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(54) Acoustic-wave measuring apparatus and method

Vorrichtung und Verfahren zur Schallwellenmessung

Appareil et procédé de mesure d'ondes acoustiques

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- **SRIRANG MANOHAR ET AL: "The Twente Photoacoustic Mammoscope: system overview and performance; Twente Photoacoustic Mammoscope", PHYSICS IN MEDICINE AND BIOLOGY, TAYLOR AND FRANCIS LTD. LONDON, GB, vol. 50, no. 11, 7 June 2005 (2005-06-07), pages 2543-2557, XP020084213, ISSN: 0031-9155, DOI: DOI:10.1088/0031-9155/50/11/007**

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Description

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001] The present invention relates to an acoustic-wave measuring apparatus and an acoustic-wave measuring method.

[0002] In particular, it relates to an acoustic-wave measuring apparatus that receives acoustic waves generated from a subject irradiated with light, as well as a method for controlling the apparatus.

Description of the Related Art

[0003] Photoacoustic tomography (PAT) is technique for in-vivo imaging using near-infrared light. In imaging with PAT, a subject, such as a living organism, is irradiated with pulsed light generated from a light source, and the light propagated and spread in the subject is absorbed by a light absorbing substance to generate acoustic waves (typically, ultrasonic waves). The mechanism of the generation of acoustic waves is known as the photoacoustic-wave effect. Tumorous tissue reacts to near-infrared light differently than peripheral tissue, it absorbs light more than the peripheral tissue to expand instantly and generate acoustic waves corresponding to the region that has absorbed the near-infrared light. A photoacoustic imaging apparatus, which is an acoustic-wave measuring apparatus, is an apparatus that receives the acoustic waves with an acoustic-wave detecting element and analyzes the received signal to thereby calculate information, such as spatial initial sound pressure distribution, on acoustic waves generated in the subject and forms an image based on the calculated information. Because the distribution of the generated sound pressure is related to a light absorption coefficient, diagnosis of a subject using the distribution related to the light absorption coefficient is currently being actively studied.

[0004] The acoustic-wave measuring apparatus that obtains readings of a living organism using the photoacoustic-wave effect uses a high-output short-pulse (several tens of nanoseconds) light source having a near-infrared wavelength. The near-infrared wavelength band, in which light absorption of living organisms is low, is known as a biological window. Near-infrared light in the biological window can reach deep into living organisms without causing damage. Nevertheless, in an acoustic-wave measuring apparatus using PAT technology it is necessary to prevent the light from irradiating the observer, in particular, the eyes.

[0005] To that end, for example, an apparatus described by Manohar, et al., entitled "Region-of-interest breast studies using the Twente Photoacoustic Mammoscope (PAM)", Proc. of SPIE Vol. 6437 643702, separates the subject and the observer from each other using a blackout curtain.

[0006] On the other hand, in order to receive acoustic waves efficiently, it is desirable for the acoustic-wave measuring apparatus to move an acoustic-wave probe, which is an acoustic-wave detecting unit, to a precise predetermined measurement position of the subject and detect the acoustic waves. Furthermore, to generate acoustic waves effectively, it is desirable to move also an irradiation unit that irradiates the subject to the predetermined measurement position and irradiate the subject. For these purposes, the observer must check the measurement position on the subject and move the acoustic-wave probe and the irradiation unit to the desired measurement position. However, since the apparatus described by Manohar, et al., separates the subject and the observer from each other with the blackout curtain, it has a problem in that the observer cannot visually observe the subject and it is difficult to move the irradiation unit to the measurement position with high accuracy. Another measuring method moves the irradiation unit to the measurement position with the blackout curtain opened so as to visually align the irradiation unit with the subject without irradiation of light. In this case, however, the operation of opening and closing the blackout curtain is performed for every measurement, which may often cause the observer to forget to close the blackout curtain or a gap to be generated due to incomplete closing of the blackout curtain.

[0007] Furthermore, the document 2008/021317 A1 discloses a system for ultrasound imaging with robotic assistance. A robotic mechanism positions a volume scanning transducer at multiple acoustic windows on a patient. Ultrasound data is acquired from the windows and combined into a wide field-of-view. The robotic mechanism operates without user contact, such as for an automated full or partial torso scan of a patient.

[0008] Still further, the document Srirang Manohar: "The Twente Photoacoustic Mammoscope: system overview and performance"; (XP020084213) provides an overall overview of the Twente Photoacoustic Mammoscope, in particular, a schematic of a specific arrangement in a hospital bed.

SUMMARY OF THE INVENTION

[0009] The present invention in its first aspect provides an acoustic-wave measuring apparatus as specified in claims

1 to 9.

[0010] The present invention in its second aspect provides an acoustic-wave measuring method as specified in claims 10 to 13.

[0011] Further features of the present invention will become apparent to persons having ordinary skill in the art from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1A is a schematic diagram showing in outline an acoustic-wave measuring apparatus according to a first embodiment.

Fig. 1B is a schematic diagram of the acoustic-wave measuring apparatus.

Fig. 2A is a schematic diagram of the apparatus as viewed from a camera.

Fig. 2B is a schematic diagram of the apparatus as viewed from the camera.

Fig. 3 is a flowchart of an exemplary process for measurement in the first embodiment.

Fig. 4 is a graph showing the relationship between the pixel coordinates of a measurement position and coordinates on a movable holding plate.

Fig. 5 is a schematic diagram of a fixed holding plate, the movable holding plate, and the camera, as viewed from the top of the apparatus.

Fig. 6 is a schematic diagram showing in outline an acoustic-wave measuring apparatus according to a second embodiment.

Fig. 7 is a flowchart of an exemplary process for measurement in the second embodiment.

Fig. 8 is a schematic diagram of the fixed holding plate, the movable holding plate, and the camera, as viewed from the top of the apparatus.

DESCRIPTION OF THE EMBODIMENTS

[0013] In the present invention, acoustic waves include sound waves, ultrasonic waves, and photoacoustic waves and refers to elastic waves generated when a subject is irradiated with light (electromagnetic waves), such as near infrared light.

First Embodiment

[0014] An acoustic-wave measuring apparatus according to a first embodiment of the present invention includes a holding apparatus which holds a subject to be examined (e.g., human tissue, such as a breast) and a camera, which is an image pickup unit that acquires an image of the subject. A measurement position is designated on an image acquired by the camera, and at least one of an irradiation unit and an acoustic-wave detecting unit is moved to a corresponding position on the subject.

Apparatus Configuration

[0015] Figs. 1A and 1B are side views showing in outline the acoustic-wave measuring apparatus according to the first embodiment of the present invention. Fig. 1A is a schematic diagram showing a state in which an irradiation unit 101 is out of the region imaged by a camera 103 (hereinafter the region imaged by camera 103 is referred to an image pickup region). Fig. 1B is a schematic diagram showing a state in which the irradiation unit 101 is moved to the image pickup region of the camera 103 and irradiates the measurement position with light.

[0016] The acoustic-wave measuring apparatus according to the embodiment of the present invention generates light (pulsed light) from a light source (not shown) and irradiates a subject 111 using the irradiation unit 101. This embodiment prevents the light irradiating the subject 111 from leaking to the outside, by using a casing 100, such as a housing or outer covering made of a material that can block the irradiating light. A light absorbing substance (the subject to be examined, such as a tumor) in the subject 111 absorbs light energy and generates acoustic waves. The generated acoustic waves propagate in the subject 111 and traverse a fixed holding plate 105 to reach an acoustic-wave probe 102. The acoustic-wave probe 102 may also be referred to as an acoustic-wave detecting unit, and the fixed holding plate 105 may be referred to as fixed section of a holding unit. The acoustic-wave probe 102 receives the acoustic waves and converts them to an electrical signal and outputs the electric signal to a photoacoustic-wave processing unit 110, which is also referred to as a signal processing unit. The photoacoustic-wave processing unit 110 generates photoacoustic image data (reconfigures an image) using the input signal. The camera 103, which is an example of an image pickup

unit, acquires an image of the subject 111 via a movable holding plate 104 to obtain image information. The movable holding plate 104 may be referred to as a movable section of the holding unit. A measurement-position designating unit 107 enables an observer to designate a measurement position on the basis of the image information obtained by the camera 103. The measurement position designated by the observer is output, as pixel coordinates, to a coordinate transforming unit 108. The coordinate transforming unit 108 may be implemented as a self-contained central processing unit (CPU) or a computer-implemented program. The coordinate transforming unit 108 transforms the pixel coordinates received from the measurement-position designating unit 107 to coordinates on the movable holding plate 104 (on-holding-plate coordinates). At that time, the coordinate transformation is performed using the distance between the fixed holding plate 105 and the movable holding plate 104, which is measured by a distance measuring unit 106. The transformed coordinates are output to a position control unit 109. The position control unit 109 may be either a computer-implemented program or hardware electronic circuit that can generate control signals based on the transformed coordinates. Specifically, the position control unit 109 controls at least one of a probe driving mechanism 113 and an irradiation-unit driving mechanism 112, which are moving units, to respectively move at least one of the acoustic-wave probe 102 and the irradiation unit 101.

