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(54) **ULTRASONIC PROBE**

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(73) Proprietor: **FUJIFILM Corporation**
Tokyo 106-8620 (JP)

(72) Inventors:
- **TSUJITA, Kazuhiro**
Ashigarakami-gun
Kanagawa 258-8538 (JP)
- **ABE, Takeya**
Ashigarakami-gun
Kanagawa 258-8538 (JP)

(74) Representative: **Klunker IP Patentanwälte PartG mbB**
Destouchesstraße 68
80796 München (DE)

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Description

Technical Field

[0001] The present invention is related to an ultrasound probe. More specifically, the present invention is related to an ultrasound probe which is employed in photoacoustic imaging. Such probe is known from WO 2010/005116 A1, which discloses the features of the preamble of claim 1.

[0002] The ultrasound examination method is known as an image examination method that enables examination of the state of the interior of living organisms in a non invasive manner. Ultrasound examination employs an ultrasound probe capable of transmitting and receiving ultrasonic waves. When the ultrasonic waves are transmitted to a subject (living organism) from the ultrasound probe, the ultrasonic waves propagate through the interior of the living organisms, and are reflected at interfaces among tissue systems. The ultrasound probe receives the reflected ultrasonic waves and images the state of the interior of the subject, by calculating distances based on the amounts of time that the reflected ultrasonic waves return to the ultrasound probe.

[0003] Photoacoustic imaging, which images the interiors of living organisms utilizing the photoacoustic effect, is also known. Generally, in photoacoustic imaging, pulsed laser beams such as laser pulses are irradiated into living organisms. Biological tissue that absorbs the energy of the pulsed laser beams generates ultrasonic waves (photoacoustic signals) by volume expansion thereof due to heat. An ultrasound probe or the like detects the photoacoustic signals, and constructs photoacoustic images based on the detected signals, to enable to enable visualization of the living organisms based on the photoacoustic signals.

[0004] In photoacoustic imaging, there are cases in which a pulsed laser beam is guided from a laser light source to an ultrasound probe, and the pulsed laser beam is emitted from a light emitting section provided on the ultrasound probe. An ultrasound probe equipped with a light emitting section is disclosed in Patent Document 1, for example. In the invention of Patent Document 1, a plurality of optical fibers are employed to guide light from a laser light source to an ultrasound probe. The output ends of the optical fibers constitute the light emitting section that emits light onto a subject. In the invention of Patent Document 1, a plurality of ultrasonic transducers that transmit and/or detect ultrasonic waves are arranged in a single dimension with predetermined intervals among the transducers. The output ends of the fibers, which are light emitting portions, are arranged in the gaps among adjacent ultrasonic transducers.

[Background Art Documents]

[Patent Documents]

[0005] [Patent Document 1] Japanese Unexamined Patent Publication No. 2010-012295

Disclosure of the Invention

[0006] In the invention of Patent Document 1, the output ends of the optical fibers emit light toward the subject. Light is concentrated at the output ends of the optical fibers, which are thin, and the energy density of light at the output ends becomes high. In the invention of Patent Document 1, it is necessary to reduce the emitted amount of light, in order to emit light at an energy density that satisfies safety standards with respect to living organisms ($20mJ/cm^2$ for light having a wavelength of 500nm, for example). Because the amount of light emitted by each optical fiber is limited in this manner, it becomes necessary to increase the number of optical fibers in order to emit a sufficient amount of light while satisfying the safety standards. In addition, the optical fibers are arranged with predetermined intervals therebetween in the invention of Patent Document 1, and fluctuations arise in the amounts of light emitted at portions directly under optical fibers and portions under the spaces among adjacent optical fibers. Therefore, light cannot be uniformly emitted onto an area to be illuminated.

[0007] The present invention has been developed in view of the foregoing circumstances. It is an object of the present invention to provide an ultrasound probe having an illumination system capable of emitting a sufficient amount of light onto a wide illumination area.

[0008] To achieve the above objective, the present invention provides an ultrasound probe, comprising the features of claim 1.

[0009] The present invention adopts a configuration, wherein:
the first light guiding portion includes a light guiding path formed in a tapered shape.

[0010] The present invention may adopt a configuration, wherein:
the first light guiding portion enlarges the width of guided light in the predetermined direction at an output end of the first light guiding portion to be at least greater than the width of the input light in the predetermined direction at the light input end.

[0011] The present invention may adopt a configuration, wherein:
the second light guiding portion is curved in a direction toward the interiors of the ultrasonic transducers.

[0012] The ultrasound probe may be provided with a plurality of the optical fibers and a plurality of the light guiding means. In this case, a configuration may be adopted, wherein the plurality of the light guiding means are arranged along the predetermined direction. The plurality of light guiding means may be arranged along a direction perpendicular to the predetermined direction instead of or in addition to being arranged in the predetermined direction so as to face the ultrasonic transducers which are interposed among the plurality of light guiding means.

[0013] The plurality of optical fibers which are arranged along the predetermined direction may are optically coupled to the light input end of a single light guiding means. Two of the light guiding means are provided; and the two light guiding means are provided to face each other with the ultrasonic transducers interposed therebetween.

[0014] The light guiding means may be a slab shaped light guiding plate having a tabular core and planar cladding layers provided on both surfaces of the tabular core. Alternatively, the light guiding means may comprise a light transmitting portion having light transmitting properties and reflective members which are formed to sandwich the light transmitting portion therebetween.

[0015] In the ultrasound probe of the present invention, it is preferable for the distance from the light input end to the boundary between the first light guiding portion and the second light guiding portion to be 8mm or greater.

[0016] The ultrasound probe of the present invention may further comprise:
an adapter that transmits light and ultrasonic waves, which is mounted to the ultrasound probe so as to cover the ultrasonic wave detecting surfaces of the ultrasonic transducers and the light output end of the light guiding means.

[0017] A configuration may be adopted, wherein the ultrasound probe of the present invention further comprises:
a diffusion plate that diffuses light at the light output side of the light output end.

[0018] Alternatively, a configuration may be adopted, wherein:
a diffusing surface that diffuses light is formed on at least one of the end surface at the light output side of the second light guiding portion and the end surface of the second light guiding portion at the boundary between the first light guiding portion and the second light guiding portion.

[0019] The ultrasound probe of the present invention couples the light guiding means to the output ends of the optical fibers that guide light to a probe main body, employs the light guiding means to guide the light to the vicinity of the ultrasonic transducers, and emits light to a subject from the vicinity of the ultrasonic transducers. The light guiding means includes the fist light guiding portion and the second light guiding portion. The first light guiding portion enlarges the cross sectional area of light to be greater than that at the light input end. Thereby, light emission onto a greater area compared to a case in which light is emitted from the output ends of optical fibers is enabled, from the light output end having a larger area than the output ends of optical fibers. In addition, the energy density of light at the light output end can be decreased compared to the energy density of light at the light input end. For these reasons, the amount of light which is input into optical fibers can be increased compared to a case in which light is emitted onto a subject from the output ends of optical fibers, and light emission with a sufficient amount of light while satisfying safety standards becomes possible.

