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(54) LIGHT IRRADIATING APPARATUS, CONTROL METHOD THEREFOR, AND OBJECT INFORMATION ACQUIRING APPARATUS

LICHTAUSSTRAHLENDE VORRICHTUNG, STEUERVERFAHREN DAFÜR UND OBJEKTINFORMATIONSERFASSUNGSVORRICHTUNG

APPAREIL D'IRRADIATION DE LUMIÈRE, SON PROCÉDÉ DE COMMANDE ET APPAREIL D'ACQUISITION D'INFORMATIONS D'OBJET

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Description

Technical Field

[0001] The present invention relates to a light irradiating apparatus, a control method therefor, and an object information acquiring apparatus.

Background Art

[0002] Attention has been focused on photoacoustic tomography (hereinafter will be referred to as "PAT") as a method of specifically imaging neovascularization which occurs due to cancer. PAT is a method including illuminating an object with illuminating light (near infrared rays) and receiving a photoacoustic wave generated from the inside of the object by means of an ultrasound probe, thereby imaging the photoacoustic wave.

[0003] Non Patent Literature 1 describes a handheld type photoacoustic apparatus. This apparatus has a bundle fiber, which is fixed to a handheld type probe, for irradiation with light from a light source. Non Patent Literature 1, however, is silent on a contact between an illuminating light emitting surface and an object. Therefore, the illuminating light is emitted not only to the object but also into other space and, hence, there is room to improve the safety against the illuminating light.

[0004] This problem can be addressed by using the technique described in Patent Literature 1. FIGs. 7A and 7B illustrate a system configuration shown in Patent Literature 1. In FIG. 7, an energy emitting surface 101 is a surface for contact with skin from which energy, such as light, is emitted. A support structure 102 fixes the energy emitting surface 101 and is housed in a housing 104 with contact sensors 103 intervening therebetween. The contact sensors 103 are each configured to detect a contact between the energy emitting surface 101 and non-illustrated skin and are disposed to circumscribe the energy emitting surface 101. Energy emission is stopped unless the contact between the contact sensors 103 and the skin is detected. By so doing, energy irradiation is conducted only when the energy emitting surface 101 is completely in intimate contact with the skin, which leads to improved safety against energy irradiation.

Citation List

Patent Literature

[0005] PTL 1: Japanese Translation of PCT Application No. 2006-525036

Non Patent Literature

[0006] NPL 1: S.A. Ermilov et al., Development of laser optoacoustic and ultrasonic imaging system for breast cancer utilizing handheld array probes, Photons Plus Ultrasound: Imaging and Sensing 2009, Proc. of SPIE vol. 7177, 2009.

[0007] *Further prior art can be found in document* WO 2004/042382 A1*, disclosing a method and an apparatus for non-invasive measurement of living body characteristics by photoacoustics, the apparatus comprising a light source generating light containing a specific wavelength component, an irradiation unit irradiating a subject with the light, and at least one acoustic signal detection unit including piezoelectric devices formed of a piezoelectric single crystal containing lead titanate detecting an acoustic signal which is generated due to the energy of the irradiation light absorbed by a specific substance present in or on a subject.* The apparatus comprises a touch sensor which detects the degree of contact of the measurement site and the body interface, and the signal of the touch sensor is used to control the measurement protocol. For example, measurement is performed when the measurement site and the body interface fully touch. If the degree of contact detected by the touch sensor is not within a normal range, control is performed by adjusting the degree of contact, or stopping the irradiation of light, so as to maintain safety.

SUMMARY OF INVENTION

Technical Problem

[0008] The conventional art, however, involves the following problems.

[0009] Since Non Patent Literature 1 is silent on the contact between an illuminating light emitting surface and the object, the illuminating light is undesirably emitted into a space other than object. Even when the operator tries to bring the energy emitting surface into intimate contact with skin carefully, it is possible that the energy emitting surface and the skin fail to be brought into intimate contact with each other completely and that, when the energy emitting surface is only partially brought into contact with the skin, the energy emitting surface leans against the skin on one side to define a clearance therebetween. For this reason, there is room to improve the safety against the illuminating light.

[0010] The problem can be relieved by using the technique described in Patent Literature 1. Specifically, the contact sensors for contact with skin are disposed around the illuminating light emitting surface to perform a control for stopping emission of the illuminating light unless the contact sensors detect the contact. In order to prevent the energy emitting surface from leaning against the skin on one side, however, a multi-stage emission preventing mechanism , such as the provision of a multiplicity of contact sensors around the illuminating light emitting surface, is needed, which results in a complicated system configuration.

[0011] The present invention has been made with the foregoing problems in view. An object of the present invention is to simplify the system configuration of an apparatus having a mechanism for irradiating the object with light, as well as to secure the safety against the illuminating light.

Solution to Problem

[0012] The present invention provides a light irradiating apparatus comprising:

a probe including an irradiating unit which guides light from a light source to an object, a housing containing the irradiating unit, and a touch sensor acquiring a contact condition amount between the object and the housing; and
a controller controlling irradiation with light from the irradiating unit based on a level of the contact condition amount and a change in the contact condition amount,
wherein in a case where the contact condition amount is equal to or more than a first reference value while the change in the contact condition amount which occurs when the housing is pressed against the object is a positive value, the controller performs a control which enables irradiation with light from the irradiating unit when the change in the contact condition amount is equal to or more than a second reference value.

[0013] The present invention also provides a method for controlling a light irradiating apparatus having: a probe including an irradiating unit which guides light from a light source to an object, a housing containing the irradiating unit, and a touch sensor acquiring a contact condition amount between the object and the housing; and a controller controlling irradiation with light from the irradiating unit,
the method comprising:

a step of causing the controller to determine whether or not a change in the contact condition amount is equal to or more than a second reference value in a case where the contact condition amount is equal to or more than a first reference value while the change in the contact condition amount which occurs when the housing is pressed against the object is a positive value; and
a step of causing the controller to perform a control which enables irradiation with light from the irradiating unit in a case where the contact condition amount is equal to or more than the first reference value while the change in the contact condition amount is determined to be equal to or more than the second reference value.

Advantageous Effects of Invention

[0014] According to the present invention, the system configuration of an apparatus having a mechanism for irradiating the object with light can be simplified while securing the safety against the illuminating light.

[0015] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Brief Description of Drawings

[0016]

FIG. 1 is a view illustrating a system configuration according to an embodiment of the present invention;
FIG. 2 is a diagram illustrating a controller according to the embodiment of the present invention;
FIGS. 3A to 3D are views illustrating the mounting of a touch sensor according to the embodiment of the present invention;
FIGS. 4A and 4B are diagrams illustrating a light illumination control method according to embodiment 1 of the present invention;
FIGS. 5A and 5B are diagrams illustrating a light illumination control method according to embodiment 2 of the present invention;
FIGS. 6A and 6B are diagrams illustrating a light illumination control method according to embodiment 3 of the present invention; and
FIGS. 7A and 7B are views illustrating the background art.

Description of Embodiments

[0017] Hereinafter, preferred embodiments of the present invention will be described with reference to the drawings. The present invention is applicable to apparatuses utilizing a photoacoustic effect for acquiring object information as image information by receiving an acoustic wave that is generated in an object by irradiating the object with light (electromagnetic wave). (Such an acoustic wave is also called a "photoacoustic wave", a typical example of which is an ultrasound wave.) Such apparatuses are called "photoacoustic apparatuses".

[0018] The object information to be acquired means a distribution of generation sources of acoustic waves generated by irradiation with light, an initial sound pressure distribution inside the object, an absorbed optical energy density distribution or absorption coefficient distribution derived from the initial sound pressure distribution, or a concentration distribution of a substance forming a tissue. The concentration distribution of a substance is meant to include, for example, an oxygen saturation distribution and an oxidized-reduced hemoglobin concentration distribution.

[0019] The "acoustic wave" is typically an ultrasound wave and is meant to include elastic waves such as called a sound wave, an ultrasound wave, an acoustic wave, a photoacoustic wave, and a photoultrasound wave. The "light", as used in the present invention, is meant by electromagnetic waves including visible rays and infrared rays. Light of a specific wavelength is simply selected to meet a component to be measured by the object information acquiring apparatus.

[0020] The following description is directed to the object, though the object does not form part of the object information acquiring apparatus of the present invention. The object information acquiring apparatus according to the present invention is capable of diagnosing malignant tumors, vascular diseases, blood sugar levels and the like of humans or animals, making follow-up of chemotherapy, and the like. Therefore, the object is assumed as a living body, specifically, a breast, finger, limb or the like of a human or animal. A light absorbing substance present inside the object is a substance having a relatively high absorption coefficient among substances present inside the object. For example, in cases where a human body is a subject of measurement, such light absorbing substances include oxidized or reduced hemoglobin and a blood vessel containing such hemoglobin, and a malignant tumor containing a number of neovascular vessels. When the object is a living body, the apparatus of the present invention can be called a "living body information processing apparatus".

[0021] Description will be made of an embodiment with reference to FIG. 1. FIG. 1 schematically illustrates a handheld type photoacoustic apparatus.