[0017] The light source, not illustrated in the present invention, may include at least one coherent or incoherent pulsed light source capable of producing pulsed light of wavelengths in the biological window. To produce a photoacoustic effect, pulsed light with a pulse width (FWHM) of several hundred nanoseconds or less and more preferably from 5 nanoseconds to 50 nanoseconds is preferable. In the case of measurement of suspect tumorous tissue, such as breast cancer or the like, the light source preferably generates light with a specified wavelength that is absorbed by a specified component (for example, hemoglobin) of components constituting a living organism. A preferably light source may be a laser that produces short pulses of light with a large output; but instead of the laser, a light-emitting diode may also be used. Examples of the laser include a solid-state laser, a gas laser, a dye laser, and a semiconductor laser, each of which may be a modulated continuous wave (CW) laser or a pulsed (e.g., mode locked) laser.

[0018] The irradiation unit 101 irradiates the subject 111 by a method suitable for measuring the light from the light source. Although in this embodiment the irradiation unit 101 irradiates the subject 111 from the side opposite to the acoustic-wave probe 102, the present invention is not limited thereto. For example, the subject 111 may be irradiated either from the same side as the acoustic-wave probe 102 or from both sides of the subject 111. Since the sound pressure of acoustic waves is proportional to the intensity of the light, the subject 111 may be irradiated not only from one side of the subject 111 but also from a plurality of sides of the subject 111, so that the signal-to-noise ratio (S/N) of the signal can be increased. Concrete examples of the irradiation unit 101 include optical components, such as a mirror or a lens that collects, magnifies, or changes the shape of light; a prism that disperses, refracts, and reflects light, one or more optical fibers, or a combination of the foregoing that can efficiently deliver light from the light source to the subject 111. Such optical components may be any components provided that they can irradiate the subject 111 with the light emitted from the light source by a desired method (irradiating direction, shape, and so on) in addition to the above. Furthermore, the irradiation region on the subject 111 may be movable on the subject 111, so that a wider irradiation region can be obtained. In addition, as illustrated in Figs. 1A and 1B, the irradiation unit 101 itself can be moved relative to the subject 111. Furthermore, the region of the subject 111 irradiated with light may be moved in synchronization with the acoustic-wave probe 102. In the case where the light source is small, the light source itself may be used as the irradiation unit 101, and the light source itself may be mechanically moved.

[0019] The acoustic-wave probe 102, which is an acoustic-wave detecting unit, converts acoustic waves into an electrical signal. The acoustic-wave probe 102 may be any conversion element that can detect acoustic waves and convert the acoustic waves to an electrical signal. To that end, for example, a conversion element that uses a piezoelectric phenomenon, a conversion element that uses resonance of light, and a conversion element that uses changes in capacitance may be used. Furthermore, an element array composed of a plurality of conversion elements may be used, so that acoustic waves can be received across a wide region. The acoustic waves are received by the acoustic-wave probe 102, and the electric signal proportional to the acoustic waves is input to the photoacoustic-wave processing unit 110. Although the acoustic-wave probe 102 in Figs. 1A and 1B is provided on the fixed holding plate 105, acoustic-wave probe 102 may be provided on the movable holding plate 104 as well.

[0020] The photoacoustic-wave processing unit 110, which may be a signal processing section, may be either a computer-implemented program or an electronic circuit that can digitize the electric signal and generate image data corresponding to the acoustic waves received by the photoacoustic-wave probe 102. The photoacoustic-wave processing unit 110 generates acoustic image data (reconfigures an image) using back projection in a time domain or a Fourier domain, which is normally used in tomography technology. The acoustic image data in the present invention is data indicating information on the interior of the subject 111, irrespective of two-dimensional or three-dimensional data, (biological information, such as an initial sound pressure distribution and a light absorption coefficient distribution of the interior of the living organism). Two-dimensional photoacoustic image data is composed of a plurality of items of pixel data, and three-dimensional photoacoustic image data is composed of a plurality of items of voxel data.

[0021] The fixed holding plate 105 and the movable holding plate 104 are holding units for holding the subject 111

and keeping the shape of at least part of the subject 111 constant. As shown in Figs. 1A and 1B, holding the subject 111 from opposing sides allows the subject 111 to be fixed in position during measurement. Advantageously, keeping the subject 111 fixed during measurement can reduce a position error due to a body motion and so on. Pressing the subject 111 allows light to efficiently reach the depths of the subject 111. A holding unit on which the irradiation unit 101 is provided (the movable holding plate 104 in Figs. 1A and 1B) may be a member having high light transmittance. A holding unit on which the acoustic-wave probe 102 is provided (the fixed holding plate 105 in Figs. 1A and 1B) may be a member having a property of acoustic matching with the subject 111 and the acoustic-wave probe 102 (having similar acoustic impedance). To enhance the acoustic matching property, an acoustic matching material, such as gel, may be interposed between the holding units and the subject 111 and between the holding units and the acoustic-wave probe 102. The holding units are not restricted to having the above-described configuration. For example, instead of having a fixed section and a movable section, both holding plates may be movable. In addition, instead of the configuration in which the subject 111 is held by holding plates from both sides, a configuration in which the subject 111 is held from below with a bowl-shaped member may be provided.

[0022] The casing 100 has the function of preventing the light irradiating the subject 111 from leaking to the outside by enclosing the peripheries of the irradiation unit 101, the acoustic-wave probe 102, and so on. This prevents the observer from being irradiated with light. The casing 100 of this embodiment also has the function of protecting the person being examined from irradiated light.

[0023] The camera 103, which is an image pickup unit, is disposed in the casing 100 and acquires image information on the subject 111. Examples of the camera 103 include a charge coupled device (CCD) sensor-based camera and a complementary metal oxide semiconductor (CMOS) sensor-based camera. The camera 103 of this embodiment is fixed to the casing 100. When the camera 103 is to acquire an image of the subject 111, the irradiation unit 101 may be moved out of the image pickup region so as not to overlap with the subject 111. Although the camera 103 in Figs. 1A and 1B is shown near the movable holding plate 104, the camera 103 may be provided near the fixed holding plate 105.

[0024] The irradiation-unit driving mechanism 112, which is a moving unit, can move the irradiation unit 101 to any position in or out of the image pickup region of the camera 103.

[0025] Figs. 2A and 2B are schematic diagrams of the apparatus as viewed from the camera 103 side. Fig. 2A is a schematic diagram showing a state in which the irradiation unit 101 is moved out of the image pickup region of the camera 103. Fig. 2B is a schematic diagram showing a state in which the irradiation unit 101 is moved into the image pickup region of the camera 103. The irradiation-unit driving mechanism 112 has a mechanism for driving the irradiation unit 101 independently in the horizontal direction and the vertical direction. Examples of the driving mechanism include a motor and a rack-and-pinion, a motor and a belt, and a linear motor. The irradiation-unit driving mechanism 112 has an origin sensor 201. The position of the origin sensor 201 is designed so that the position of the irradiation unit 101 defined by the origin sensor 201 is out of the image pickup region of the camera 103. Examples of the origin sensor 201 include a contact sensor, an optical sensor, and an origin marker of an absolute encoder. The irradiation-unit driving mechanism 112 is controlled by the position control unit 109. To move the irradiation unit 101 out of the image pickup region of the camera 103, an instruction to move the irradiation unit 101 to the original position is sent from the position control unit 109 to the irradiation-unit driving mechanism 112. Thus, the state in Fig. 1A is achieved by moving the irradiation unit 101 out of the image pickup region of the camera 103, as shown in Fig. 2A. To move the irradiation unit 101 into the image pickup region of the camera 103, an instruction to move the irradiation unit 101 to a position in the image pickup region is sent from the position control unit 109 to the irradiation-unit driving mechanism 112. Thus, the state in Fig. 1B is achieved by moving the irradiation unit 101 into the image pickup region of the camera 103, as shown in Fig. 2B.

[0026] The probe driving mechanism 113, which is a moving unit, should move the acoustic-wave probe 102 to a position opposing the irradiation unit 101, with the subject 111 therebetween. The probe driving mechanism 113 is controlled by the position control unit 109. In the case where the camera 103 is disposed near the acoustic-wave probe 102, the irradiation unit 101 should be moved as described above so as to prevent the subject 111 from overlapping with the acoustic-wave probe 102 during image acquisition.

[0027] The distance measuring unit 106 measures the distance between the fixed holding plate 105 and the movable holding plate 104. The distance here is a distance in the optical axis of the camera 103. One end of the distance measuring unit 106 is fixed to the fixed holding plate 105, and the other end is fixed to the movable holding plate 104. Distances that differ depending on the characteristics (sizes and so on) of the individual subjects 111 are output to the coordinate transforming unit 108.

[0028] The measurement-position designating unit 107 is for the observer to designate a measurement position on an image acquired by the camera 103, such as mouse, keyboard or touch panel. An image is displayed on a display, such as a monitor, using image information from the camera 103. An observer designates a measurement position on the displayed image with a mouse or designates a measurement position on a screen having a contact position detection sensor with a finger. The measurement position may be designated by inputting the coordinates of a measurement position on the image using a keyboard or the like. The designated measurement position is output as pixel coordinates

on the image to the coordinate transforming unit 108.

[0029] The coordinate transforming unit 108 transforms the pixel coordinates output from the measurement-position designating unit 107 to the coordinates of a position corresponding to the pixel coordinates on the movable holding unit (on the movable holding plate 104 in this embodiment). At that time, the transformation is made using the distance between the fixed holding plate 105 and the movable holding plate 104 measured by the distance measuring unit 106. The transformed coordinates are output to the position control unit 109.

