(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 759 246 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
03.02.2016 Bulletin 2016/05

(21) Application number: **12833882.9**

(22) Date of filing: **20.09.2012**

(51) Int Cl.:
A61B 1/00 *(2006.01)* ***G01N 21/27*** *(2006.01)*
A61B 5/00 *(2006.01)*

(86) International application number:
PCT/JP2012/074096

(87) International publication number:
WO 2013/042742 (28.03.2013 Gazette 2013/13)

(54) CALIBRATION APPARATUS AND CALIBRATION METHOD

KALIBRIERVORRICHTUNG UND KALIBRIERVERFAHREN

APPAREIL D'ÉTALONNAGE ET PROCÉDÉ D'ÉTALONNAGE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **20.09.2011 US 201161536736 P**

(43) Date of publication of application:
30.07.2014 Bulletin 2014/31

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EP 2 759 246 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Field

[0001] The present invention relates to a calibration system and a calibration method that calibrate an optical measurement apparatus that measures, as an amount of scattering and absorption of light, information related to an internal structure of an object to be measured. Background

[0002] Conventionally, backward scattered returned light from a comparatively weak scattering medium such as body tissue has been known to be observed as light that increases interference according to a degree of spatial coherence of illumination light thereof (see Non-Patent Literature 1). A technique of measuring spectroscopic information using this phenomenon is called low-enhanced backscattering spectroscopy (LEBS), and characteristics of an interference pattern with respect to a scattering mean free path (a reciprocal of a scattering coefficient) in a scattering medium have been well studied (see Non-Patent Literature 2). This scattering mean free path has a correlation with an internal structural change in the scattering medium and is used in detecting a minute tissue structural change as seen in early cancer. For example, distinguishment of colorectal cancer using an interference pattern of scattered returned light has been known to be possible (Non-Patent Literature 3).

[0003] A technique of applying the above mentioned LEBS to noninvasive measurement within a body through a small diameter probe inserted in an endoscope is known (see Patent Literature 1). In this technique, in order to obtain an interference pattern, detection fibers are arranged at different plural positions in a plane on which the interference pattern is formed, and signals are detected by detectors corresponding to the respective detection fibers.

Citation List

Patent Literature

[0004] Patent Literature 1: U. S. Patent Application Publication No. 2009/0009759

Non-Patent Literature

[0005]

Non-Patent Literature 1: Young L. Kim, et.al :Low-Coherence Enhanced Backscattering; Review of Principles and Applications for Colon Cancer Screening, Journal of Biomedical Optics, 11(4), 041125 2006

Non-Patent Literature 2: V, Turzhitsky, et.al :Characterization of Light Transport in Scattering Media at Subdiffusion Length Scales with Low-Coherence Enhanced Backscattering, IEEE journal of selected topics in quantum electronics, Vol. 16, No. 3, 619 (2010)

Non-Patent Literature 3: Hemant K. Roy, et. al :Association Between Rectal Optical Signatures and Colonic Neoplasia: Potential Applications for Screening, Cancer Research, 69(10), 4476 (2009)

[0006] US 2002/097400 A1 concerns optical characteristic measuring systems and methods for determining the color or other optical characteristics of teeth. Perimeter receiver fiber optics are spaced apart from a source fiber optic and receive light from the surface of the object/tooth being measured. Light from the perimeter fiber optics pass to a variety of filters. The system utilizes the perimeter receiver fiber optics to determine information regarding the height and angle of the probe with respect to the object/tooth being measured. Under processor control, the optical characteristics measurements are made at a predetermined height and angle. Various color spectral photometer arrangements are disclosed. Translucency, fluorescence, gloss and/or surface texture data also may be obtained.

Summary

Technical Problem

[0007] In the above mentioned LEBS, in order to obtain accurate measurement results, plural calibration items need to be performed, including correction of detection efficiencies of the respective plural detection fibers and plural detectors, correction of an irradiation intensity spectrum of illumination light irradiated by an illumination fiber, correction of a detection signal affected by a deviation in a detection range on the scattering medium, correction of removing ambient light from anything other than the scattering medium, and correction of an intensity reference. Therefore, individual devices must be used to respectively measure necessary data for the different calibration items and these complicated operations have been a burden on users.

[0008] The present invention has been made in view of the above, and an object thereof is to provide a calibration system and a calibration method that are able to measure a plurality of calibration items in one operation.

Solution to Problem

[0009] In order to solve the problem and achieve the object described above, a system according to the present invention comprises the features of claim 1.

[0010] Moreover, in the system according to the present invention as set forth in the invention described above, the material forming the reference reflection plate has the scattering mean free path that is greater than twice the spatial coherence length and has an anisotropic parameter that is equal to or less than 0.85.

[0011] Moreover, in the system according to the present invention as set forth in the invention described above, the material forming the reference reflection plate has the scattering mean free path that is approximately equal to twice the spatial coherence length and has an anisotropic parameter is greater than 0.85.

[0012] Moreover, the system according to the present invention as set forth in the invention described above further includes a drive unit that moves the reference reflection plate towards the distal end of the measurement probe when the optical measurement apparatus obtains the calibration data.

[0013] Moreover, the system according to the present invention as set forth in the invention described above further includes an accommodation portion that accommodates the reference reflection plate, wherein the insertion portion and the accommodation portion are connected to each other or arranged changeably between each other.

[0014] Moreover, in the system according to the present invention as set forth in the invention described above, the insertion portion has a light absorption portion provided with, on an inner surface thereof, a light absorption member that absorbs light, the light absorption portion being tubular, and the plurality of calibration data are: reference reflection plate calibration data when measurement is performed in the accommodation portion; and internal reflection calibration data of the measurement probe when measurement is performed in the insertion portion.

[0015] Moreover, in the system according to the present invention as set forth in the invention described above, the insertion portion has an opening at an end thereof, is bottomed and tubular, has, on an inner surface at a position near an insertion opening through which the measurement probe is inserted, a light absorption portion provided with a light absorption member that absorbs light, and has the reference reflection plate provided on a bottom portion thereof.

[0016] Moreover, in the system according to the present invention as set forth in the invention described above, the insertion portion is bent.

[0017] Moreover, the system according to the present invention as set forth in the invention described above further includes: a first container provided inside thereof with an optical absorption member that absorbs light; a second container that accommodates the reference reflection plate; a change portion that changes, with respect to the insertion portion, positions of the first container and the second container; and a change drive unit that drives the change unit.

[0018] Moreover, a calibration method according to the present invention comprises the features of claim 10.

Advantageous Effects of Invention

[0019] According to the present invention, a reference reflection plate is included, which is arranged at a position separated by a predetermined distance L from a distal end portion of a measurement probe in a state in which the measurement probe has been inserted in an insertion portion, has a reflectivity that is uniform in an irradiation plane in a wavelength range to be measured, and has stable reflection properties, and a scattering mean free path of a material forming the reference reflection plate is greater than a spatial coherence length at a predetermined distance. As a result, an effect of being able to easily perform complicated plural calibration items in one operation is demonstrated.

Brief Description of Drawings

[0020]

FIG. 1 is a block diagram schematically illustrating a configuration of an optical measurement apparatus and a calibration apparatus according to a first embodiment of the present invention;

FIG. 2 is a diagram schematically illustrating a cross section of a distal end of a measurement probe of the optical measurement apparatus according to the first embodiment of the present invention, the cross section being cut to include a central axis in a longitudinal direction of the measurement probe;

FIG. 3 is a front view of the measurement probe of the optical measurement apparatus according to the first embodiment of the present invention, the front view being viewed from the distal end thereof;

FIG. 4 is a diagram illustrating a situation in which the optical measurement apparatus according to the first embodiment of the present invention is used in an endoscopic system;

FIG. 5 is a diagram schematically illustrating an interference pattern detected by the optical measurement apparatus according to the first embodiment of the present invention;

FIG. 6 is a diagram schematically illustrating an intensity of a signal detected by the optical measurement apparatus according to the first embodiment of the present invention;

FIG. 7 is a diagram schematically illustrating a signal intensity detected by each detection unit in a signal when light of uniform intensity is irradiated to the measurement probe of the optical measurement apparatus according to the first embodiment of the present invention;

FIG. 8 is a diagram schematically illustrating a signal intensity detected by each detection unit before calibration when light of uniform intensity is irradiated to the measurement probe of the optical measurement apparatus according to the first embodiment of the present invention;

FIG. 9 is a diagram schematically illustrating a signal intensity when a signal intensity detected by each detection unit upon irradiation of light of uniform intensity to the measurement probe of the optical measurement apparatus according to the first embodiment of the present invention is calibrated;

FIG. 10 is a diagram schematically illustrating an illumination area to which the measurement probe of the optical measurement apparatus according to the first embodiment of the present invention is irradiated and a detection area over which returned light of the illumination light is detected;

FIG. 11 is a diagram illustrating a relation between a value of a ratio of a scattering mean free path to a spatial coherence length and a value of a ratio obtained by dividing an apparent light source size by a full width at half maximum of an interference pattern;

FIG. 12 is a diagram schematically illustrating a full width at half maximum of an interference pattern;

FIG. 13 is a diagram schematically illustrating a quantity represented by a ratio of a core diameter of an illumination fiber to a distance to a reference reflection plate;

FIG. 14 is a diagram corresponding to a case in which an interference peak corresponding to a full width at half maximum of an interference pattern fits within a core of the illumination fiber;

FIG. 15 is a diagram illustrating a case in which core diameters and cladding thicknesses differ between an illumination fiber and detection fibers;

FIG. 16 is a flow chart illustrating an outline of a calculation process including a calibration process executed by the optical measurement apparatus according to the first embodiment of the present invention;

FIG. 17 is a diagram schematically illustrating a cross section of a calibration apparatus according to a second embodiment of the present invention;

FIG. 18 is a diagram schematically illustrating a cross section of a calibration apparatus according to a modified example of the second embodiment of the present invention;

FIG. 19 is a diagram schematically illustrating a cross section of a calibration apparatus according to a third embodiment of the present invention;

FIG. 20 is a diagram schematically illustrating an outline of a calibration process executed by an optical measurement apparatus according to the third embodiment of the present invention using the calibration apparatus;

FIG. 21 is a diagram schematically illustrating a cross section of a calibration apparatus according to a fourth embodiment of the present invention;

FIG. 22 is a diagram schematically illustrating a cross section of a calibration apparatus according to a fifth embodiment of the present invention;

FIG. 23 is a diagram schematically illustrating the cross section of the calibration apparatus according to the fifth embodiment of the present invention;

FIG. 24 is a diagram schematically illustrating a cross section of a calibration apparatus according to a sixth embodiment of the present invention; and

FIG. 25 is a diagram schematically illustrating a cross section of a state in which a measurement probe of an optical measurement apparatus is installed in a calibration apparatus according to a seventh embodiment of the present invention.