Brief Description of the Drawings

[0020]

Figure 1 is a block diagram that illustrates a photoacoustic image diagnosis apparatus that includes an ultrasound probe according to a first embodiment of the present invention.
Figure 2A is a sectional diagram of the ultrasound probe not forming part of the invention in the lateral direction.
Figure 2B is a sectional diagram of the ultrasound probe not forming part of the invention in the frontal direction.
Figure 3 is a light guiding plate viewed from the lateral surface thereof.
Figure 4A is a diagram that illustrates an example of an alternate light guiding plate.
Figure 4B is a diagram that illustrates another example of an alternate light guiding plate.
Figure 5 is a perspective view of a light guiding plate which is employed in an ultrasound probe according to a second embodiment of the present invention.
Figure 6 is an image that illustrates the distribution of light at a boundary surface between a first light guiding portion and a second light guiding portion.
Figure 7 is a graph that illustrates the relationship between the length of the first light guiding portion and the energy density of light at the boundary surface.
Figure 8 is a sectional diagram of an ultrasound probe according to a third embodiment of the present invention in the lateral direction.
Figure 9 is a sectional diagram of an ultrasound probe according to a fourth embodiment of the present invention in the lateral direction.
Figure 10 is a sectional diagram of an ultrasound probe according to a fifth embodiment of the present invention in the lateral direction.

[0021] Best Mode for Carrying out the Invention Hereinafter, embodiments of the present invention will be described in detail with reference to the attached drawings. Figure 1 illustrates a photoacoustic image diagnosis apparatus that includes an ultrasound probe according to a first embodiment of the present invention. The photoacoustic image diagnosis apparatus includes: an ultrasound probe 10; a light source unit 31; and an ultrasonic wave unit 32. The ultrasound probe 10 includes: a light emitting section that emits light onto subjects; and ultrasonic transducers which are capable at least of detecting ultrasonic waves from subjects. The light source unit 31 is a laser unit that generates pulsed laser beams, for example, and generates light to be emitted onto subjects by the ultrasound probe 10. The ultrasonic wave unit 32 generates photoacoustic images based on ultrasonic wave signals detected by the ultrasound probe 10.

[0022] The ultrasound probe 10 includes: an array portion, in which a plurality of ultrasonic transducers are arranged in a predetermined direction; and a grip portion which is held by an operator when utilizing the probe, for example. The arrangement of the ultrasonic transducers may be one dimensional or two dimensional. The ultrasound probe 10 is connected to the light source unit 31 via optical fibers 21. The optical fibers 21 include a plurality of optical fibers, for example. The pulsed laser beam generated by the light source unit is guided to the ultrasound probe 10 by the optical fibers 21, and emitted onto a subject from the light emitting section of the ultrasound probe 10. In addition, the ultrasound probe 10 is connected to the ultrasonic wave unit 32 via an electrical cable 22.

[0023] Figure 2A is a sectional view of the ultrasound probe 10 in the lateral direction, and Figure 2B is a sectional view of the ultrasound probe 10 in the frontal direction. Note that the electrical cable 22 is omitted in Figure 2A and Figure 2B. As illustrated in Figure 2A, the ultrasound probe 10 has ultrasonic transducers 12 on the surface thereof toward the side that contacts a subject. Light guiding plates (light guiding means) 11a and 11d that form light guiding paths or wave guiding paths are provided at both sides of the ultrasonic transducers 12. A light input end of the light guiding plate 11a is optically coupled with an optical fiber 21a, and a light input end of the light guiding plate 11d is optically coupled with an optical fiber 21d. Quartz fibers or hollow fibers may be employed as the optical fibers 21a and 21d. Bundled fibers, in which a plurality of optical fibers are bundled, may also be employed as the optical fibers 21a and 21d.

[0024] The surfaces of the light guiding plates 11a and 11d opposite the light input ends thereof constitute light output ends. The light output ends are provided in the vicinity of the ultrasonic transducers. The light guiding plates 11a and 11d guide light input into the light input ends thereof to the light output ends thereof. The light guiding plates 11a and 11d are slab shaped light guiding plates having tabular cores and planar cladding layers provided on both surfaces of the tabular cores. The refractive indices of the cores and the cladding layers are different. Therefore, total reflection occurs at the boundaries between the cores and the cladding layers, and light propagates therethrough with substantially no loss. Alternatively, reflective films may be coated on the tabular cores, to guide light waves, or light waves may be guided by total reflection caused due to differences in refractive indices between the cores and air. Light diffusing plates 13 are provided at the light output ends of the light guiding plates 11a and 11d. The light output surfaces of the light diffusing plates 13 constitute the light emitting section of the ultrasound probe 10.

[0025] The light guiding plates 11a and 11d face each other in a direction perpendicular to the direction in which the ultrasonic transducers 12 are arranged, with the ultrasonic transducers interposed therebetween. As illustrated in Figure 2B, three light guiding plates 11a through 11c that include the light guiding plate 11a are provided on the side of the ultrasonic transducers 12 at which the light guiding plate 11a is provided. The light guiding plates 11a through 11c are arranged along the direction in which the ultrasonic transducers 12 are arranged. An optical fiber 21b is optically coupled with the light guiding plate 11b, and an optical fiber 21c is optically coupled with the light guiding plate 11c. Although not illustrated in Figure 2B, three light guiding plates that include the light guiding plate lid are provided on the ultrasonic transducers 12 at which the light guiding plate 11d is provided. These three light guiding plates are also arranged along the direction in which the ultrasonic transducers 12 are arranged, and are optically coupled to corresponding optical fibers.

[0026] Figure 3 is a diagram that illustrates a light guiding plate 11. In Figure 3, the light guiding plate 11 is illustrated as viewed from the lateral direction (the same direction as Figure 2A). The light guiding plate 11 has: a first light guiding portion 41 that includes a light input end 51; and a second light guiding portion 42 that includes a light output end 52. The first light guiding portion 41 guides light input into the light input end 51 toward the light output end 52. The second light guiding portion 42 guides the light guided thereto by the first light guiding portion 41 to the light output end 52.

[0027] The first light guiding portion 41 is formed by a glass material. The first light guiding portion 41 includes a light guiding path which is formed as a tapered shape, for example. The first light guiding portion 41 enlarges the cross sectional area of light at a light output end of the first light guiding portion 41 compared to the cross sectional area of light input at the light input end 51. For example, the first light guiding portion 41 enlarges the width of guided light in the direction in which the ultrasonic transducers are arranged at the output end of the first light guiding portion 41 to be at least greater than the width of the input light in the direction in which the ultrasonic transducers are arranged at the light input end 51. Meanwhile, the second light guiding portion 42 is formed by a resin material, such as acryl. The second light guiding portion 42 emits light toward a subject from the light output end 52.

[0028] Light output by the light source unit 31 (Figure 1) propagates through the optical fibers 21 and is guided to the ultrasound probe 10. The optical fibers 21 include a plurality of optical fibers, and each optical fiber is optically coupled with the light input end 51 (Figure 3) of a light guiding plate 11 corresponding thereto. The light that enters the light guiding plates 11 through the light input ends 51 propagates through the first light guiding portions 41, which are formed into tapered shapes, while enlarging the range of light. The light which has passed through the first light guiding portions 41 enter the second light guiding portions 42, and is guided to the light output ends 52. The guided light is emitted onto the subject from the light output end 52 via the light diffusing plates 13 (Figure 2A and Figure 2B) .