[0030] The position control unit 109 controls the probe driving mechanism 113 and the irradiation-unit driving mechanism 112 to move at least one of the acoustic-wave probe 102 and the irradiation unit 101. For example, the irradiation unit 101 can be moved to the coordinate position output from the coordinate transforming unit 108 or to an original position defined by the origin sensor 201. Measurement Flow

[0031] The measurement flow of this embodiment is shown in Fig. 3. The individual steps of the measurement flow will be described in detail with reference to Figs. 1A and 1B and Fig. 3. The following description is made using a configuration example in which the holding units composed of the fixed holding unit and the movable holding unit is provided, and the acoustic-wave probe 102 is provided on the fixed holding unit side, and the irradiation unit 101 is provided nearer to the movable holding unit, as in Figs. 1A and 1B. However, the present invention is not limited to such a configuration, as described above.

[0032] First, the measurement process is started at step 301 (abbreviated in the drawing as S301), the subject 111 is positioned between the fixed holding plate 105 and the movable holding plate 104, and the observer moves the movable holding plate 104 to hold the subject 111 in the desired position at step 302. At that time, the subject 111 may be pressed to be held as thin as possible, so as to optimize the S/N ratio of a received signal obtained and the depth of measurement. After completion of the holding, that is - once the subject 111 is positioned and held in the desired position - the distance between the fixed holding plate 105 and the movable holding plate 104 is measured by the distance measuring unit 106.

[0033] In step 303, the irradiation unit 101 is moved to the original position. The irradiation-unit driving mechanism 112 is driven by the position control unit 109, and the irradiation unit 101 is moved to the original position designated by the origin sensor 201.

[0034] In step 304 (image pickup step), an image of the subject 111 is acquired by the camera 103. Since the irradiation unit 101 has been moved to the original position outside the image pickup region of the camera 103 in step 303, an image of the entire subject 111 including the measurement position can be acquired.

[0035] In step 305, the observer designates the measurement position on the image using pixel coordinates on the basis of the image information on the subject 111 obtained in step 304, and thus, the pixel coordinates of the measurement position (measurement-position pixel coordinates) can be obtained.

[0036] A process in step 306 (coordinate transforming step) will be described with reference to Figs. 4 and 5. Fig. 4 is a graph showing pixel coordinates on the image and coordinates on the movable holding plate 104. The coordinate transforming unit 108 transforms the pixel coordinates (X_m, Y_m) of the measurement position designated by the observer in step 305 to measurement position coordinates (x_m, y_m) on the movable holding plate 104 (on-movable-holding-plate measurement position coordinates). The on-movable-holding-plate measurement position coordinates are expressed, for example, by values in millimeters or micrometers.

[0037] Next, transformation equations will be described. Fig. 5 is a schematic diagram of the fixed holding plate 105, the movable holding plate 104, and the camera 103, as viewed from the top of the apparatus. The movable holding plate 104 can take any distance L . Reference numerals 501 and 502 denote the positions of the movable holding plate 104 when $L = L_1$ and $L = L_2$, respectively. The image pickup width of the camera 103 at distance L is denoted by $W(L)$. As shown in Fig. 5, the image pickup width W changes depending on the position of the movable holding plate 104. The distance between the movable holding plate 104 and the camera 103 when $L = L_1$ is denoted by Dis . Dis can be expressed as the following Exp. (1) from the relation of an isosceles triangle with the vertex at the angle of view in Fig. 5.

Exp. (1)

$$Dis = (L_2 - L_1) \left(1 - \frac{W(L_2)}{W(L_1)} \right)^{-1}$$

[0038] From the coordinate relationship shown in Fig. 4, transformation equation for transforming measurement-position pixel coordinates to on-movable-holding-plate measurement position coordinates can be expressed using Dis in Exp. (1),

Exp. (2)

$$\begin{aligned}
 x_m &= x_c + \left(X_m - \frac{X_w}{2} \right) \times \frac{W(L_1) \times \left(\frac{Dis - (L - L_1)}{Dis} \right)}{X_w} \\
 y_m &= y_c - \left(Y_m - \frac{Y_w}{2} \right) \times \frac{W(L_1) \times \left(\frac{Dis - (L - L_1)}{Dis} \right)}{X_w}
 \end{aligned}$$

[0039] Transformation of pixel coordinate X_m to position coordinate x_m by Exp. (2) will be described below. Referring to Fig. 4, reference sign X denotes a horizontal pixel coordinate axis, Y denotes a vertical pixel coordinate axis, X_m denotes a measurement-position horizontal pixel coordinate, Y_m denotes a measurement-position vertical pixel coordinate, X_w denotes an image-pickup-region-end horizontal pixel coordinate, and Y_w denotes an image-pickup-region-end vertical pixel coordinate. Reference sign x denotes an on-movable-holding-plate horizontal coordinate axis, y denotes an on-movable-holding-plate vertical coordinate axis, x_m denotes a measurement-position horizontal coordinate, y_m denotes a measurement-position vertical coordinate, x_c denotes a horizontal coordinate at the center of image pickup region, and y_c denotes a vertical coordinate at the center of image pickup region.

Exp. (3)

$$W(L_1) \times \left(\frac{Dis - (L - L_1)}{Dis} \right)$$

[0040] Exp. (3) in Exp. (2) is a transformation coefficient determined from the distance between the camera 103 and a measurement position. Exp. (3) expresses an image pickup width $W(L)$ at any distance L . By dividing the image pickup width $W(L)$ expressed as Exp. (3) by the image-pickup-region-end horizontal pixel coordinate X_w in Fig. 4, the distance of an on-movable-holding-plate coordinates per pixel (Exp. (4)) can be given.

Exp. (4)

$$\frac{W(L_1) \times \left(\frac{Dis - (L - L_1)}{Dis} \right)}{X_w}$$

[0041] By multiplying Exp. (5), which is the amount of pixels from the center of the image to the measurement-position horizontal pixel coordinate X_m in Exp. (2), by Exp. (4),

Exp. (5)

$$\left(X_m - \frac{X_w}{2} \right)$$

the distance of an on-movable-holding-plate coordinates, expressed as Exp. (6) can be obtained.

Exp. (6)

$$\chi_m - \chi_c = \left(X_m - \frac{X_w}{2} \right) \times \frac{W(L_1) \times \left(\frac{Dis - (L - L_1)}{Dis} \right)}{X_w}$$

[0042] By transposing x_c in Exp. (6) to the left term, x_m in Exp. (2) can be found. Although the above is for the horizontal direction, the same applies to the vertical direction, that is, transformation from Y_m to y_m .

[0043] L_1 , L_2 , $W(L_1)$, and $W(L_2)$ are known values measured in advance, and x_c , x_w , X_w , and Y_w are given in advance as specification values of the apparatus. By substituting the distance between the fixed holding plate 105 and the movable holding plate 104 measured in step 302 for L in Exp. (2), and substituting the measurement-position pixel coordinates obtained in step 305 for (X_m, Y_m) in Exp. (2), the on-movable-holding-plate measurement position coordinates (x_m, y_m) can be given. Even if the distance between the movable holding plate 104 and the camera 103 changes, the relationship between the pixel coordinates (X_m, Y_m) and the on-movable-holding-plate measurement position coordinates (x_m, y_m) can be corrected properly by performing step 306.

[0044] Referring back to Fig. 3, in step 307 (position control step), the irradiation unit 101 is moved by the position control unit 109 to the on-movable-holding-plate measurement position coordinates (x_m, y_m) obtained in step 306. Since transformation with consideration of the distance between the fixed holding plate 105 and the movable holding plate 104 is performed in step 306, the irradiation unit 101 can be moved with high accuracy. In this step, not only the irradiation unit 101 but also the acoustic-wave probe 102 should be moved to the coordinates (x_m, y_m) of the measurement position on the fixed holding plate 105. Here, the measurement position is a position on the subject 111 to be measured in more detail or a start position in the case where measurement is performed while the acoustic-wave probe 102 and the irradiation unit 101 are being moved.

[0045] In step 308, the irradiation unit 101 irradiates the subject 111 with light, and the acoustic-wave probe 102 detects generated acoustic waves to obtain a receiver signal. In step 309, the photoacoustic-wave processing unit 110 generates photoacoustic image data using the receiver signal obtained in step 308. The photoacoustic image data is presented to the observer as, for example, numerical information or an image, on a display unit (not shown), and the measurement ends at step 310.

[0046] Providing an image pickup unit, such as the camera 103, allows designation of a measurement position even in an acoustic-wave measuring apparatus in which visual designation of a measurement position is difficult. Furthermore, providing the irradiation-unit driving mechanism 112 that moves the irradiation unit 101 out of the image pickup region of the camera 103 and the distance measuring unit 106 allows high-accuracy designation of a measurement position.

Second Embodiment

[0047] In a second embodiment, a case in which the distance between the image pickup unit that acquires an image of the subject and the movable holding unit is held constant will be particularly described. The other configurations are the same as those of the first embodiment.