[0022] A light source 1, an illuminating optical system 2 and a bundle fiber 3 are constituent elements for illuminating a non-illustrated object with near infrared rays. A pulse laser, such as an Nd:YAG laser or an alexandrite laser, is used as the light source 1. Alternatively, use may be made of a Ti:Sa laser or OPO laser which uses Nd:YAG laser light as excitation light. Yet alternatively, a light source other than such lasers, such as a xenon lamp, may be used. The illuminating optical system 2 expands illuminating light from the light source 1 and causes the illuminating light to become incident on the bundle fiber 3. The illuminating light passes through the bundle fiber 3 to illuminate the object. Though the bundle fiber shown in FIG. 1 is branched into two, the number of branches is any desired number. Though FIG. 1 does not show an illuminating optical system for guiding the illuminating light from the bundle fiber 3 to the object, it is possible to illuminate the object directly from an irradiating end 3a of the bundle fiber 3 or to provide any desired optical system such as a diffuser . The irradiating end 3a is equivalent to the "irradiating unit" defined by the present invention.

[0023] An ultrasound probe 4 is configured to receive a photoacoustic wave generated from the object. A one- or two-dimensional array of detecting elements such as PZTs or CMUTs, for example, can be used as the ultrasound probe 2. Alternatively, an ultrasound probe formed of a single element may be used. A processing device 5 acquires a photoacoustic signal received by the ultrasound probe 4 at the timing of input of a trigger signal for causing emission of illuminating light. The processing device 5 performs amplification, digital conversion, detection and like processing of the photoacoustic signal to create image information and causes a monitor 6 to display the image information.

[0024] A housing 7 is configured to be fitted with the ultrasound probe 4 and the irradiating end 3a of the bundle fiber. The housing 7 is provided with a touch sensor 8. The touch sensor 8 is a sensor configured to measure the contact condition amount between the object and the housing 7. The output of the touch sensor 8 is inputted to a controller 9. The controller 9 generates a light emission control signal from the output of the touch sensor 8 and transmits the signal to the light source 1. A handheld probe 10 comprises the light irradiating end 3a of the bundle fiber, ultrasound probe 4, housing 7, and touch sensor 8. Whether irradiation of the object with light is permitted or has to be stopped depends on the signal from the controller.

[0025] The processing device 5 and the controller 9 can be implemented by using an information processor for example. The information processor may perform different processing operations by using respective circuits dedicated thereto or may be implemented in the form of a program for operating a computer having a CPU or the like.

[0026] With reference to FIG. 2, description is made below of a control method carried out by the controller 9.

[0027] As shown in FIG. 2, the condition amount of contact with the object outputted from the touch sensor 8 is inputted to the controller 9. The controller 9 determines a contact condition from the contact condition amount and permits illumination when the contact is adequate. When the contact is inadequate, the controller 9 stops illumination. The control signal is transmitted to the light source 1 and is used for light emission control.

[0028] A method for determination of the contact condition is carried out by comparing the contact condition amount indicative of the degree of contact to a first reference value and comparing the degree of change in the contact condition amount (e.g., temporal differential) to a second reference value. The condition for permitting illumination is that the contact condition amount is equal to or more than the first reference value while the change in contact condition is equal to or more than the second reference value. With respect to the change in contact condition, a change that occurs in pressing the housing against the object is expressed as a positive value, while a change that occurs in separating the housing from the object is expressed as a negative value. A certain negative value serves as the second reference value. For example, illumination is permitted on condition that the temporal differential of a condition amount measured by the touch sensor 8 is equal to or more than the second reference value.

[0029] When the contact condition amount indicative of the degree of contact is equal to or more than the first reference value, the housing 7 is determined as being in adequate contact with the object without leaning against the object on one side. When the temporal differential of the contact condition amount is equal to or less than the second reference value, the handheld probe 10 is determined as being about to separate from the object. That is, the handheld probe 10 can be determined as assuming not only a condition in which the handheld probe 10 is about to completely separate from the object but also a condition in which the handheld probe 10 is about to lean against the object on one side. For this reason, even when sensors for detection of contact are disposed in such a manner as not to circumscribe the illuminating area, the illumination control signal can be quickly transmitted to the light source 1 before the handheld probe 10 is separated from the object. Therefore, the safety against laser irradiation can be secured without the need to provide a multiplicity of sensors.

[0030] The present invention is characterized by an illuminating light emission control based on the condition of contact with the object. Therefore, constituent elements provided on the optical path are not limited to the illuminating optical system 2 and the bundle fiber 3. For example, instead of the bundle fiber 3, a mirror, a prism and a light-shielding tube accommodating these components therein are provided to secure the optical path extending up to a position for illuminating the object.

[0031] Either a method including opening and closing an internal shutter of the light source 1 or a method including controlling an internal trigger signal is effective for the light emission control over the light source 1. While the control signal from the controller 9 has been described as a signal for the light emission control over the light source 1, there is no limitation to this feature. For example, it is possible that an external shutter is provided between the light source 1 and the illuminating optical system 2 while the opening and closing of the shutter is controlled by such a control signal.

[0032] The following description is directed to the touch sensor 8. The touch sensor 8 used in the present invention may be a sensor of any type that is capable of measuring the contact condition amount between the housing 7 and the object. For example, use can be made of any type of sensor that can measure the condition amount, such as force, pressure and distance, based on a principle utilizing optics, resistance, electrostatic capacitance or the like. Here, an arrangement using a strain gauge as the touch sensor 8 is described.

[0033] FIG. 3A is a side elevational view of the housing 7, FIG. 3B is a bottom view of the housing 7, and FIG. 3C is a perspective view of the housing 7. As shown in the bottomview of FIG. 3B, the bottom surface of the housing 7 is divided into an opening area for illuminating the object and a photoacoustic wave receiving area. In mounting a strain gauge 8a on the housing 7, the strain gauge 8a is bonded to a flat spring 7a forming part of the housing 7. By so doing, the strain gauge 8a produces an output with increased sensitivity to the condition of contact with the object. For this reason, the contact condition amount (i.e., strain of the flat spring 7a) can be measured highly precisely. Therefore, the stability of the control by the controller 9 is improved and, hence, the safety against light irradiation can be secured even when the number of touch sensors 8 is reduced by disposing touch sensors 8 in such a manner as not to circumscribe the illuminating opening. Further, the improved stability of the control by the controller 9 leads to reduced occurrence of errors such as illuminating in non-contact condition and failing to illuminate in a contact condition, thereby making it possible to use the photoacoustic apparatus stably.

[0034] The position of the strain gauge 8a is not limited the position at which the strain gauge 8a is bonded to the flat spring 7a. As shown in the side elevational view of FIG. 3D, it is possible that the housing 7 is formed from a material which is easy to strain while the strain gauge 8a is bonded to a side surface of the housing 7.

[0035] Alternatively, touch sensors 8 (strain gauges 8a), the number of which is two or so, may be disposed across the illuminating opening (illuminating optical path) as shown in FIG. 3C. With this arrangement, the light emission control based on the contact condition amount and the change in the contact condition amount makes it possible to secure the safety as well as to simplify the system configuration.

Embodiment 1

[0036] In Embodiment 1, the control method carried out by the controller 9 is described more specifically with reference to FIG. 4A. The controller 9 carries out the following process to control emission of illuminating light based on the condition amount of contact with the object inputted from the touch sensor 8.

[0037] The controller 9 determines whether or not the contact condition is equal to or more than the predetermined first reference value (step S11). In cases where the strain gauge 8a is used as the touch sensor 8, if the strain amount $\varepsilon i \geqq a$ (first reference value), the process proceeds to the subsequent step S12. If $\varepsilon i < a$, the process proceeds to step S14. In these expressions, i represents the channel number of the strain gauge 8a (i.e., touch sensor 8).

[0038] The controller 9 determines whether or not the change in contact condition is equal to or more than the predetermined second reference value (step S12). More specifically, the controller 9 determines whether or not the temporal differential of the contact condition is equal to or more than the second reference value. In cases where the strain gauge 8a is used as the touch sensor 8, if $d\varepsilon i/dt \geq b$, the process proceeds to the subsequent step S13. If $d\varepsilon i/dt < b$, the process proceeds to step S14. The change in contact condition which occurs in pressing the handheld probe 10 against the object is expressed as a positive value, while that occurs in separating the handheld probe 10 from the object is expressed as a negative value. The second reference value b is a negative value.

[0039] The controller 9 controls the light source 1 to permit illumination (step S13). Alternatively, the controller 9 may control a non-illustrated shutter or both of the light source and the shutter.

[0040] The controller 9 controls the light source 1 to stop illumination (step S14). Alternatively, the controller 9 may control the non-illustrated shutter or both of the light source and the shutter.

[0041] Step S11 and step S12 may be replaced with each other.

[0042] According to the control method of the present embodiment, the control is performed such that illumination is permitted when each of the contact condition amount (horizontal axis: strain amount εi) and the change thereof (vertical axis: dεi / dt) in FIG. 4B falls within an illumination permitted region (hatched region) while illumination is stopped when the contact condition amount and the change thereof fall within an illumination inhibited region. In one example using the strain gauge 8a mounted on the flat spring 7a as in Embodiment 1, control was performed under the conditions: the first reference value a = 0.05; and the second reference value b = -0.1. As a result, the handheld probe 10 and the object were brought into intimate contact with each other without leaning against each other on one side. There is no limitation to these values, but the values have to be varied to meet the conditions including the material of the flat spring 7a, the shape and size of the flat spring 7a, and the elasticity modulus of the object.

