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(54) **PHOTO-ACOUSTIC DEVICE**

FOTOAKUSTISCHE VORRICHTUNG

DISPOSITIF PHOTO-ACOUSTIQUE

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Description

Technical Field

[0001] The present invention relates to a photoacoustic apparatus which irradiates an inspection target with light so that photoacoustic waves are generated and which receives the photoacoustic waves.

Background Art

[0002] Prior art which is related to this field of technology can be found in e.g. non-patent literature Justin Rajesh Rajian et. al., Optics Express, vol. 17, no. 6, 16 March 2009, pages 4879-4889, disclosing quantitative photoacoustic measurement of tissue optical absorption spectrum aided by an optical contrast agent, and in non-patent literature Hao F. Zhang, et. al., Nature Protocols, Nature Publishing Group, GB, vol. 2, no. 4, 5 April 2007, page 797-804, disclosing in vivo imaging of subcutaneous structures using functional photoacoustic microscopy.

[0003] An optical imaging apparatus which irradiates a living body with light and which images information on an inside of the living body obtained in accordance with the incident light has been actively researched in a medical field. An example of such an optical imaging technique includes photoacoustic tomography (PAT). In the photoacoustic tomography, a living body is irradiated with pulsed light generated from a light source so that acoustic waves generated from body tissues which absorb energy of the pulsed light which is propagated and dispersed in the living body are detected (Patent Literature 1). Specifically, elastic waves, that is, photoacoustic waves, generated when a detection target absorbs the irradiated light energy and therefore is momentarily expanded are received by a transducer by utilizing a difference between an optical energy absorption rate of the detection target such as a tumor and optical energy absorption rates of other tissues. By performing analysis processing on the detection signals, an optical characteristic distribution, and especially, an optical-energy absorption density distribution are obtained. This information may be used for quantitative measurement of a specific substance included in the inspection target such as glucose and hemoglobin included in blood, for example. Accordingly, the photoacoustic tomography may be utilized to specify a portion which includes a malignant tumor and growing new blood vessels.

[0004] Furthermore, Non Patent Literature 1 discloses an example of a case where a photoacoustic microscope is employed. According to Non Patent Literature 1, ultrasonic waves obtained by irradiating an inspection target with pulsed light are received by a transducer which performs imaging. Furthermore, by changing a wavelength of the pulsed light, spectroscopic characteristics of the inspection target are imaged.

Citation List

Patent Literature

[0005] PTL 1: United States Patent No. 5840023

Non Patent Literature

[0006] NPL 1: IEEE Journal of Selected Topics in Quantum Electronics, Vol.14, No.1, 171-179 (2008)

Summary of Invention

Technical Problem

[0007] When the PAT is used, information on local light absorption can be obtained by measuring acoustic waves generated due to absorption of light at a local inspection target portion. An initial acoustic pressure P is represented by Expression (1) below using a distance r between a light irradiation point to the inspection target portion.

$$P(d) = \Gamma\mu_a(r)\Phi(r) \qquad \text{Expression (1)}$$

where Γ denotes a Gruneisen coefficient (heat-acoustic conversion efficiency), $\mu_a(r)$ denotes an absorption coefficient in a position corresponding to the distance r, and $\Phi(r)$ denotes a light intensity in the position corresponding to the distance r. The Gruneisen coefficient serving as an elastic characteristic value is obtained by dividing a product of a square of a thermal expansion coefficient β and a square of an acoustic velocity c by a constant pressure specific heat

Cp. Since the value Γ is substantially a constant value for the same living tissues, when change of acoustic pressures P serving as amounts of acoustic waves is measured in a time division manner, a product of the values μ_a and Φ, that is, an optical-energy absorption density distribution H is obtained. Furthermore, $\mu_a(r)$ is obtained by dividing the optical energy absorption density distribution H by the light intensity $\Phi(r)$.

[0008] Here, a pulse laser used to generate photoacoustic waves may not generate pulsed light of a constant light quantity due to a fundamental function thereof, and temporal output fluctuation occurs to some degree. Specifically, the light quantity fluctuation may reach 10% or more. When the quantity of the pulsed light is varied, a light quantity $\Phi(r)$ in a local region included in an inspection target is also varied. As described above, since the light quantity $\Phi(r)$ and the intensity P of a photoacoustic wave have the proportional relationship, the photoacoustic waves similarly varies for individual laser pulses. Accordingly, when the optical energy absorption density H distribution and the absorption coefficient μ_a distribution are imaged, unevenness of intensity occurs in a screen obtained after reconstruction and a quantitative performance of measurement may be deteriorated.

[0009] However, Patent Literature 1 above does not include a description relating to temporal output fluctuation of a light source. Furthermore, although Non Patent Literature 1 discloses a technique of correcting a light quantity using a sensor which is used to measure a pulsed-light quantity, a measurement method, usage, and a correction target are not clearly referred to. Especially, since the description has been made on the assumption that a photoacoustic microscope is used, light attenuation in a depth direction which is important for measurement of a thick inspection target is not clearly described.

[0010] The present invention has been made in view of the background technique and recognition of the problem. An object of the present invention is to provide a photoacoustic apparatus capable of reducing an adverse effect on an image caused when a quantity of light output from a light source varies with time.

[0011] To address the above problem, the present invention provides a photoacoustic apparatus as specified in the independent claims.

[0012] According to the present invention, a photoacoustic apparatus which includes a light-quantity measurement unit and which corrects intensities of photoacoustic signals taking a temporal change of an output light quantity measured by the light-quantity measurement unit into consideration so that adverse effect of the output fluctuation on an image becomes negligible even when temporal output fluctuation of light output from a light source occurs can be provided.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a diagram schematically illustrating a configuration of a photoacoustic apparatus according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a diagram illustrating output fluctuation of laser pulses.

[Fig. 3] Fig. 3 is a flowchart illustrating an example of a process of determining correction amounts of intensities of detection signals according to the first embodiment of the present invention.

[Fig. 4] Fig. 4 is a diagram illustrating arrangements of a photosensor according to the present invention.

[Fig. 5] Fig. 5 is a diagram schematically illustrating a configuration of a photoacoustic apparatus according to a second embodiment of the present invention.

[Fig. 6] Fig. 6 is a flowchart illustrating an example of a process of determining correction amounts of intensities of detection signals according to the second embodiment of the present invention.

[Fig. 7] Fig. 7 is a diagram schematically illustrating a configuration of a photoacoustic apparatus according to a third embodiment of the present invention.

Description of Embodiments

[0014] Hereinafter, the present invention will be described with reference to the accompanying drawings. Note that the same components are basically denoted by the same reference numerals and redundant descriptions thereof are omitted.

First Embodiment: Photoacoustic Apparatus

[0015] First, a configuration of a photoacoustic apparatus according to this embodiment will be described with reference to Fig. 1.

[0016] The photoacoustic apparatus of this embodiment corresponds to a photoacoustic imaging apparatus which images information on an inside of an inspection target. When the inspection target is a living body, the photoacoustic apparatus enables imaging of information on the living body in order to perform diagnosis of a malignant tumor or a blood vessel disease and follow-up of chemical treatment. The "information on an inside of an inspection target" in the present invention corresponds to information on a distribution of sources which generated acoustic waves in response to light irradiation, and includes information on a distribution of initial acoustic pressures in the living body, information on an optical energy absorption density distribution obtained from the information on a distribution of initial acoustic pressures, and information on a density distribution of a substance included in a living tissue obtained from the information on a distribution of initial acoustic pressures in the living body and the information on optical energy absorption density distribution obtained from the information on a distribution of initial acoustic pressures. For example, the density distribution of a substance corresponds to oxygen saturation.

[0017] The photoacoustic apparatus of this embodiment includes a pulse laser 2a, a detector 5, and a photosensor 8a as a basic hard configuration. The pulse laser 2a is a light source used to irradiate the inspection target with pulsed light.

[0018] An inspection target 3 such as a living body is fixed to plates 4a and 4b which presses and fixes the inspection target 3 from both sides of the inspection target 3 where appropriate. Light emitted from the light source is guided to a surface of the plate 4b by an optical system (not shown) including a lens, a mirror, and an optical fiber so that the inspection target is irradiated with the light. When part of light energy propagated through the inspection target 3 is absorbed by an optical absorber such as blood vessels, the optical absorber generates acoustic waves (typically, ultrasonic waves) due to thermal expansion. These acoustic waves may be referred to as "photoacoustic waves". That is, a temperature of the optical absorber is increased due to absorption of pulsed light, the increased temperature causes volume expansion, and accordingly, photoacoustic waves are generated. Here, a duration of a light pulse preferably corresponds to a degree in which a heat/stress sealing condition is satisfied so that absorption energy is efficiently sealed in the optical absorber. Typically, the duration of a light pulse corresponds to approximately 1 nanosecond to approximately 0.2 seconds.

[0019] A detector 5 used to detect acoustic waves detects the acoustic waves generated in the inspection target and converts the acoustic waves into analog electric signals. The detection signals obtained from the detector are referred to as "photoacoustic signals" where appropriate.

[0020] A signal processor 15 which processes the photoacoustic signals so as to obtain information on an inside of the inspection target includes a reception amplifier 6, an A/D converter 7, a signal correction unit 11, an image reconstruction processing unit 12, and an optical attenuation correction unit 16 in this embodiment. The photoacoustic signals obtained from the detector 5 are amplified by the reception amplifier 6 and converted into digital photoacoustic signals by the A/D converter 7. The signal correction unit 11 which is one of characteristic components of this embodiment performs correction of intensities of the digital signals. Then, after the image reconstruction processing unit 12 performs calculation processing on three-dimensional information, the optical attenuation correction unit 16 performs correction on obtained voxel data taking light attenuation in the inspection target into consideration. Then, a photoacoustic image of the inspection target is displayed in an image display unit 13 where appropriate. Furthermore, all the components are controlled by a system controller 1. Here, the "photoacoustic image" is obtained by representing the obtained information on the inside of the inspection target by a coordinate in a three-dimensional space and converting the information into luminance information.