[0029] In the present embodiment, the light guiding plates 11 are coupled to the output ends of the optical fibers that guide light to the probe main body, the light guiding plates 11 are employed to guide light to the vicinity of the ultrasonic transducers, and light is emitted onto the subject from the vicinity of the ultrasonic transducers, instead of emitting light directly toward the subject from the output ends of the optical fibers . The light guiding plates 11 include the first light guiding portions 41 and the second light guiding portions 42. The first light guiding portions 41 enlarge the cross sectional area of light to be greater than that at the light input ends 51. Therefore, light can be emitted from a greater area compared to a case in which light is emitted from the output ends of optical fibers. In addition, the energy density of light at the output side can be reduced compared to the energy density of light at the light input ends 51 for the amount of increase in the light emission area. For this reason, the amount of light caused to enter the optical fibers can be increased compared to a case in which light is emitted onto a subject from the output ends of optical fibers, and a sufficient amount of light can be emitted while satisfying safety standards.

[0030] In the present embodiment, the light guiding plates 11 increase the width of light in the direction in which the ultrasonic transducers 12 are arranged. If light is emitted from optical fibers without employing the light guiding plates 11, the light will be emitted discretely in the direction in which the ultrasonic transducers are arranged. Therefore, portions directly under the optical fibers will be illuminated with large amounts of light, while portions among adjacent optical fibers will be illuminated with smaller amounts of light. Because the present embodiment increases the width of light in the direction in which the ultrasonic transducers 12 are arranged, light can be emitted over a wide range in the direction in which the ultrasonic transducers 12 are arranged from a single optical fiber. For this reason, fluctuations in the amounts of light emitted in the direction that the ultrasonic transducers 12 are arranged are resolved compared to cases in which optical fibers directly emit light. Therefore, light can be uniformly emitted onto a wide area to be illuminated.

[0031] Here, in order to increase the amount of light which is output from the light output ends 52, it is necessary to cause a greater amount of light to enter the optical fibers, and the energy density increases at the light output ends of the optical fibers and at the light input ends 51. If the energy density at these locations becomes great, there is a possibility that the light input ends 51 will be damaged. Therefore, the first light guiding portions 41 that include the light input ends 51 are formed by a glass material in the present embodiment. Damage to the light input ends 51 (the first light guiding portions 41) can be prevented even when light enters the light input ends 51 at a high energy density, by employing glass as the material thereof. Meanwhile, the second light guiding portions 42 are formed by a resin material in the present embodiment. Resin materials are advantageous in that they are easily processed.

[0032] Figure 4A and Figure 4B illustrate an example of a modified light guiding plate 11. In Figure 4A, the light guiding plate 11 is illustrated as viewed from the lateral direction (the same direction as Figure 2A). In Figure 4B, the light guiding plate 11 is illustrated as viewed from the frontal direction (the same direction as Figure 2B). As illustrated in Figure 4A, the second light guiding portion 42 is curved in this example. In addition, as illustrated in Figure 4B, the second light guiding portion 42 enlarges light in the direction that the ultrasonic transducers are arranged toward the light output end 52. In this case, an advantageous effect that uniformity of light at the light output ends 52 is improved can be expected, compared to a case in which the second light guiding portion 42 is formed in a linear shape (a rectangular plate) as illustrated in Figure 2B. The first light guiding portion 41 that includes the light input end 51 is the same as that illustrated in Figure 3.

[0033] The second light guiding portion 42 of the light guiding plate 11 illustrated in Figure 4A and Figure 4B is curved toward the interior of the ultrasonic transducers within a range that satisfies conditions for total reflection, for example. When light is emitted toward a subject from the sides of the ultrasonic transducers as illustrated in Figure 2B, there are cases in which it is difficult for light to reach the portion directly under the ultrasonic transducers 12. Employing the light guiding plates 11 which are curved toward the interior of the ultrasonic transducers as illustrated in Figure 4A to output light in oblique directions from the light output ends 52 facilitates light emission to the portion directly under the ultrasonic transducers 12 from the light guiding plates provided at the sides of the ultrasonic transducers 12. Such three dimensional processing is easy because the second light guiding portions 42 are formed by a resin material.

[0034] Note that in Figure 2A and Figure 2B, a plurality of combinations of optical fibers and light guiding plates are provided. However, it is not necessary for a plurality of optical fibers and a plurality of light guiding plates to be provided. For example, a configuration may be adopted, wherein a single optical fiber guides light from the light source unit 31 (Figure 1) to the ultrasound probe 10, and a single light guiding plate 11 provided within the ultrasound probe 10 spreads the width of the light within a range in which the ultrasonic transducers 12 are arranged. In addition, it is not necessary for the plurality of light guiding plates to be provided at both sides of the ultrasonic transducers 12. For example, a configuration may be adopted, wherein a plurality of light guiding plates provided along the arrangement direction of the ultrasonic transducers 12 at a single side of the ultrasonic transducers emit light from the single side of the ultrasonic transducers 12.

[0035] Next, a second embodiment of the present invention will be described. Figure 5 illustrates a light guiding plate 60 which is employed in an ultrasound probe according to the second embodiment of the present invention. The light guiding plate 60 of the present embodiment has a first light guiding portion 61 formed by glass and a second light guiding portion 62 formed by resin, in the same manner as the light guiding plate 11 of the first embodiment. In the first embodiment, the three optical fibers 21a through 21c and the three light guiding plates 11a through 11c were coupled to each other, respectively (Figure 2B). In the present embodiment, a plurality of optical fibers 21 are optically coupled to the light input end of a single light guiding plate 60.

[0036] In Figure 5, the longitudinal direction of the light guiding plate 60 in Figure 5 corresponds to the direction in which the ultrasonic transducers 12 (Figure 2A and Figure 2B) are arranged. Four optical fibers 21 are arranged at equidistant intervals along the arrangement direction of the ultrasonic transducers, for example. The four optical fibers 21 are optically coupled to the light input end of the light guiding plate. The ultrasound probe may be equipped with two light guiding plates 60, which are provided to face each other with the ultrasonic transducers interposed therebetween.

[0037] The light guiding plate 60 (the first light guiding portion 61 and the second light guiding portion 62) is formed to be of a parallelepiped shape, for example. The length of the first light guiding portion 61 in the direction in which light is guided is designated as A, and the length of the second light guiding portion 62 in the direction in which light is guided is designated as B. The first light guiding portion 61 guides light that enters thereinto from the side of the light input end to the second light guiding portion 62, while enlarging the cross sectional area of the light. For example, if the length of the first light guiding portion 61 is 11mm, the fiber core diameters of the optical fibers 21 are 0.3mm, and the fiber light output has a NA (Numerical Aperture) equivalent to 0.22, the first light guiding portion 61 enlarges the cross sectional area of the light from φ0.3mm=$7 \cdot 10^{-4}$cm^2 to φ2.8mm=0.062cm^2. The second light guiding portion 62 guides the light guided thereto by the first light guiding portion 61 to the light output end thereof in the vicinity of the ultrasonic transducers.

[0038] Figure 6 is an image that illustrates the distribution of light at a boundary surface between the first light guiding portion 61 and the second light guiding portion 62. A light guiding plate 60 having a cross section with a width of 40mm and a height of 3mm will be considered. It is assumed that the fiber core diameters of the optical fibers 21 are 0.3mm, and the fiber light output has a NA (Numerical Aperture) equivalent to 0.22. In addition, it is assumed that the refractive index of the first light guiding portion 61 is 1.45. Figure 6 is an image that illustrates the distribution of light in the case that the length A of the first light guiding portion 61 is 12mm. In other words, Figure 6 illustrates the distribution of light at a cross section 12mm remote from the light input end of the light guiding plate 60. The black portions in the image correspond to portions where the light is weak, and the white portions correspond to portions where the light is strong.