Description of Embodiments

[0021] Hereinafter, preferred embodiments of an optical measurement apparatus and a calibration apparatus according to the present invention will be described in detail with reference to the drawings. Further, in describing the drawings, the same portions are appended with the same reference signs. Further, the drawings are schematic, and it is to be noted that the relation between the thickness and width of each component and the ratios among the respective components are different from the actual. Further, a portion is included, which has different size relations and ratios among the drawings. The present invention is not limited by the embodiments.

First Embodiment

[0022] FIG. 1 is a block diagram that schematically illustrates a configuration of an optical measurement apparatus and a calibration apparatus according to a first embodiment of the present invention and is a diagram that illustrates a state in which the calibration apparatus has been connected to the optical measurement apparatus.

[0023] First, the optical measurement apparatus is described. An optical measurement apparatus 1 illustrated in FIG. 1 includes a main body unit 2 that performs optical measurement with respect to an object to be measured such as body tissue, which is a scattering media, and measures characteristics (properties) of the object to be measured, and a measurement probe 3 that is detachable from the main body unit 2, inserted into a subject, and of a disposable-type.

[0024] The main body unit 2 has a power source 20, a light source unit 21, a connector unit 22, a first detection unit 23, a second detection unit 24, a third detection unit 25, an input unit 26, an output unit 27, a recording unit 28, and a control unit 29. The power source 20 supplies electric power to each component of the main body unit 2.

[0025] The light source unit 21 irradiates to the measurement probe 3, via the connector unit 22, illumination light of incoherent light to be irradiated onto the object to be measured. The light source unit 21 is realized by using an incoherent light source such as a white light emitting diode (LED), a xenon lamp, a tungsten lamp, or a halogen lamp, and a plurality of lenses. Examples of such lenses include condenser lenses and collimator lenses. The light source unit 21 irradiates illumination light having a wavelength component included in a predetermined wavelength band.

[0026] To the connector unit 22, the measurement probe 3 is detachably connected. The connector unit 22 propagates, to the measurement probe 3, the illumination light irradiated by the light source unit 21, and propagates a plurality of light beams entering from the measurement probe 3 respectively to the first detection unit 23, the second detection unit 24, and the third detection unit 25.

[0027] The first detection unit 23 detects returned light of the illumination light that has been irradiated from the measurement probe 3 and reflected and/or scattered by the object to be measured, and outputs a result of this detection to the control unit 29. Specifically, the first detection unit 23 detects a spectral component and an intensity distribution of scattered light entering from the measurement probe 3, and outputs a result of this detection to the control unit 29. The first detection unit 23 is realized using a spectrometer, a light receiving sensor, or the like.

[0028] The second detection unit 24 is realized by the same configuration as that of the first detection unit 23, detects the returned light of the illumination light that has been irradiated from the measurement probe 3 and reflected and/or scattered by the object to be measured, and outputs a result of this detection to the control unit 29.

[0029] The third detection unit 25 is realized by the same configuration as that of the first detection unit 23, detects the returned light of the illumination light that has been irradiated from the measurement probe 3 and reflected and/or scattered by the object to be measured, and outputs a result of this detection to the control unit 29.

[0030] The input unit 26 receives and outputs to the control unit 29, input of an instruction signal instructing activation of the main body unit 2, an instruction signal instructing start of measurement of a measurement object S1 by the main body unit 2, an instruction signal instructing a calibration process, and the like. The input unit 26 is realized using a push-type switch, a touch panel, or the like.

[0031] The output unit 27 outputs, under control by the control unit 29, various information in the main body unit 2, for example, a result of measurement on the object to be measured. The output unit 27 is realized using a display of a liquid crystal, organic electroluminescence (EL), or the like, and a speaker or the like.

[0032] The control unit 29 comprehensively controls the main body unit 2 by carrying out transfer or the like of instruction information or data corresponding to each component of the main body unit 2. The control unit 29 is configured using a central processing unit (CPU) or the like. The control unit 29 has a calculation unit 291.

[0033] The calculation unit 291 performs a plurality of calculation processes based on detection results respectively detected by the first detection unit 23, the second detection unit 24, and the third detection unit 25, to calculate characteristic values related to the characteristics of the object to be measured.

[0034] Next, the measurement probe 3 will be described. FIG. 2 is a diagram that schematically illustrates a cross section of the distal end of the measurement probe 3, the cross section being cut to include a central axis in a longitudinal direction of the measurement probe 3. FIG. 3 is a front view of the measurement probe 3 viewed from the distal end thereof.

[0035] The measurement probe 3 illustrated in FIGS. 1 to 3 includes an illumination fiber 31, a first detection fiber 32, a second detection fiber 33, a third detection fiber 34, a fiber holding portion 35, and a rod lens (optical element) 36. The illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 are each realized using an optical fiber having a core diameter of ρ_1 and a cladding thickness of ρ_2.

[0036] The illumination fiber 31 irradiates, via the rod lens 36, the illumination light entering, via the connector unit 22, from the light source unit 21, to the object to be measured or a calibration apparatus 4.

[0037] The first detection fiber 32 detects (receives), via the rod lens 36, the returned light of the illumination light that has been irradiated by the illumination fiber 31 and reflected and/or scattered by the object to be measured or the calibration apparatus 4, and propagates the received returned light to the first detection unit 23.

[0038] The second detection fiber 33 detects, via the rod lens 36, the returned light of the illumination light that has been irradiated by the illumination fiber 31 and reflected and/or scattered by the object to be measured or the calibration apparatus 4, and propagates the received returned light to the second detection unit 24.

[0039] The third detection fiber 34 detects, via the rod lens 36, the returned light of the illumination light that has been irradiated by the illumination fiber 31 and reflected and/or scattered by the object to be measured or the calibration apparatus 4, and propagates the received returned light to the third detection unit 25.

[0040] The fiber holding portion 35 holds respective distal ends of the illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 to be arranged in a straight line or irregularly. Specifically, the fiber holding portion 35 holds the illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 so that optical axes of the illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 become parallel to one another. Further, the fiber holding portion 35 fixes the illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 respectively at predetermined positions so that the returned light of the illumination light enters therein at different angles. For example, the fiber holding portion 35 holds the illumination fiber 31 and the first detection fiber 32 so that a return of the illumination light irradiated from the illumination fiber 31 enters the first detection fiber 32 at an angle θ. The fiber holding portion 35 is realized using a glass, a resin, a metal, or the like.

[0041] The rod lens 36 is provided on a distal end of the fiber holding portion 35. The rod lens 36 is realized using a glass, a plastic, or the like having a predetermined transmissivity, and is column-shaped so that distances from the respective distal ends of the illumination fiber 31, the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 to the object to be measured or to the calibration apparatus 4 become constant.

[0042] Next, the calibration apparatus 4 will be described. The calibration apparatus 4 includes a container 41, a stopper portion 42 that prevents insertion of the measurement probe 3, and a reference reflection plate 43 used in a calibration process.

[0043] The container 41 is tubular and has an insertion portion 41a through which the measurement probe 3 is insertable, and an accommodation portion 41b that accommodates the reference reflection plate 43. The container 41 is integrally formed of the insertion portion 41a and the accommodation portion 41b.

[0044] The stopper portion 42 is ring-shaped and provided in the accommodation portion 41b. The stopper portion 42 prevents the measurement probe 3 from being inserted into the accommodation portion 41b. An inner diameter of the stopper portion 42 is smaller than an outer diameter of the measurement probe 3. The stopper portion 42 keeps a predetermined distance L from an end of the rod lens 36 of the measurement probe 3 to the reference reflection plate 43 constant.

[0045] The reference reflection plate 43 is arranged at a position which is away by the predetermined distance L from a distal end portion of the measurement probe 3 in a state in which the measurement probe 3 has been inserted in the insertion portion 41a. The reference reflection plate 43 formed of a material having light reflectivity that is uniform over a wavelength range to be measured in an irradiation plane of the illumination light irradiated by the measurement probe 3. Specifically, a scattering mean free path of a material forming the reference reflection plate 43 is set to be of a larger value than that of a spatial coherence length at the predetermined distance L.

[0046] In the optical measurement apparatus 1 configured as described above, after a calibration process is performed by the calibration apparatus 4, as illustrated in FIG. 4, the measurement probe 3 is inserted into the subject via a treatment tool channel 51a provided in an endoscopic device 51 (endoscope) of an endoscopic system 5, the illumination fiber 31 irradiates the illumination light to the object to be measured, and the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 respectively detect, at different scattering angles, the returned light of the illumination light that has been reflected and/or scattered by the object to be measured and propagate the detected returned light to the first detection unit 23, the second detection unit 24, and the third detection unit 25. Thereafter, the calculation unit 291 calculates the characteristic values representing the characteristics of the object to be measured, based on detection results detected respectively by the first detection unit 23, the second detection unit 24, and the third detection unit 25.

[0047] Next, calibration items of the optical measurement apparatus 1 will be described in detail. FIG. 5 is a diagram that schematically illustrates an interference pattern detected by the optical measurement apparatus 1. FIG. 6 is a diagram that schematically illustrates intensities of signals detected by the optical measurement apparatus 1. In FIGS. 5 and 6, the illumination fiber 31 is described as an illumination fiber S, and the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 are respectively described as a first detection fiber d_1, a second detection fiber d_2, and a third detection fiber d_3. Further, in FIGS. 5 and 6, the first detection fiber d_1 and the second detection fiber d_2 correspond to intensities at skirt portions of the interference pattern, and the third detection fiber d_3 corresponds to an intensity of a scattered light component of a degree that allows influence of interference to be ignored. Further, in FIG. 6, an intensity detected by a detection fiber S for a case in which the illumination fiber 31 is supposed to be the detection fiber S is also illustrated. In FIG. 6, signal values corresponding to particular wavelengths are illustrated.

[0048] As illustrated in FIGS. 5 and 6, because the signal value detected by the detection fiber S corresponds to the maximum value of the interference pattern, the intensity thereof is the largest. Further, the signal values detected respectively by the first detection fiber d_1 and the second detection fiber d_2 are of the same intensities, because they are at positions away from the detection fiber S by the same distances. Further, the signal value detected by the third detection fiber d_3 is of the smallest intensity. However, the signal values are influenced by variation in light guiding efficiency of detection routes, and variation in detection sensitivity of each of the first detection unit 23, the second detection unit 24, and the third detection unit 25. Accordingly, as illustrated in FIG. 7, even if light of uniform intensity is irradiated to the measurement probe 3, the signal values detected respectively by the first detection fiber d_1, the second detection fiber d_2, and the third detection fiber d_3 do not become constant (see FIG. 8). Therefore, as illustrated in FIG. 9, calibration to make detection intensities respectively detected by the first detection fiber d_1, the second detection fiber d_2, and the third detection fiber d_3 constant is needed.