[0021] Here, characteristic portions of this embodiment will be briefly described. A quantity of light output from the laser 2a is measured by the photosensor 8a serving as a light-quantity measurement device. When the quantity of light output from the laser 2a varies with time, this variation is also measured by the photosensor 8a. Then, the signal correction unit 11 corrects intensities of the photoacoustic signals so as to suppress variations of the intensities of the photoacoustic signals. That is, the variations of the intensities of the photoacoustic signals caused by the variation of the quantity of output light with time (temporal change) can be reduced.

Light Source and Variation of Quantity of Light Output from Light Source

[0022] The laser light generated by the laser 2a varies with respect to each pulse. An example of light quantity variation is shown in Fig. 2. In Fig. 2, a temporal change of a measurement output obtained when a YAG laser of approximately 5 W (500 mJ) generates pulsed light of 10 Hz for 60 seconds is measured. According to Fig. 2, the output light quantity having light quantity variation of approximately 10% is recognized.

[0023] When the inspection target is a living body, the light source emits light having a specific wavelength which is absorbed by a specific constituent among constituents included in the living body. A pulse light source capable of generating pulsed light of 1 nanosecond order to 0.2 nanoseconds order is preferably used as the light source. Although a laser is preferably used as the light source, a light-emitting diode may be used instead of the laser. Examples of the laser include a solid-state laser, a gas laser, a dye laser, and a semiconductor laser.

[0024] Note that the variation of the output light quantity of the laser shown in Fig. 2 is supposed to be mainly caused by variation of a light quantity of a flash lamp serving as a laser excitation light source. Therefore, when the flash lamp or a laser generated from the flash lamp serving as the excitation light source is used as the light source of the present invention, an effect of the present invention is efficiently obtained. However, the light source of the present invention is apparently not limited to these, and a semiconductor laser or a light-emitting diode which does not include a flash lamp may employ the present invention as long as the light source generates the light quantity variation.

[0025] Note that, although an example of a case where a single light source is employed is described in this embodiment, a plurality of light sources may be used. When a plurality of light sources are used, the light sources which oscillate in the same wavelength may be used in order to increase an intensity of light emitted to the living body. Alternatively, light source having different oscillation wavelengths may be used in order to measure differences among optical characteristic value distributions depending on wavelengths. Note that, if pigments in which oscillation wavelengths can be change or OPOs (Optical Parametric Oscillators) is used as light sources, differences among optical characteristic value distributions depending on wavelengths can be measured. A wavelength to be used is selected from a wavelength band in a range from 700 nm to 1100 nm which is merely absorbed in the living body. Note that, when an optical characteristic value distribution of living tissues comparatively in the vicinity of a surface of the living body is to be obtained, a wavelength is selected from a wavelength band in a range from 400 nm to 1600 nm which is larger than the above wavelength band.

[0026] The light emitted from the light source may be propagated using an optical waveguide where appropriate. Although not shown in Fig. 1, an optical fiber is preferably used as the optical waveguide. When an optical fiber is used, a plurality of optical fibers may be used for each light source so as to guide light to the surface of the living body. Alternatively, light beams emitted from a plurality of light sources may be guided to a single optical fiber so that all the light beams are guided to the living body only using the single optical fiber. Furthermore, light may be guided by an optical member such as a mirror which mainly reflects light or a lens which collects and enlarges light and which changes a shape of the light. Any optical member may be used as long as light emitted from a light source is encountered on a light irradiation region included in the surface of the inspection target in a desired shape.

First Correction of Detection Signals

[0027] Correction of detection signals according to this embodiment will be described in detail hereinafter.

[0028] A case where the inspection target is fixed on the plates as shown in Fig. 1, the region in which the laser 2a irradiates with light is set on the surface of the inspection target in a two-dimensional manner, and the light irradiation region is sufficiently larger than an imaging range will be described as an example. A quantity of pulsed light emitted onto the surface of the inspection target is represented by Φ_0. In the inspection target, light in portions farther than the surface is attenuated in an exponential manner due to absorption and scattering. That is, the following expression is obtained:

$$\Phi(r) = \Phi_0 \cdot \exp(-\mu_{eff} \cdot r) \qquad \text{Expression (2)}$$

where μeff denotes an average effective attenuation coefficient of the inspection target. According to Expressions (2) and (1), the following expression is obtained.

$$P(r) = \Gamma \mu_a(d) \Phi_0 \cdot \exp(-\mu_{eff} \cdot r) \qquad \text{Expression (3)}$$

In the present invention, a problem arises in that the value $\Phi 0$ varies with respect to pulses. For example, when a first pulse has an output light amount Φ_{01} and a second pulse has an output light amount Φ_{02} which is equal to $0.9\Phi_{01}$, an acoustic pressure $P_2(r)$ of a photoacoustic wave generated by the second pulse is equal to $0.9P_1(r)$.

[0029] Therefore, since an image (μ_a distribution) of the inside of the inspection target generated from the first pulse and an image generated from the second pulse have different luminance signals relative to the acoustic pressures, image reproducibility is not obtained. Accordingly, when the same portion is measured several times, information on the inside of the inspection target is misrecognized due to deterioration of the image reproducibility. Furthermore, when measurement is performed while the surface of the inspection target is scanned using a laser and a detector, a single image is generated using acoustic pressures obtained in response to a plurality of pulses. In this case, unevenness of luminance occurs in the image due to the light quantity variation described above, and this also causes misrecognition of the information on the inside of the inspection target.

[0030] Therefore, in this embodiment, output light quantities Φ_{0n} of pulses are measured using the photosensor 8a. Then, intensities of detection signals of photoacoustic waves are corrected so that acoustic pressures $P_n(r)$ are supposed to be normally obtained in accordance with a reference light quantity such as a constant initial light quantity Φ_0. In the foregoing example, assuming that the acoustic pressure $P_1(r)$ is used as a reference and an intensity corresponding to 1/0.9 an acoustic pressure $P_2(r)$ is obtained, detection signals are corrected. By this, even when outputs of the light source vary with time, influence cased by the variation can be reduced and information on positions of sound sources and acoustic pressures can be obtained.

[0031] Note that, an inverse number of a ratio of the output light quantity Φ_{02} of the second pulse to the output light quantity Φ_0 of the first pulse, that is, Φ_{01}/Φ_{02} is referred to as a "correction coefficient" in this specification. Furthermore, the correction of detection signals described above may be performed on analog signals and digital signals. However, in this embodiment, the correction is performed on amounts converted into digital signals by the A/D converter 7. When digital signals are to be corrected, since the A/D converter 7 outputs values of the acoustic pressures P(r) for individual sampling frequencies, the correction is performed by multiplying a digital signal representing an acoustic pressure P(r) corresponding to a certain pulse by a correction coefficient of the pulse.

[0032] Hereinafter, further details are described. In this embodiment, after the photosensor 8a detects a pulse light quantity of the laser 2a for each pulse, the pulse light quantity is stored in a light-quantity memory 9a. Such a memory used to store an output light quantity is preferably provided in terms of reliability of signal processing. A correction-amount determination unit 10 reads data regarding a temporal change of the output light quantity stored in the light-quantity memory 9a, and determines correction amounts (correction coefficients) for detection signals. In accordance with the determined correction amounts, the signal correction unit 11 corrects intensities of the detection signals.

[0033] Fig. 3 is a processing flow of correction amount calculation. The correction-amount determination unit 10 reads data from the light-quantity memory 9a (in step S301) . In accordance with light quantities of pulses obtained from the light-quantity memory 9a, correction coefficients for the pulses are calculated (in step S302). A light quantity measured in advance is used as a reference value for the correction coefficients. In this specification, a set of correction coefficients of a plurality of pulses is referred to as a "correction amount table". Then, the correction amount table is transmitted to the signal correction unit 11 (in step S304) where obtained photoacoustic signals are calculated using the correction amount table. That is, digital signals of acoustic pressures P(d) obtained for individual sampling frequencies are multiplied by the correction coefficients.

Image Reconstruction and Optical Attenuation Correction

[0034] The image reconstruction processing unit 12 performs image reconstruction on the digital signals which have been corrected as described above. The image reconstruction of the PAT is performed to obtain a distribution $P_0(r)$ of initial acoustic pressures generated in the inspection target from acoustic pressures $P_d(r_d, t)$ received by the detector, and is referred to as an "inverse problem" in the mathematical field. A universal back projection (UBP) method representatively used as the image reconstruction method of the PAT has been described in Physical Review E 71, 016706 (2005) and Review of Scientific Instruments, 77, 042201 (2006).

[0035] As described above, the distribution of initial acoustic pressures serving as the information on the inside of the inspection target and a product of the Value μ_a and the value Φ, that is, an optical energy absorption density distribution H are obtained. Assuming that the value Φ is a constant value, when a value H is divided by the value Φ, a distribution of absorption coefficients $\mu_a(r)$ in the inspection target is obtained. However, since a quantity of light emitted to a local region of the inspection target attenuates in an exponential manner as described above, when two tissues have the same absorption coefficient, an acoustic pressure of an acoustic wave generated from one of the tissues which is located farther from the surface of the inspection target is smaller than that of the other tissue which is located nearer the surface of the inspection target. Therefore, in order to obtain a reliable absorption coefficient distribution, such influence of light attenuation is preferably corrected. This correction is referred to as "light attenuation correction" in this specification.

[0036] Specifically, the optical attenuation correction unit 16 performs a process of dividing voxel data items representing the absorption density distribution H of optical energy output from the image reconstruction processing unit 12 by corresponding light quantities in positions of the voxels. The light quantities in the positions of the corresponding voxels are calculated by Expression (2) above.

[0037] With this configuration, a reliable absorption coefficient distribution in the inspection target can be imaged taking the influence of the optical attenuation into consideration.