[0043] In the foregoing description, the amount of the change in contact condition which occurs in pressing the handheld probe 10 against the object is expressed as a positive value, while that occurs in separating the handheld probe 10 from the object is expressed as a negative value, and the second reference value b is a negative value . However, the reverses of the plus, minus and inequality signs are effective. In steps S11 and S12, the expressions: εi ≧ a; and dεi / dt ≧ b as the conditions to be satisfied have equality signs. However, the expressions: εi > a; and dεi/dt > b without the equality signs are also effective. It is possible to find the moving average value of the condition amount of contact (strain amount εi) with the object and then use the moving average value for the determinations in steps S11 and S12. This holds true for the following Embodiments.

[0044] The amount of change in contact condition has been described as the temporal differential of the contact condition amount. The sampling time Δt is set arbitrarily. For example, the sampling time may be a sampling frequency (about 1 kHz) with which the output of the touch sensor 8 is inputted to the controller 9 or may be about several seconds for which sampling is performed to determine a difference to be used as the amount of change in contact condition.

[0045] According to the present embodiment, the illumination control signal can be quickly transmitted to the light source 1 before the handheld probe 10 is separated from the object even when the sensors for detection of contact are disposed in such a manner as not to circumscribe the illuminating area. Therefore, the safety against laser irradiation can be secured without the need to provide a multiplicity of such sensors. Further, the number of sensors for detection of contact can be reduced and, hence, the housing 7 can be downsized. As a result, the handheld probe 10 can be wholly downsized.

[0046] While the foregoing description has been made of the photoacoustic apparatus as an example, the subject to which the present invention is applicable is not limited to such a photoacoustic apparatus. The present invention is applicable to other object information acquiring apparatuses including an AOT (Acousto-Optical Tomography) apparatus and a DOT (Diffuse Optical Tomography) apparatus. Further, the present invention is applicable to light irradiation control for laser therapy apparatuses without limitation to such object information acquiring apparatuses. That is, the present invention can be said to be applicable to any light irradiating apparatus including a handheld probe with a light irradiating mechanism.

Embodiment 2

[0047] In the control method described in Embodiment 1, the first reference value a of the contact condition amount (strain amount εi) and the second reference value b of the change in the contact condition amount (temporal differential of the strain amount dεi/dt) are predetermined values . These values may be varied to meet the contact condition.

[0048] In Embodiment 2, the reference value of the contact condition amount (i.e., first reference value) is varied in accordance with the change in the contact condition amount. This is because the contact condition amount between the handheld probe 10 and the object varies due to a difference in intimate contact condition between the operation of pressing the handheld probe 10 against the object and the operation of separating the handheld probe 10 from the object. For example, a force of not less than 8 N is needed to bring the handheld probe 10 and the object into intimate contact with each other in the operation of pressing the handheld probe 10 against the object, whereas a force of about 3 N is needed to bring the handheld probe 10 and the object into intimate contact with each other in the operation of separating the handheld probe 10 from the object. For this reason, the first reference value of the contact condition amount (strain amount εi) is determined in accordance with the temporal differential of the contact condition (dεi / dt).

[0049] In a method for the determination of the first reference value, an expression is stored in the controller 9 for determining the first reference value as a function of the temporal differential of the contact condition. Alternatively, a table may be stored in the controller 9 for determining the reference value of the contact condition amount in accordance with the temporal differential of the contact condition. Yet alternatively, it is possible that with the first reference value being two-valued, whether the handheld probe 10 has to be pressed against the object or separated from the object is determined from the temporal differential of the contact condition, followed by selection of a reference value of the contact condition amount based on the determination thus made.

[0050] As shown in FIG. 5A, the controller 9 carries out the following process to control emission of illuminating light based on the contact condition amount between the touch sensor 8 and the object.

[0051] The controller 9 calculates the change in contact condition (step S21). In cases where the strain gauge 8a is used as the touch sensor 8, the controller 9 calculates $d\varepsilon i / dt$. In the expression, i represents the channel number of the strain gauge 8a (i.e., touch sensor 8).

[0052] The controller 9 determines the first reference value of the contact condition amount (step S22). In cases where the strain gauge 8a is used as the touch sensor 8, the controller 9 determines the reference value a of the strain amount.

[0053] The controller 9 determines whether or not the contact condition is equal to or more than the first reference value determined in step S22 (step S23). In cases where the strain gauge 8a is used as the touch sensor 8, if $\varepsilon i \geqq a$ (reference value), the process proceeds to the subsequent step S24. If $ei < a$, the process proceeds to step S26.

[0054] The controller 9 determines whether or not the change in contact condition is equal to or more than the predetermined second reference value (step S24). More specifically, the controller 9 determines whether or not the temporal differential of the contact condition is equal to or more than the second reference value b. In cases where the strain gauge 8a is used as the touch sensor 8, if $d\varepsilon i / dt \geq b$, the process proceeds to the subsequent step S25. If $d\varepsilon i/dt < b$, the process proceeds to step S26. The change in contact condition which occurs in pressing the handheld probe 10 against the object is expressed as a positive value, while that occurs in separating the handheld probe 10 from the object is expressed as a negative value. The second reference value b is a negative value.

[0055] The controller 9 controls the light source 1 to permit illumination (step S25). Alternatively, the controller 9 may control a non-illustrated shutter or both of the light source and the shutter.

[0056] The controller 9 controls the light source 1 to stop illumination (step S26). Alternatively, the controller 9 may control the non-illustrated shutter or both of the light source and the shutter.

[0057] Step S23 and step S24 may be replaced with each other.

[0058] According to the control method of the present embodiment, the first reference value a used in pressing the handheld probe 10 against the object is set to a low value as shown in FIG. 5B. On the contrary, the first reference value a used in separating the handheld probe 10 from the object is set to a high value. By so doing, illumination is permitted even when the intimate contact between the handheld probe 10 and the object is weak in pressing the handheld probe 10 against the object. For this reason, there is no need to exert a force more than necessary on the object in pressing the handheld probe 10 against the object, which leads to improvement in the operability of the apparatus.

Embodiment 3

[0059] In Embodiment 3, the second reference value is determined from the contact condition amount. This is because the intimate contact condition between the handheld probe 10 and the object differs according to the condition in which the handheld probe 10 is pressed against the object. For example, after the handheld probe 10 has been pressed against the object with a relatively strong force, the pressing force is relieved while maintaining the intimate contact. Even when this operation causes a large change in the contact condition amount to occur in the direction away from object, the intimate contact can be maintained. Therefore, the second reference value b of the change in contact condition ($d\varepsilon i / dt$) is determined in accordance with the contact condition amount (strain amount εi). In a method for the determination of the second reference value b, an expression is stored in the controller 9 for determining the second reference value b as a function of the contact condition amount. Alternatively, a table may be stored in the controller 9 for determining the reference value of the change in contact condition in accordance with the contact condition amount.

[0060] As shown in FIG. 6A, the controller 9 carries out the following process to control emission of illuminating light based on the contact condition amount between the touch sensor 8 and the object.

[0061] The controller 9 determines the second reference value from the contact condition amount (step S31). In cases where the strain gauge 8a is used as the touch sensor 8, the controller 9 determines the second reference value b for determination of the change in strain amount (the temporal differential).

[0062] The controller 9 determines whether or not the contact condition is equal to or more than the predetermined first reference value (step S32). In cases where the strain gauge 8a is used as the touch sensor 8, if the strain amount $\varepsilon i \geqq a$ (reference value), the process proceeds to the subsequent step S33. If $\varepsilon i < a$, the process proceeds to step S35. In these expressions, i represents the channel number of the gauge 8a (i.e., touch sensor 8).

[0063] The controller 9 determines whether or not the change in contact condition is equal to or more than the second reference value determined in step S31 (step S33). More specifically, the controller 9 determines whether or not the temporal differential of the contact condition is equal to or more than the predetermined second reference value b. In cases where the strain gauge 8a is used as the touch sensor 8, if $d\varepsilon i / dt \geqq b$, the process proceeds to the subsequent step S34. If $d\varepsilon i/dt < b$, the process proceeds to step S35. The change in contact condition which occurs in pressing the handheld probe 10 against the object is expressed as a positive value, while that occurs in separating the handheld probe 10 from the object is expressed as a negative value. The second reference value b is a negative value.

[0064] The controller 9 controls the light source 1 to permit illumination (step S34). Alternatively, the controller 9 may control a non-illustrated shutter or both of the light source and the shutter.

[0065] The controller 9 controls the light source 1 to stop illumination (step S35). Alternatively, the controller 9 may control the non-illustrated shutter or both of the light source and the shutter.

[0066] Step S32 and step S33 may be replaced with each other.

[0067] According to the control method of the present embodiment, when the handheld probe 10 is strongly brought into intimate contact with the object, the second reference value b is set to a relatively low value to permit illumination even when the change in contact condition becomes large in the direction away from the object. On the contrary, when the handheld probe 10 is weakly brought into intimate contact with the object, the second reference value b is set to a relatively high value based on which whether or not to illuminate is determined. By so doing, illumination is permitted even when the intimate contact between the handheld probe 10 and the object is somewhat relieved in pressing the handheld probe 10 against the object strongly, but unless the change in contact condition is in the pressing direction to reach the intimate contact, illumination is inhibited when the intimate contact is weak. This feature can suppress, for example, the occurrence of an inconvenience such that laser light emission is undesirably stopped even when the pressing force is relieved with the intimate contact maintained after the handheld probe 10 has been pressed against the object with a relatively strong force. For this reason, the operability of the apparatus is further improved.