[0049] Further, as illustrated in FIG. 10, an illumination area A to which the illumination fiber 31 irradiates the illumination light does not coincide with a detection area B for which the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 each detect the returned light of the illumination light, and thus variation in the signal values is generated. For example, as illustrated in FIG. 10, the illumination area A to which the illumination fiber 31 irradiates the illumination light and the detection area B over which the third detection fiber 34 detects the returned light of the illumination light are different from each other. Therefore, the optical measurement apparatus 1 needs to perform correction of detection signals according to variation in a detection range of the object to be measured.

[0050] Next, the reference reflection plate 43 of the calibration apparatus 4 will be described in detail. In the calibration apparatus 4, for the above mentioned calibration items, material properties of the reference reflection plate 43 are set, correspondingly with a degree of spatial coherence on the reference reflection plate 43, i.e., a spatial coherence length Lsc, to satisfy Condition (1) or Condition (2).

$$(1):\ ls^* \geq 2Lsc,\ \text{AND}\ g \leq 0.85$$

$$(2):\ ls^* \approx 2Lsc,\ \text{AND}\ g > 0.85$$

Herein, ls* represents the scattering mean free path of the material forming the reference reflection plate 43, and "g" represents an anisotropic parameter in a scattering direction of the reference reflection plate 43. For Condition (2), a range of ls*/Lsc = 1 to 3 is only needed.

[0051] Further, as illustrated in FIG. 1, when a length in a fiber longitudinal direction of the rod lens 36 is "R", a distance from the distal end of the measurement probe 3 to the reference reflection plate 43 is "L", a refractive index of the rod lens 36 at a prescribed wavelength λ is "n", and a core diameter of the illumination fiber 31 is ρ_1, the spatial coherence length Lsc at a detection position of the reference reflection plate 43 is defined by Equation (3) below.

$$Lsc = \lambda(R/n + L)\ /\ \pi\rho_1 \qquad (3)$$

[0052] As described above, in the calibration apparatus 4, based on Condition (1) or Condition (2): the scattering mean free path ls* of the reference reflection plate 43 is preset and the distance L is set such that the spatial coherence length Lsc satisfies Condition (1) or Condition (2); or the distance L of the reference reflection plate 43 is preset and the material of the reference reflection plate 43 is adjusted or selected such that the scattering mean free path ls* satisfies Condition (1) or Condition (2). In this case, because for the reference reflection plate 43, a material having reflectivity that is constant regardless of wavelength needs to be selected, preferably, the scattering mean free path ls* of the reference reflection plate 43 is set, and the distance L is set such that the spatial coherence length Lsc satisfies Condition (1) or Condition (2). Even if a value of the scattering mean free path ls* of the material forming the reference reflection plate 43 is not accurately known, intensity change detected by any of the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 may be detected by changing a position of the reference reflection plate 43 and the distance L may be set to a position at which the detection intensities of the first detection fiber 32 and the second detection fiber 33 are of the minimum values.

[0053] Condition (1) and Condition (2) will now be described in detail. According to Condition (1) and Condition (2), a shape of the interference pattern, which is formed at the distal end of the measurement probe 3 when the illumination light from the measurement probe 3 is reflected and/or scattered and becomes the returned light, is determined by the spatial coherence length Lsc at a position of the reference reflection plate 43 and the scattering mean free path ls* of the reference reflection plate 43 (see Non-Patent Literature 2).

[0054] FIG. 11 is a diagram that illustrates a relation between a value of a ratio of the scattering mean free path ls* to the spatial coherence length Lsc and a value of a ratio obtained by dividing an apparent light source size by a full width at half maximum (FWHM) w of the interference pattern. FIG. 12 is a diagram that schematically illustrates the full width at half maximum w.

[0055] As illustrated in FIG. 11, when the anisotropic parameter g in the scattering direction of the reference reflection plate 43 is less than 0.85, a value of α/w tends to converge from around where a value of ls*/Lsc becomes greater than 2. Further, when the anisotropic parameter g in the scattering direction of the reference reflection plate 43 is greater than 0.85, the value α/w becomes maximum around where the value of ls*/Lsc is 2. Therefore, when the value becomes maximum around where the value of ls*/Lsc is 2, the full width at half maximum w of the interference pattern becomes the smallest.

[0056] As described above, under the condition where the full width at half maximum w of the interference pattern becomes the smallest, the interference pattern does not enter the first detection fiber 32 to the third detection fiber 34 and at a position of the detection fiber, a luminous flux of uniform intensity is obtained. Accordingly, from a relation between the full width at half maximum w and scattering properties of a scattering medium (ls*/Lsc and g) illustrated in FIG. 11, Condition (1) and Condition (2) are able to be derived as conditions under which the full width at half maximum w becomes the smallest.

[0057] Further, the apparent light source size α illustrated in FIGS. 11 and 12, is, as illustrated in FIG. 13, a quantity represented by Equation (4) below where a numerator is the core diameter ρ_1 of the illumination fiber 31 and a denominator is a sum of the distance L from the illumination fiber 31 to the reference reflection plate 43 and a value R/n obtained by dividing the length R of the rod lens 36 by the refractive index n of the rod lens 36.

$$\alpha = \rho_1 / (R/n + L) \qquad (4)$$

When α of Equation (4) is small (α < 0.1), α becomes equal to an angle α'[rad] illustrated in FIG. 13. Therefore, the vertical axis α/w of FIG. 11 can be said to be an index indicating the extent to which the full width at half maximum w of the interference pattern fits in an angle range α corresponding to the core ρ_1 of the illumination fiber 31.

[0058] FIG. 14 is a diagram when α/w = 1, and an interference peak corresponding to the full width at half maximum w of the interference pattern fits in the core ρ_1 of the illumination fiber 31.

[0059] As illustrated in FIG. 14, the optical measurement apparatus 1 considers a condition under which skirt of the interference pattern is not in the respective cores of the first detection fiber 32 and the second detection fiber 33. Under this condition, the core of the detection fiber 32 is positioned outer than about a position corresponding to twice (2w) the full width at half maximum w. Specifically, it is important that the skirt of the interference pattern is not in the respective cores of the first detection fiber 32 and the second detection fiber 33. In FIG. 14, a case in which α/w = 1 is illustrated, but the full width at half maximum w is not necessarily in the core ρ_1 of the illumination fiber 31. For example, if α/w = 1 is not true, the full width at half maximum w just needs to be not in the respective cores of the first detection fiber 32 and the second detection fiber 33. Such a situation would be a case in which the thicknesses of the claddings of the first detection fiber 32 to the third detection fiber 34 and the illumination fiber 31 are thick.

[0060] Further, as illustrated in FIG. 3, when the core diameter of the illumination fiber 31 is ρ_1 and the thickness of the cladding thereof (hereinafter, "cladding thickness") is ρ_2, the full width at half maximum w satisfies Condition (5) below.

$$(5): (\rho_1 + 4\rho_2) / (R/n + L) > 2w$$

[0061] As illustrated in FIG. 15, when the core diameter of the illumination fiber 31 is ρ_1, the cladding thickness thereof is ρ_2, the respective core diameters of the first detection fiber 32, the second detection fiber 33, and the third detection fiber 34 are ρ_3, and the cladding thicknesses thereof are ρ_4, the full width at half maximum w satisfies Condition (6) below.

$$(6): (\rho_1 + 2\rho_2 + 2\rho_4) / (R/n + L) > 2w$$

[0062] As described above, in the measurement probe 3, because a light guiding property of each fiber is maintained and thus the cladding thicknesses are set to be thick, the above Condition (5) or Condition (6) is satisfied.

[0063] Next, a calculation process including the calibration process performed by the optical measurement apparatus 1 is described. FIG. 16 is a flow chart that illustrates an outline of the calculation process including the calibration process performed by the optical measurement apparatus 1. Hereinafter, "ch" represents each detection fiber number and λ represents wavelength.

[0064] As illustrated in FIG. 16, the optical measurement apparatus 1 obtains internal reflection calibration data BA (ch, λ) in the insertion portion 41a of the calibration apparatus 4 (Step S101). Specifically, the optical measurement apparatus 1 obtains, by irradiating, in the insertion portion 41a of the calibration apparatus 4, the illumination light to the illumination fiber 31, internal reflection calibration data in a measurement probe detected by the first detection unit 23, the second detection unit 24, and the third detection unit 25.

[0065] Subsequently, the optical measurement apparatus 1 obtains, in a state in which the distal end of the measurement probe 3 has come into contact with the stopper portion 42, reference reflection plate calibration data IS (ch, λ) of the reference reflection plate 43 (Step S102). Specifically, the optical measurement apparatus 1, obtains, by the illumination fiber 31 irradiating the illumination light to the reference reflection plate 43 in a state in which the distal end of the rod lens 36 of the measurement probe 3 has come into contact with the stopper portion 42, reference reflection plate calibration data of the reference reflection plate 43, the reference reflection plate calibration data having been detected by each of the first detection unit 23, the second detection unit 24, and the third detection unit 25.

[0066] Thereafter, the optical measurement apparatus 1 obtains measured data T (ch, λ) of the object to be measured (Step S103). Specifically, the optical measurement apparatus 1 obtains, by the illumination fiber 31 irradiating the illumination light to the object to be measured, measured data detected by each of the first detection unit 23, the second detection unit 24, and the third detection unit 25.

[0067] Subsequently, the calculation unit 291 converts, using the internal reflection calibration data BA (ch, λ) and the reference reflection plate calibration data IS (ch, λ), the measured data T (ch, λ) into calibrated data S (ch, λ) (Step S104). Specifically, the calculation unit 291 converts the measured data T (ch, λ) into the calibrated data S (ch, λ) by Equation (7) below.

$$S(ch, \lambda) = (T(ch, \lambda) - BA(ch, \lambda)) / (IS(ch, \lambda) - BA(ch, \lambda)) \qquad (7)$$

[0068] According to the above described first embodiment of the present invention, the reference reflection plate 43 is included, which is arranged at the position away by the predetermined distance L from the distal end portion of the measurement probe 3 in the state in which the measurement probe 3 has been inserted in the insertion portion 41a, and for the reference reflection plate 43, the scattering mean free path of the material forming the reference reflection plate 43 is set to be larger than the spatial coherence length Lsc determined using the predetermined distance L. As a result, complicated plural calibration items are readily obtainable in one operation.

Second Embodiment

[0069] Next, a second embodiment of the present invention will be described. In the second embodiment, a configuration of a calibration apparatus is different from the calibration apparatus according to the above described first embodiment. Therefore, hereinafter, the configuration of the calibration apparatus according to the second embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.

[0070] FIG. 17 is a diagram that schematically illustrates a cross section of the calibration apparatus according to the second embodiment of the present invention. A calibration apparatus 6 illustrated in FIG. 17 includes a container 61 that is approximately a cuboid and a stopper portion 62 that prevents insertion of the measurement probe 3.