Example of First Signal Correction

[0038] Note that although a case where correction for light quantity variations with respect to pulses is performed on data which corresponds to digital signals obtained by the A/D converter 7 and has not been subjected to the image reconstruction processing is described in this embodiment, the present invention is not limited to this. The correction may be performed on voxel data which has been subjected to the image reconstruction processing. That is, correction of photoacoustic signals may be similarly performed by inputting the correction coefficients calculated by the correction-amount determination unit 10 to the optical attenuation correction unit 16 so that correction calculation is performed. Furthermore, the correction may be performed on analog data which has not been subjected to the A/D conversion. In this case, a method for controlling a gain of the reception amplifier 6 using an output from the correction-amount determination unit 10 may be employed. That is, the "detection signals" in this specification includes analog signals, digital signals obtained through the A/D conversion, and luminance data obtained by performing the image reconstruction on the digital data.

[0039] Furthermore, if a light quantity distribution in the inspection target obtained when light is emitted can be set, when light is emitted from opposite sides of the plate 4 or when light is emitted from various directions, the correction of photoacoustic signals can be similarly performed.

[0040] Moreover, although the photoacoustic signals are obtained in a state in which the detector 5 and the laser 2a are fixed in the foregoing embodiment, even when photoacoustic signals are obtained while scanning is performed using the detector 5 and the laser 2a, the correction of photoacoustic signals can be similarly performed by obtaining light-quantity measurement data in various scanning positions.

[0041] In addition, the laser pulse 2a to be used is a laser beam having a certain width. When spatial unevenness of an intensity of a section of the laser beam occurs, the correction of photoacoustic signals can be similarly performed by calculating correction light quantities in a three-dimensional space taking the light quantity distribution into consideration.

Detailed Descriptions of Configurations

[0042] The detector (probe) 5 detects acoustic waves such as sonic waves and ultrasonic waves and converts the acoustic waves into electric signals. Any acoustic wave detector such as a transducer utilizing piezoelectric phenomenon, a transducer utilizing optical resonance, or a transducer utilizing change of capacitance may be used as long as the acoustic wave detector can detect acoustic wave signals. The detector 5 in this embodiment is preferably an array type detector having a plurality of transducer elements. When the transducer elements arranged in a two-dimensional manner are used, acoustic waves are simultaneously detected in a plurality of portions. Accordingly, a period of time required for the detection can be reduced and influence of vibration of the inspection target can be reduced. Furthermore, an acoustic impedance matching agent such as gel or water is preferably used between the detector 5 and the plate 4b and between the plate 4b and the inspection target 3 so as to suppress reflection of acoustic waves.

[0043] Examples of a typical light-quantity measurement device include a photosensor as typified by a photodiode and a pyroelectric sensor. When a one-dimensional or a two-dimensional photosensor array is required, a CCD image sensor, a CMOS image sensor, a light dependent resistor (LDR), or the like may be used to obtain a similar effect.

[0044] A preferable arrangement of the photosensor 8a serving as the light-quantity measurement device will be described with reference to Fig. 4. A reference numeral 18 denotes a reflection mirror and a reference numeral 19 denotes a laser.

[0045] Fig. 4(a) shows a case where light leaked from a reflection mirror disposed in the optical system is detected before light reaches the plate 4b. As shown in Fig. 4(a), since the photosensor 8a is disposed after the reflection mirror, part of the light emitted from the light source can be detected. If a rate of the leakage light is known in advance, variation of quantities of light emitted from the light source can be calculated.

[0046] Fig. 4(b) shows a case where part of light reflected by the plate 4b is detected. As shown in Fig. 4(b), the photosensor 8a may be disposed in the vicinity of the plate 4b.

[0047] Fig. 4(c) shows a case where part of light which has been propagated inside the plate 4b is detected. As shown in Fig. 4(c), the photosensor 8a may be disposed at an end portion of the plate 4b. Especially, when light is obliquely entered relative to the plate 4b, light propagated inside the plate 4b is increased, which is preferable.

[0048] As a memory, a memory included in a PC or a control board may be employed. However, a similar effect can be obtained when a memory attached to a photosensor unit is used or a hard disk is used as long as a speed higher than a laser pulse cycle is ensured.

First Example

[0049] Hereinafter, as a first example, a case where the photoacoustic apparatus according to the present invention is employed in a breast examination will be described in detail. In the breast examination of this example, breast compression similar to that generally performed in X-ray mammography is performed. That is, in the breast, photoacoustic signals within a depth of 4 cm which is an average thickness of the breast compression should be obtained.

[0050] In this embodiment, as the light source, a Q switch YAG laser which has a wavelength of 1064 nm, which is driven in 10 Hz, which has a pulse width of 5 nanoseconds, and which has an output per pulse of 1.6J is used. Under this condition, since a human body allows to be irradiated with laser light having an intensity of 100 mJ/cm2 or smaller according to JIS, an illumination optical system which enlarges emitted laser light to square 4 cm on a side is designed.

[0051] Then, it is assumed that a range in which photoacoustic signals are generated in response to light emitted from both sides of the breast while the breast is compressed has a depth of 4 cm and a width of 4cm. Furthermore, in order to obtain the photoacoustic signals within this range, an ultrasonic transducer has 4 cm on a side. Furthermore, a two-dimensional probe having 400 elements is configured while an element pitch is set to 2 mm. In addition, a frequency of

1 MHz is used. A PIN photodiode S5973 manufactured by Hamamatsu Photonics K.K. is used as a photosensor.

[0052] When photoacoustic signals are to be obtained under the condition described above, a quantity of irradiated light obtained at a time of laser irradiation is normally stored in a light-quantity memory. Correction coefficients for pulses are calculated using the maximum value of a measured light-quantity variation of 1. Correction of detection signals is performed in accordance with the correction method described with reference to the configuration shown in Fig. 1. A photoacoustic image generated through image reconstruction is stored as volume data and displayed in a screen.

[0053] Although unevenness of an intensity of the photoacoustic image can be improved using this method, since reproducibility of the photoacoustic signals based on electric noise is approximately 2% to approximately 3% and unevenness of distribution of irradiated light is approximately 2%, unevenness of an image remains in a similar degree. However, when this method is employed, the unevenness of image of approximately 8% to approximately 10% can be reduced to approximately 3% to 4%.

[0054] Note that distribution of irradiated light can be measured by additionally disposing a CCD sensor or the like in an optical path. The reproducibility of the photoacoustic signals can be measured by operating this system in a state in which laser irradiation is not performed. The image unevenness is defined to be three times standard deviation of luminance value variation at the same pixel obtained when image capturing is performed a plurality of times.

[0055] Note that, although the case where the photoacoustic apparatus is used for the breast examination is described in detail in this embodiment, similar effects are obtained when the other portions of the human body and inspection bodies other than a human body are measured by similar processing.

Second Embodiment

[0056] In the first embodiment, the laser light is emitted only from one side. In a second embodiment, a correction method employed when laser light is emitted from opposite sides of a plate 4 will be described. Fig. 5 shows an example of a photoacoustic apparatus according to this embodiment. Irradiation of laser pulses, light-quantity data, and photoacoustic signals are obtained similarly to the first embodiment. This embodiment is different from the first embodiment in that the laser light is emitted from opposite sides, that is, from lasers 2a and 2b and outputs of the lasers 2a and 2b are detected by photosensors 8a and 8b, respectively. Detected light quantities are stored in light-quantity memories 9a and 9b and transmitted to correction-amount determination units 10a and 10b. Then, two correction coefficients are calculated using a method similar to that of the first embodiment, and the correction coefficients are transmitted to a signal correction unit 11.

[0057] Processes performed by the correction-amount determination units 10a and 10b and a processes performed by a signal correction unit 16 will be described in detail with reference to Fig. 6. Correction coefficients for light quantities of lasers obtained from the light-quantity memories 9a and 9b (in step S601) are calculated by setting the maximum value of light-quantity variations measured in advance to 1 (in step S602). Then, relative attenuation amounts in a depth direction are calculated using standardized light quantities and the coefficients so that two correction-amount tables are generated using two light-quantity data items (in step S603). The correction-amount tables in the depth direction are added to each other relative to the same depth so that a synthesized correction-amount table is generated (in step S604).

[0058] That is, acoustic pressures obtained in accordance with light emitted from one side of the plate 4 is represented similarly to Expression (3) described above.

$P(r) = \Gamma\mu_a(r)\Phi_{0A}\cdot\exp(-\mu_{eff}\cdot r)$ Expression (3)

[0059] However, an acoustic pressure obtained in accordance with light emitted from the other side is represented by the following expression.

$$P(r) = \Gamma\mu_a(r)\Phi_{0B}\cdot\exp(-\mu_{eff}\cdot(D-r)) \qquad \text{Expression (4)}$$

[0060] Here, D denotes a distance between the compression plates 4a and 4b, and Φ_{0A} denotes an initial light quantity obtained after pulsed light emitted from the laser 2a is multiplied by a corresponding one of the correction coefficients of the light quantity variations. Furthermore, Φ_{0B} denotes an initial light quantity obtained after pulsed light emitted from the laser 2b is multiplied by a corresponding one of the correction coefficients of the light quantity variations. Each of the correction-amount tables is obtained by quantifying the light quantity in the above expression and light attenuation in accordance with a sampling frequency and adding them with each other, and therefore, is represented by the following expression.

$$C(r) = 1/(\Phi_{0A}\cdot(\exp(-\mu_{eff}\cdot r) + \Phi_{0B}\exp(-\mu_{eff}\cdot(D-r))))$$

Expression (5)

[0061] Here, C(r) denotes values of the correction-amount tables, Φ_{0A}, Φ_{0B}, D, and μ_{eff} can be obtained since they are known in advance. Then, synthesized correction-amount table C(d) is multiplied by obtained image reconstruction data (in step S605). At this time, the correction-amount tables are functions in the depth direction (a straight-line distance from a surface of an inspection target). On the other hand, the image reconstruction data is three-dimensional data but multiplication is performed only in the depth direction and a certain process is performed in a height and width direction (in an in-plane direction of the surface of the inspection target). Thereafter, a photoacoustic image is stored as volume data and displayed in a screen. With this method, a process of correcting digital data which has been subjected to the image reconstruction taking the variations of quantities of light supplied from a light source into consideration and a process of correcting digital data which has been subjected to the image reconstruction taking light attenuation in the depth direction into consideration are collectively performed. In this case, detection signals may be acoustic pressure signals which have been converted into luminance signals.