[0068] Embodiments 2 and 3 may be combined with each other in such a manner that the reference value of the contact condition amount and the reference value of the change in the direction away from the object are each determined in accordance with the contact condition amount measured by the touch sensor 8.

[0069] 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 such modifications and equivalent structures and functions.

Claims

1. A light irradiating apparatus comprising:

   a probe (10) including an irradiating unit (3a) adapted to guide light from a light source (1) to an object, a housing (7) containing the irradiating unit (3a), and a touch sensor (8) adapted to acquire a contact condition amount between the object and the housing (7); and

   a controller (9) adapted to control irradiation with light from the irradiating unit (3a) based on a level of the contact condition amount and a change in the contact condition amount,

   characterized in that

   in a case where the change in the contact condition amount which occurs when the housing (7) is pressed against the object is a positive value, the controller (9) is adapted to perform a control which enables irradiation with light from the irradiating unit (3a) in a case where the contact condition amount is equal to or more than a first reference value and the change in the contact condition amount is equal to or more than a second reference value.

2. The light irradiating apparatus according to claim 1, wherein the change in the contact condition amount is a temporal differential of the contact condition amount.

3. The light irradiating apparatus according to claim 1 or 2, wherein the controller (9) is adapted to perform the control using predetermined values as the first reference value and the second reference value.

4. The light irradiating apparatus according to claim 1 or 2, wherein the controller (9) is adapted to perform the control by decreasing the first reference value as a value of the change in the contact condition amount is increased.

5. The light irradiating apparatus according to claim 1 or 2, wherein the controller (9) is adapted to perform the control by decreasing the second reference value as a value of the contact condition amount is increased.

6. The light irradiating apparatus according to any one of claims 1 to 5, wherein

   the touch sensor (8) is a strain gauge disposed on the housing (7), and

   the contact condition amount is a strain amount of the housing (7).

7. The light irradiating apparatus according to any one of claims 1 to 6, wherein the second reference value is a negative value.

8. The light irradiating apparatus according to any one of claims 1 to 7, wherein

   the controller (9) is adapted to inhibit irradiation with light from the irradiating unit (3a) in a case where the change in the contact condition amount is less than the second reference value.

9. The light irradiating apparatus according to any one of claims 1 to 8, wherein the controller (9) is adapted to inhibit irradiation with light from the irradiating unit (3a) in a case where the contact condition amount is less than the first reference value.

10. An object information acquiring apparatus comprising:

the light irradiating apparatus according to any one of claims 1 to 9;
an ultrasound probe (4) included in the probe (10) and adapted to acquire an acoustic wave that is generated when the object is irradiated with light from the irradiating unit (3a); and
a processor (5) adapted to create image information about an internal part of the object from the acoustic wave.

11. A method for controlling a light irradiating apparatus having: a probe (10) including an irradiating unit (3a) which guides light from a light source (1) to an object, a housing (7) containing the irradiating unit (3a), and a touch sensor (8) acquiring a contact condition amount between the object and the housing (7); and a controller (9) controlling irradiation with light from the irradiating unit (3a),
characterized in that the method comprising:

a step of causing (S12) the controller (9) to determine whether or not the contact condition amount is equal to or more than a first reference value and a change in the contact condition amount is equal to or more than a second reference value in a case where the change in the contact condition amount which occurs when the housing (7) is pressed against the object is a positive value; and
a step of causing (S13) the controller (9) to perform a control which enables irradiation with light from the irradiating unit (3a) in a case where the contact condition amount is equal to or more than the first reference value and the change in the contact condition amount is determined to be equal to or more than the second reference value.

12. The method according to claim 11, wherein the second reference value is a negative value.

13. The method according to claims 11 or 12, further comprising
a step of causing (S13) the controller (9) to perform a control which inhibits irradiation with light from the irradiating unit (3a) in a case where the change in the contact condition amount is less than the second reference value.

14. The method according to any one of claims 11 to 13, further comprising
a step of causing (S13) the controller (9) to perform a control which inhibits irradiation with light from the irradiating unit (3a) in a case where the contact condition amount is less than the first reference value.

Patentansprüche

1. Lichtstrahlvorrichtung, mit

einer Sonde (10) einschließlich einer Strahleinheit (3a), die dazu eingerichtet ist, um Licht von einer Lichtquelle (1) zu einem Objekt zu führen, einem Gehäuse (7), das die Strahleinheit (3a) umfasst, und eines Berührsensors (8), der dazu eingerichtet ist, um ein Kontaktbedingungsausmaß zwischen dem Objekt und dem Gehäuse (7) zu erlangen, und
einem Steuerelement (9), das dazu eingerichtet ist, um eine Bestrahlung mit Licht von der Strahleinheit (3a) basierend auf einem Pegel des Kontaktbedingungsausmaßes und einer Änderung des Kontaktbedingungsausmaßes zu steuern,
dadurch gekennzeichnet, dass
in einem Fall, in dem die Änderung des Kontaktbedingungsausmaßes, die, wenn das Gehäuse (7) gegen das Objekt gedrückt ist, ein positiver Wert ist, das Steuerelement (9) dazu eingerichtet ist, um eine Steuerung durchzuführen, die eine Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall zu ermöglichen, in dem das Kontaktbedingungsausmaß gleich wie oder größer als ein erster Referenzwert und die Änderung des Kontaktbedingungsausmaßes gleich wie oder größer als ein zweiter Referenzwert ist.

2. Lichtstrahlvorrichtung nach Anspruch 1, wobei die Änderung des Kontaktbedingungsausmaßes ein Zeitdifferential des Kontaktbedingungsausmaßes ist.

3. Lichtstrahlvorrichtung nach einem der Ansprüche 1 oder 2, wobei das Steuerelement (9) dazu eingerichtet ist, um die Steuerung unter Verwendung von vorbestimmten Werten als der erste Referenzwert und der zweite Referenzwert durchzuführen.

4. Lichtstrahlvorrichtung nach Anspruch 1 oder 2, wobei das Steuerelement (9) dazu eingerichtet ist, um die Steuerung durch Verringerung des ersten Referenzwerts mit Erhöhung eines Werts der Änderung des Kontaktbedingungsausmaßes durchzuführen.

5. Lichtstrahlvorrichtung nach Anspruch 1 oder 2, wobei das Steuerelement (9) dazu eingerichtet ist, um die Steuerung durch Verringerung des zweiten Referenzwerts mit Erhöhung eines Werts des Kontaktbedingungsausmaßes durchzuführen.

6. Lichtstrahlvorrichtung nach einem der Ansprüche 1 bis 5, wobei

der Berührsensor (8) ein Dehnungsmessstreifen ist, der an dem Gehäuse (7) angeordnet ist, und
das Kontaktbedingungsausmaß ein Dehnungsausmaß des Gehäuses (7) ist.

7. Lichtstrahlvorrichtung nach einem der Ansprüche 1 bis 6, wobei der zweite Referenzwert ein negativer Wert ist.

8. Lichtstrahlvorrichtung nach einem der Ansprüche 1 bis 7, wobei
das Steuerelement (9) dazu eingerichtet ist, um Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall zu hemmen, in dem die Änderung des Kontaktbedingungsausmaßes geringer als der zweite Referenzwert ist.

9. Lichtstrahlvorrichtung nach einem der Ansprüche 1 bis 8, wobei
das Steuerelement (9) dazu eingerichtet ist, um Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall zu hemmen, in dem das Kontaktbedingungsausmaß geringer als der erste Referenzwert ist.

10. Objektinformationserlangungsvorrichtung, mit

der Lichtstrahlvorrichtung nach einem der Ansprüche 1 bis 9,
einer Ultraschallsonde (4), die in der Sonde (10) enthalten ist und dazu eingerichtet ist, um eine akustische Welle zu erlangen, die erzeugt ist, wenn das Objekt mit Licht von der Strahleinheit (3a) bestrahlt ist, und
einem Prozessor (5), der dazu eingerichtet ist, um Bildinformation bezüglich eines internen Teils des Objekts aus der akustischen Welle zu erzeugen.

11. Verfahren zur Steuerung einer Lichtstrahlvorrichtung, mit: einer Sonde (10) einschließlich einer Strahleinheit (3a), die Licht von einer Lichtquelle (1) zu einem Objekt leitet, einem Gehäuse (7), das die Strahleinheit (3a) umfasst, und eines Berührsensors (8), der ein Kontaktbedingungsausmaß zwischen dem Objekt und dem Gehäuse (7) erlangt, und einem Steuerelement (9), das eine Bestrahlung mit Licht von der Strahleinheit (3a) steuert,
dadurch gekennzeichnet, dass das Verfahren aufweist:

einen Schritt eines Dazubringens (S12) des Steuerelements (9), zu bestimmen, ob das Kontaktbedingungsausmaß gleich wie oder größer als ein erster Referenzwert und eine Änderung des Kontaktbedingungsausmaßes gleich wie oder größer als ein zweiter Referenzwert ist oder nicht in einem Fall, in dem die Änderung des Kontaktbedingungsausmaßes, die auftritt, wenn das Gehäuse (7) gegen das Objekt gedrückt wird, ein positiver Wert ist, und
einen Schritt eines Dazubringens (S13) des Steuerelements (9), eine Steuerung durchzuführen, die Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall ermöglicht, in dem das Kontaktbedingungsausmaß gleich wie oder größer als der erste Referenzwert ist und die Änderung des Kontaktbedingungsausmaßes bestimmt ist, gleich wie oder größer als der zweite Referenzwert zu sein.