[0071] The container 61 has an insertion portion 61a into which the measurement probe 3 is insertable, and an accommodation portion 61b having an inner surface formed of a reference reflection member.

[0072] The stopper portion 62 is ring-shaped and provided in the accommodation portion 61b. The stopper portion 62 prevents the measurement probe 3 from being inserted into the accommodation portion 61b. An inner diameter of the stopper portion 62 is smaller than an outer diameter of the measurement probe 3. The stopper portion 62 keeps a distance L from the end of the rod lens 36 of the measurement probe 3 to a bottom surface of the accommodation portion 61b constant.

[0073] According to the above described second embodiment of the present invention, just by inserting the measurement probe 3 into the insertion portion 61a of the calibration apparatus 6, complicated plural calibration items are able to be readily performed in one operation.

[0074] In the second embodiment, a spherical formation may be employed. FIG. 18 is a diagram that schematically illustrates a cross section of a calibration apparatus according to a modified example of the second embodiment. A calibration apparatus 7 illustrated in FIG. 18 includes a container 71 that is approximately spherical and a stopper portion 72 that prevents insertion of the measurement probe 3.

[0075] The container 71 has an insertion portion 71a into which the measurement probe 3 is insertable, and an accommodation portion 71b having an inner surface formed of a reference reflection member.

[0076] According to the above described modified example of the second embodiment of the present invention, just by inserting the measurement probe 3 into the calibration apparatus 7, complicated plural calibration items are able to be readily performed in one operation.

Third Embodiment

[0077] Next, a third embodiment of the present invention will be described. The third embodiment has a different configuration for a calibration apparatus. Therefore, hereinafter, the configuration of the calibration apparatus according to the third embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.
[0078] FIG. 19 is a diagram that schematically illustrates a cross section of the calibration apparatus according to the third embodiment. A calibration apparatus 8 illustrated in FIG. 19 includes a container 81, a stopper portion 42, and the reference reflection plate 43.
[0079] The container 81 has an insertion portion 81a through which the measurement probe 3 is insertable, and an accommodation portion 81b that accommodates the reference reflection plate 43, and the container 81 is formed integrally of the insertion portion 81a and the accommodation portion 81b.
[0080] The insertion portion 81a has, on an inner surface thereof, a light absorption portion 81c provided with a member that does not reflect light or a light absorption member that absorbs wavelength of light irradiated by the light source unit 21. Specifically, the light absorption portion 81c is coated in black.
[0081] A calibration process performed using the calibration apparatus 8 configured as above will be described. FIG. 20 is a diagram that schematically illustrates an outline of the calibration process, which the optical measurement apparatus 1 performs, using the calibration apparatus 8.
[0082] As illustrated in FIG. 20, the optical measurement apparatus 1 obtains, when the illumination fiber 31 irradiates the illumination light to the light absorption portion 81c in the insertion portion 81a, internal reflection calibration data detected by each of the first detection unit 23, the second detection unit 24, and the third detection unit 25 (FIG. 20(a) to FIG. 20(b)). In this case, the optical measurement apparatus 1 may obtain the internal reflection calibration data when a user stops the insertion of the measurement probe 3 midway through the insertion portion 81a. Further, the calculation unit 291 may continuously obtain the internal reflection calibration data until the measurement probe 3 comes into contact with the stopper portion 42 and select, as an internal reflection calibration data to be used in the calibration process, data indicating the minimum intensity, from the obtained internal reflection calibration data.
[0083] Subsequently, the optical measurement apparatus 1 obtains the reference reflection plate calibration data detected by the first detection unit 23, the second detection unit 24, and the third detection unit 25 when the illumination fiber 31 irradiates the illumination light to the reference reflection plate 43 (FIG. 20(b)). Preferably, the calculation unit 291 selects, as the reference reflection plate calibration data, data indicating the maximum intensity detected by the first detection unit 23, the second detection unit 24, and the third detection unit 25 when the distal end of the measurement probe 3 comes into contact with the stopper portion 42.
[0084] According to the above described third embodiment of the present invention, just by a single operation of inserting the measurement probe 3 into the insertion portion 81a of the calibration apparatus 8, plural calibration items are able to be performed simultaneously. As a result, complicated operations are able to be lessened, and damage to the measurement probe 3 during calibration processes and forgetting to take calibration data are preventable.
[0085] Further, according to the third embodiment, plural calibration items are able to be performed simultaneously with a simple configuration.
[0086] In the third embodiment of the present invention, a position of the reference reflection plate 43 may be movably provided by a drive unit such as a motor, and while adjusting the distance from the measurement probe 3 to the reference reflection plate 43, the optical measurement apparatus 1 may measure the reference reflection plate calibration data and the internal reflection calibration data.

Fourth Embodiment

[0087] Next, a fourth embodiment of the present invention will be described. The fourth embodiment has a different configuration for a calibration apparatus. Therefore, hereinafter, the configuration of the calibration apparatus according to the fourth embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.
[0088] FIG. 21 is a diagram that schematically illustrates a cross section of the calibration apparatus according to the fourth embodiment. A calibration apparatus 9 illustrated in FIG. 21 includes a container 91, the stopper portion 42, and the reference reflection plate 43.
[0089] The container 91 has an insertion portion 91a through which the measurement probe 3 is inserted, and an

accommodation portion 91b that accommodates the reference reflection plate 43. The container 91 is integrally formed of the insertion portion 91a and the accommodation portion 91b. The insertion portion 91a is tubular and connected to the accommodation portion 91b with a portion of the insertion portion 91a being bent.

[0090] When a calibration process is performed using the calibration apparatus 9 configured as above, the optical measurement apparatus 1 obtains internal reflection correction data before the bend of the insertion portion 91a. When this is done, the illumination light irradiated from the measurement probe 3 will not be irradiated to the reference reflection plate 43 and thus the returned light of the illumination light is preventable from influencing the measurement probe 3.

[0091] According to the above described fourth embodiment of the present invention, because the portion of the insertion portion 91a is bent, upon the calibration of the internal reflection correction, the influence by the returned light from the reference reflection plate 43 is preventable and thus an accurate calibration process is able to be performed.

[0092] According to the fourth embodiment, an angle of the bend of the insertion portion 91a is approximately 90 degrees, but the insertion portion 91a only needs to be bent to an extent such that the reference reflection plate 43 is not visible at the front of the measurement probe 3 and the angle of the bend may be changed as appropriate in order to ensure operability.

[0093] In the fourth embodiment of the present invention, the position of the reference reflection plate 43 may be movably provided by a drive unit such as a motor, and while adjusting the distance from the measurement probe 3 to the reference reflection plate 43, the optical measurement apparatus 1 may measure the reference reflection plate calibration data and the internal reflection calibration data.

Fifth Embodiment

[0094] Next, a fifth embodiment of the present invention will be described. The fifth embodiment has a different configuration for a calibration apparatus. Therefore, hereinafter, the configuration of the calibration apparatus according to the fifth embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.

[0095] FIGS. 22 and 23 are diagrams that each schematically illustrates a cross section of the calibration apparatus according to the fifth embodiment. A calibration apparatus 10 illustrated in FIGS. 22 and 23 includes a container 101, the stopper portion 42, the reference reflection plate 43, a shutter 102, and a drive unit 103.

[0096] The container 101 has an insertion portion 101a through which the measurement probe 3 is inserted, and an accommodation portion 101b that accommodates the reference reflection plate 43. The container 101 is integrally formed of the insertion portion 101a and the accommodation portion 101b. Further, the insertion portion 101a has a hole 101c provided therein, through which the shutter 102 is retractably insertable. Further, the insertion portion 101a has the stopper portion 42 provided therein.

[0097] The shutter 102 is circular and shields the illumination light irradiated by the measurement probe 3. The shutter 102 is formed using a black plate, which uses a light absorption member or the like.

[0098] The drive unit 103 retractably drives the shutter 102 with respect to the hole 101c. The drive unit 103 is configured using a DC motor, a stepping motor, or the like.

[0099] A calibration process performed by the optical measurement apparatus 1 using the calibration apparatus configured as above will be described. The optical measurement apparatus 1 obtains the internal reflection calibration data. In this case, as illustrated in FIG. 22, the shutter 102 is arranged on an optical axis of the illumination light irradiated by the measurement probe 3, and shields the illumination light irradiated by the measurement probe 3.

[0100] Subsequently, by driving the drive unit 103, the calibration apparatus 10 retracts the shutter 102 from the hole 101c of the insertion portion 101a (see FIG. 23).

[0101] Thereafter, the optical measurement apparatus 1 obtains the reference reflection plate calibration data by irradiating the illumination light to the reference reflection plate 43.

[0102] According to the above described fifth embodiment of the present invention, calibration items of the optical measurement apparatus 1 are automatically changeable, and thus plural calibration items are able to be readily performed in one operation.

Sixth Embodiment

[0103] Next, a sixth embodiment of the present invention will be described. The sixth embodiment has a different configuration for a calibration apparatus. Therefore, hereinafter, the configuration of the calibration apparatus according to the sixth embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.

[0104] FIG. 24 is a diagram that schematically illustrates a cross section of the calibration apparatus according to the sixth embodiment. A calibration apparatus 11 illustrated in FIG. 24 includes: an accommodation unit 111b, which has a space inside, and into which the measurement probe 3 is inserted through an insertion portion 111a; the stopper portion 42, which is provided in the accommodation unit 111b and prevents insertion of the measurement probe 3; a rotation plate 112, which rotates about a predetermined axis; a drive unit 113, which causes the rotation plate 112 to rotate; a first container 114, which has an inner surface provided with a light absorption member and used when the internal reflection calibration data are obtained; and a second container 115, which accommodates the reference reflection plate 43 that is away from the stopper portion 42 by a distance L.

[0105] A calibration process performed by the optical measurement apparatus 1 using the calibration apparatus 11 configured as above will be described. The optical measurement apparatus 1 inserts the measurement probe 3 into the insertion portion 111a. In this case, in the calibration apparatus 11, by the drive unit 113 driving, the rotation plate 112 rotates and the first container 114 moves to a position of the insertion portion 111a. Accordingly, the optical measurement apparatus 1 is able to obtain the internal reflection calibration data.

[0106] Subsequently, in the calibration apparatus 11, by the drive unit 113 driving, the rotation plate 112 rotates and the second container 115 moves to the position of the insertion portion 111a. Accordingly, the optical measurement apparatus 1 is able to obtain the reference reflection plate calibration data.

[0107] According to the above described sixth embodiment of the present invention, calibration items of the optical measurement apparatus 1 are automatically changeable and thus without performing complicated operations, data of calibration processes are obtainable in one operation.

