increased when the ultrasonic wave **24** enters the arm **6***a* from the acoustic lens **63**. In addition, since the acoustic lens **63** is a concave lens, the ultrasonic measurement apparatus **61** can emit the ultrasonic wave **24** to a place wider than the width of the acoustic lens **63** in the second direction **26**.

Fourth Embodiment

[0129] Next, an embodiment of the ultrasonic measurement apparatus will be described with reference to FIGS. **17** and **18**. The present embodiment is different from the first embodiment in that the moving body **16** moves obliquely with respect to the first direction **25**. In addition, the explanation of the same points as in the first embodiment will be omitted.

[0130] FIGS. **17** and **18** are schematic side sectional views showing the structure of an ultrasonic probe. FIG. **17** is a diagram when the moving body has moved to the center, and FIG. **18** is a diagram when the moving body has moved in the +Y direction. That is, in the present embodiment, as shown in FIG. **17**, an ultrasonic probe **68** provided in an ultrasonic measurement apparatus **67** includes an acoustic lens **13**. The acoustic lens **13** is pressed against the skin of the arm **6***a*, and is used in contact with the skin of the arm **6***a*.

[0131] A bottomed rectangular tubular first support body **69** is provided on the −Z direction side of the acoustic lens **13**. A moving body **71** that moves along an oblique second direction **70** crossing the first direction **25** is provided inside the first support body **69**. The moving body **71** includes a substrate **72**, and an ultrasonic element array **18** is provided on the surface of the substrate **72** on the +Z direction side.

[0132] A linear guide **73** as a movement restriction unit is provided on both sides of the substrate **72** on the +X and −X direction sides. The moving body **71** is moved in the second direction **70** by the linear guide **73**. When the moving body **71** moves in the second direction **70**, the distance between the moving body **71** and the acoustic lens **13** is changed. The packing **28** has elasticity, and expands and contracts in the first direction **25**. Therefore, the gel **14** is held between the ultrasonic element array **18** and the acoustic lens **13**.

[0133] As shown in FIG. **18**, the insertion needle **8***a* is inserted in the +Y direction. At this time, the control device **3** moves the moving body **71** to the +Y direction side along the second direction **70**. The ultrasonic wave **24** travels to bend in the +Y direction due to the acoustic lens **13**. Then, since the ultrasonic wave **24** passes through the distal end portion **8***b* of the insertion needle **8***a*, the ultrasonic element array **18** detects reflected waves from the distal end portion **8***b* of the insertion needle **8***a*.

[0134] When the moving body **71** moves along the second direction **70**, the position of the moving body **71** in the first direction **25** with respect to the arm **6***a* is changed. A place where the ultrasonic wave **24** concentrates due to the acoustic lens **13** is defined as a focal point **24***a*. When the moving body **71** moves along the second direction **70**, the position of the focal point **24***a* in the first direction **25** with respect to the arm **6***a* is changed. When the distal end portion **8***b* of the insertion needle **8***a* is located on the −Y direction side, the distal end portion **8***b* is located in a shallow place of the arm **6***a*. Then, when the moving body **71** is located on the −Y direction side, the focal point **24***a* is also located in a shallow place of the arm **6***a*. In a place close to the focal point **24***a*, it is possible to make an ultrasonic image clear compared with a place far from the focal point **24***a*. Therefore, it is possible to make an insertion needle image corresponding to the distal end portion **8***b* clear.

[0135] When the distal end portion **8***b* of the insertion needle **8***a* is located on the +Y direction side, the distal end portion **8***b* is located in a deep place of the arm **6***a*. Then, when the moving body **71** is located on the +Y direction side, the focal point **24***a* is also located in a deep place of the arm **6***a*. Therefore, it is possible to make an insertion needle image corresponding to the distal end portion **8***b* clear.

[0136] As described above, according to the present embodiment, the following effect is obtained.

[0137] (1) According to the present embodiment, since the ultrasonic probe **68** changes the position of the focal point **24***a* according to the movement of the moving body **71**, an image corresponding to the distal end portion **8***b* of the insertion needle **8***a* in an ultrasonic image can be made clear.