12. Verfahren nach Anspruch 11, wobei der zweite Referenzwert ein negativer Wert ist.

13. Verfahren nach Anspruch 11 oder 12, ferner mit einem Schritt eines Dazubringens (S13) des Steuerelements (9), eine Steuerung durchzuführen, die Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall hemmt, in dem die Änderung des Kontaktbedingungsausmaßes geringer als der zweite Referenzwert ist.

14. Verfahren nach einem der Ansprüche 11 bis 13, ferner mit
einem Schritt eines Dazubringens (S13) des Steuerelements (9), eine Steuerung durchzuführen, die Bestrahlung mit Licht von der Strahleinheit (3a) in einem Fall hemmt, in dem das Kontaktbedingungsausmaß geringer als der erste Referenzwert ist.

Revendications

1. Appareil d'irradiation de lumière comprenant :

une sonde (10) comprenant une unité d'irradiation (3a) conçue pour guider une lumière à partir d'une source de lumière (1) vers un objet, un boîtier (7) contenant l'unité d'irradiation (3a), et un capteur tactile (8) conçu pour acquérir une ampleur de condition de contact entre l'objet et le boîtier (7) ; et
un dispositif de commande (9) conçu pour com-

mander une irradiation avec une lumière venant de l'unité d'irradiation (3a) en fonction d'un niveau de l'ampleur de condition de contact et d'un changement dans l'ampleur de condition de contact,

caractérisé en ce que :

dans un cas où le changement dans l'ampleur de condition de contact qui se produit lorsque le boîtier (7) est appuyé contre l'objet est une valeur positive, le dispositif de commande (9) est conçu pour effectuer une commande qui permet une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où l'ampleur de condition de contact est supérieure ou égale à une première valeur de référence et le changement dans l'ampleur de condition de contact est supérieur ou égal à une deuxième valeur de référence.

2. Appareil d'irradiation de lumière selon la revendication 1, dans lequel le changement dans l'ampleur de condition de contact est un différentiel temporel de l'ampleur de condition de contact.

3. Appareil d'irradiation de lumière selon la revendication 1 ou 2, dans lequel le dispositif de commande (9) est conçu pour effectuer la commande à l'aide de valeurs prédéterminées comme première valeur de référence et deuxième valeur de référence.

4. Appareil d'irradiation de lumière selon la revendication 1 ou 2, dans lequel le dispositif de commande (9) est conçu pour effectuer la commande par la diminution de la première valeur de référence lorsqu'une valeur du changement dans l'ampleur de condition de contact est accrue.

5. Appareil d'irradiation de lumière selon la revendication 1 ou 2, dans lequel le dispositif de commande (9) est conçu pour effectuer la commande par la diminution de la deuxième valeur de référence lorsqu'une valeur de l'ampleur de condition de contact est accrue.

6. Appareil d'irradiation de lumière selon l'une quelconque des revendications 1 à 5, dans lequel :

le capteur tactile (8) est une jauge de contrainte disposée sur le boîtier (7), et
l'ampleur de condition de contact est une ampleur de contrainte du boîtier (7).

7. Appareil d'irradiation de lumière selon l'une quelconque des revendications 1 à 6, dans lequel la deuxième valeur de référence est une valeur négative.

8. Appareil d'irradiation de lumière selon l'une quelconque des revendications 1 à 7, dans lequel
le dispositif de commande (9) est conçu pour inhiber une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où le changement dans l'ampleur de condition de contact est inférieur à la deuxième valeur de référence.

9. Appareil d'irradiation de lumière selon l'une quelconque des revendications 1 à 8, dans lequel
le dispositif de commande (9) est conçu pour inhiber une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où l'ampleur de condition de contact est inférieure à la première valeur de référence.

10. Appareil d'acquisition d'information d'objet, comprenant :

l'appareil d'irradiation de lumière selon l'une quelconque des revendications 1 à 9 ;
une sonde à ultrasons (4) incluse dans la sonde (10), et conçue pour acquérir une onde acoustique qui est générée lorsque l'objet est irradié avec une lumière venant de l'unité d'irradiation (3a) ; et
un processeur (5) conçu pour créer une information d'image concernant une partie interne de l'objet à partir de l'onde acoustique.

11. Procédé pour commander un appareil d'irradiation de lumière comportant : une sonde (10) comprenant une unité d'irradiation (3a) qui guide une lumière à partir d'une source de lumière (1) vers un objet, un boîtier (7) contenant l'unité d'irradiation (3a), et un capteur tactile (8) acquérant une ampleur de condition de contact entre l'objet et le boîtier (7) ; et un dispositif de commande (9) commandant une irradiation avec une lumière venant de l'unité d'irradiation (3a),
le procédé étant **caractérisé en ce qu'**il comprend :

une étape consistant à amener (S12) le dispositif de commande (9) à déterminer si oui ou non l'ampleur de condition de contact est supérieure ou égale à une première valeur de référence et un changement dans l'ampleur de condition de contact est supérieur ou égal à une deuxième valeur de référence dans un cas où le changement dans l'ampleur de condition de contact qui se produit lorsque le boîtier (7) est appuyé contre l'objet est une valeur positive ; et
une étape consistant à amener (S13) le dispositif de commande (9) à réaliser une commande qui permet une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où l'ampleur de condition de contact est supérieure ou égale à la première valeur de référence et le changement dans l'ampleur de condition de contact est déterminé comme étant supérieur

ou égal à la deuxième valeur de référence.

12. Procédé selon la revendication 11, dans lequel la deuxième valeur de référence est une valeur négative.

13. Procédé selon les revendications 11 ou 12, comprenant en outre
une étape consistant à amener (S13) le dispositif de commande (9) à réaliser une commande qui inhibe une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où le changement dans l'ampleur de condition de contact est inférieur à la deuxième valeur de référence.

14. Procédé selon l'une quelconque des revendications 11 à 13, comprenant en outre
une étape consistant à amener (S13) le dispositif de commande (9) à réaliser une commande qui inhibe une irradiation avec une lumière venant de l'unité d'irradiation (3a) dans un cas où l'ampleur de condition de contact est inférieure à la première valeur de référence.

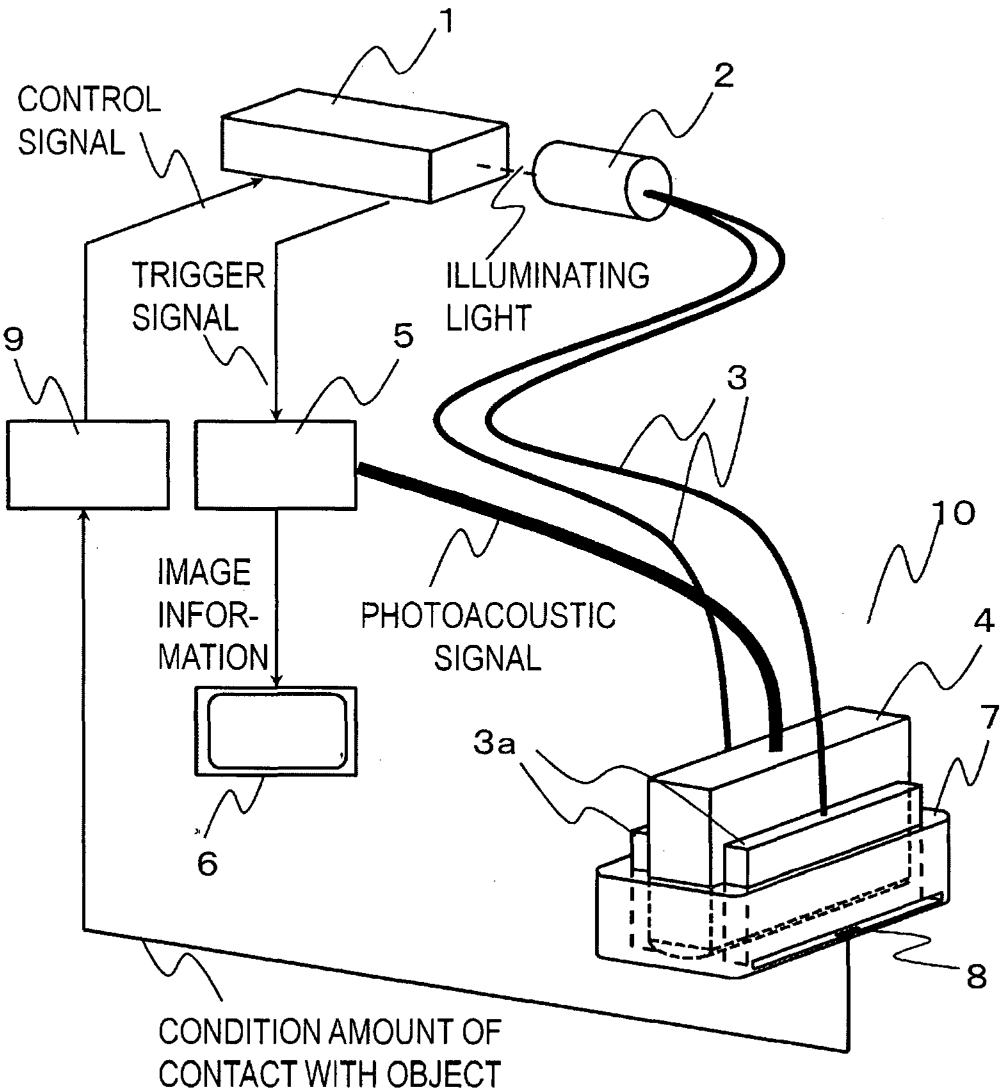
1
2
CONTROL SIGNAL
TRIGGER SIGNAL
ILLUMINATING LIGHT
9
5
3
10
IMAGE INFOR-MATION
PHOTOACOUSTIC SIGNAL
4
3a
7
6
8
CONDITION AMOUNT OF CONTACT WITH OBJECT