Apparatus Configuration

[0048] Fig. 6 is a schematic diagram showing the configuration of an acoustic-wave measuring apparatus according to a second embodiment of the present invention. In this embodiment, although the details of processing in the coordinate transforming unit differ from those of the first embodiment, the other components are the same as those of the first embodiment; therefore, descriptions of the same terms are omitted.

[0049] A fixing member 801, which is a distance fixing unit, fixes the movable holding plate 104 and the camera 103 a predetermined distance. The fixing member 801 is designed to fix the distance between the movable holding plate 104 and the camera 103 to a certain value. Therefore, even if the movable holding plate 104 moves, the distance between the movable holding plate 104 and the camera 103 is kept constant. The fixing member 801 may be disposed out of the image pickup region of the camera 103. The coordinate transforming unit 108 transforms pixel coordinates output from the measurement-position designating unit 107 to coordinates on the movable holding plate 104. At that time, the transformation is performed using the distance determined depending on the fixing member 801. The transformed coordinates are output to the position control unit 109.

Measurement Flow

[0050] The measurement flow of the second embodiment is shown in Fig. 7. Although the coordinate transforming step (step 906) of this embodiment differs from step 306 of the first embodiment, the other steps are the same as in Fig. 3; therefore, descriptions thereof will be omitted.

[0051] A process in step 906 will be described with reference to Fig. 8. Fig. 8 is a schematic diagram of the fixed holding plate 105, the movable holding plate 104, and the camera 103, as viewed from the top of the apparatus. Reference numerals 1001 and 1002 denote the positions of the camera 103 when the distance between the fixed holding plate 105 and the movable holding plate 104 is L_1 and L_2 , respectively. Since the distance Dis_0 between the movable holding plate 104 and the camera 103 is constant by means of the fixing member 801, the image pickup width W of the camera 103 depends on Dis_0 at either of the distances L_1 and L_2 . Referring to Figs. 4 and 8, transformation equations for transforming measurement-position pixel coordinates to on-movable-holding-plate measurement position coordinates can be expressed as Exp. (7).

Exp. (7)

$$\begin{aligned} x_m &= x_c + \left(\frac{x_m - \frac{x_w}{2}}{x_w} \right) \times W(Dis_0) \\ y_m &= y_c - \left(\frac{y_m - \frac{y_w}{2}}{x_w} \right) \times W(Dis_0) \end{aligned}$$

[0052] $W(Dis_0)$ in Exp. (7) is a transformation coefficient determined from the distance between the image pickup unit and a measurement position. Since Dis_0 is a specification value of the apparatus, determined depending on the fixing member 801, the transformation coefficient $W(Dis_0)$ is given in advance. By substituting the measurement-position pixel coordinates obtained in step 305 for (X_m, Y_m) in Exp. (2), the on-movable-holding-plate measurement position coordinates (x_m, y_m) can be obtained.

[0053] Thus, providing the camera 103 allows designation of a measurement position even in an acoustic-wave measuring apparatus in which visual designation of a measurement position is difficult. Furthermore, providing the fixing member 801 prevents the distance between the movable holding plate 104 and the camera 103 from changing even if the subject holding thickness changes, thereby facilitating the process of the coordinate transforming step.

[0054] In accordance with at least one embodiment of the present invention, an acoustic-wave measuring apparatus enables, among other things, designation of a measurement position with high accuracy and accurate detection of acoustic waves at a desired position. While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all modifications and equivalent structures and functions.

Claims

1. An acoustic-wave measuring apparatus comprising:

holding means (104, 105) arranged to hold a subject;
 irradiation means (101) arranged to irradiate the subject with light;
 acoustic-wave detecting means (102) arranged to receive acoustic waves generated in the subject due to irradiation with the light via the holding means (104, 105);
 an image pickup unit (103) arranged to acquire an image of the subject;
 position designation means (107) configured to designate a measurement position on the image acquired by the image pickup unit (103);
 coordinate transforming means (108) arranged to transform coordinates of the measurement position on the image acquired by the image pickup unit (103) to coordinates of a corresponding position on the holding means

(104, 105); and

position control means (109) arranged to move at least one of the irradiation means (101) and the acoustic-wave detecting means (102) to the corresponding position on the holding means (104, 105).

- 5 **2.** The acoustic-wave measuring apparatus according to Claim 1, wherein the coordinate transforming means (108) transforms the coordinates of the measurement position on the image to the coordinates of the corresponding position on the holding means (104, 105) using a transformation coefficient determined based on a distance between the holding means (104, 105) and the image pickup unit (103).
- 10 **3.** The acoustic-wave measuring apparatus according to Claim 1, wherein:

the holding means (104, 105) includes a fixed holding section and a movable holding section arranged to hold the subject from opposite sides;

the coordinate transforming means (108) transforms the coordinates of the measurement position on the image to the coordinates of the corresponding position on the movable holding section using a transformation coefficient determined based on a distance between the movable holding section and the image pickup unit (103).
- 15 **4.** The acoustic-wave measuring apparatus according to Claim 3, further comprising distance measuring means (106) arranged to measure the distance between the movable holding section and the image pickup unit (103).
- 20 **5.** The acoustic-wave measuring apparatus according to Claim 3, further comprising distance fixing means (801) arranged to keep a distance between a movable holding section and the image pickup unit (103) constant, wherein the holding means (104, 105) includes a fixed holding section and the movable holding section arranged to hold the subject from opposite sides.
- 25 **6.** The acoustic-wave measuring apparatus according to any one of Claims 1 to 5, further comprising a casing, wherein the casing is configured to suppress a leakage of light with which the subject is irradiated by the irradiation means to the outside of the casing.
- 30 **7.** The acoustic-wave measuring apparatus according to claim 6, wherein the image pickup unit is disposed inside the casing.
- 35 **8.** The acoustic-wave measuring apparatus according to any one of claims 1 to 7, wherein the holding means holds the subject from below.
- 40 **9.** The acoustic-wave measuring apparatus according to any one of claims 1 to 8, wherein the holding means is a bowl-shaped member.
- 45 **10.** An acoustic-wave measuring method, carried out on an apparatus according to any of claims 1 - 9, wherein acoustic waves generated in a subject when irradiated with light by irradiation means (101) are received by an acoustic-wave detecting means (102) via holding means (104, 105), the method comprising:

an image pickup step of acquiring an image of the subject;

a coordinate transforming step of transforming coordinates of a measurement position, designated by an observer on the image acquired in the image pickup step to coordinates of a corresponding position on the holding means (104, 105); and

a position control step of moving at least one of the irradiation means (101) and the acoustic-wave detecting means (102) to the corresponding position on the holding means (104, 105).
- 50 **11.** The acoustic-wave measuring method according to claim 10, wherein in the coordinate transforming step, the coordinates of the measurement position on the image are transformed to the coordinates of the corresponding position on the holding means (104, 105) using a transformation coefficient determined based on a distance between the holding means (104, 105) and the image pickup unit (103).
- 55 **12.** The acoustic-wave measuring method according to claim 10, wherein:

the holding means (104, 105) include a fixed holding section and a movable holding section configured to hold the subject from opposite sides; and

in the coordinate transforming step, the coordinates of the measurement position on the image are transformed to the coordinates of the corresponding position on the movable holding section using a transformation coefficient determined based on a distance between the movable holding section and the image pickup unit (103).

13. The acoustic-wave measuring method according to claim 12, further comprising a distance measuring step of measuring the distance between the movable holding section and the image pickup unit (103).

Patentansprüche

1. Akustikwellen-Messvorrichtung, mit:

einer Halteeinrichtung (104, 105), die eingerichtet ist, um ein Subjekt zu halten;
 einer Bestrahlungseinrichtung (101), die eingerichtet ist, um das Subjekt mit Licht zu bestrahlen;
 einer Akustikwellen-Erfassungseinrichtung (102), die eingerichtet ist, um akustische Wellen zu empfangen, die in dem Subjekt aufgrund der Bestrahlung mit dem Licht über die Halteeinrichtung (104, 105) erzeugt werden;
 einer Bildaufnahmeeinheit (103), die eingerichtet ist, um ein Bild des Subjekts zu erfassen;
 einer Positionszuweisungseinrichtung (107), die konfiguriert ist, um eine Messposition auf dem von der Bildaufnahmeeinheit (103) erfassten Bild zuzuweisen;
 einer Koordinatentransformationseinrichtung (108), die eingerichtet ist, um Koordinaten der Messposition auf dem von der Bildaufnahmeeinheit (103) erfassten Bild in Koordinaten einer entsprechenden Position auf der Halteeinrichtung (104, 105) zu transformieren; und
 einer Positionssteuerungseinrichtung (109), die eingerichtet ist, um mindestens eine, die Bestrahlungseinrichtung (101) und die Akustikwellen-Erfassungseinrichtung (102), in die entsprechende Position auf der Halteeinrichtung (104, 105) zu bewegen.

2. Akustikwellen-Messvorrichtung gemäß Anspruch 1, wobei die Koordinatentransformationseinrichtung (108) die Koordinaten der Messposition auf dem Bild in die Koordinaten der entsprechenden Position auf der Halteeinrichtung (104, 105) unter Verwendung eines Transformationskoeffizienten transformiert, der auf der Grundlage eines Abstands zwischen der Halteeinrichtung (104, 105) und der Bildaufnahmeeinheit (103) bestimmt wird.