Fifth Embodiment

[0138] Next, an embodiment using an ultrasonic measurement apparatus will be described with reference to FIGS. **19** and **20**. The present embodiment is different from the first embodiment in that the blood vessel **7** that is obliquely located in the arm **6***a* is imaged. In addition, the explanation of the same points as in the first embodiment will be omitted.

[0139] FIGS. **19** and **20** are schematic side sectional views for explaining a method of detecting a blood vessel using ultrasonic waves. FIG. **19** is a diagram when the moving body has moved to the center, and FIG. **20** is a diagram when the moving body has moved in the −Y direction. That is, in the present embodiment, as shown in FIG. **19**, the blood vessel **7** is disposed obliquely with respect to a surface **6***b* of the arm **6***a*. In the second direction **26**, the moving body **16** is located at the center of the ultrasonic probe **2**. At this time, the ultrasonic wave **24** emitted from the ultrasonic element array **18** passes through the acoustic lens **13** to travel in the first direction **25**.

[0140] The ultrasonic wave **24** emitted to the blood vessel **7** is reflected by the blood vessel **7**. Since the blood vessel **7** is oblique with respect to the first direction **25**, a main portion of the reflected wave of the ultrasonic wave **24** travels obliquely with respect to the first direction **25**. Then, the strength of the reflected wave of the ultrasonic wave **24** traveling in the first direction **25** becomes low. Therefore, the strength of the ultrasonic wave **24** received by the ultrasonic element array **18** is low. For this reason, in the ultrasonic image displayed on the display device **9** by the ultrasonic measurement apparatus **1**, an image corresponding to the blood vessel **7** becomes thin. Accordingly, it is difficult to check the image. In particular, since the strength of the reflected wave is low on the inner wall of the blood vessel **7**, it is difficult to check an image corresponding to the inner wall of the blood vessel **7** in the ultrasonic image.

[0141] As shown in FIG. **20**, when the moving body **16** moves in the −Y direction, the ultrasonic wave **24** emitted from the ultrasonic element array **18** passes through the acoustic lens **13** to travel in the −Y direction and +Z direction. The ultrasonic wave **24** emitted to the blood vessel **7** is reflected by the blood vessel **7**. The traveling direction of the ultrasonic wave **24** and the direction in which the blood vessel **7** extends are approximately perpendicular to each other. At this time, a main portion of the reflected wave of the ultrasonic wave **24** travels toward the ultrasonic element array **18**. Then, the strength of the reflected wave of the ultrasonic wave **24** traveling toward the ultrasonic element array **18** becomes high. Accordingly, the strength of the ultrasonic wave **24** received by the ultrasonic element array **18** is high. For this reason, in the ultrasonic image displayed on the display device **9** by the ultrasonic measurement apparatus **1**, an image corresponding to the blood vessel **7** becomes clear. Accordingly, it is easy to check the image. Also on the inner wall of the blood vessel **7**, the strength of the reflected wave is high. Therefore, it is easy to check the image corresponding to the blood vessel **7** in the ultrasonic image.

[0142] As described above, according to the present embodiment, the following effect is obtained.

[0143] (1) According to the present embodiment, the ultrasonic probe **2** can change the traveling direction of the ultrasonic wave **24** according to the movement of the moving body **16**. Even when the blood vessel **7** is oblique with respect to the first direction **25**, the image corresponding to the blood vessel **7** can be made clear by changing the traveling direction of the ultrasonic wave **24** by moving the moving body **16**.

[0144] The invention is not limited to the embodiments described above, and various modifications or improvements can be made within the technical idea of the invention by those skilled in the art. Modification examples will be described below.

Modification Example 1

[0145] In the first embodiment described above, the linear motor **29** moves the moving body **16**. Without being limited thereto, an operator may press the moving body **16** with a finger. Since the linear motor **29** and the motor driving circuit **31** are not necessary, it is possible to manufacture the ultrasonic measurement apparatus **1** with good productivity. When using a motor, motors other than the linear motor **29** may be used. A ball screw and a motor having a rotary shaft may be combined. Alternatively, a piezoelectric motor may be used.

Modification Example 2

[0146] In the first embodiment described above, the ultrasonic probe **2** and the control device **3** are connected to each other by the wiring line **4**. The ultrasonic probe **2** and the control device **3** may wirelessly communicate with each other. It is possible to easily provide the control device **3** in a place where the display device **9** is easy to see.