[0108] In the sixth embodiment of the present invention, a positional relation between the measurement probe 3 and the first container 114 or the second container 115 need only be relatively changeable, and for example, the insertion portion 111a may be rotatably provided with respect to a principal plane of the accommodation unit 111b.

Seventh Embodiment

[0109] Next, a seventh embodiment of the present invention will be described. In the seventh embodiment, a calibration process is performed in a state in which a calibration apparatus is installed to a measurement probe. Therefore, hereinafter, the configuration of the calibration apparatus according to the seventh embodiment will be described. Configurations that are the same as those of the optical measurement apparatus 1 and the calibration apparatus 4 according to the above described first embodiment will be described being appended by the same reference signs.

[0110] FIG. 25 is a diagram that schematically illustrates a cross section of a state in which a measurement probe of an optical measurement apparatus is installed in the calibration apparatus according to the seventh embodiment. A calibration apparatus 12 illustrated in FIG. 25 is a bottomed cuboid and has the reference reflection plate 43 at a position that is away from the measurement probe 3 by the predetermined distance L. Further, the calibration apparatus 12 protects the distal end of the measurement probe 3 from an external force.

[0111] The calibration apparatus 12 configured as above is removed from the measurement probe 3 after the optical measurement apparatus 1 obtains the reference reflection plate calibration data. Thereafter, the optical measurement apparatus 1 obtains the internal reflection calibration data by irradiating the illumination light to the container provided with the light absorption member inside thereof.

[0112] According to the above described seventh embodiment of the present invention, variation in the predetermined distance L from the measurement probe 3 to the reference reflection plate 43 is preventable and a more accurate calibration process is able to be performed.

[0113] In the seventh embodiment of the present invention, when the treatment tool channel 51a of the endoscopic device 51 is usable as a light absorption space, the optical measurement apparatus 1 may obtain the internal reflection correction data inside the treatment tool channel 51a of the endoscopic device 51.

Reference Signs List

[0114]

1	Optical measurement apparatus
2	Main body unit
3	Measurement Probe
4, 6, 7, 8, 9, 10, 11, 12	Calibration apparatus
5	Endoscopic system
20	Power source
21	Light source unit
22	Connector unit
23	First detection unit

24	Second detection unit
25	Third detection unit
26	Input unit
27	Output unit
28	Recording unit
29	Control unit
31	Illumination fiber
32	First detection fiber
33	Second detection fiber
34	Third detection fiber
35	Fiber holding portion
36	Rod lens
41, 61, 71, 81, 91, 101, 111	Container
41a, 61a, 71a, 81a, 91a, 101a, 111a	Insertion portion
41b, 61b, 71b, 81b, 91b, 101b, 111b	Accommodation portion
42, 62	Stopper portion
43	Reference reflection plate
51	Endoscopic apparatus
51a	Treatment tool channel
101c	Hole
102	Shutter
103, 113	Drive unit
112	Rotation plate
114	First container
115	Second container
291	Calculation unit

Claims

1. A system comprising a calibration apparatus (4) connected to an optical measurement apparatus (1), the calibration apparatus (4) being configured to obtain a plurality of calibration data used when the optical measurement apparatus (1) corrects returned light from an object to be measured, the optical measurement apparatus (1) including:

a measurement probe (3) having a rod lens (36), an illumination fiber (31) configured to irradiate via the rod lens (36) to the object to be measured illumination light including at least light of wavelength to be measured, and a plurality of detection fibers (32, 33, 34) configured to receive via the rod lens (36) the returned light, which is of the illumination light reflected and/or scattered by the object to be measured; and
a plurality of detection units (23, 24, 25) configured to detect the returned light respectively received by the plurality of detection fibers (32, 33, 34);
the calibration apparatus (4) comprising:
an insertion portion (41a) into which the measurement probe (3) is inserted; and
a reference reflection plate (43) that is arranged at a position away from a distal end of the measurement probe (3) by a predetermined distance in a state in which the measurement probe (3) has been inserted in the insertion portion (41a) and that has uniform reflectivity of light in a range of the wavelength to be measured in an irradiation plane of the illumination light, wherein
a material forming the reference reflection plate (43) satisfies condition (1) or condition (2) as follows:

$$(1): ls^* \geq 2Lsc, \text{ AND } g \leq 0.85$$

$$(2): ls^* \approx 2Lsc, \text{ AND } g > 0.85,$$

wherein
ls* represents a scattering mean free path of the material forming the reference reflection plate (43), g represents

an anisotropic parameter in a scattering direction of the reference reflection plate (43), and Lsc represents a spatial coherence length at a detection position of the reference reflection plate (43) and fulfills equation (3) as follows:

$$(3): Lsc = \lambda(R/n + L) / \pi\rho,$$

wherein
a length in a fiber longitudinal direction of the rod lens (36) is R, a distance from the distal end of the measurement probe (3) to the reference reflection plate (43) is L, a refractive index of the rod lens (36) at a prescribed wavelength λ is n, and a core diameter of the illumination fiber (31) is ρ.

2. The system according to claim 1, wherein the material forming the reference reflection plate (43) has the scattering mean free path that is greater than twice the spatial coherence length and has an anisotropic parameter that is equal to or less than 0.85.

3. The system according to claim 1, wherein the material forming the reference reflection plate has the scattering mean free path that is approximately equal to twice the spatial coherence length and has an anisotropic parameter is greater than 0.85.

4. The system according to any one of claims 1 to 3, further comprising a drive unit configured to move the reference reflection plate (43) towards the distal end of the measurement probe (3) when the optical measurement apparatus (1) obtains the calibration data.

5. The system according to any one of claims 1 to 4, further comprising an accommodation portion configured to accommodate the reference reflection plate (43), wherein the insertion portion (41a) and the accommodation portion are connected to each other or arranged changeably between each other.

6. The system according to claim 5, wherein
the insertion portion (41a) has a light absorption portion (81c) provided with, on an inner surface thereof, a light absorption member configured to absorb light, the light absorption portion being tubular, and
the plurality of calibration data are: reference reflection plate calibration data when measurement is performed in the accommodation portion; and internal reflection calibration data of the measurement probe (3) when measurement is performed in the insertion portion (41a).

7. The system according to any one of claims 1 to 4, wherein the insertion portion (41a)
has an opening at an end thereof,
is bottomed and tubular,
has, on an inner surface at a position near an insertion opening through which the measurement probe (3) is inserted, a light absorption portion (81c) provided with a light absorption member that absorbs light, and
has the reference reflection plate (43) provided on a bottom portion thereof.

8. The system according to claim 7, wherein the insertion portion (41a) is bent.

9. The system according to any one of claims 1 to 4, further comprising:

a first container (114) provided inside thereof with an optical absorption member that is configured to absorb light;
a second container (115) that accommodates the reference reflection plate (43);
a change portion configured to change, with respect to the insertion portion (41a), positions of the first container (114) and the second container (115); and
a change drive unit configured to drive the change unit.

10. A calibration method of obtaining calibration data using the system of any one of the preceding claims, the calibration method comprising:

a first step of obtaining data for internal reflection calibration of the measurement probe (3) detected by the detection units (23, 24, 25) when the measurement probe (3) is caused to irradiate the illumination light to the insertion portion (41a) that is provided, inside the calibration apparatus (4), with a light absorption member that absorbs light; and

a second step of obtaining reference reflection plate calibration data detected by the detection units (23, 24, 25) when the measurement probe (3) irradiates the illumination light to the reference reflection plate (43) in the calibration apparatus (4).

Patentansprüche

1. System, das eine mit einem optischen Messgerät (1) verbundene Kalibriervorrichtung (4) umfasst, wobei die Kalibriervorrichtung (4) dazu eingerichtet ist, eine Mehrzahl von Kalibrierdaten zu erhalten, die verwendet werden, wenn das optische Messgerät (1) von einem zu messenden Objekt rückgestreutes Licht korrigiert, wobei das optische Messgerät (1) umfasst:

eine Messsonde (3), die eine Stablinse (36), eine Beleuchtungsfaser (31), die dazu eingerichtet ist, über die Stablinse (36) auf das zu messende Objekt Beleuchtungslicht abzustrahlen, das zumindest Licht einer zu messenden Wellenlänge enthält, und eine Mehrzahl von Erfassungsfasern (32, 33, 34) umfasst, die dazu eingerichtet sind, über die Stablinse (36) das rückgestreute Licht zu empfangen, das aus dem durch das zu messende Objekt reflektierten und/oder gestreuten Beleuchtungslicht besteht; und

eine Mehrzahl von Erfassungseinheiten (23, 24, 25), die dazu eingerichtet sind, das rückgestreute Licht zu erfassen, das jeweils durch die Mehrzahl von Erfassungsfasern (32, 33, 34) empfangen wird;

wobei die Kalibriervorrichtung (4) umfasst:

einen Einführabschnitt (41a), in dem die Messsonde (3) eingeführt ist; und

eine Referenzreflexionsplatte (43), die in einem Zustand, in dem die Messsonde (3) in den Einführabschnitt (41a) eingeführt ist, an einer Position angeordnet ist, die von einem distalen Ende der Messsonde (3) um einen vorbestimmten Abstand entfernt ist und die ein gleichmäßiges Reflexionsvermögen von Licht in einem Bereich der zu messenden Wellenlänge in einer Bestrahlungsebene des Beleuchtungslichts hat, wobei

ein die Referenzreflexionsplatte (43) bildendes Material die folgende Bedingung (1) oder die folgende Bedingung (2) erfüllt:

$$(1):\ ls^* \geq 2Lsc,\ \text{AND}\ g \leq 0{,}85$$

$$(2):\ ls^* \approx 2Lsc,\ \text{AND}\ g > 0{,}85,$$

wobei

ls* eine mittlere freie Streuungsweglänge des die Referenzreflexionsplatte (43) bildenden Materials darstellt, g einen Anisotropie-Parameter in einer Streurichtung der Referenzreflexionsplatte (43) darstellt und Lsc eine räumliche Kohärenzlänge an einer Erfassungsposition der Referenzreflexionsplatte (43) darstellt und die folgende Gleichung (3) erfüllt:

$$(3):\ Lsc = \lambda(R/n + L)\ /\ \pi\rho,$$

wobei

eine Länge in einer Faserlängsrichtung der Stablinse (36) R ist, ein Abstand von dem distalen Ende der Messsonde (3) zu der Referenzreflexionsplatte (43) L ist, ein Brechungsindex der Stablinse (36) bei einer vorgeschriebenen Wellenlänge λ n ist, und ein Kerndurchmesser der Beleuchtungsfaser (31) ρ ist.

2. System gemäß Anspruch 1, bei dem das die Referenzreflexionsplatte (43) bildende Material die mittlere freie Streuungsweglänge hat, die größer ist als das Doppelte der räumlichen Kohärenzlänge, und einen Anisotropie-Parameter hat, der gleich oder kleiner als 0,85 ist.