3. Akustikwellen-Messvorrichtung gemäß Anspruch 1, wobei:

die Halteeinrichtung (104, 105) einen festen Halteabschnitt und einen beweglichen Halteabschnitt aufweist, die angeordnet sind, um das Subjekt von gegenüberliegenden Seiten halten;
 die Koordinatentransformationseinrichtung (108) die Koordinaten der Messposition auf dem Bild in die Koordinaten der entsprechenden Position auf dem beweglichen Halteabschnitt unter Verwendung eines Transformationskoeffizienten transformiert, der auf der Grundlage eines Abstands zwischen dem beweglichen Halteabschnitt und der Bildaufnahmeeinheit (103) bestimmt wird.

4. Akustikwellen-Messvorrichtung gemäß Anspruch 3, weiterhin mit einer Abstandsmesseinrichtung (106), die eingerichtet ist, um den Abstand zwischen dem beweglichen Halteabschnitt und der Bildaufnahmeeinheit (103) zu messen.

5. Akustikwellen-Messvorrichtung gemäß Anspruch 3, weiterhin mit einer Abstandsfixiereinrichtung (801), die eingerichtet ist, um den Abstand zwischen einem beweglichen Halteabschnitt und der Bildaufnahmeeinheit (103) konstant zu halten,
 wobei die Halteeinrichtung (104, 105) einen festen Halteabschnitt und den beweglichen Halteabschnitt umfasst, die angeordnet sind, um das Subjekt von gegenüberliegenden Seiten halten.

6. Akustikwellen-Messvorrichtung gemäß einem der Ansprüche 1 bis 5, weiterhin mit einem Gehäuse, wobei das Gehäuse konfiguriert ist, um ein Lichtleck zu unterdrücken, durch das das Subjekt durch die Bestrahlungseinrichtung nach außerhalb des Gehäuses bestrahlt wird.

7. Akustikwellen-Messvorrichtung gemäß Anspruch 6, wobei die Bildaufnahmeeinheit im Inneren des Gehäuses angebracht ist.

8. Akustikwellen-Messvorrichtung gemäß einem der Ansprüche 1 bis 7, wobei die Haltevorrichtung das Subjekt von unten hält.

9. Akustikwellen-Messvorrichtung gemäß einem der Ansprüche 1 bis 8, wobei die Haltevorrichtung ein schalenförmiges Element ist.

10. Akustikwellen-Messverfahren, das an einer Vorrichtung gemäß einem der Ansprüche 1 bis 9 ausgeführt wird, wobei in einem Subjekt erzeugte akustische Wellen, wenn sie durch eine Bestrahlungseinrichtung (101) mit Licht bestrahlt werden, von einer Akustikwellen-Erfassungseinrichtung (102) über eine Halteeinrichtung (104, 105) empfangen werden, wobei das Verfahren umfasst:

einen Bildaufnahmeschritt zum Beziehen eines Bildes des Subjekts;

einen Koordinatentransformationsschritt zum Transformieren von Koordinaten einer Messposition, die durch einen Beobachter auf dem im Bildaufnahmeschritt erfassten Bild zugewiesen wurde, in Koordinaten einer entsprechenden Position auf der Halteeinrichtung (104, 105); und

einen Positionssteuerungsschritt zum Bewegen mindestens einer, der Bestrahlungseinrichtung (101) und der Schallwellenerfassungseinrichtung (102), auf die entsprechende Position auf der Halteeinrichtung (104, 105).

11. Akustikwellen-Messverfahren gemäß Anspruch 10, wobei in dem Koordinatentransformationsschritt die Koordinaten der Messposition auf dem Bild in die Koordinaten der entsprechenden Position auf der Halteeinrichtung (104, 105) unter Verwendung eines Transformationskoeffizienten transformiert werden, der auf der Grundlage eines Abstands zwischen der Halteeinrichtung (104, 105) und der Bildaufnahmeeinheit (103) bestimmt wird.

12. Akustikwellen-Messverfahren gemäß Anspruch 10, wobei:

die Halteeinrichtung (104, 105) einen festen Halteabschnitt und einen beweglichen Halteabschnitt umfasst, die konfiguriert sind, um das Subjekt von gegenüberliegenden Seiten zu halten; und

in dem Koordinatentransformationsschritt die Koordinaten der Messposition auf dem Bild in die Koordinaten der entsprechenden Position auf dem beweglichen Halteabschnitt unter Verwendung eines Transformationskoeffizienten transformiert werden, der auf der Grundlage eines Abstands zwischen dem beweglichen Halteabschnitt und der Bildaufnahmeeinheit bestimmt wird (103).

13. Akustikwellen-Messverfahren gemäß Anspruch 12, weiterhin mit einem Abstandsmessschritt zum Messen des Abstands zwischen dem beweglichen Halteabschnitt und der Bildaufnahmeeinheit (103).

Revendications

1. Appareil de mesure d'ondes acoustiques, comprenant :

un moyen de maintien (104, 105) conçu pour maintenir un sujet ;

un moyen d'exposition à un rayonnement (101) conçu pour exposer le sujet à un rayonnement de lumière ;

un moyen de détection d'ondes acoustiques (102) conçu pour recevoir des ondes acoustiques générées dans le sujet suite à l'exposition au rayonnement de la lumière par le biais du moyen de maintien (104, 105) ;

un moyen de prise d'image (103) conçu pour acquérir une image du sujet ;

un moyen de désignation de position (107) configuré pour désigner une position de mesure sur l'image acquise par le moyen de prise d'image (103) ;

un moyen de transformation de coordonnées (108) conçu pour transformer des coordonnées de la position de mesure sur l'image acquise par l'unité de prise d'image (103) en coordonnées d'une position correspondante sur le moyen de maintien (104, 105) ; et

un moyen de commande de position (109) conçu pour déplacer au moins l'un du moyen d'exposition à un rayonnement (101) et du moyen de détection d'ondes acoustiques (102) jusqu'à la position correspondante sur le moyen de maintien (104, 105).

2. Appareil de mesure d'ondes acoustiques selon la revendication 1, dans lequel le moyen de transformation de coordonnées (108) transforme les coordonnées de la position de mesure sur l'image en les coordonnées de la position correspondante sur le moyen de maintien (104, 105) au moyen d'un coefficient de transformation déterminé sur la base d'une distance entre le moyen de maintien (104, 105) et l'unité de prise d'image (103).

3. Appareil de mesure d'ondes acoustiques selon la revendication 1, dans lequel :

le moyen de maintien (104, 105) comprend une section de maintien fixe et une section de maintien mobile conçues pour maintenir le sujet depuis des côtés opposés ;
le moyen de transformation de coordonnées (108) transforme les coordonnées de la position de mesure sur l'image en les coordonnées de la position correspondante sur la section de maintien mobile au moyen d'un coefficient de transformation déterminé sur la base d'une distance entre la section de maintien mobile et l'unité de prise d'image (103).

4. Appareil de mesure d'ondes acoustiques selon la revendication 3, comprenant en outre un moyen de mesure de distance (106) conçu pour mesurer la distance entre la section de maintien mobile et l'unité de prise d'image (103) .

5. Appareil de mesure d'ondes acoustiques selon la revendication 3, comprenant en outre un moyen de fixation de distance (801) conçu pour maintenir constante une distance entre une section de maintien mobile et l'unité de prise d'image (103),
dans lequel le moyen de maintien (104, 105) comprend une section de maintien fixe et la section de maintien mobile conçues pour maintenir le sujet depuis des côtés opposés.

6. Appareil de mesure d'ondes acoustiques selon l'une quelconque des revendications 1 à 5, comprenant en outre un boîtier, dans lequel le boîtier est configuré pour supprimer une fuite de lumière au moyen de laquelle le sujet fait l'objet d'une exposition à un rayonnement par le moyen d'exposition à un rayonnement vers l'extérieur du boîtier.

7. Appareil de mesure d'ondes acoustiques selon la revendication 6, dans lequel l'unité de prise d'image est disposée à l'intérieur du boîtier.

8. Appareil de mesure d'ondes acoustiques selon l'une quelconque des revendications 1 à 7, dans lequel le moyen de maintien maintient le sujet depuis le dessous.

9. Appareil de mesure d'ondes acoustiques selon l'une quelconque des revendications 1 à 8, dans lequel le moyen de maintien est un élément en forme de bol.

10. Procédé de mesure d'ondes acoustiques, exécuté sur un appareil selon l'une quelconque des revendications 1 à 9, dans lequel des ondes acoustiques générées dans un sujet lors de son exposition à un rayonnement de lumière par un moyen d'exposition à un rayonnement (101) sont reçues par un moyen de détection d'ondes acoustiques (102) par le biais d'un moyen de maintien (104, 105), le procédé comprenant :

une étape de prise d'image consistant à acquérir une image du sujet ;
une étape de transformation de coordonnées consistant à transformer des coordonnées d'une position de mesure, désignée par un observateur sur l'image acquise à l'étape de prise d'image en coordonnées d'une position correspondante sur le moyen de maintien (104, 105) ; et
une étape de commande de position consistant à déplacer au moins l'un du moyen d'exposition à un rayonnement (101) et du moyen de détection d'ondes acoustiques (102) jusqu'à la position sur le moyen de maintien (104, 105).