[0039] Figure 7 is a graph that illustrates the relationship between the distance from the light input and the energy density of light. The horizontal axis of the graph represents the distance from the light input end to the boundary surface between the first light guiding portion 61 and the second light guiding portion 62, that is, the length of the first light guiding portion 61. The vertical axis represents the maximum value of the energy density of light (for example, the energy density at a portion in which the average energy density is highest within a 1mm·1mm region) at the boundary surface between the first light guiding portion 61 and the second light guiding portion 62. Cases were considered in which the energy input to the optical fiber is 12.5mJ and 10mJ. Referring to Figure 7, it can be understood that the maximum values of the energy density of light become greater as the length of the first light guiding portion 61 becomes shorter. This is because the cross sectional area of light is smaller as the length of the first light guiding portion 61 is shorter.

[0040] Here, if the energy density of light that enters the second light guiding portion 62 is excessively high, there is a possibility that the resin, polycarbonate for example, that constitutes the second light guiding portion 62 will be damaged. It is known that resin will be damaged if light having an energy density of 180mJ/cm^2 or greater enters thereinto, based on the heat resistance standards (temperature, etc.) of polycarbonate and experimental results. Referring to Figure 7, cases in which the energy density at the boundary surface between the first light guiding portion 61 and the second light guiding portion 62 exceeds 180mJ/cm^2 (threshold level) occur when the length of the first light guiding portion 61 is less than 11mm in the case that the energy input into the optical fibers is 12.5mJ, and when the length of the first light guiding portion 61 is less than 8mm in the case that the energy input into the optical fibers is 10mJ. It is desirable for the length of the first light guiding portion 61 to be 8mm or greater, because energy which is practically capable of being input to the optical fibers is approximately 10mJ. With respect to the length of the second light guiding portion 62, this length is not particularly limited, and may be selected as appropriate according to targets of measurement, etc.

[0041] A plurality of optical fibers are coupled to a single light guiding plate 60 in the present embodiment. Even in such a case, the same advantageous effects as those obtained by the first embodiment are obtained, because the light guiding plate 60 includes the first light guiding portion 61 formed by glass and the second light guiding portion 62 formed by resin. In addition, the energy density of light that enters the second light guiding portion

62 can be made lower than the threshold level by setting ht length of the first light guiding portion 61 to be 8mm or greater, thereby preventing damage to the second light guiding portion 62.

[0042] Next, a third embodiment of the present invention will be described. Figure 8 is a sectional diagram of an ultrasound probe 10 according to the third embodiment of the present invention in the lateral direction. The ultrasound probe 10 is equipped with two light guiding plates 70 that face each other with the ultrasonic transducers 12 interposed therebetween. The light guiding plates 70 have first light guiding portions 71 formed by glass and second light guiding portions 72 formed by resin. The first light guiding portions 71 correspond to the first light guiding portion 41 illustrated in Figure 3 or the first light guiding portion 61 illustrated in Figure 5. The second light guiding portions 72 correspond to the second light guiding portion 42 illustrated in Figure 3 or the second light guiding portion 62 illustrated in Figure 5. The second light guiding portions 72 are curved toward the ultrasonic transducers.

[0043] In the present embodiment, the ultrasound probe 10 is further equipped with an adapter 14, which is a resin gel adapter or the like. The adapter 14 has light transmitting properties and ultrasonic wave transmitting properties. The adapter 14 is mounted onto the ultrasound probe 10 so as to cover ultrasonic wave detecting surfaces of the ultrasonic transducers 12 and the light output surfaces of the light guiding plates 70. Light guided by the light guiding plates 70 is emitted onto a subject via the adapter 14. Light emission onto regions directly under the ultrasonic transducers, which are difficult to emit light onto, is facilitated by use of the adapter 14. The ultrasound probe of the third embodiment is the same as those of the first and second embodiments in the remaining points.

[0044] Next, a fourth embodiment of the present invention will be described. Figure 9 is a sectional diagram of an ultrasound probe 10 according to the fourth embodiment of the present invention in the lateral direction. The ultrasound probe 10 is equipped with two light guiding plates 80 that face each other with the ultrasonic transducers 12 interposed therebetween. The light guiding plates 80 have first light guiding portions 81 formed by glass and second light guiding portions 82 formed by resin. The first light guiding portions 81 correspond to the first light guiding portion 41 illustrated in Figure 3 or the first light guiding portion 61 illustrated in Figure 5. The second light guiding portions 82 correspond to the second light guiding portion 42 illustrated in Figure 3 or the second light guiding portion 62 illustrated in Figure 5.

[0045] Light diffusing surfaces are formed at the end surfaces of the second light guiding portions 82 toward the light output sides thereof. For example, protrusions and recesses that diffuse light are formed on the end surfaces of the second light guiding portions 82 toward the light output sides thereof. Light diffusing surfaces may be formed at the end surfaces of the second light guiding portions 82 toward the light input sides thereof (toward the boundaries thereof with the first light guiding portions 81) instead of or in addition to the light diffusing surfaces on the end surfaces toward the light output sides thereof. The need to provide separate light diffusing plates 13 (Figure 2A and Figure 2B) is obviated, by imparting the second light guiding portions 82 with the function of diffusing light.

[0046] In addition, in the present embodiment, the light guiding plates 80 are provided at predetermined angles with respect to the ultrasonic wave detecting surfaces of the ultrasonic transducers 12 such that the light output from the light guiding plates 80 will propagate in directions toward the interiors of the ultrasonic transducers 12, instead of forming the second light guiding portions to be curved toward the interiors of the ultrasonic transducers. By providing the light guiding plates 80 such that they are inclined in this manner, light can be emitted toward a direction directly under the ultrasonic transducers from the light output surfaces of the light guiding plates 80.

[0047] Next, a fifth embodiment of the present invention will be described. Figure 10 is a sectional diagram of an ultrasound probe 10 according to the fifth embodiment of the present invention in the lateral direction. The ultrasound probe 10 is equipped with two light guiding plates 90 that face each other with the ultrasonic transducers 12 interposed therebetween. The light guiding plates 90 have first light guiding portions 91 formed by glass and second light guiding portions 92 formed by resin. The first light guiding portions 91 correspond to the first light guiding portion 41 illustrated in Figure 3 or the first light guiding portion 61 illustrated in Figure 5. The second light guiding portions 92 correspond to the second light guiding portion 42 illustrated in Figure 3 or the second light guiding portion 62 illustrated in Figure 5. Light diffusing surfaces may be formed on at least one of the end surfaces of the second light guiding portions 92 toward the light input sides and the light output sides thereof.

[0048] Each of the light guiding plates 90 includes a light transmitting portion that has light transmitting properties and reflecting members which are formed to sandwich the light transmitting portion therebetween. In Figure 10, the first light guiding portions 91 correspond to the light transmitting portions, and reflective films 93 correspond to the reflecting members. Inorganic materials, aluminum, etc. may be employed as the material of the reflective films 93. The reflective films 93 are provided on the first light guiding portions 91 in Figure 10. An alternate configuration, in which the reflective films 93 are provided on the second light guiding portions 92, may be adopted. Another alternate configuration, in which a material having a lower refractive index than that of the core light transmitting portions is provided to sandwich the core instead of sandwiching the core with the reflective members, may also be adopted. An organic material such as CYTOP may be employed as the material having the lower refractive index. Even if these configurations are adopted, light that enters the light guiding plates from the optical fiber can be prevented from leaking out from the lateral surfaces of the light guiding plates.