3. System gemäß Anspruch 1, bei dem das die Referenzreflexionsplatte (43) bildende Material die mittlere freie Streuungsweglänge hat, die ungefähr gleich bis das Doppelte der räumlichen Kohärenzlänge ist, und einen Anisotropie-Parameter hat, der größer als 0,85 ist.

4. System gemäß einem der Ansprüche 1 bis 3, das ferner eine Antriebseinheit umfasst, die dazu eingerichtet ist, die Referenzreflexionsplatte (43) in Richtung des distalen Endes der Messsonde (3) zu bewegen, wenn das optische Messgerät (1) die Kalibrierdaten erhält.

5. System gemäß einem der Ansprüche 1 bis 4, das ferner einen Aufnahmeabschnitt umfasst, der dazu eingerichtet ist, die Referenzreflexionsplatte (43) aufzunehmen, wobei der Einführabschnitt (41a) und der Aufnahmeabschnitt miteinander verbunden oder wechselbar zwischen einander angeordnet sind.

6. System gemäß Anspruch 5, bei dem
der Einführabschnitt (41a) einen Lichtabsorptionsabschnitt (81c) hat, der an seiner Innenfläche mit einem Lichtabsorptionselement versehen ist, welches dazu eingerichtet ist, Licht zu absorbieren, wobei der Lichtabsorptionsabschnitt rohrförmig ist, und
die Mehrzahl von Kalibrierdaten sind: Referenzreflexionsplattenkalibrierdaten, wenn eine Messung in dem Aufnahmeabschnitt durchgeführt wird; und interne Reflexionskalibrierdaten der Messsonde (3), wenn eine Messung in dem Einführabschnitt (41a) durchgeführt wird.

7. System gemäß einem der Ansprüche 1 bis 4, bei dem der Einführabschnitt (41a)
eine Öffnung an seinem Ende hat,
einen Boden hat und rohrförmig ist,
an einer Innenfläche an einer Position in der Nähe einer Einführöffnung, durch die die Messsonde (3) eingeführt ist, einen Lichtabsorptionsabschnitt (81c) hat, welcher mit einem Absorptionselement versehen ist, das Licht absorbiert, und
die Referenzreflexionsplatte (43) an seinem Bodenabschnitt vorgesehen hat.

8. System gemäß Anspruch 7, bei dem der Einführabschnitt (41a) gebogen ist.

9. System gemäß einem der Ansprüche 1 bis 4, das ferner umfasst:

einen ersten Behälter (114), der in seinem Inneren mit einem optischen Absorptionselement versehen ist, das dazu eingerichtet ist, Licht zu absorbieren;
einen zweiten Behälter (115), der die Referenzreflexionsplatte (43) aufnimmt;
einen Wechselabschnitt, der dazu eingerichtet ist, Positionen des ersten Behälters (114) und des zweiten Behälters (115) des Einführabschnitt (41a) zu wechseln; und
eine Wechselantriebseinheit, die dazu eingerichtet ist, die Wechseleinheit anzutreiben.

10. Kalibrierverfahren zum Erhalten von Kalibrierdaten unter Verwendung des Systems gemäß einem der vorhergehenden Ansprüche, wobei das Kalibrierverfahren umfasst:

einen ersten Schritt zum Erhalten von Daten für eine interne Reflexionskalibrierung der Messsonde (3), die von den Erfassungseinheiten (23, 24, 25) erfasst werden, wenn die Messsonde (3) dazu veranlasst wird, das Beleuchtungslicht auf den Einführabschnitt (41a) abzustrahlen, der im Inneren der Kalibriervorrichtung (4) mit einem Lichtabsorptionselement versehen ist, das Licht absorbiert; und
einen zweiten Schritt zum Erhalten von Referenzreflexionsplattenkalibrierdaten, die durch die Erfassungseinheiten (23, 24, 25) erfasst werden, wenn die Messsonde (3) das Beleuchtungslicht auf die Referenzreflexionsplatte (43) in der Kalibriervorrichtung (4) abstrahlt.

Revendications

1. Système comprenant un appareil (4) d'étalonnage connecté à un appareil (1) de mesure optique, l'appareil (4) d'étalonnage étant configuré pour obtenir une pluralité de données d'étalonnage utilisées lorsque l'appareil (1) de mesure optique corrige une lumière renvoyée d'un objet à mesurer, l'appareil (1) de mesure optique incluant :

une sonde (3) de mesure ayant une lentille barreau (36), une fibre (31) d'illumination configurée pour projeter

par l'intermédiaire de la lentille barreau (36) sur l'objet à mesurer une lumière d'illumination incluant au moins une lumière d'une longueur d'onde à mesurer, et une pluralité de fibres (32, 33, 34) de détection configurées pour recevoir par l'intermédiaire de la lentille barreau (36) la lumière renvoyée, qui est de la lumière d'illumination réfléchie et/ou diffusée par l'objet à mesurer ; et
une pluralité d'unités (23, 24, 25) de détection configurées pour détecter la lumière renvoyée respectivement reçue par la pluralité de fibres (32, 33, 34) de détection ;
l'appareil (4) d'étalonnage comprenant :

une partie (41a) d'insertion dans laquelle la sonde (3) de mesure est insérée ; et
une plaque (43) de réflexion de référence qui est agencée en une position distante d'une extrémité distale de la sonde (3) de mesure d'une distance prédéterminée dans un état dans lequel la sonde (3) de mesure a été insérée dans la partie (41a) d'insertion et qui a une réflectivité uniforme de la lumière dans une plage de la longueur d'onde à mesurer dans un plan de projection de la lumière d'illumination, dans lequel
un matériau formant la plaque (43) de réflexion de référence satisfait à la condition (1) ou la condition (2) comme suit :

$$(1) : Is^* \geq 2Lsc, \text{ ET } g \leq 0{,}85$$

$$(2) : Is^* \approx 2Lsc, \text{ ET } g > 0{,}85,$$

dans lesquelles
Is* représente un libre parcours moyen de diffusion du matériau formant la plaque (43) de réflexion de référence, g représente un paramètre anisotrope dans un sens de diffusion de la plaque (43) de réflexion de référence, et Lsc représente une longueur de cohérence spatiale au niveau d'une position de détection de la plaque (43) de réflexion de référence et satisfait à l'équation (3) comme suit :

$$(3) : Lsc = \lambda(R/\ n + L)\ /\ \pi\rho,$$

dans laquelle
une longueur dans un sens longitudinal de fibre de la lentille barreau (36) est R, une distance de l'extrémité distale de la sonde (3) de mesure à la plaque (43) de réflexion de référence est L, un indice de réfraction de la lentille barreau (36) à une longueur d'onde prescrite λ est n, et un diamètre de noyau de la fibre (31) d'illumination est ρ.

2. Système selon la revendication 1, dans lequel le matériau formant la plaque (43) de réflexion de référence a le libre parcours moyen de diffusion qui est supérieur à deux fois la longueur de cohérence spatiale et a un paramètre anisotrope qui est égal ou inférieur à 0,85.

3. Système selon la revendication 1, dans lequel le matériau formant la plaque (43) de réflexion de référence a le libre parcours moyen de diffusion qui est approximativement égal à deux fois la longueur de cohérence spatiale et a un paramètre anisotrope qui est supérieur à 0,85.

4. Système selon l'une quelconque des revendications 1 à 3, comprenant en outre une unité d'entraînement configurée pour déplacer la plaque (43) de réflexion de référence vers l'extrémité distale de la sonde (3) de mesure lorsque l'appareil (1) de mesure optique obtient les données d'étalonnage.

5. Système selon l'une quelconque des revendications 1 à 4, comprenant en outre une partie de réception configurée pour recevoir la plaque (43) de réflexion de référence, dans lequel la partie (41a) d'insertion et la partie de réception sont connectées l'une à l'autre ou agencées de façon changeable l'une avec l'autre.

6. Système selon la revendication 5, dans lequel
la partie (41a) d'insertion a une partie (81c) d'absorption de lumière prévue avec, sur une surface intérieure de celle-

ci, un élément d'absorption de lumière configuré pour absorber une lumière, la partie d'absorption de lumière étant tubulaire, et
la pluralité de données d'étalonnage sont : des données d'étalonnage de plaque de réflexion de référence lorsqu'une mesure est effectuée dans la partie de réception ; et des données d'étalonnage de réflexion interne de la sonde (3) de mesure lorsqu'une mesure est effectuée dans la partie (41a) d'insertion.

7. Système selon l'une quelconque des revendications 1 à 4, dans lequel la partie (41a) d'insertion
a une ouverture à une extrémité de celle-ci,
a un fond et est tubulaire,
a, sur une surface intérieure en une position à côté d'une ouverture d'insertion à travers laquelle la sonde (3) de mesure est insérée, une partie (81c) d'absorption de lumière prévue avec un élément d'absorption de lumière qui absorbe une lumière, et
a la plaque (43) de réflexion de référence prévue sur une partie de fond de celle-ci.

8. Système selon la revendication 7, dans lequel la partie (41a) d'insertion est courbe.

9. Système selon l'une quelconque des revendications 1 à 4, comprenant en outre :

un premier récipient (114) prévu à l'intérieur de celui-ci avec un élément d'absorption optique qui est configuré pour absorber une lumière ;
un deuxième récipient (115) qui reçoit la plaque (43) de réflexion de référence ;
une partie de changement configurée pour changer, par rapport à la partie (41a) d'insertion, des positions du premier récipient (114) et du deuxième récipient (115) ; et
une unité d'entraînement de changement configurée pour entraîner l'unité de changement.

10. Procédé d'étalonnage pour obtenir des données d'étalonnage en utilisant le système selon l'une quelconque des revendications précédentes, le procédé d'étalonnage comprenant :

une première étape d'obtention de données pour un étalonnage de réflexion interne de la sonde (3) de mesure détectées par les unités (23, 24, 25) de détection lorsque la sonde (3) de mesure est fait projeter la lumière d'illumination sur la partie (41a) d'insertion qui est prévue, à l'intérieur de l'appareil (4) d'étalonnage, avec un élément d'absorption de lumière qui absorbe une lumière ; et
une deuxième étape d'obtention de données d'étalonnage de plaque de réflexion de référence détectées par les unités (23, 24, 25) de détection lorsque la sonde (3) de mesure projette la lumière d'illumination sur la plaque (43) de réflexion de référence dans l'appareil (4) d'étalonnage.