11. Procédé de mesure d'ondes acoustiques selon la revendication 10, dans lequel
à l'étape de transformation de coordonnées, les coordonnées de la position de mesure sur l'image sont transformées en les coordonnées de la position correspondante sur le moyen de maintien (104, 105) au moyen d'un coefficient de transformation déterminé sur la base d'une distance entre le moyen de maintien (104, 105) et l'unité de prise d'image (103).

12. Procédé de mesure d'ondes acoustiques selon la revendication 10, dans lequel :

le moyen de maintien (104, 105) comprend une section de maintien fixe et une section de maintien mobile configurées pour maintenir le sujet depuis des côtés opposés ; et
à l'étape de transformation de coordonnées, les coordonnées de la position de mesure sur l'image sont transformées en les coordonnées de la position correspondante sur la section de maintien mobile au moyen d'un coefficient de transformation déterminé sur la base d'une distance entre la section de maintien mobile et l'unité de prise d'image (103).

13. Procédé de mesure d'ondes acoustiques selon la revendication 12, comprenant en outre une étape de mesure de

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distance consistant à mesurer la distance entre la section de maintien mobile et l'unité de prise d'image (103) .

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FIG. 1A

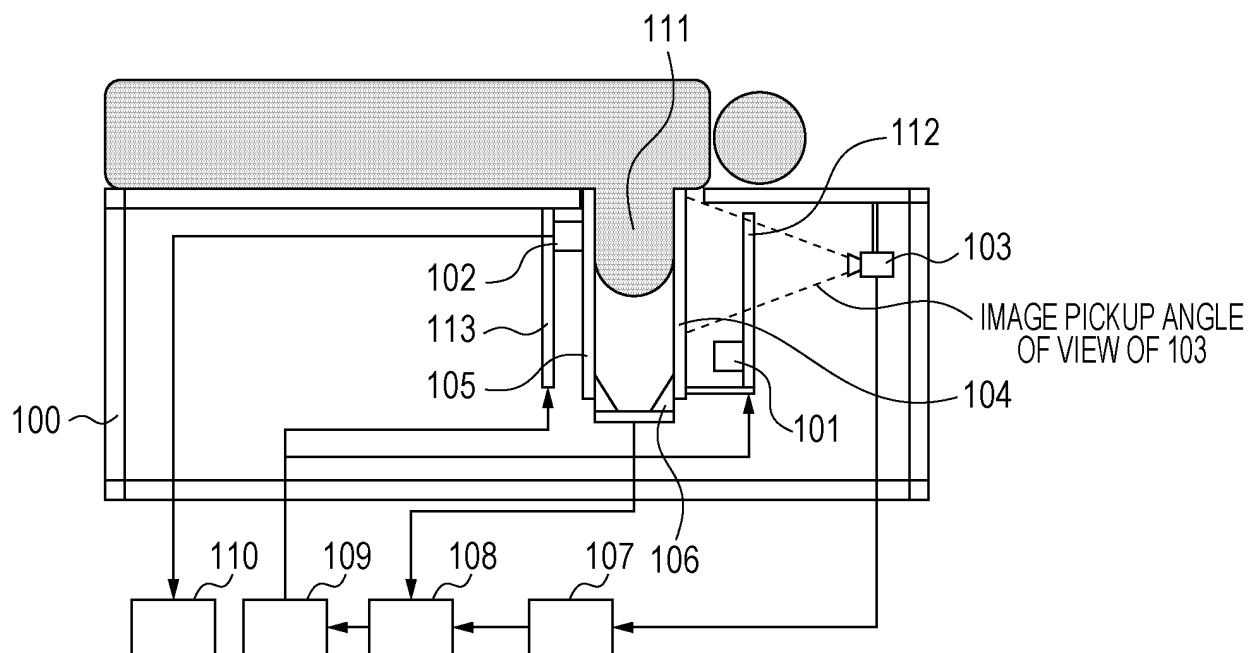


FIG. 1B

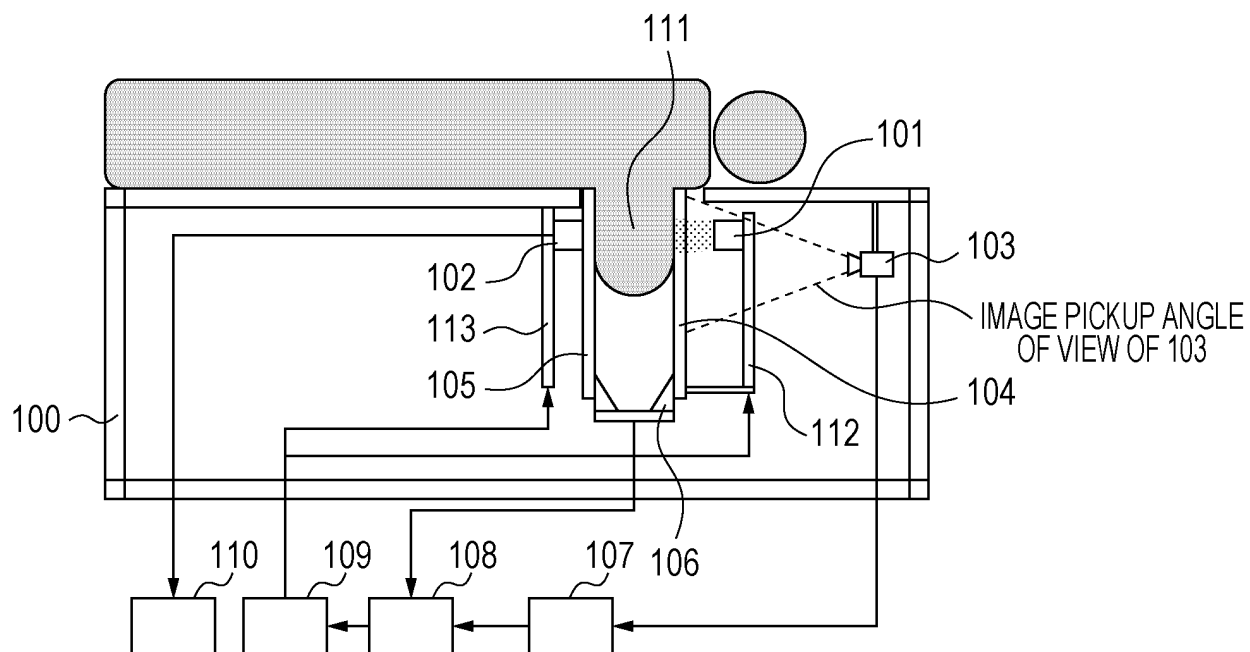


FIG. 2A

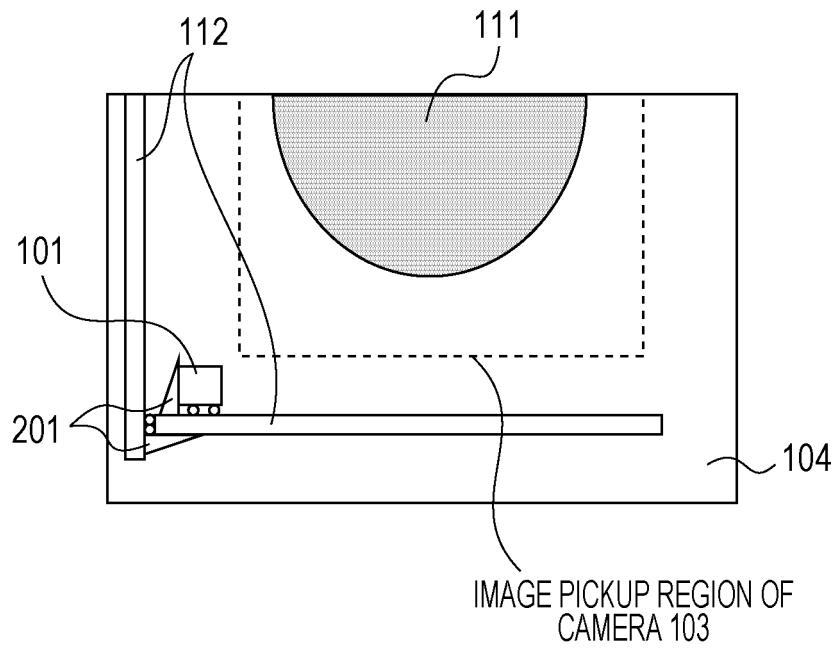


FIG. 2B

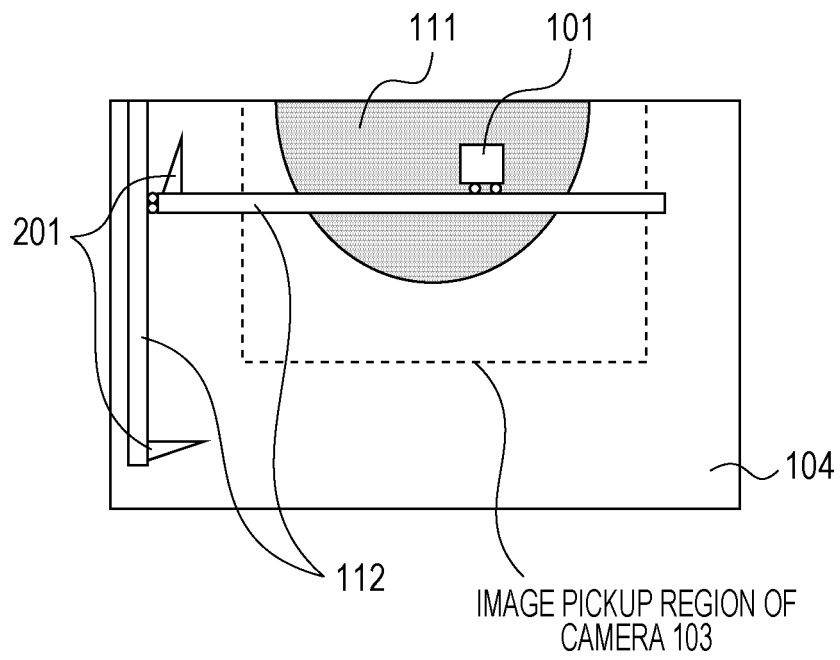


FIG. 3

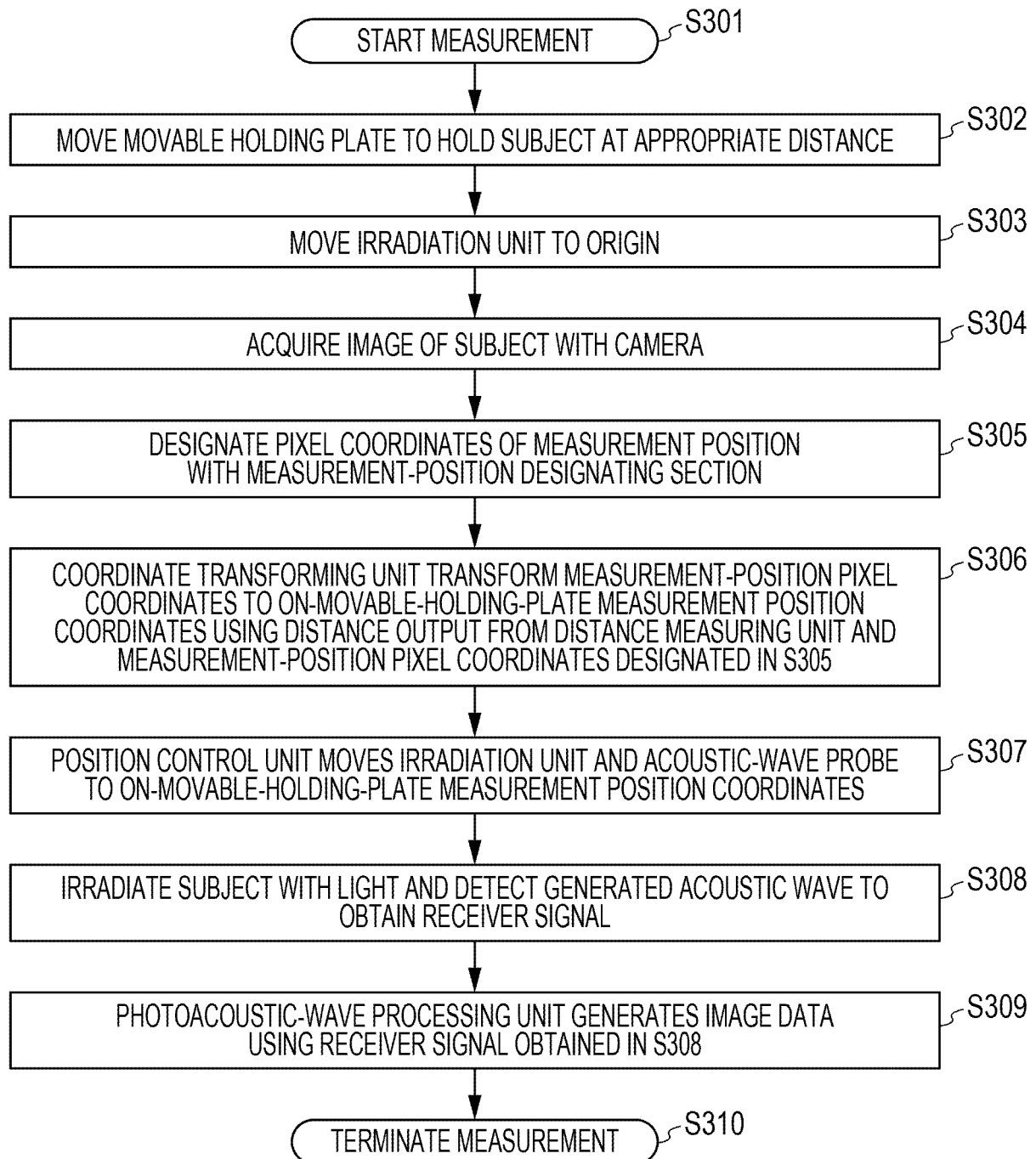


FIG. 4

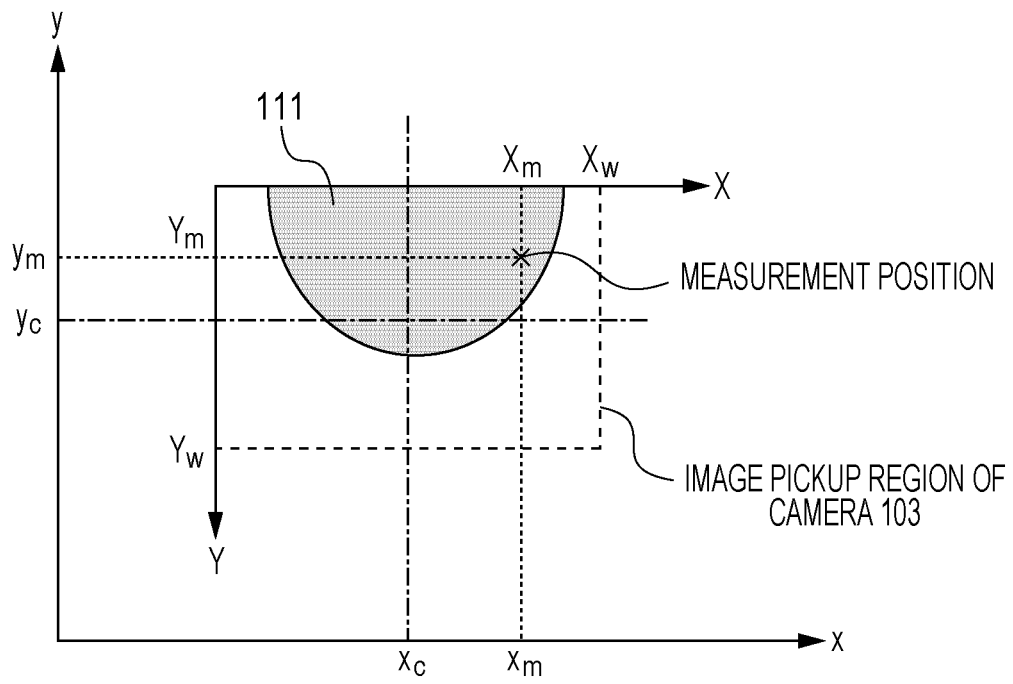


FIG. 5

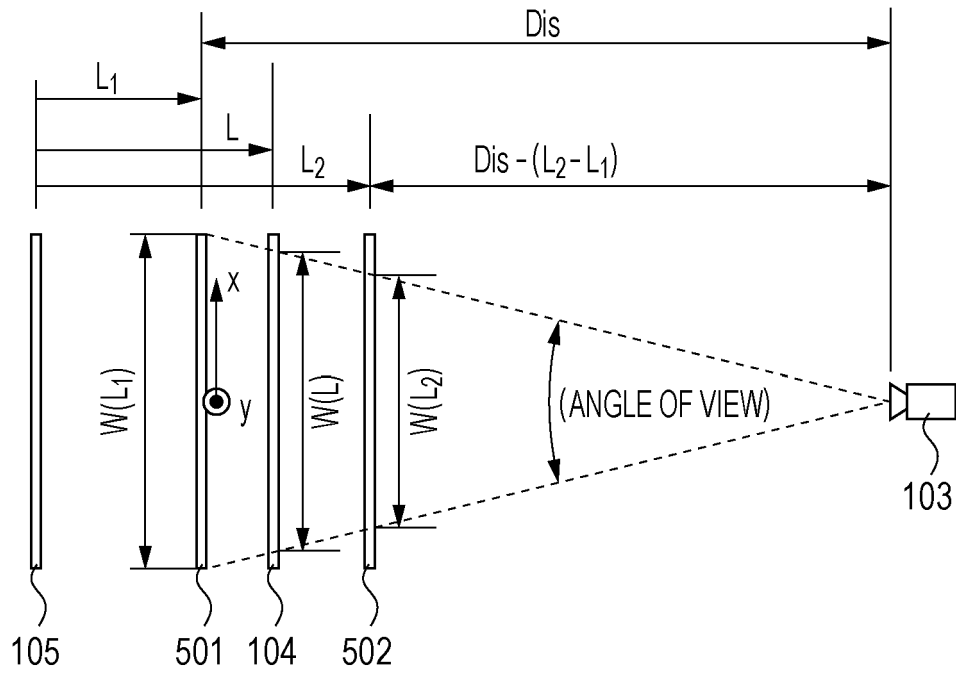


FIG. 6

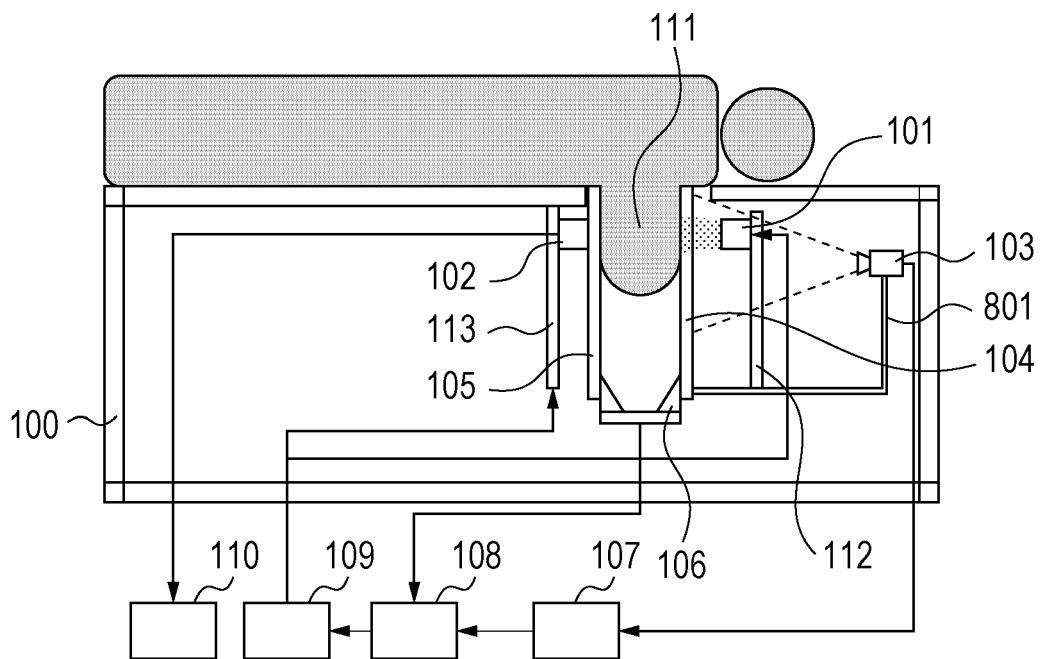


FIG. 7

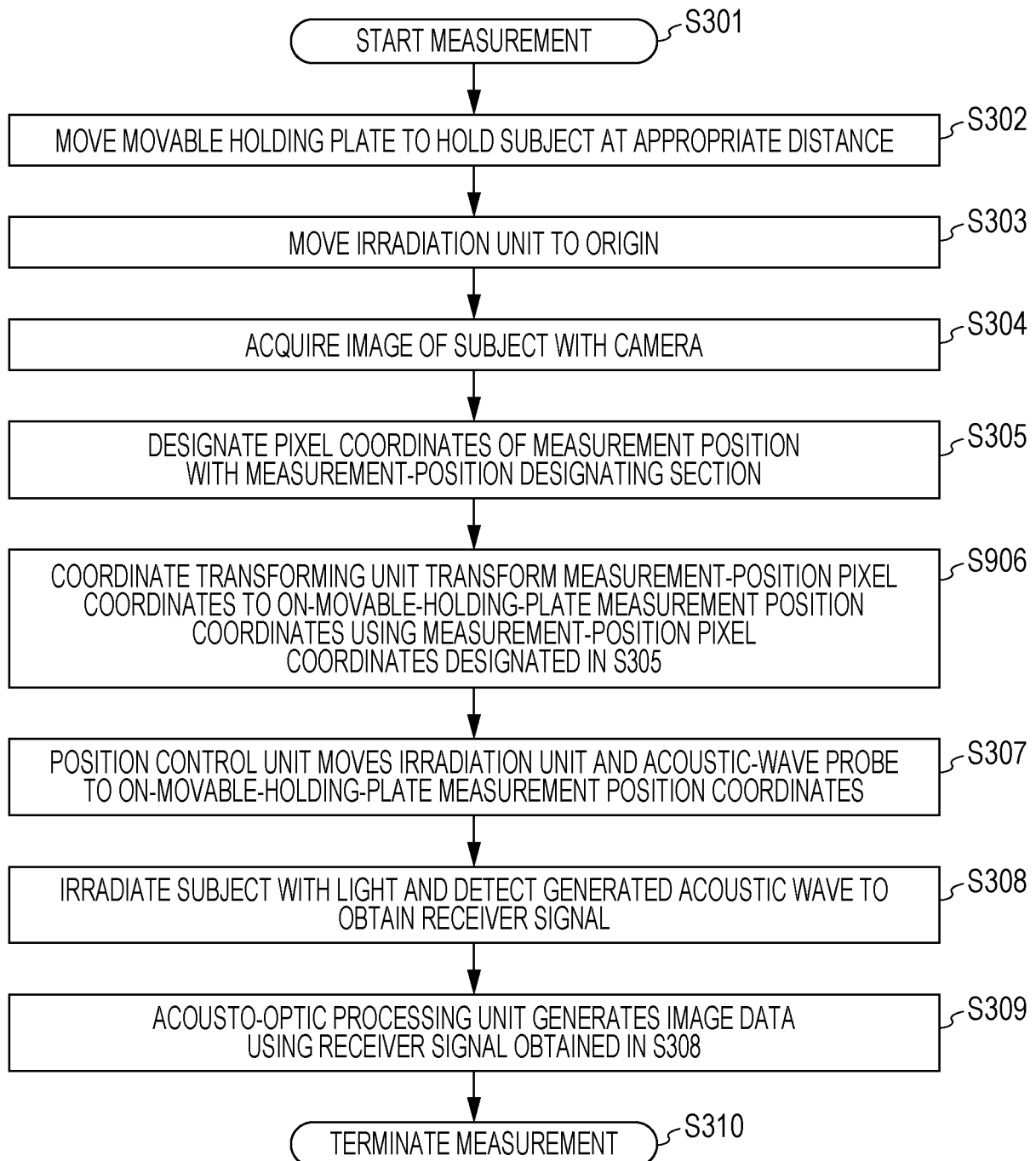