[0049] The present invention has been described above based on preferred embodiments. However, the ultrasound probe of the present invention is not limited to the above embodiments. Various changes and modifications to the above embodiments are included within the scope of the present invention.

Claims

1. An ultrasound probe (10), comprising:

    a probe main body;
    a plurality of ultrasonic transducers (12) which are arranged along a predetermined direction;
    an optical fiber (21) that guides light emitted from a light source (31) to said probe main body; and
    at least two light guiding means (11, 60, 70, 80, 90) provided to face each other with the ultrasonic transducers interposed therebetween, adapted to guide light from a light input end which is optically coupled with the optical fiber (21) to a light output end (52) provided in the vicinity of the ultrasonic transducers (12);
    the light guiding means (11, 60, 70, 80, 90) including:

        a first light guiding portion (41) formed by a glass material that includes the light input end (51) and guides light from the light input end (51) toward the light output end (52) and that enlarges the cross sectional area of input light at the light input end (51) at an output end of the first light guiding portion (41); and
        a second light guiding portion (42) formed by a resin material that includes the light output end (52), guides light guided by the first light guiding portion (41) to the light output end (52), and emits light from the light output end toward a subject,

    characterized in that the light guiding means (11, 60, 70, 80, 90) is provided inclined at a predetermined angle with respect to ultrasonic wave detecting surfaces of the ultrasonic transducers (12) such that the light output from the light guiding means will propagate in directions toward the ultrasonic transducers (12), and that the first light guiding portion (41) includes a light guiding path formed in a tapered shape.

2. An ultrasound probe (10) as defined in either one of Claim 1, wherein:

    the first light guiding portion (41) enlarges the width of guided light in the predetermined direction at an output end of the first light guiding portion (41) to be at least greater than the width of the input light in the predetermined direction at the light input end (51).

3. An ultrasound probe (10) as defined in any one of Claims 1 and 2, wherein:

    the second light guiding portion (42) is curved in a direction toward the interiors of the ultrasonic transducers (12).

4. An ultrasound probe (10) as defined in any one of Claims 1 through 3, wherein:

    a plurality of the optical fibers (21) and a plurality of the light guiding means (11) are provided; and
    the plurality of the light guiding means (11) are arranged along the predetermined direction.

5. An ultrasound probe (10) as defined in Claim 4, wherein:

    the plurality of light guiding means are arranged along a direction perpendicular to the predetermined direction instead of or in addition to being arranged in the predetermined direction so as to face the ultrasonic transducers (12) which are interposed among the plurality of light guiding means (11).

6. An ultrasound probe (10) as defined in any one of Claims 1 through 3, wherein:

    a plurality of the optical fibers (21) are provided; and
    the plurality of optical fibers (21) which are arranged along the predetermined direction are optically coupled to the light input end of a single light guiding means (11,60).

7. An ultrasound probe (10) as defined in any one of Claims 1 through 6, wherein:

    the light guiding means (11) is a slab shaped light guiding plate having a tabular core and planar cladding layers provided on both surfaces of the tabular core.

8. An ultrasound probe (10) as defined in any one of Claims 1 through 6, wherein:

    the light guiding means (11, 90) comprises a light transmitting portion (91) having light transmitting properties and reflective members (93) which are formed to sandwich the light transmitting portion (91) therebetween.

9. An ultrasound probe (10) as defined in any one of Claims 1 through 8, wherein:

the distance from the light input end (51) to the boundary between the first light guiding portion (41) and the second light guiding portion (42) is 8mm or greater.

10. An ultrasound probe (10) as defined in any one of Claims 1 through 8, further comprising:

an adapter (14) that transmits light and ultrasonic waves, which is mounted to the ultrasound probe (10) so as to cover the ultrasonic wave detecting surfaces of the ultrasonic transducers (12) and the light output end of the light guiding means (11, 70).

11. An ultrasound probe (10) as defined in any one of Claims 1 through 10, further comprising:

a diffusion plate (13) that diffuses light at the light output side of the light output end (52).

12. An ultrasound probe (10) as defined in any one of Claims 1 through 10, wherein:

a diffusing surface that diffuses light is formed on at least one of the end surface at the light output side of the second light guiding portion (42, 82) and the end surface of the second light guiding portion (42, 82) at the boundary between the first light guiding portion (41, 81) and the second light guiding portion (42, 82).

Patentansprüche

1. Ultraschallsonde (10), umfassend:

einen Sondenhauptkörper;
mehrere Ultraschallwandler (12), die entlang einer vorbestimmten Richtung angeordnet sind;
eine optische Faser (21), die von einer Lichtquelle (31) emittiertes Licht zu dem Sondenhauptkörper leitet; und
mindestens zwei Lichtleiteinrichtungen (11, 16, 17, 18, 19), einander gegenüberliegend mit den dazwischen befindlichen Ultraschallwandlern vorgesehen, ausgebildet zum Leiten von Licht von einem Lichteintrittsende, das optisch mit der optischen Faser (21) gekoppelt ist, zu einem Lichtaustrittsende (52) in der Nähe der Ultraschallwandler (12);

wobei die Lichtleiteinrichtung (11, 60, 70, 80, 90) enthält:

einen ersten Lichtleitabschnitt (41) aus einem Glasmaterial, der das Lichteintrittsende (51) enthält und das Licht von dem Lichteintrittsende (51) in Richtung des Lichtaustrittsendes (52) leitet, und der die Querschnittsfläche des eingetretenen Lichts an dem Lichteintrittsende (51) an einem Ausgangsende des ersten Lichtleitabschnitts (41) vergrößert; und
einen zweiten Lichtleitabschnitt (42) aus einem Harzmaterial, der das Lichtaustrittsende (52) enthält und von dem ersten Lichtleitabschnitt (41) geführtes Licht zu dem Lichtaustrittsende (52) leitet und das aus dem Lichtaustrittsende kommende Licht in Richtung eines Objekts emittiert,

dadurch gekennzeichnet, dass die Lichtleiteinrichtung (11, 60, 70, 80, 90) unter einem vorbestimmten Winkel bezüglich Ultraschallwellen-Detektorflächen der Ultraschallwandler (12) derart geneigt angeordnet ist, dass das von der Lichtleiteinrichtung ausgegebene Licht sich in Richtungen zu den Ultraschallwandlern (12) ausbreitet, und dass
der erste Lichtleitabschnitt (41) einen in einer sich verjüngenden Form ausgebildeten Lichtleitweg enthält.

2. Ultraschallsonde (10) nach Anspruch 1, bei der:

der erste Lichtleitabschnitt (41) die Breite des geführten Lichts in der vorbestimmten Richtung am Ausgangsende des ersten Lichtleitabschnitts (41) so vergrößert, dass sie zumindest größer ist als die Breite des Eingangslichts in der vorbestimmten Richtung an dem Lichteintrittsende (51).

3. Ultraschallsonde (10) nach einem der Ansprüche 1 und 2, bei der:

der zweite Lichtleitabschnitt (42) in einer Richtung zu den Innenbereichen der Ultraschallwand (12) gekrümmt ist.

4. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 3, bei der:

mehrere optische Fasern (41) und mehrere Lichtleiteinrichtungen (11) vorgesehen sind; und
die mehreren Lichtleiteinrichtungen (11) entlang der vorbestimmten Richtung angeordnet sind.