FIG. 1

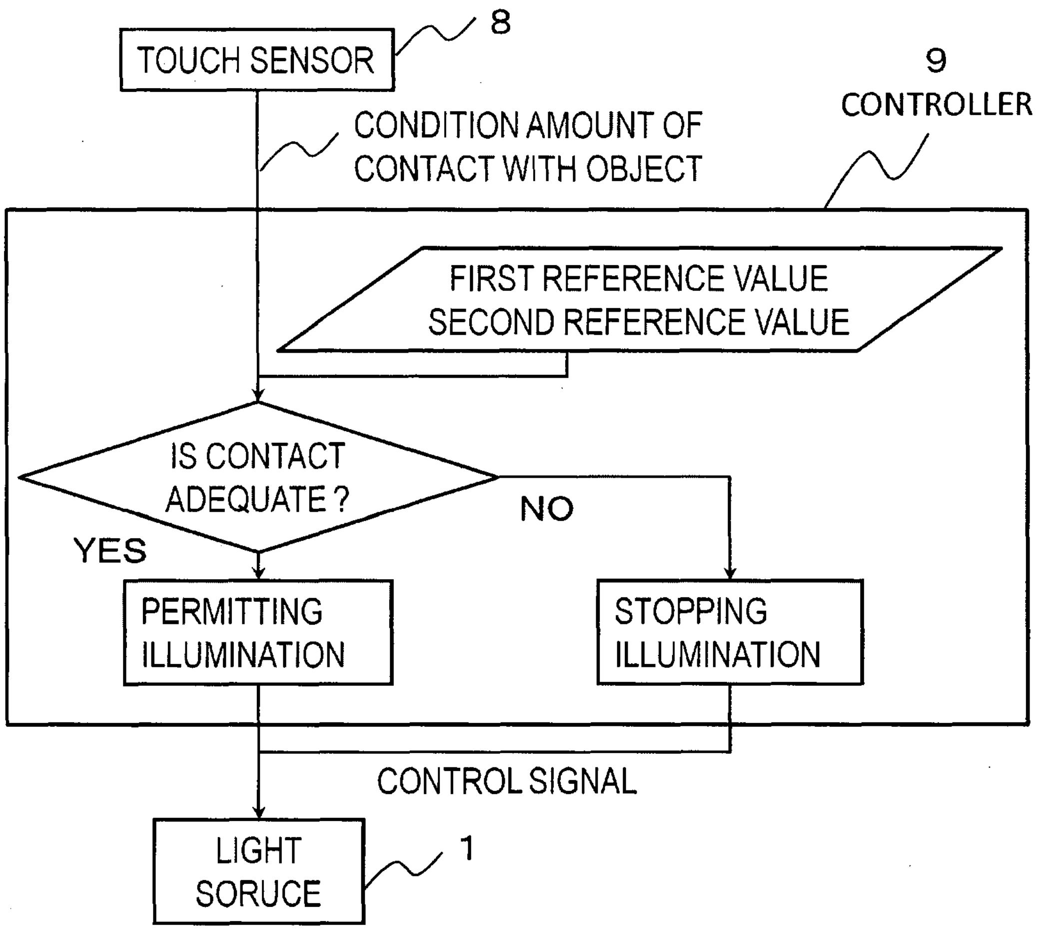
TOUCH SENSOR
8
9
CONTROLLER
CONDITION AMOUNT OF
CONTACT WITH OBJECT
FIRST REFERENCE VALUE
SECOND REFERENCE VALUE
IS CONTACT
ADEQUATE ?
NO
YES
PERMITTING
ILLUMINATION
STOPPING
ILLUMINATION
CONTROL SIGNAL
LIGHT
SORUCE
1