[0062] According to this embodiment, as with the first embodiment, even when the light is emitted from opposite sides of the plate 4, image unevenness can be improved.

Third Embodiment

[0063] In the first and second embodiments, the intensities of the photoacoustic signals are corrected assuming that the surface of the inspection target is irradiated with the constant light quantity Φ_0 irrespective of portions. In a third embodiment, a correction method employed when intensity distribution of initial light quantities is generated on a surface to which a laser is encountered (a surface of an inspection target) will be described.

[0064] Fig. 7 shows an example of a photoacoustic apparatus of this embodiment. Emission of laser pulses and obtainment of light-quantity data and photoacoustic signals are performed similarly to the second embodiment. Laser to be emitted to an inspection target 3 is enlarged to square 4 cm on a side which is the same as a detector 5 and is emitted. Intensity distribution is included in a plane. This is especially observed when a multimode laser is used. The in-plane intensity distribution is measured in advance and stored in light-quantity distribution memories 14a and 14b.

[0065] Note that a correction amount used for correction is obtained by reflecting the light intensity distribution. That is, the correction amount corresponds to a function of the initial light quantity and an attenuation coefficient obtained by multiplying the light intensity distribution, a Gruneisen coefficient, an absorption coefficient, and a correction coefficient, and is calculated using light propagation simulation since the light intensity distribution is not analytically obtained. A light-quantity distribution in a three-dimensional direction is obtained through the calculation, and Expression (3) is replaced by the following expression:

$$P(r) = \Gamma\mu_a(d)\Phi_0(x, y, r, t)\cdot\exp(-\mu_{eff}\cdot r) \qquad \text{Expression (6)}$$

where a light quantity $\Phi_0(x, y, r, t)$ corresponds to a function of a space (x, y, r) distribution and each pulse oscillated every time period t. This light quantity Φ_0 is calculated through the simulation, and after coefficients are multiplied, inversed numbers are obtained whereby correction coefficients in portions in the three-dimensional space are obtained.

[0066] The correction-amount calculation of this embodiment is excellent in that signal correction is performed taking, in addition to light-quantity variations with time, spatial irradiation light quantity distribution in a surface of the inspection target into consideration. Reproducibility of the photoacoustic signals is the same as that of the first embodiment. When a photoacoustic image is obtained and corrected taking these factors into consideration, unevenness of an intensity of the photoacoustic image which is 8% to 10% in a state in which the light-quantity distribution correction has not been performed can be reduced to approximately 3%, that is, reduced to a degree substantially the same as the reproducibility of the photoacoustic signals.

Fourth Embodiment

[0067] In the first to third embodiments, the photoacoustic signals are obtained while the detector 5 and the laser 2a are fixed. In a fourth embodiment, a case where photoacoustic signals are obtained while a detector 5 and a laser 2a are moved along a plate 4 for scanning.

[0068] A system configuration is shown in Fig. 4. However, in this embodiment, a movement mechanism which moves the laser 2a, a laser 2b, and the detector 5 relative to an inspection target is provided. Note that as long as a light incidence portion of the inspection target in which light is incident from a light source is scanned, the lasers themselves are not required to be moved for scanning. In this case, a light-quantity variation generated during the scanning which is not taken into consideration in the first to third embodiments should be corrected.

[0069] Assuming that breast is scanned using the light source and the ultrasonic transducer described above, a scanning region corresponds to a range of 20 cm x 20 cm and a stripe width is 4 cm, and accordingly, a stripe pattern of 4 cm x 20 cm is formed five times. Furthermore, a step-and-repeat method, that is, a method for repeating move and stop of the transducer and performing laser irradiation while the transducer is stopped is employed in the scanning performed by the transducer, and in this way, photoacoustic signals are obtained. On the other hand, at a time of laser irradiation, an irradiation light quantity is normally stored in a light-quantity memory.

[0070] Standardization of light quantities, calculation processing, and correction of photoacoustic signals are performed similarly to the second embodiment. However, corrected photoacoustic signals are temporarily stored in a memory until scanning is terminated. Then, after the scanning is completely terminated, image reconstruction is performed using the corrected photoacoustic signals, and a generated photoacoustic image is stored as volume data and displayed in a screen.

[0071] Intensity unevenness of a photoacoustic image can be improved through this method. Reproducibility of a photoacoustic signals corresponds to approximately 2% to approximately 3% while an S/N ratio is increased four or five times as an effect of averaging of the photoacoustic signals by the scanning. Taking such influence into consideration, image unevenness corresponding to approximately 8% to approximately 10% in a state in which the light-quantity correction has not been performed in conventional scanning is reduced to 1% or less.

Fifth Embodiment

[0072] Furthermore, the present invention may be realized by performing the following processing. Specifically, software (a program) which realizes the functions of the foregoing embodiments is supplied to a system or an apparatus through a network or various storage media, and a computer (a CPU, an MPU, or the like) included in the system of the apparatus reads and execute the program.

Reference Signs List

[0073]

1	SYSTEM CONTROLLER
2a, 2b	LASER
3	INSPECTION TARGET
4a, 4b	PLATE
5	DETECTOR
6	RECEPTION AMPLIFIER
7	ANALOG-DIGITAL CONVERTER
8a, 8b	PHOTOSENSOR
9a, 9b	LIGHT-QUANTITY MEMORY
10	CORRECTION-AMOUNT CALCULATION UNIT
11	SIGNAL CORRECTION UNIT
12	IMAGE RECONSTRUCTION PROCESSOR
15	SIGNAL PROCESSOR
16	LIGHT ATTENUATION CORRECTION UNIT

Claims

1. A photoacoustic apparatus comprising:

a light source (2a, 2b) adapted to irradiate an inspection target with a plurality of pulsed light;
a detector (5) adapted to detect acoustic waves generated in the inspection target due to the irradiation with the plurality of pulsed light; and to output analog detection signals corresponding to the detected acoustic waves;
a light-quantity measurement unit (8a, 8b, 9a, 9b) adapted to measure a quantity of light output from the light source (2a, 2b); and
a signal processor (15), which includes an A/D converter (7) adapted to convert the analog detection signals into digital detection signals, and which is adapted to obtain information on an inside of the inspection target (3),

a correction-amount determination unit (10, 10a, 10b) adapted to determine correction amounts for either the digital or analog detection signals,
wherein the signal processor (15) further includes
a signal correction unit (11) adapted to correct either the digital or analog detection signals based on a quantity of light measured by the light-quantity measurement unit (8a, 8b, 9a, 9b) so that variations in the intensities of either of the digital or analog detection signals, caused by a temporal change in the quantity of light output from the light source (2a, 2b), are suppressed, and
wherein the signal correction unit (11) is configured to correct the intensities of either the digital or analog detection signals using the correction amounts determined by the correction-amount determination unit (10, 10a, 10b),
characterized in that
the correction-amount determination unit (10, 10a, 10b) is configured to determine the correction amounts based on a constant reference light quantity for each pulsed light input in advance and the quantity of light measured by the light-quantity measurement unit (8a, 8b, 9a, 9b).

2. A photoacoustic apparatus according to Claim 1,
wherein the correction-amount determination unit (10, 10a, 10b) is configured to employ an inverse number of a ratio of the output light quantity to the constant reference light quantity as a correction coefficient, and
wherein the for each pulsed light signal correction unit (11) is configured to correct intensity of either the digital or analog detection signals by multiplying the correction coefficient by the digital or analog detection signals.

3. The photoacoustic apparatus according to Claim 2, further comprising:

a memory (9a, 9b) adapted to store the quantity of light measured by the light-quantity measurement unit (8a, 8b, 9a, 9b),
wherein the correction-amount determination unit (10, 10a, 10b) reads data of the quantity of light stored in the memory (9a, 9b).

4. The photoacoustic apparatus according to any one of Claims 1 to 3,
wherein the signal correction unit (11) corrects the digital detection signals so that an influence of light attenuation caused inside the inspection target is also suppressed.

5. The photoacoustic apparatus according to any one of Claims 1 to 3,
wherein the signal processor (15) includes an image reconstruction processor (12) which processes the digital detection signals and performs image reconstruction so as to obtain the information on the inside of the inspection target (3), and
the signal processor (15) is configured to apply an optical attenuation correction to output data from an image reconstruction processor (12).

6. The photoacoustic apparatus according to Claim 5,
wherein the signal processor (15) obtains a quantity of light inside an inspection target (3) based on light attenuation inside the inspection target (3), and obtains information inside the inspection target (3) using image reconstruction data and the quantity of light inside the inspection target (3).

7. The photoacoustic apparatus according to Claim 5,
wherein the signal processor (15) obtains a quantity of light inside an inspection target (3) based on light attenuation inside the inspection target (3) and irradiation-light-quantity distribution on a surface of the inspection target (3), and obtains information inside the inspection target (3) using image reconstruction data and the quantity of light inside the inspection target (3).

8. The photoacoustic apparatus according to any one of Claims 1 to 7, further comprising:

a plurality of light sources (2a, 2b); and
a plurality of light-quantity measurement units (8a, 8b, 9a, 9b) adapted to measure quantities of light output from the light sources (2a, 2b),
wherein the correction-amount determination unit (10, 10a, 10b) determines correction amounts for the detection signals based on the quantities of light measured by the light-quantity measurement units (8a, 8b, 9a, 9b).

9. The photoacoustic apparatus according to any one of Claims 1 to 8, further comprising:

a movement mechanism adapted to move a portion in which light output from the light source (2a, 2b) is incident on, and the detector (5).