5. Ultraschallsonde (10) nach Anspruch 4, bei der:

die mehreren Lichtleiteinrichtungen entlang einer Richtung rechtwinklig zu der vorbestimmten Richtung angeordnet sind, und zwar anstelle von oder zusätzlich zu ihrer Anordnung in der vorbestimmten Richtung gegenüber den Ultraschallwandlern (12), die sich zwischen den mehreren Lichtleiteinrichtungen (11) befinden.

6. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 3, bei der:

mehrere optische Fasern (21) vorgesehen sind; und
die mehreren optischen Fasern (21), die entlang der vorbestimmten Richtung angeordnet sind, optisch mit dem Lichteintrittsende einer einzelnen Lichtleiteinrichtung (11, 60) gekoppelt sind.

7. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 6, bei der:

die Lichtleiteinrichtung (11) eine blockförmige Lichtleitplatte mit einem rohrförmigen Kern und planaren Mantelschichten auf beiden Seiten des rohrförmigen Kerns ist.

8. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 6, bei der:

die Lichtleiteinrichtung (11, 90) einen Lichtsendeabschnitt (91) mit Lichtsendeeigenschaften und reflektierende Elemente (93), welche den Lichtsendeabschnitt (91) zwischen sich einfassen, aufweist.

9. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 8, bei der:

der Abstand von dem Lichteintrittsende (51) zu der Grenze zwischen dem ersten Lichtleiterabstand (41) und dem zweiten Lichtleiterabschnitt (42) acht Millimeter oder mehr beträgt.

10. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 8, weiterhin umfassend:

einen Adapter (14), welcher Licht und Ultraschallwellen überträgt, der an der Ultraschallsonde (10) angebracht ist, um die Ultraschallwellen-Detektorflächen der Ultraschallwandler (12) und das Lichtaustrittsende der Lichtleiteinrichtung (11, 70) abzudecken.

11. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 10, weiterhin umfassend:

eine Diffusionsplatte (13), die Licht an der Lichtaustrittsseite des Lichtaustrittsendes (52) diffundiert.

12. Ultraschallsonde (10) nach einem der Ansprüche 1 bis 10, bei der:

eine lichtdiffundierende Diffusionsfläche an mindestens einer von der Stirnfläche der Lichtausgangsseite des zweiten Lichtleitabschnitts (42, 82) und der Stirnfläche des zweiten Lichtleitabschnitts (42, 82) an der Grenze zwischen dem ersten Lichtleitabschnitt (41, 81) und dem zweiten Lichtleitabschnitt (42, 82) ausgebildet ist.

Revendications

1. Sonde ultrasonore (10), comprenant :

un corps principal de sonde ;
une pluralité de transducteurs ultrasonores (12), laquelle est agencée le long d'une direction prédéterminée ;
une fibre optique (21), laquelle guide la lumière émise à partir d'une source lumineuse (31) vers ledit corps principal de sonde, et
au moins deux moyens de guidage de lumière (11, 60, 70, 80, 90) prévus pour être l'un en face de l'autre, les transducteurs ultrasonores étant intercalés entre eux, aptes à guider la lumière d'une extrémité d'entrée de lumière, laquelle est couplée par voie optique avec la fibre optique (21), jusqu'à une extrémité de sortie de lumière (52) prévue dans le voisinage des transducteurs ultrasonores (12) ;
les moyens de guidage de lumière (11, 60, 70, 80, 90) incluant :

une première portion de guidage de lumière (41) formée par un matériau de verre, laquelle inclut l'extrémité d'entrée de lumière (51), guide la lumière de l'extrémité d'entrée de lumière (51) vers l'extrémité de sortie de lumière (52), et agrandit la section transversale de la lumière d'entrée sur l'extrémité d'entrée de lumière (51) sur une extrémité de sortie de la première portion de guidage de lumière (41), et
une seconde portion de guidage de lumière (42) formée par un matériau de résine, laquelle inclut l'extrémité de sortie de lumière (52), guide la lumière guidée par la première portion de guidage de lumière (41) jusqu'à l'extrémité de sortie de lumière (52), et émet une lumière de l'extrémité de sortie de lumière vers un sujet,

caractérisée en ce que les moyens de guidage de lumière (11, 60, 70, 80, 90) sont fournis inclinés avec un angle prédéterminé par rapport

à des surfaces de détection d'ondes ultrasonores des transducteurs ultrasonores (12), de telle sorte que la lumière produite à partir des moyens de guidage de lumière se propage dans des directions allant vers les transducteurs ultrasonores (12), et **en ce que**
la première portion de guidage de lumière (41) inclut un trajet de guidage de lumière présentant une forme à amincissement progressif.

2. Sonde ultrasonore (10) selon la revendication 1, dans laquelle :

la première portion de guidage de lumière (41) agrandit la largeur de la lumière guidée dans la direction prédéterminée sur une extrémité de sortie de la première portion de guidage de lumière (41) de manière à ce que celle-ci soit plus grande que la largeur de la lumière d'entrée dans la direction prédéterminée sur l'extrémité d'entrée de lumière (51).

3. Sonde ultrasonore (10) selon la revendication 1 ou 2, dans laquelle :

la seconde portion de guidage de lumière (42) est incurvée dans une direction allant vers les intérieurs des transducteurs ultrasonores (12).

4. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 3, dans laquelle :

une pluralité des fibres optiques (21) et une pluralité des moyens de guidage de lumière (11) sont fournies, et
la pluralité des moyens de guidage de lumière (11) est agencée le long de la direction prédéterminée.

5. Sonde ultrasonore (10) selon la revendication 4, dans laquelle :

la pluralité de moyens de guidage de lumière est agencée le long d'une direction perpendiculaire à la direction prédéterminée, au lieu d'être agencée dans la direction prédéterminée, ou en plus de cela, afin de faire face aux transducteurs ultrasonores (12), lesquels sont intercalés parmi la pluralité de moyens de guidage de lumière (11).

6. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 3, dans laquelle :

une pluralité des fibres optiques (21) est fournie, et
la pluralité des fibres optiques (21), laquelle est agencée le long de la direction prédéterminée, est couplée par voie optique à l'extrémité d'entrée de lumière d'un moyen de guidage de lumière unique (11, 60).

7. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 6, dans laquelle :

le moyen de guidage de lumière (11) est une plaque de guidage en forme de dalle présentant un noyau tabulaire et des couches de revêtement planaires prévues sur les deux surfaces du noyau tabulaire.

8. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 6, dans laquelle :

le moyen de guidage de lumière (11, 90) comprend une portion de transmission de lumière (91) présentant des propriétés de transmission de lumière et des éléments réfléchissants (93), lesquels sont formés pour prendre en sandwich la portion de transmission de lumière (91).

9. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 8, dans laquelle :

la distance de l'extrémité d'entrée de lumière (51) à la frontière entre la première portion de guidage de lumière (41) et la seconde portion de guidage de lumière (42) est supérieure ou égale à 8 mm.

10. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 8, comprenant en outre :

un adaptateur (14) transmettant de la lumière et des ondes ultrasonores, lequel est monté sur la sonde ultrasonore (10) de manière à couvrir les surfaces de détection d'ondes ultrasonores des transducteurs ultrasonores (12) et l'extrémité de sortie de lumière des moyens de guidage de lumière (11, 70).

11. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 10, comprenant en outre :

une plaque de diffusion (13), laquelle diffuse la lumière sur le côté de sortie de lumière de l'extrémité de sortie de lumières (52).

12. Sonde ultrasonore (10) selon l'une quelconque des revendications 1 à 10, dans laquelle :

une surface de diffusion, laquelle diffuse de la lumière, est formée sur au moins une surface parmi la surface d'extrémité sur le côté de sortie de lumière de la seconde portion de guidage de lumière (42, 82), et la surface d'extrémité de la seconde portion de guidage de lumière (42, 82) sur la frontière entre la première portion de guidage de lumière (41, 81) et la seconde portion de guidage de lumière (42, 82).

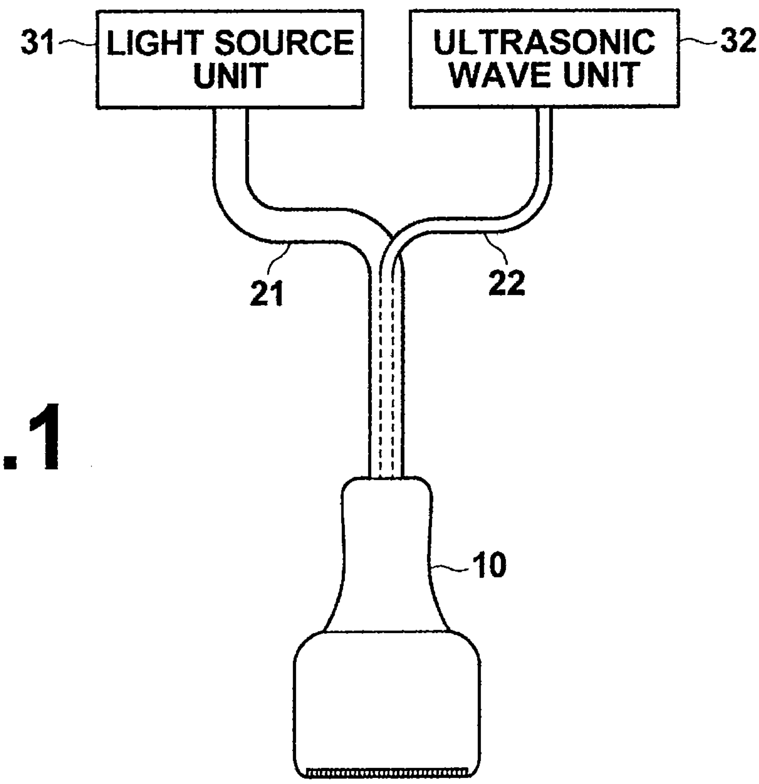


FIG.1

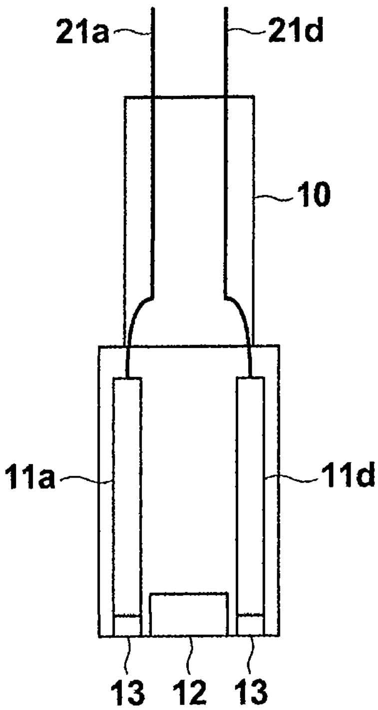


FIG.2A

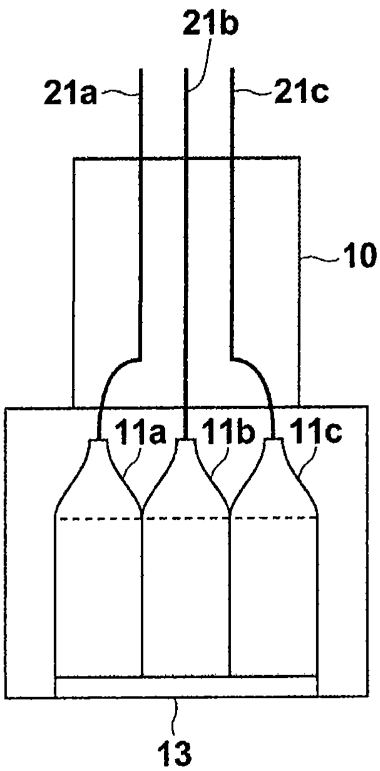


FIG.2B

FIG.3

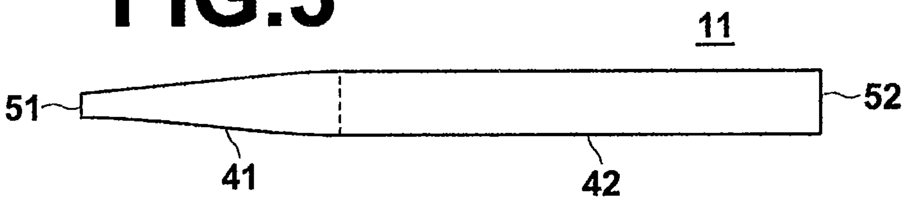


FIG.4A

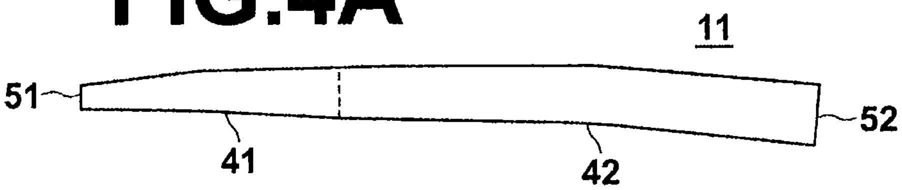


FIG.4B