FIG. 2

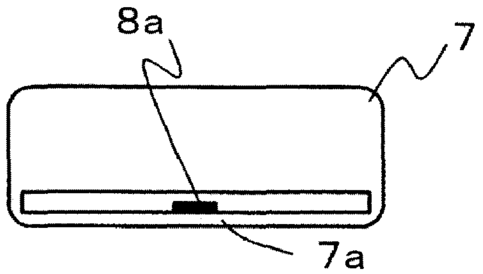

FIG. 3A

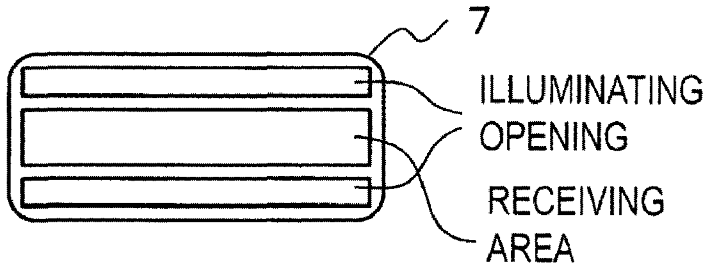

FIG. 3B

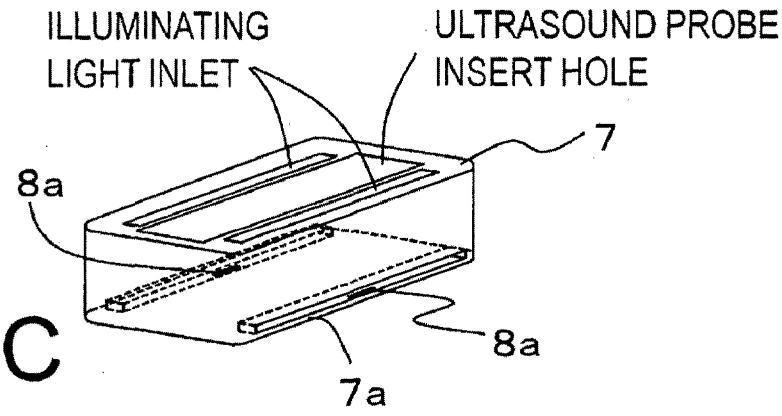

FIG. 3C

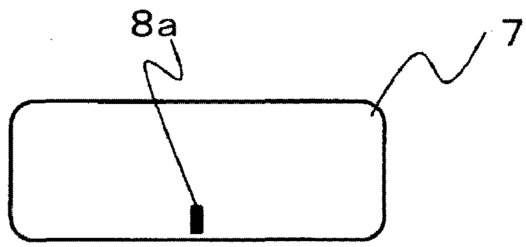

FIG. 3D

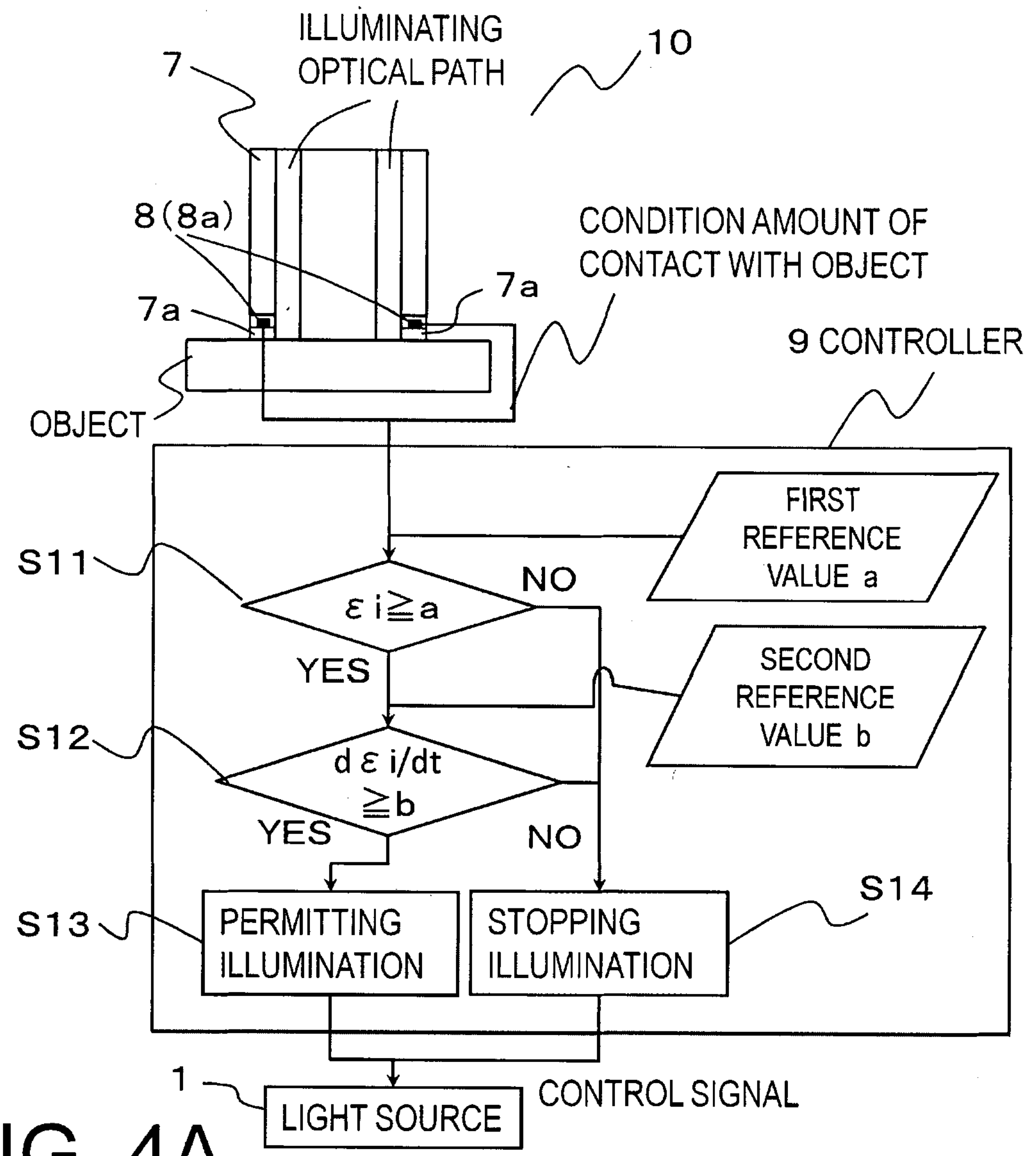
ILLUMINATING
OPTICAL PATH
7
10
8 (8a)
7a
7a
CONDITION AMOUNT OF
CONTACT WITH OBJECT
9 CONTROLLER
OBJECT
FIRST
REFERENCE
VALUE a
S11
ε i≧a
NO
YES
SECOND
REFERENCE
VALUE b
S12
d ε i/dt
≧b
YES
NO
S13
PERMITTING
ILLUMINATION
STOPPING
ILLUMINATION
S14
1
LIGHT SOURCE
CONTROL SIGNAL

FIG. 4A

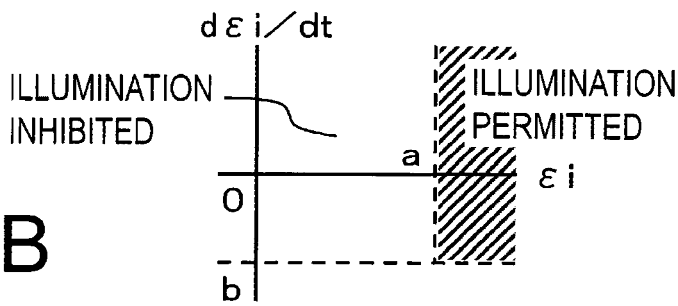
d ε i／dt
ILLUMINATION
INHIBITED
ILLUMINATION
PERMITTED
a
ε i
0
b

FIG. 4B

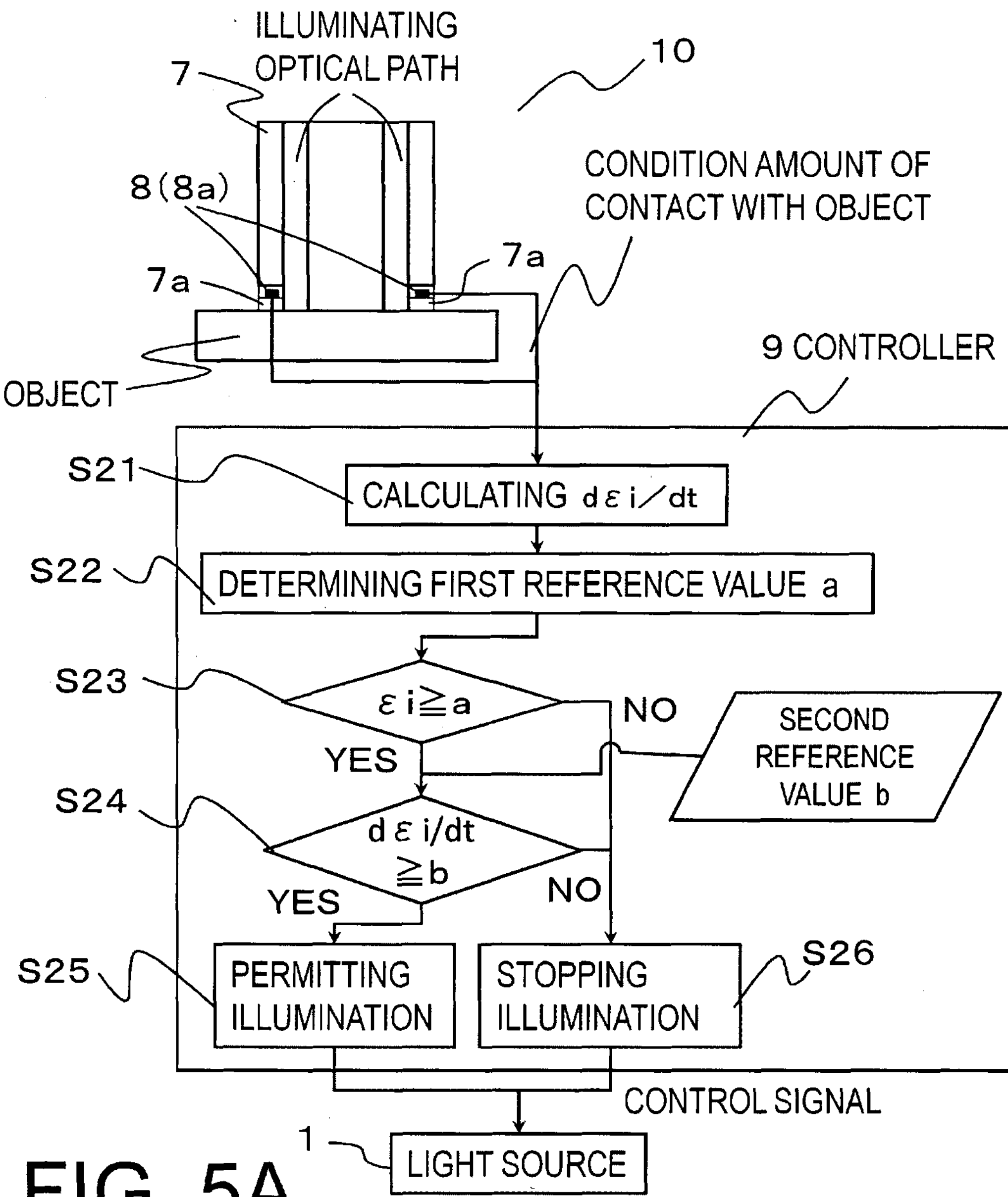
ILLUMINATING
OPTICAL PATH
7
10
8(8a)
CONDITION AMOUNT OF
CONTACT WITH OBJECT
7a
7a
OBJECT
9 CONTROLLER
S21
CALCULATING dεi/dt
S22
DETERMINING FIRST REFERENCE VALUE a
S23
εi≧a
NO
SECOND
REFERENCE
VALUE b
YES
S24
dεi/dt
≧b
YES
NO
S25
PERMITTING
ILLUMINATION
STOPPING
ILLUMINATION
S26
CONTROL SIGNAL
1
LIGHT SOURCE

FIG. 5A

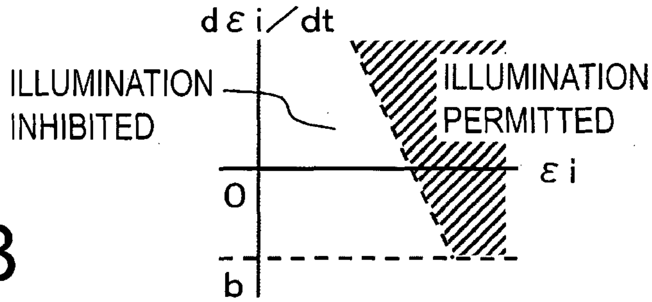
dεi/dt
ILLUMINATION
INHIBITED
ILLUMINATION
PERMITTED
εi
0
b