10. A program which causes a computer to execute the steps of:

obtaining analog detection signals of acoustic waves generated in an inspection target by irradiating the inspection target with a plurality of pulsed light;
measuring a quantity of output pulsed light;
converting the analog detection signals into digital detection signals;
determining correction amounts for either the digital or analog detection signals;
correcting intensities of the either the analog or digital detection signals in accordance with a temporal change of the quantity of the output pulsed light so that variations of the intensities of either the analog or digital detection signals caused by a temporal change in the quantity of output pulsed light, are suppressed; and
obtaining information on an inside of the inspection target using the corrected detection signals,
wherein the intensities of either the digital or analog detection signals are corrected using the determined correction amounts,
characterized in that
the correction amounts, are determined based on a constant reference light quantity for each pulsed light input in advance and the measured quantity of light.

Patentansprüche

1. Photoakustische Vorrichtung, mit:

einer Lichtquelle (2a, 2b), die zum Bestrahlen eines Inspektionsobjekts mit einer Vielzahl von gepulstem Licht angepasst ist;
einer Erfassungseinrichtung (5), die dazu angepasst ist, um in dem Inspektionsobjekt aufgrund der Bestrahlung mit der Vielzahl von gepulstem Licht erzeugte akustische Wellen zu erfassen; und um den erfassten akustischen Wellen entsprechende analoge Erfassungssignale auszugeben;
einer Lichtmengenmesseinheit (8a, 8b, 9a, 9b), die zum Messen einer von der Lichtquelle (2a, 2b) ausgegebenen Lichtmenge angepasst ist; und
einem Signalprozessor (15) mit einem A/D-Wandler (7), der zum Umwandeln von analogen Erfassungssignalen in digitale Erfassungssignale angepasst ist, und der für den Erhalt von Informationen auf einer Innenseite des Untersuchungsobjekts (3) angepasst ist,
einer Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b), die zum Bestimmen von Korrekturbeträgen für entweder die digitalen oder die analogen Entdeckungssignale angepasst ist,
wobei der Signalprozessor (15) ferner umfasst:

eine Signalkorrektureinheit (11), die zum Korrigieren von entweder den digitalen oder den analogen Erfassungssignalen basierend auf einer von der Lichtmengenmesseinheit (8a, 8b, 9a, 9b) gemessen Lichtmenge angepasst ist, so dass Variationen in den Intensitäten von entweder den digitalen oder den analogen Erfassungssignalen unterdrückt werden, die durch eine temporäre Änderung in der von der Lichtquelle (2a, 2b) ausgegebenen Lichtmenge verursacht werden, und
wobei die Signalkorrektureinheit (11) zum Korrigieren der Intensitäten von entweder den digitalen oder den analogen Erfassungssignalen unter Verwendung der durch die Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b) bestimmten Korrekturbeträge eingerichtet ist,
dadurch gekennzeichnet, dass
die Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b) zum Bestimmen der Korrekturbeträge für jedes gepulste Licht basierend auf einer im voraus eingegeben konstanten Referenzlichtmenge und der durch die Lichtmengenmesseinheit (8a, 8b, 9a, 9b) gemessenen Lichtmenge eingerichtet ist.

2. Photoakustische Vorrichtung nach Anspruch 1,
wobei die Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b) zur Verwendung des Kehrwerts eines Verhältnisses der Ausgabelichtmenge zu der konstanten Referenzlichtmenge als ein Korrekturkoeffizient für jedes gepulste Licht eingerichtet ist, und

wobei die Signalkorrektureinheit (11) zur Korrektur der Intensität von entweder den digitalen oder den analogen Erfassungssignalen durch Multiplizieren der Korrekturkoeffizienten mit den digitalen oder den analogen Erfassungssignalen eingerichtet ist.

3. Photoakustische Vorrichtung nach Anspruch 2, ferner mit:

einem Speicher (9a, 9b), der zum Speichern der mit der Lichtmengen-Messeinheit (8a, 8b, 9a, 9b) gemessenen Lichtmenge angepasst ist,
wobei die Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b) die in dem Speicher (9a, 9b) gespeicherten Daten der Lichtmenge liest.

4. Photoakustische Vorrichtung nach einem der Ansprüche 1 bis 3,
wobei die Signalkorrektureinheit (11) die digitalen Erfassungssignale korrigiert, so dass ein Einfluss der in dem Inspektionsobjekt erzeugten Lichtdämpfung auch unterdrückt ist.

5. Photoakustische Vorrichtung nach einem der Ansprüche 1 bis 3,
wobei der Signalprozessor (15) einen Bildrekonstruktionsprozessor (12) beinhaltet, der die digitalen Erfassungssignale verarbeitet und Bildrekonstruktion durchführt, um die Informationen über das Innere des Inspektionsobjekts (3) zu erhalten, und
der Signalprozessor (15) zum Anwenden einer optischen Dämpfungskorrektur für die Ausgabe von Daten von dem Bildrekonstruktionsprozessor (12) eingerichtet ist.

6. Photoakustische Vorrichtung nach Anspruch 5,
wobei der Signalprozessor (15) eine Lichtmenge innerhalb eines Inspektionsobjekts (3) basierend auf der Lichtdämpfung innerhalb des Inspektionsobjekts (3) erhält, und Informationen innerhalb des Inspektionsobjekts (3) unter Verwendung von Bildrekonstruktionsdaten und der Lichtmenge innerhalb des Inspektionsobjekts (3) erhält.

7. Photoakustische Vorrichtung nach Anspruch 5,
wobei der Signalprozessor (15) eine Lichtmenge innerhalb eines Inspektionsobjekts (3) basierend auf der Lichtdämpfung innerhalb des Inspektionsobjekts (3) sowie der Bestrahlungslichtmengenverteilung auf einer Oberfläche des Inspektionsobjekts (3) erhält, und Informationen innerhalb des Inspektionsobjekts (3) unter Verwendung von Bildrekonstruktionsdaten und der Lichtmenge innerhalb des Inspektionsobjekts (3) erhält.

8. Photoakustische Vorrichtung nach einem der Ansprüche 1 bis 7, ferner mit:

einer Vielzahl von Lichtquellen (2a, 2b); und
einer Vielzahl von Lichtmengenmesseinheiten (8a, 8b, 9a, 9b), die zum Messen der von den Lichtquellen (2a, 2b) ausgegebenen Lichtmengen angepasst ist,
wobei die Korrekturbetrag-Bestimmungseinheit (10, 10a, 10b) die Korrekturbeträge für die Erfassungssignale basierend auf den von den Lichtmengenmesseinheiten (8a, 8b, 9a, 9b) gemessenen Lichtmengen bestimmt.

9. Photoakustische Vorrichtung nach einem der Ansprüche 1 bis 8, ferner mit:

einem Bewegungsmechanismus, der zum Bewegen eines Abschnitts, auf den von der Lichtquelle (2a, 2b) ausgegebenes Licht fällt, und der Erfassungseinrichtung (5) angepasst ist.

10. Programm, das auf einem Computer die folgenden Schritte ausführt:

Erhalten von analogen Erfassungssignalen von akustischen Wellen, die in einem Inspektionsobjekt durch Bestrahlen des Inspektionsobjekts mit einer Vielzahl von gepulstem Licht erzeugt werden;
Messen einer Menge des ausgegebenen gepulsten Lichtes;
Umwandeln der analogen Erfassungssignale in digitale Erfassungssignale;
Bestimmten von Korrekturbeträgen für entweder die digitalen oder die analogen Erfassungssignale;
Korrigieren von Intensitäten entweder der analogen oder der digitalen Erfassungssignale gemäß einer temporären Änderung der Menge des ausgegebenen gepulsten Lichts, so dass Variationen der Intensitäten von entweder den analogen oder den digitalen Erfassungssignalen, die durch eine temporäre Änderung in der Menge des ausgegebenen gepulsten Lichts verursacht werden, unterdrückt werden; und
Erhalten von Informationen über das Innere des Inspektionsobjekts unter Verwendung der korrigierten Erfas-

sungssignale,
wobei die Intensitäten von entweder den digitalen oder den analogen Erfassungssignalen unter Verwendung der bestimmten Korrekturbeträge korrigiert werden,
dadurch gekennzeichnet, dass
die Korrekturbeträge für jedes Impulslicht basierend auf einer im Voraus eingegebenen konstanten Referenzlichtmenge und der gemessenen Lichtmenge bestimmt werden.

Revendications

1. Appareil photo-acoustique comprenant :

une source de lumière (2a, 2b) conçue pour irradier une cible d'inspection avec une pluralité de lumières pulsées ;
un détecteur (5) conçu pour détecter les ondes acoustiques générées dans la cible d'inspection du fait de l'irradiation par la pluralité de lumières pulsées ; et pour délivrer des signaux de détection analogiques correspondant aux ondes acoustiques détectées ;
une unité de mesure de quantité de lumière (8a, 8b, 9a, 9b) conçue pour mesurer une quantité de lumière délivrée par la source de lumière (2a, 2b) ; et
un processeur de signaux (15), qui comprend un convertisseur analogique-numérique (7) conçu pour convertir les signaux de détection analogiques en des signaux de détection numériques, et qui est conçu pour obtenir des informations concernant l'intérieur de la cible d'inspection (3),
une unité de détermination de quantité de correction (10, 10a, 10b) conçue pour déterminer des quantités de correction pour les signaux de détection numériques ou les signaux de détection analogiques,
dans lequel le processeur de signaux (15) comprend en outre
une unité de correction de signal (11) conçue pour corriger les signaux de détection numériques ou les signaux de détection analogiques sur la base d'une quantité de lumière mesurée par l'unité de mesure de quantité de lumière (8a, 8b, 9a, 9b) de sorte que les variations des intensités des signaux de détection numériques ou des signaux de détection analogiques, provoquées par une variation dans le temps de la quantité de lumière délivrée par la source de lumière (2a, 2b), soient supprimées, et
dans lequel l'unité de correction de signal (11) est configurée pour corriger les intensités des signaux de détection numériques ou des signaux de détection analogiques en utilisant les quantités de correction déterminées par l'unité de détermination de quantité de correction (10, 10a, 10b),
caractérisé en ce que
l'unité de détermination de quantité de correction (10, 10a, 10b) est configurée pour déterminer les quantités de correction pour chaque lumière pulsée sur la base d'une quantité de lumière de référence constante entrée à l'avance et de la quantité de lumière mesurée par l'unité de mesure de quantité de lumière (8a, 8b, 9a, 9b).