FIG.1

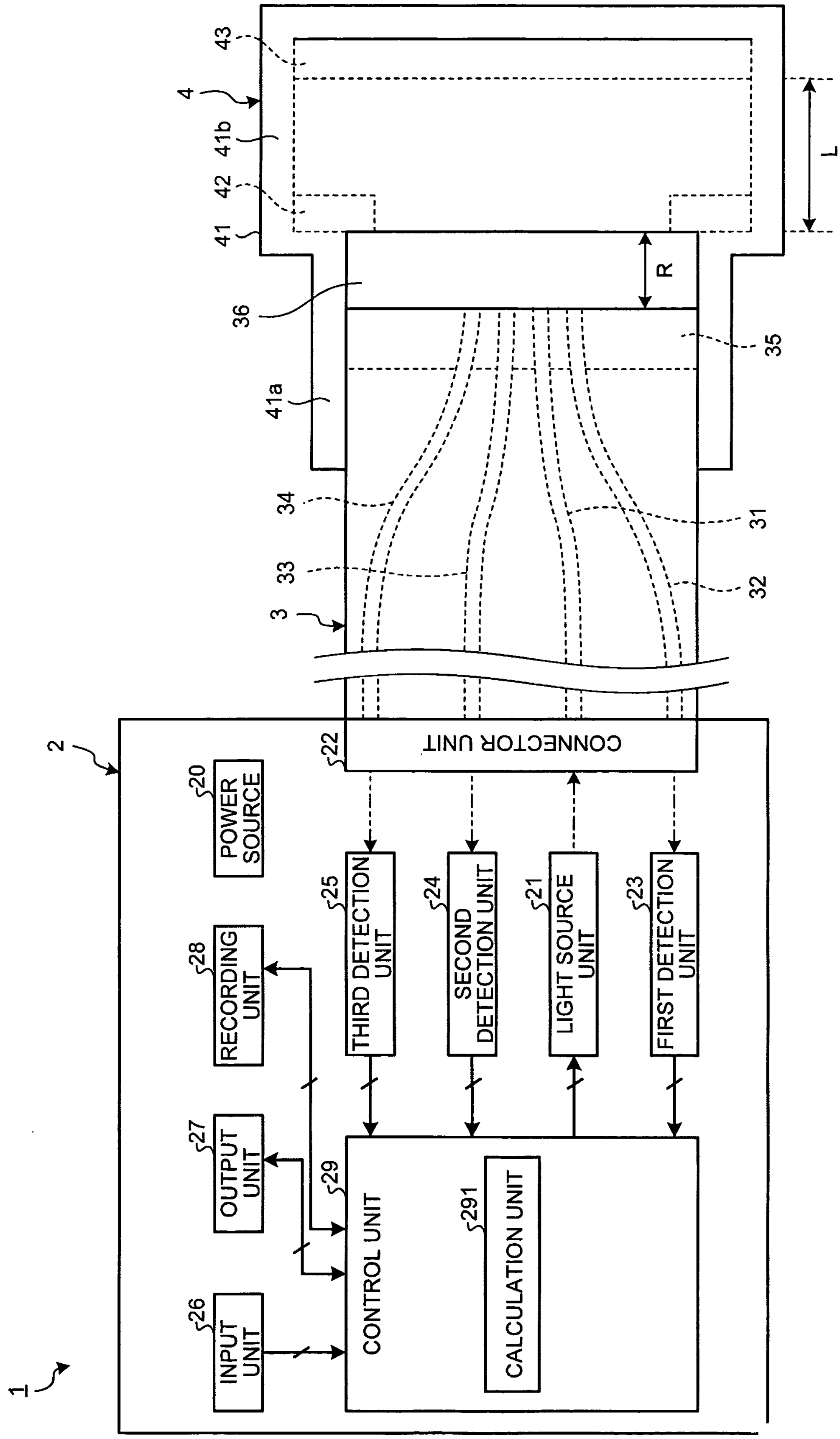

1
2
3
4
20
POWER SOURCE
28
RECORDING UNIT
27
OUTPUT UNIT
26
INPUT UNIT
29
CONTROL UNIT
291
CALCULATION UNIT
25
THIRD DETECTION UNIT
24
SECOND DETECTION UNIT
21
LIGHT SOURCE UNIT
23
FIRST DETECTION UNIT
22
CONNECTOR UNIT
31
32
33
34
35
36
41
41a
41b
42
43
R
L