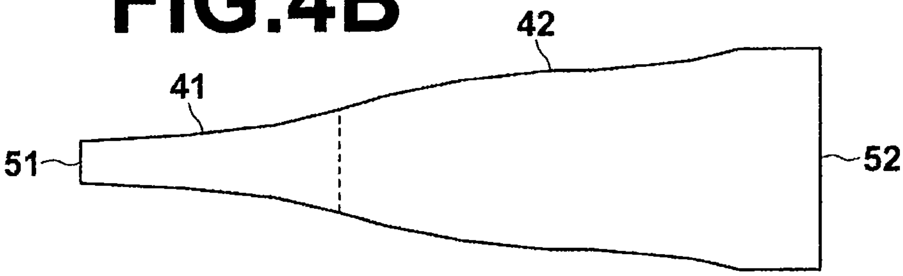


FIG.5

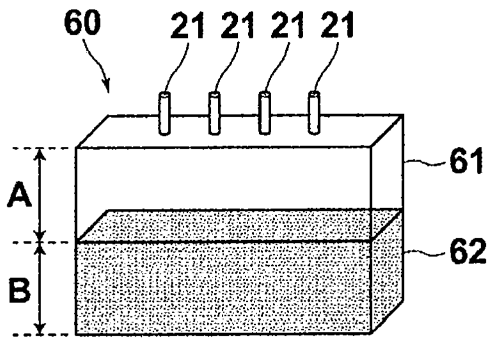


FIG.6

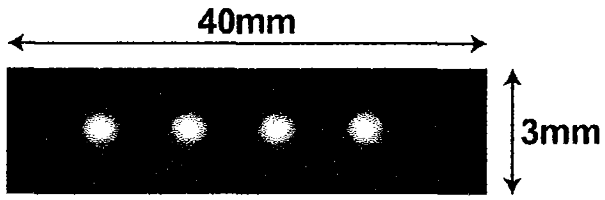


FIG.7

ENERGY DENSITY AND LIGHT GUIDING PLATE LENGTH

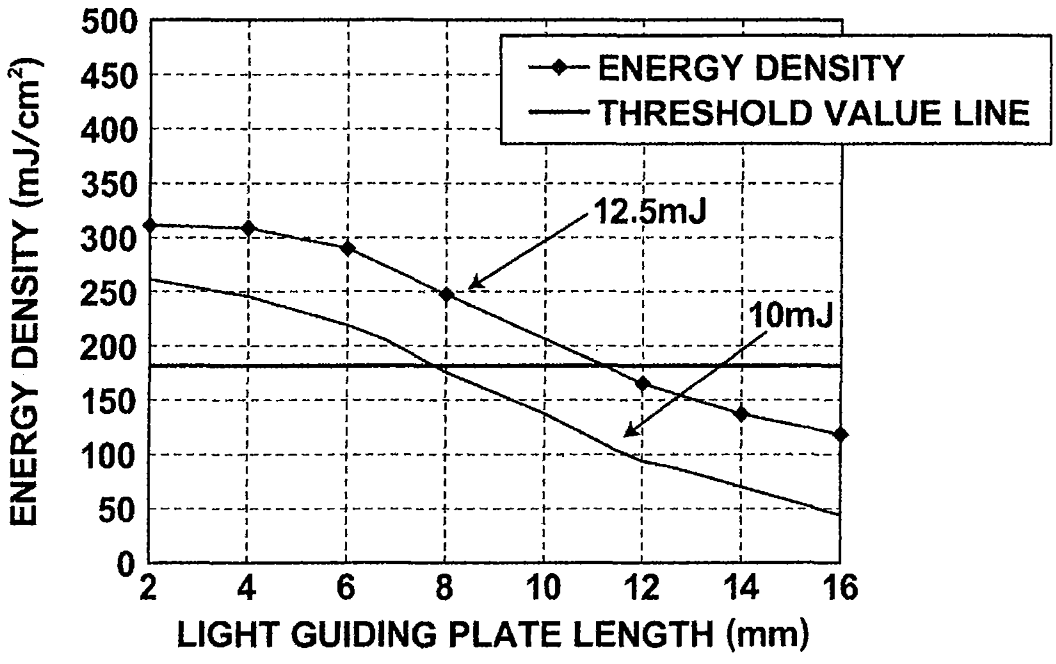


FIG.8

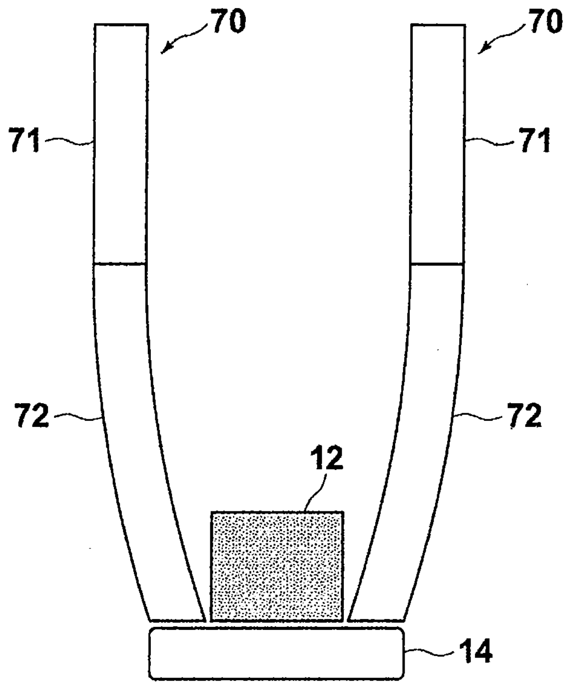


FIG.9

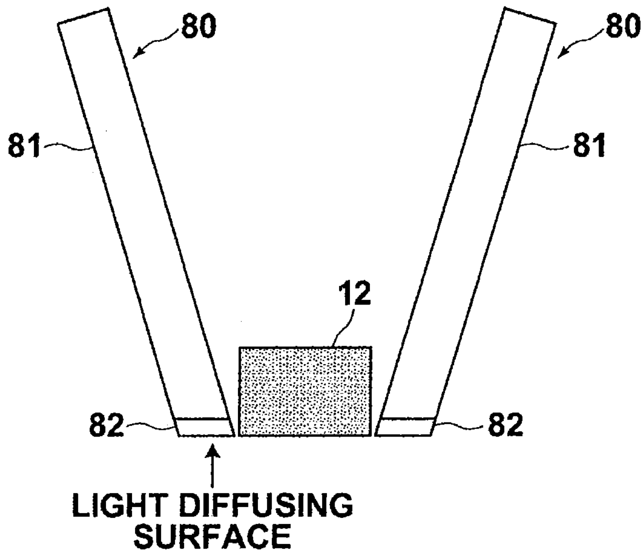
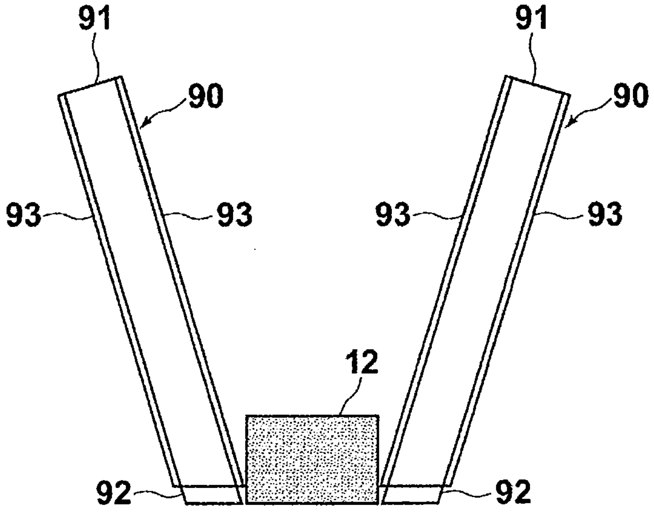


FIG.10



REFERENCES CITED IN THE DESCRIPTION

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- JP 2010012295 A **[0005]**

专利名称(译)	超声波探头		
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申请(专利权)人(译)	富士胶片株式会社		
当前申请(专利权)人(译)	富士胶片株式会社		
[标]发明人	TSUJITA KAZUHIRO ABE TAKEYA		
发明人	TSUJITA, KAZUHIRO ABE, TAKEYA		
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其他公开文献	EP2674107A1 EP2674107A4		
外部链接	Espacenet		

摘要(译)

[目的]在足够光量的宽照明区域发光。 [构成]光纤（21）将从光源输出的光引导至超声波探头（10）。导光板（11）引导来自光输入端的光，光输入端与光纤（21）光学耦合到设置在超声换能器附近的光输出端。导光板（11）具有包括光输入端的第一导光部分和包括光输出端的第二导光部分。第一导光部分由玻璃形成，并放大输入光。第二导光部分由树脂形成，并且从光输出端朝向对象发射光。