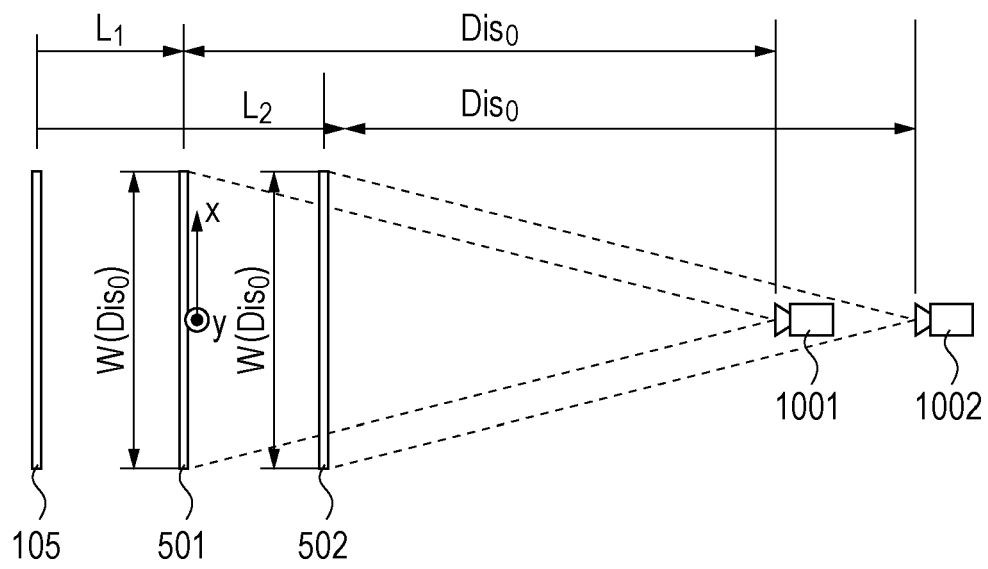


FIG. 8



REFERENCES CITED IN THE DESCRIPTION

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- **SRIRANG MANOHAR.** *The Twente Photoacoustic Mammoscope: system overview and performance* [0008]

专利名称(译)	声波测量装置和方法		
公开(公告)号	EP2380490B1	公开(公告)日	2020-06-10
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申请(专利权)人(译)	佳能株式会社		
当前申请(专利权)人(译)	佳能株式会社		
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代理机构(译)	TBK		
优先权	2010101300 2010-04-26 JP		
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外部链接	Espacenet		

摘要(译)

声波测量装置包括：被布置为保持对象的保持装置（104、105）和被布置为以光照射对象的照射装置（101）。声波检测装置（102）检测由于光的照射而在被检体内产生的声波。图像拾取单元（103）获取被摄体的图像；然后，指定在由图像拾取单元（103）获取的图像上的测量位置。坐标变换装置（108）将图像上的测量位置的坐标变换为保持装置（104、105）上的对应位置的坐标；位置控制装置（109）将辐照装置（101）和声波检测装置（102）中的至少一个移动到保持装置（104、105）上的相应位置。

Exp. (1)

$$Dis = (L_2 - L_1) \left(1 - \frac{W(L_2)}{W(L_1)} \right)^{-1}$$