2. Appareil photo-acoustique selon la revendication 1,
dans lequel l'unité de détermination de quantité de correction (10, 10a, 10b) est configurée pour utiliser un nombre inverse d'un rapport entre la quantité de lumière de sortie et la quantité de lumière de référence constante en tant que coefficient de correction pour chaque lumière pulsée, et
dans lequel l'unité de correction de signal (11) est configurée pour corriger les intensités des signaux de détection numériques ou des signaux de détection analogiques en multipliant le coefficient de correction par les signaux de détection numériques ou analogiques.

3. Appareil photo-acoustique selon la revendication 2, comprenant en outre :

une mémoire (9a, 9b) conçue pour mémoriser la quantité de lumière mesurée par l'unité de mesure de quantité de lumière (8a, 8b, 9a, 9b),
dans lequel l'unité de détermination de quantité de correction (10, 10a, 10b) lit les données de la quantité de lumière mémorisées dans la mémoire (9a, 9b).

4. Appareil photo-acoustique selon l'une quelconque des revendications 1 à 3,
dans lequel l'unité de correction de signal (11) corrige les signaux de détection numériques de sorte qu'une influence d'une atténuation de la lumière provoquée à l'intérieur de la cible d'inspection soit également supprimée.

5. Appareil photo-acoustique selon l'une quelconque des revendications 1 à 3,
dans lequel le processeur de signaux (15) comprend un processeur de reconstruction d'image (12) qui traite les

signaux de détection numériques et effectue une reconstruction d'image de manière à obtenir les informations concernant l'intérieur de la cible d'inspection (3), et
le processeur de signaux (15) est configuré pour appliquer une correction d'atténuation optique aux données de sortie provenant d'un processeur de reconstruction d'image (12).

6. Appareil photo-acoustique selon la revendication 5,
dans lequel le processeur de signaux (15) obtient une quantité de lumière à l'intérieur d'une cible d'inspection (3) sur la base d'une atténuation de la lumière à l'intérieur de la cible d'inspection (3), et obtient des informations de l'intérieur de la cible d'inspection (3) en utilisant les données de reconstruction d'image et la quantité de lumière à l'intérieur de la cible d'inspection (3).

7. Appareil photo-acoustique selon la revendication 5,
dans lequel le processeur de signaux (15) obtient une quantité de lumière à l'intérieur d'une cible d'inspection (3) sur la base d'une atténuation de la lumière à l'intérieur de la cible d'inspection (3) et d'une distribution de quantité de lumière d'irradiation sur une surface de la cible d'inspection (3), et obtient des informations de l'intérieur de la cible d'inspection (3) en utilisant les données de reconstruction d'image et la quantité de lumière à l'intérieur de la cible d'inspection (3).

8. Appareil photo-acoustique selon l'une quelconque des revendications 1 à 7, comprenant en outre :

une pluralité de sources de lumière (2a, 2b) ; et
une pluralité d'unités de mesure de quantité de lumière (8a, 8b, 9a, 9b) conçues pour mesurer les quantités de lumière délivrées par les sources de lumière (2a, 2b),
dans lequel l'unité de détermination de quantité de correction (10, 10a, 10b) détermine des quantités de correction pour les signaux de détection sur la base des quantités de lumière mesurées par les unités de mesure de quantité de lumière (8a, 8b, 9a, 9b).

9. Appareil photo-acoustique selon l'une quelconque des revendications 1 à 8, comprenant en outre :

un mécanisme de déplacement conçu pour déplacer une partie que la lumière délivrée par la source de lumière (2a, 2b) frappe, et le détecteur (5).

10. Programme qui amène un ordinateur à exécuter les étampes :

d'obtention de signaux de détection analogiques des ondes acoustiques générées dans une cible d'inspection en irradiant la cible d'inspection avec une pluralité de lumières pulsées ;
de mesure d'une quantité de lumière pulsée de sortie ;
de conversion des signaux de détection analogiques en des signaux de détection numériques ;
de détermination de quantités de correction pour les signaux de détection numériques ou les signaux de détection analogiques ;
de correction des intensités des signaux de détection numériques ou des signaux de détection analogiques conformément à un changement dans le temps de la quantité de lumière pulsée de sortie de sorte que les variations des intensités des signaux de détection numériques ou des signaux de détection analogiques provoquées par un changement dans le temps de la quantité de lumière pulsée de sortie soient supprimées ; et
d'obtention d'informations concernant l'intérieur de la cible d'inspection en utilisant les signaux de détection corrigés,
dans lequel les intensités des signaux de détection numériques ou des signaux de détection analogiques sont corrigées en utilisant les quantités de correction déterminées,
caractérisé en ce que
les quantités de correction pour chaque lumière pulsée sont déterminées sur la base d'une quantité de lumière de référence constante entrée à l'avance et de la quantité de lumière mesurée.

FIG. 1

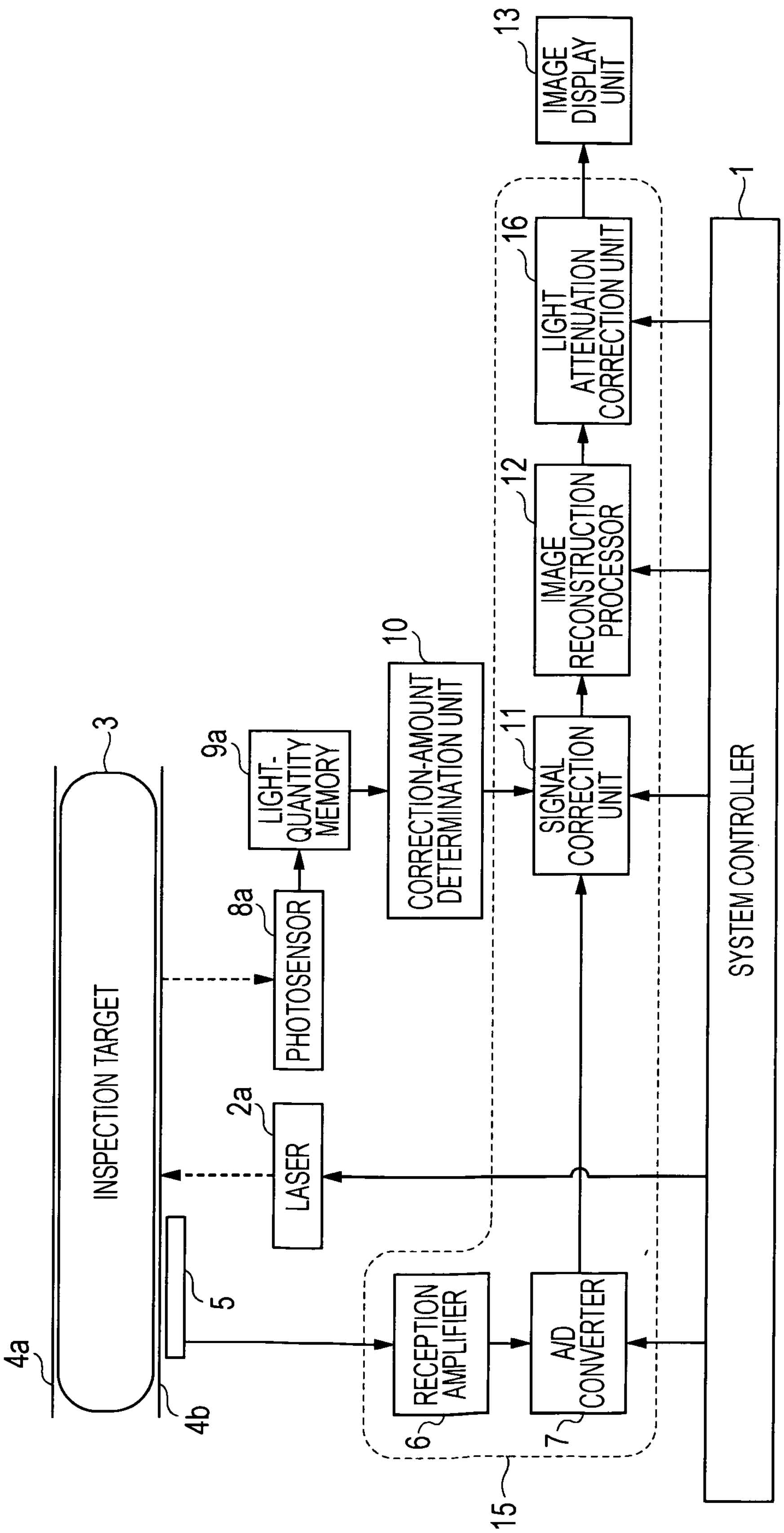

INSPECTION TARGET
3
4a
4b
5
LASER
2a
PHOTOSENSOR
8a
LIGHT-QUANTITY MEMORY
9a
CORRECTION-AMOUNT DETERMINATION UNIT
10
RECEPTION AMPLIFIER
6
A/D CONVERTER
7
SIGNAL CORRECTION UNIT
11
IMAGE RECONSTRUCTION PROCESSOR
12
LIGHT ATTENUATION CORRECTION UNIT
16
IMAGE DISPLAY UNIT
13
15
SYSTEM CONTROLLER
1