FIG. 5B

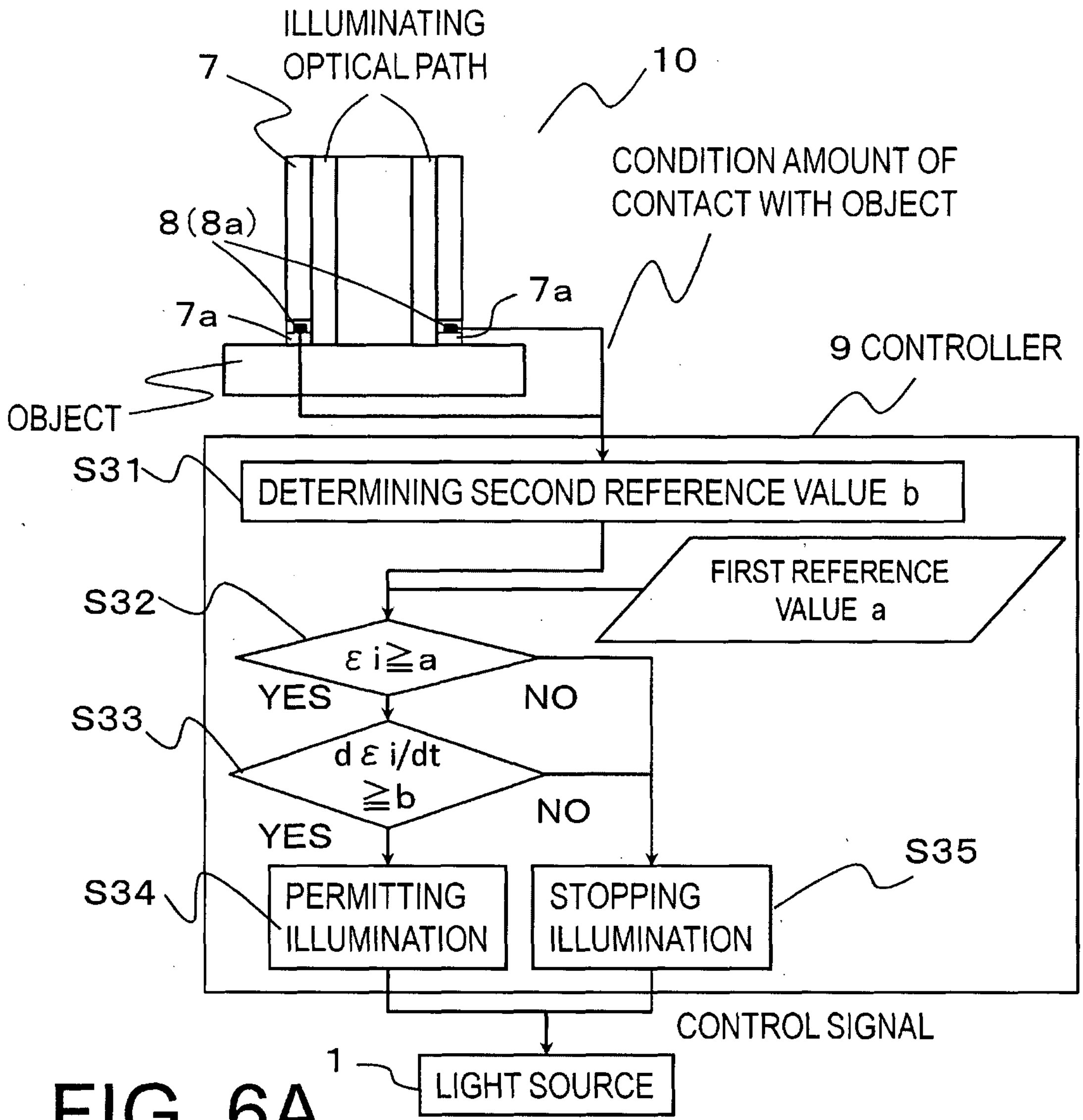
ILLUMINATING
OPTICAL PATH
7
10
CONDITION AMOUNT OF
CONTACT WITH OBJECT
8 (8a)
7a
7a
9 CONTROLLER
OBJECT
S31
DETERMINING SECOND REFERENCE VALUE b
S32
FIRST REFERENCE
VALUE a
ε i≧a
YES
NO
S33
d ε i/dt
≧b
YES
NO
S35
S34
PERMITTING
ILLUMINATION
STOPPING
ILLUMINATION
CONTROL SIGNAL
1
LIGHT SOURCE

FIG. 6A

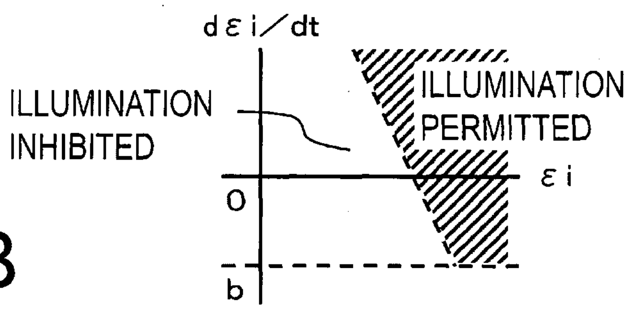
d ε i／dt
ILLUMINATION
INHIBITED
ILLUMINATION
PERMITTED
ε i
0
b

FIG. 6B

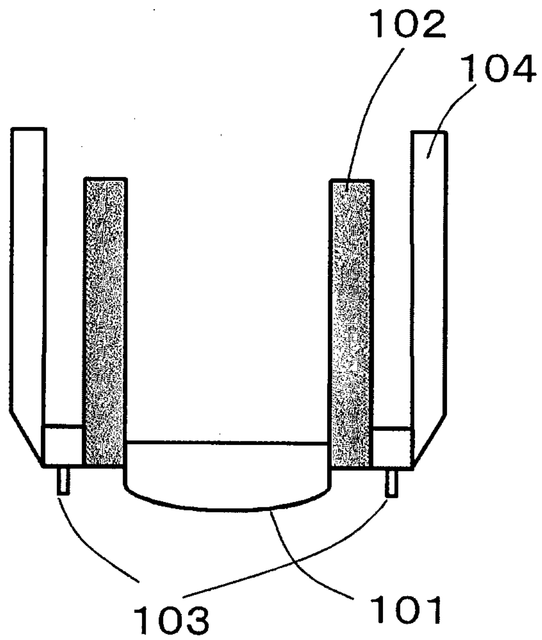

FIG. 7A

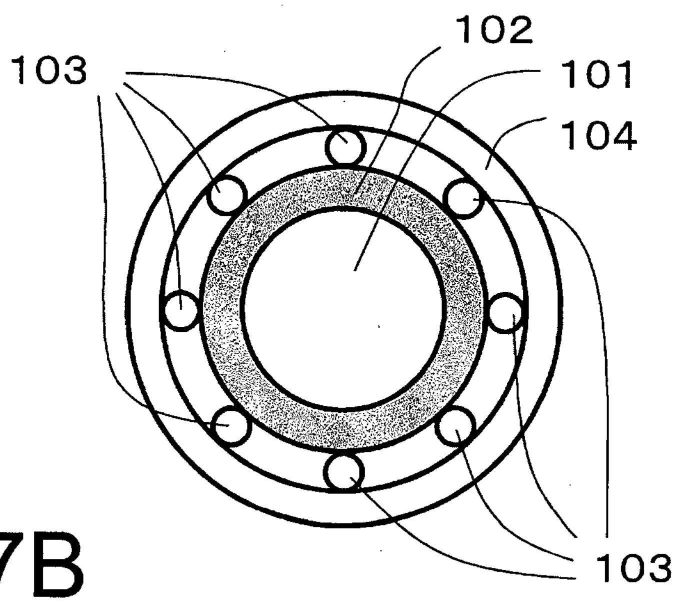

FIG. 7B

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2006525036 W **[0005]**
- WO 2004042382 A1 **[0007]**

Non-patent literature cited in the description

- **S.A. ERMILOV et al.** Development of laser optoacoustic and ultrasonic imaging system for breast cancer utilizing handheld array probes, Photons Plus Ultrasound: Imaging and Sensing 2009. *Proc. of SPIE,* 2009, vol. 7177 **[0006]**

专利名称(译)	光照射装置，其控制方法和物体信息获取装置

公开(公告)号	EP2704622B1	公开(公告)日	2019-06-12
申请号	EP2012726238	申请日	2012-04-25

[标]申请(专利权)人(译)	佳能株式会社
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
[标]发明人	TOKITA TOSHINOBU
发明人	TOKITA, TOSHINOBU
IPC分类号	A61B5/00
CPC分类号	A61B5/0095 A61B5/6843
代理机构(译)	TBK
优先权	2011102841 2011-05-02 JP
其他公开文献	EP2704622A1
外部链接	Espacenet

摘要(译)

一种光照射装置，其特征在于具有：探头，其包括将光引导到物体的照射单元，包含照射单元的壳体，以及获取物体和壳体之间的接触条件量的触摸传感器;控制器基于接触条件量的水平和接触条件量的变化来控制来自照射单元的光的照射，其中，在接触条件量等于或大于第一参考值的情况下，当壳体压在物体上时发生的接触条件量的变化是正值，控制器执行控制，当接触条件量的变化等于或大于a时，能够用来自照射单元的光照射。第二参考值。

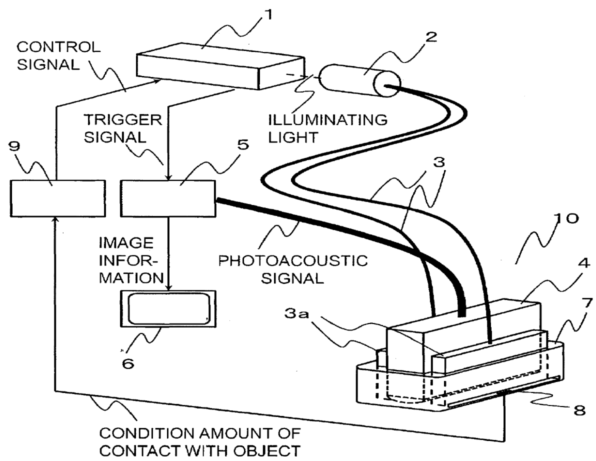

FIG. 1