Modification Example 3

[0147] In the first embodiment described above, an example of injection into the blood vessel **7** is shown. In addition, at the time of injection into nerves or at the time of injection into an organ, the ultrasonic measurement apparatus **1** may be used. Also at this time, it is possible to accurately insert the insertion needle **8*a*** to the target location. In addition, it is possible to suppress complications caused by damaging the nerve. In addition, when sampling the tissue of a lesion part for biological tissue diagnosis, the ultrasonic measurement apparatus **1** may be used. In addition, the ultrasonic measurement apparatus **1** maybe used for percutaneous radiofrequency ablation therapy. In the percutaneous radiofrequency ablation therapy, the electrode needle is inserted into the center of the tumor through the skin. Then, the current of the wavelength of the radio wave is applied to generate heat around the needle. The tumor is necrotized by the heat. The electrode needle is inserted to the center of the tumor while observing the tumor in the ultrasonic image formed by the ultrasonic measurement apparatus **1**. Therefore, it is possible to locate the electrode needle with high positional accuracy.

[0148] The entire disclosure of Japanese Patent Application NO. 2016-041857 filed on Mar. 4, 2016 is expressly incorporated by reference herein.

What is claimed is:

1. An ultrasonic measurement apparatus, comprising:
an ultrasonic wave transmission unit that emits an ultrasonic wave in a first direction;
a columnar acoustic lens that changes a traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit; and
a movement restriction unit that restricts a movement direction such that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in a second direction crossing the first direction and a column axis direction of the acoustic lens.

2. The ultrasonic measurement apparatus according to claim **1**,
wherein the acoustic lens is a convex lens, and
a material of the acoustic lens is a material in which a traveling speed of an ultrasonic wave is higher than that of an ultrasonic wave in a subject under examination.

3. The ultrasonic measurement apparatus according to claim **1**,
wherein the acoustic lens is a concave lens, and
a material of the acoustic lens is a material in which a traveling speed of an ultrasonic wave is lower than that of an ultrasonic wave in a subject under examination.

4. The ultrasonic measurement apparatus according to claim **1**, further comprising:
a moving unit that moves the acoustic lens and the ultrasonic wave transmission unit relatively each other;
a control unit that controls a relative position between the acoustic lens and the ultrasonic wave transmission unit; and
an input unit that receives an input of the relative position.

5. The ultrasonic measurement apparatus according to claim **1**, further comprising:
a moving unit that moves the acoustic lens and the ultrasonic wave transmission unit relatively each other;
a control unit that controls the moving unit;
an ultrasonic wave receiving unit that receives a reflected wave reflected by a subject under examination;
an image forming unit that forms an ultrasonic image from data of the reflected wave;
a determination unit that determines a subject of the ultrasonic image; and
a display unit that displays the ultrasonic image,
wherein, when the ultrasonic image does not include the subject, the control unit controls the moving unit such that the ultrasonic image includes the subject.

6. The ultrasonic measurement apparatus according to claim **5**,
wherein the subject is a rod-shaped member having a distal end portion, and
the control unit detects the distal end portion, and displays the ultrasonic image including the distal end portion on the display unit.

7. The ultrasonic measurement apparatus according to claim **1**,
wherein a liquid material is disposed between the ultrasonic wave transmission unit and the acoustic lens.

8. An ultrasonic probe, comprising:
an ultrasonic wave transmission unit that emits an ultrasonic wave in a first direction;

a columnar acoustic lens that changes a traveling direction of the ultrasonic wave emitted from the ultrasonic wave transmission unit; and

a movement restriction unit that restricts a movement direction such that the acoustic lens and the ultrasonic wave transmission unit move relatively each other in a second direction crossing the first direction and a column axis direction of the acoustic lens.

* * * * *

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摘要(译)

一种超声波测量装置，包括：超声波元件阵列，用于沿第一方向发射超声波;柱状声透镜，用于改变从超声波元件阵列发射的超声波的行进方向;线性引导件用于限制移动方向，使得声透镜和超声波元件阵列在与声透镜的第一方向和柱轴方向交叉的第二方向上彼此相对移动。