FIG. 2

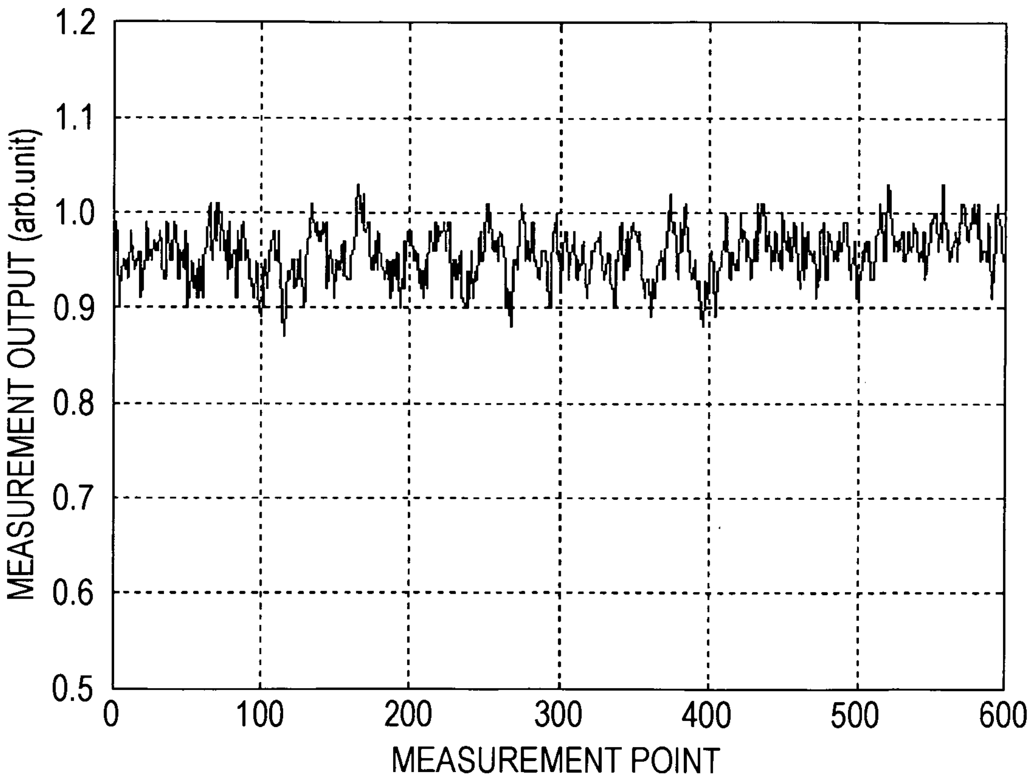

MEASUREMENT OUTPUT (arb.unit)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0
100
200
300
400
500
600
MEASUREMENT POINT

FIG. 3

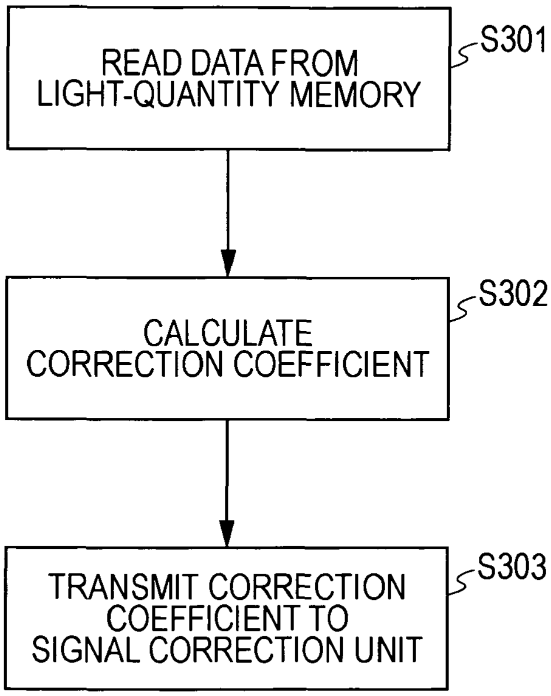
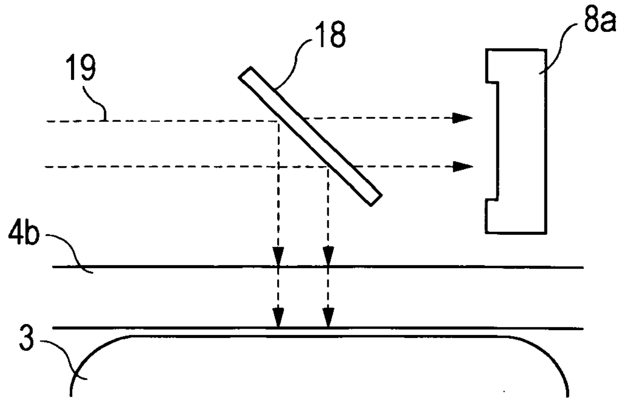
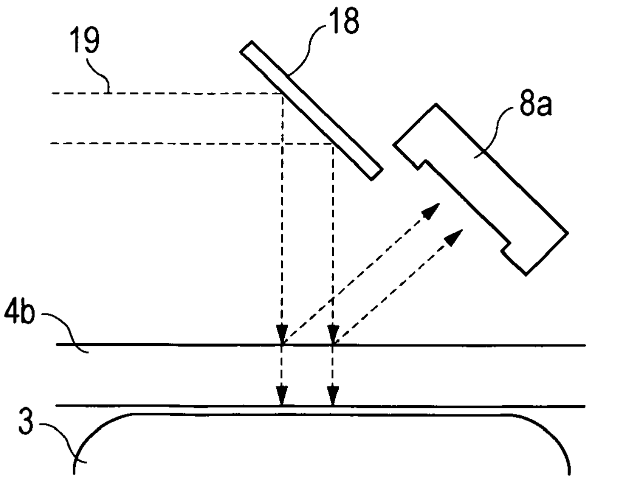

READ DATA FROM LIGHT-QUANTITY MEMORY
S301
CALCULATE CORRECTION COEFFICIENT
S302
TRANSMIT CORRECTION COEFFICIENT TO SIGNAL CORRECTION UNIT
S303

FIG. 4

(a)



(b)



(c)

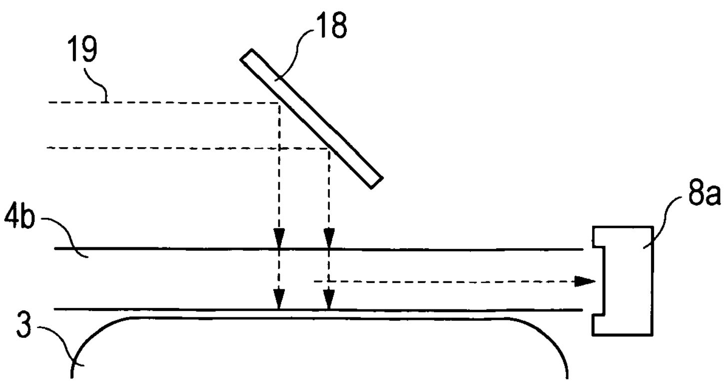


FIG. 5

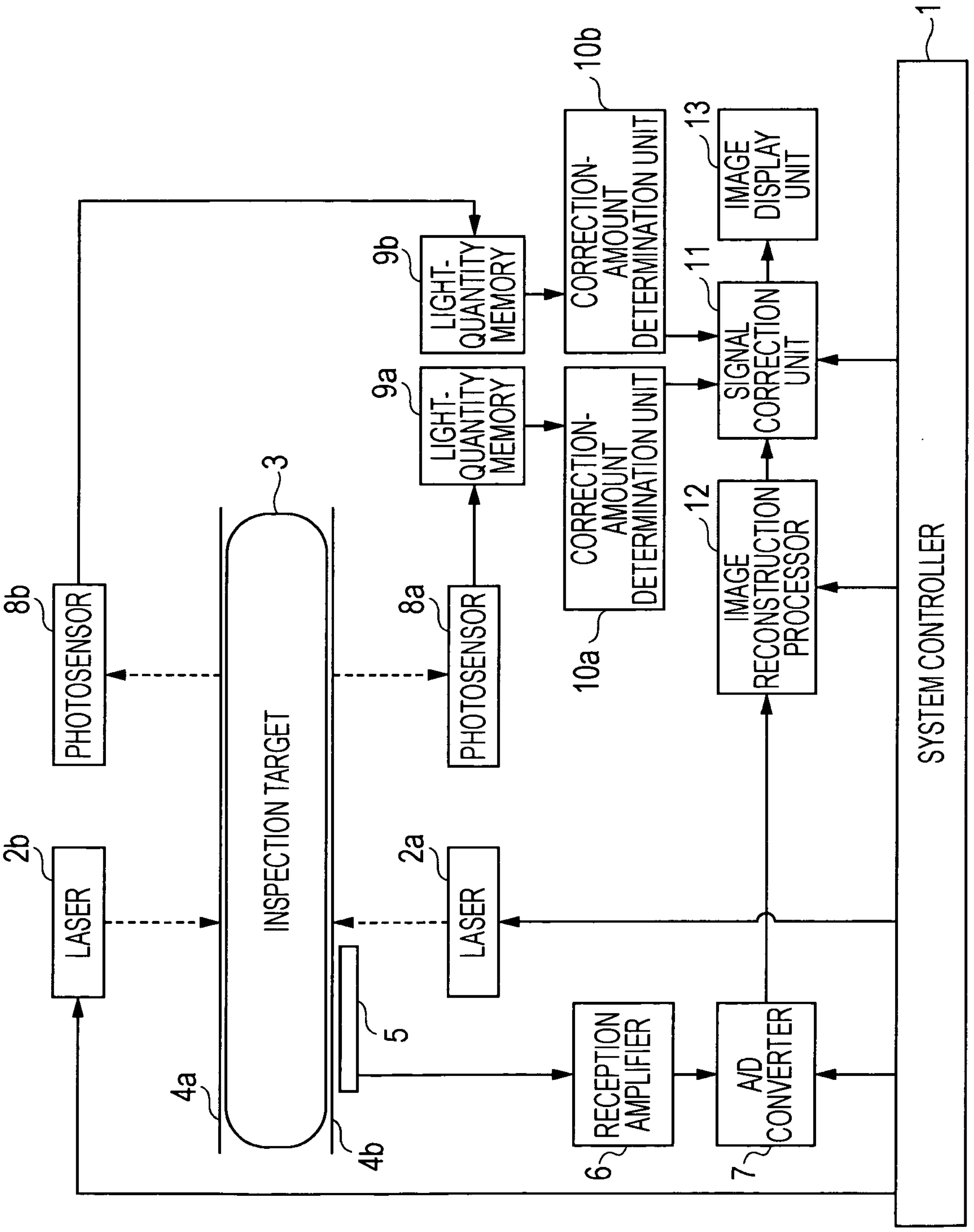

LASER
2b
PHOTOSENSOR
8b
INSPECTION TARGET
3
4a
4b
5
LASER
2a
PHOTOSENSOR
8a
LIGHT-QUANTITY MEMORY
9a
LIGHT-QUANTITY MEMORY
9b
RECEPTION AMPLIFIER
6
CORRECTION-AMOUNT DETERMINATION UNIT
10a
CORRECTION-AMOUNT DETERMINATION UNIT
10b
A/D CONVERTER
7
IMAGE RECONSTRUCTION PROCESSOR
12
SIGNAL CORRECTION UNIT
11
IMAGE DISPLAY UNIT
13
SYSTEM CONTROLLER
1

FIG. 6

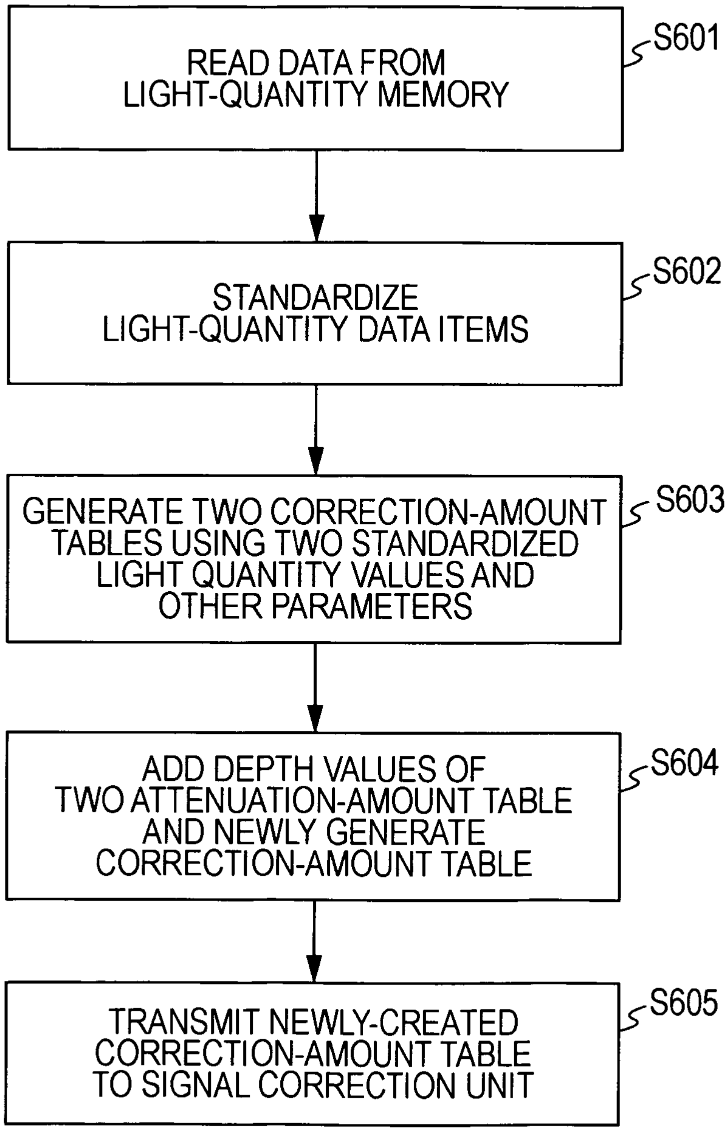
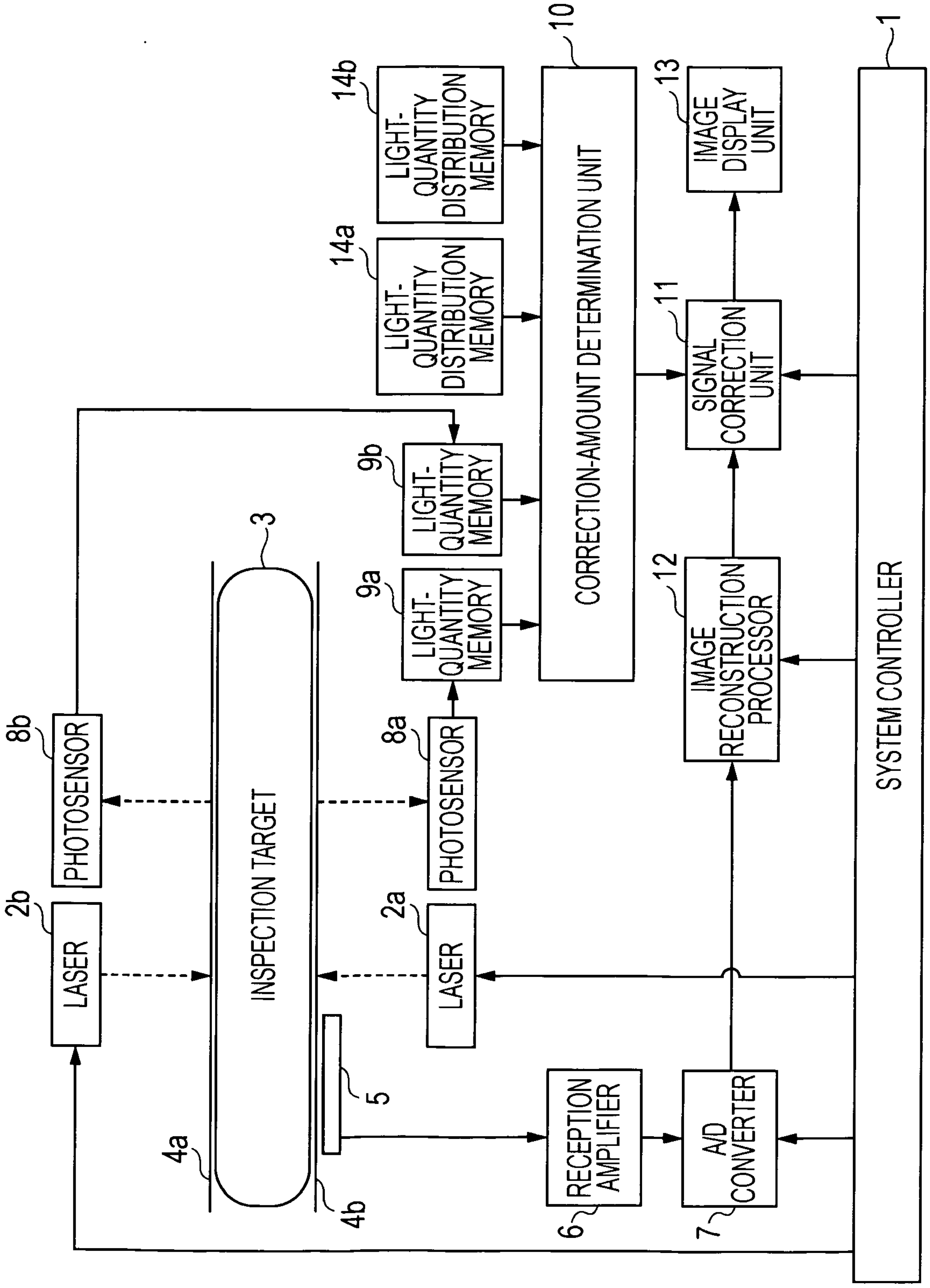

READ DATA FROM LIGHT-QUANTITY MEMORY
S601
STANDARDIZE LIGHT-QUANTITY DATA ITEMS
S602
GENERATE TWO CORRECTION-AMOUNT TABLES USING TWO STANDARDIZED LIGHT QUANTITY VALUES AND OTHER PARAMETERS
S603
ADD DEPTH VALUES OF TWO ATTENUATION-AMOUNT TABLE AND NEWLY GENERATE CORRECTION-AMOUNT TABLE
S604
TRANSMIT NEWLY-CREATED CORRECTION-AMOUNT TABLE TO SIGNAL CORRECTION UNIT
S605

FIG. 7


LASER
2b
PHOTOSENSOR
8b
INSPECTION TARGET
3
4a
4b
5
LASER
2a
PHOTOSENSOR
8a
LIGHT-QUANTITY MEMORY
9a
LIGHT-QUANTITY MEMORY
9b
LIGHT-QUANTITY DISTRIBUTION MEMORY
14a
LIGHT-QUANTITY DISTRIBUTION MEMORY
14b
CORRECTION-AMOUNT DETERMINATION UNIT
10
RECEPTION AMPLIFIER
6
A/D CONVERTER
7
IMAGE RECONSTRUCTION PROCESSOR
12
SIGNAL CORRECTION UNIT
11
IMAGE DISPLAY UNIT
13
SYSTEM CONTROLLER
1

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- **HAO F. ZHANG.** Nature Protocols. Nature Publishing Group, 05 April 2007, vol. 2, 797-804 **[0002]**
- *IEEE Journal of Selected Topics in Quantum Electronics,* 2008, vol. 14 (1), 171-179 **[0006]**
- *Physical Review,* 2005, vol. E 71, 016706 **[0034]**
- *Review of Scientific Instruments,* 2006, vol. 77, 042201 **[0034]**

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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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IPC分类号	A61B8/08 A61B5/00		
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外部链接	Espacenet		

摘要(译)

提供一种能够减少由于从光源输出的光量的时间变化而产生的图像不均匀性的光声装置。根据本发明的光声装置包括：光源2a，其用脉冲光照射检查目标;检测器5，其检测由于脉冲光而在检查目标3中产生的声波;光量测量单元8a，其测量从光源2a输出的光量和信号处理器15，信号处理器15使用由检测器5获得的检测信号获得关于检查目标内部的信息。信号处理器校正检测信号的强度以抑制变化由输出光量的时间变化引起的检测信号的强度。