FIG.2

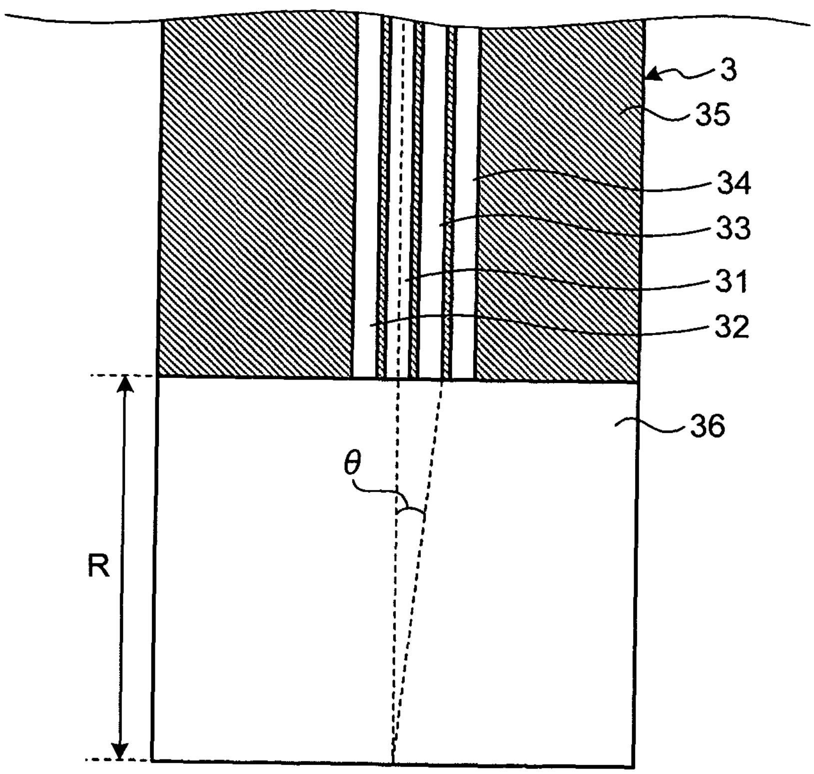


FIG.3

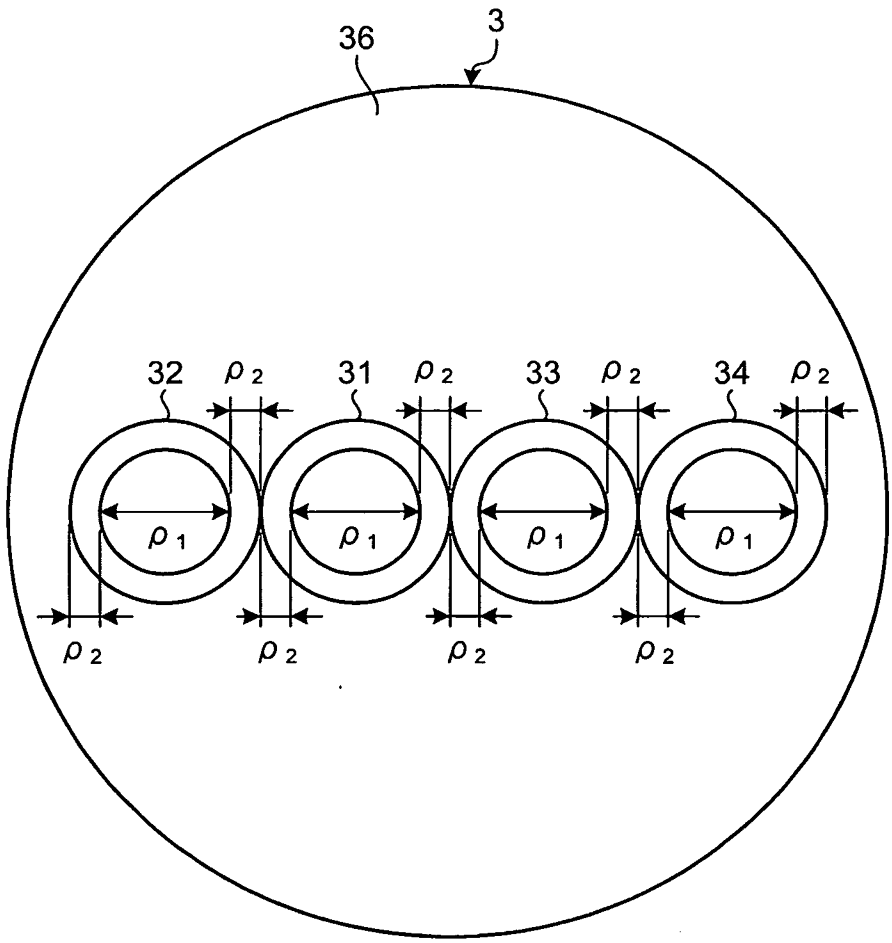

36
3
32
ρ_2
31
ρ_2
33
ρ_2
34
ρ_2
ρ_1
ρ_1
ρ_1
ρ_1
ρ_2
ρ_2
ρ_2
ρ_2

FIG.4

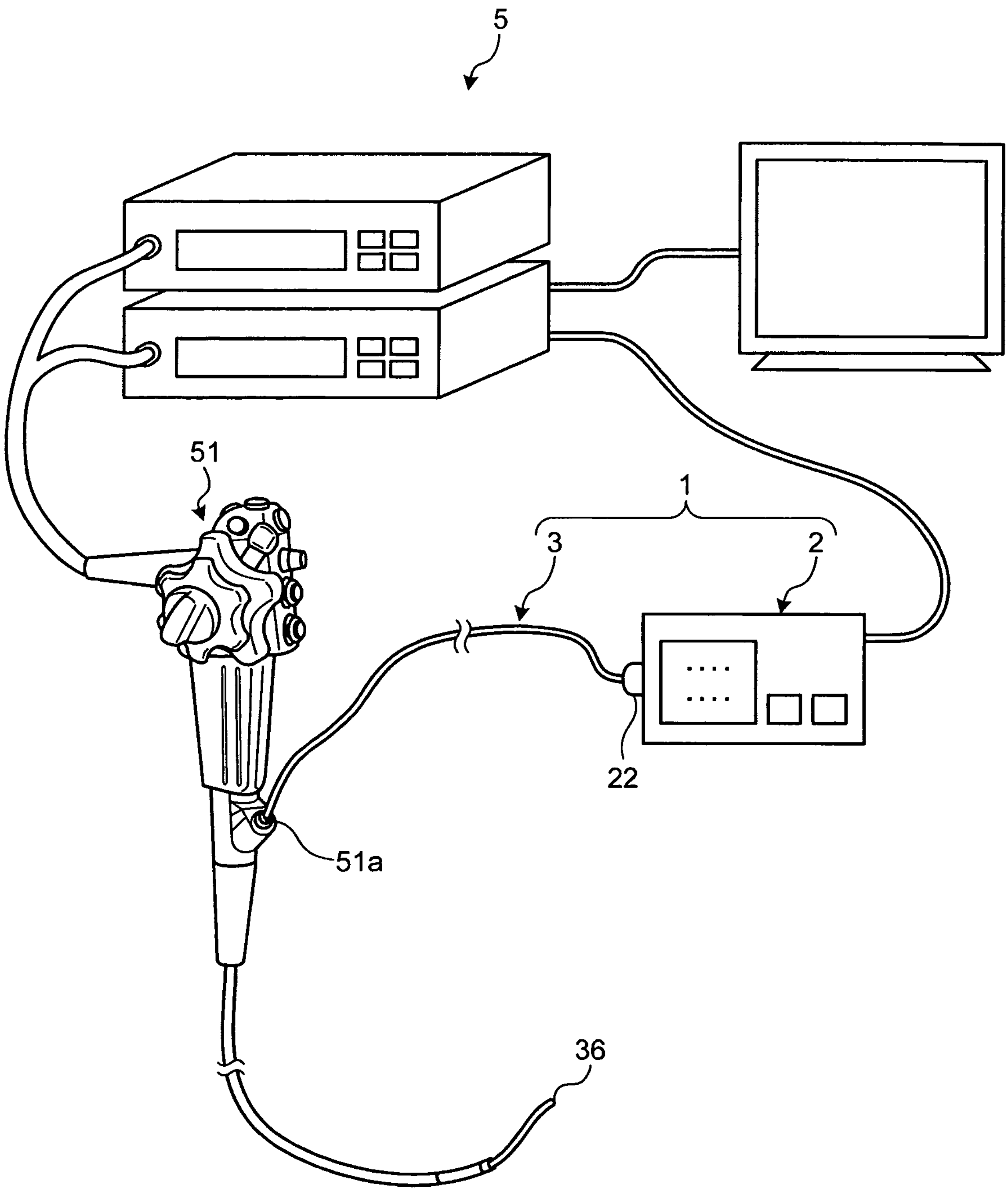


FIG.5

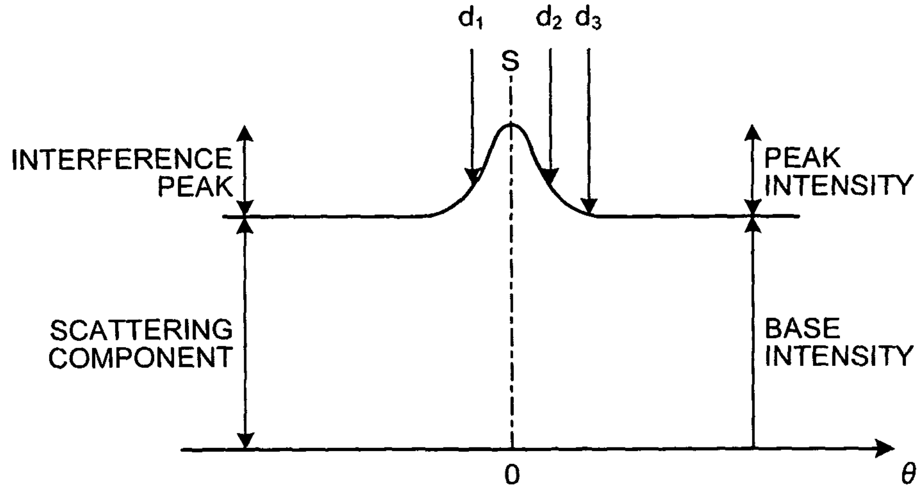

d1
d2 d3
S
INTERFERENCE
PEAK
PEAK
INTENSITY
SCATTERING
COMPONENT
BASE
INTENSITY
0
θ

FIG.6

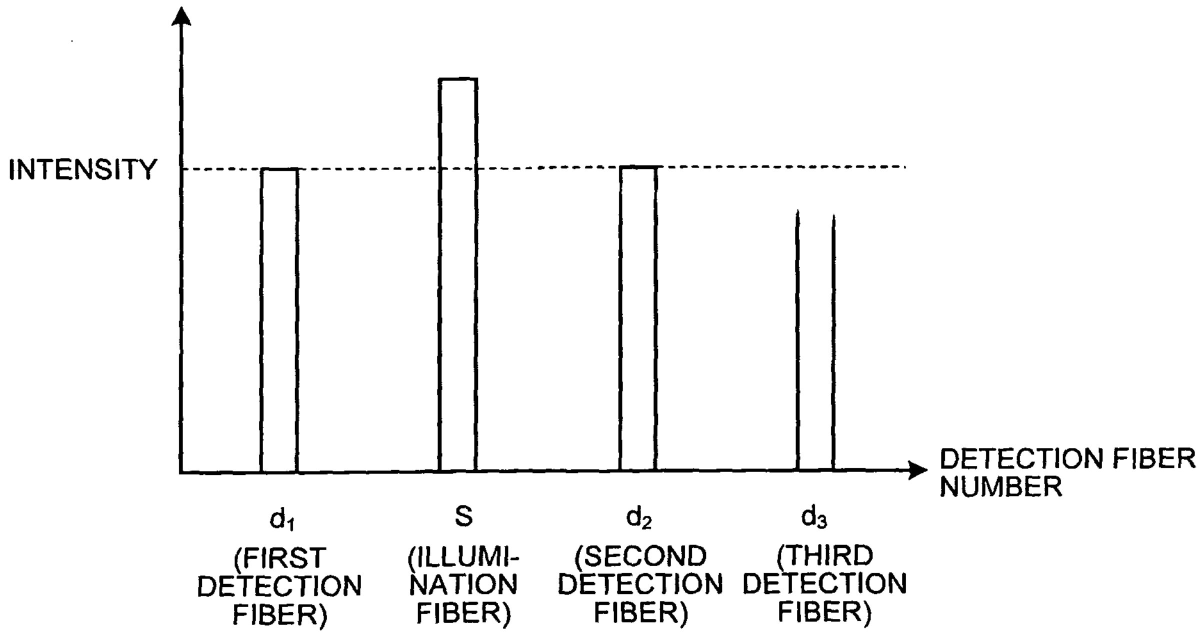

INTENSITY
DETECTION FIBER
NUMBER
d1
(FIRST
DETECTION
FIBER)
S
(ILLUMI-
NATION
FIBER)
d2
(SECOND
DETECTION
FIBER)
d3
(THIRD
DETECTION
FIBER)

FIG.7

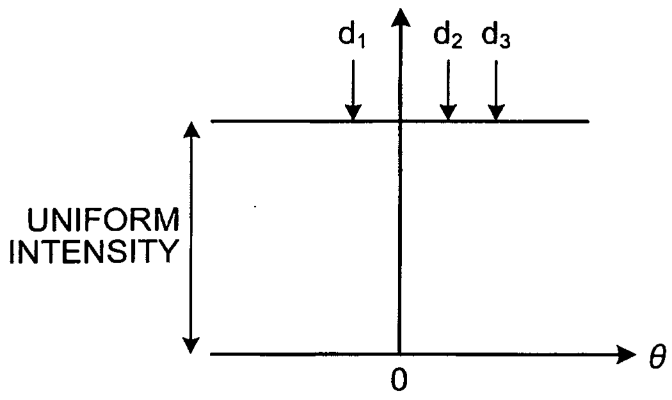

d1
d2
d3
UNIFORM INTENSITY
0
θ

FIG.8

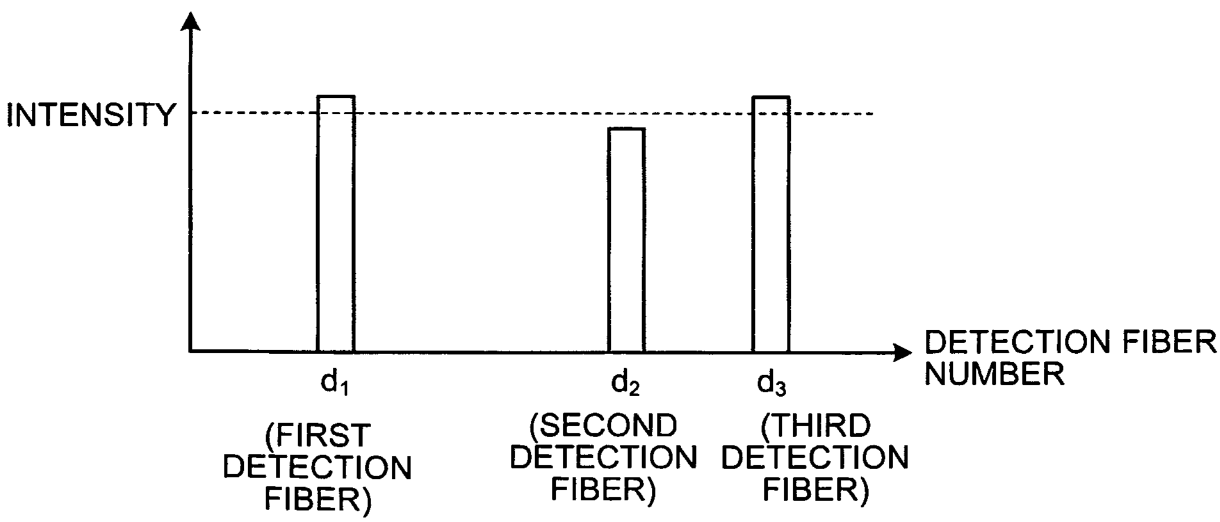

INTENSITY
DETECTION FIBER NUMBER
d1
(FIRST DETECTION FIBER)
d2
(SECOND DETECTION FIBER)
d3
(THIRD DETECTION FIBER)

FIG.9

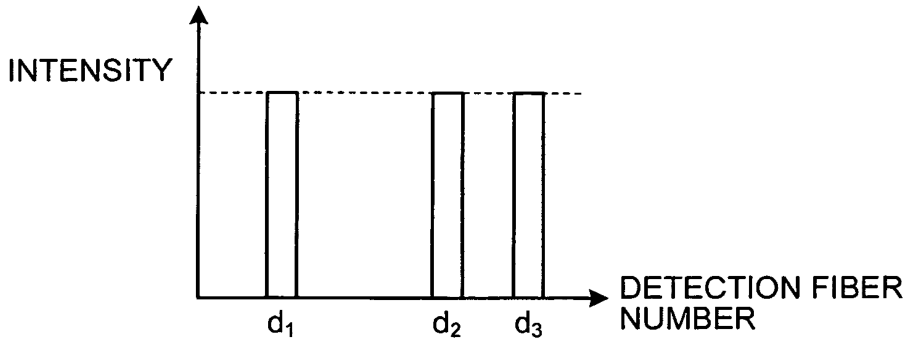

INTENSITY
DETECTION FIBER NUMBER
d_1
d_2
d_3

FIG.10

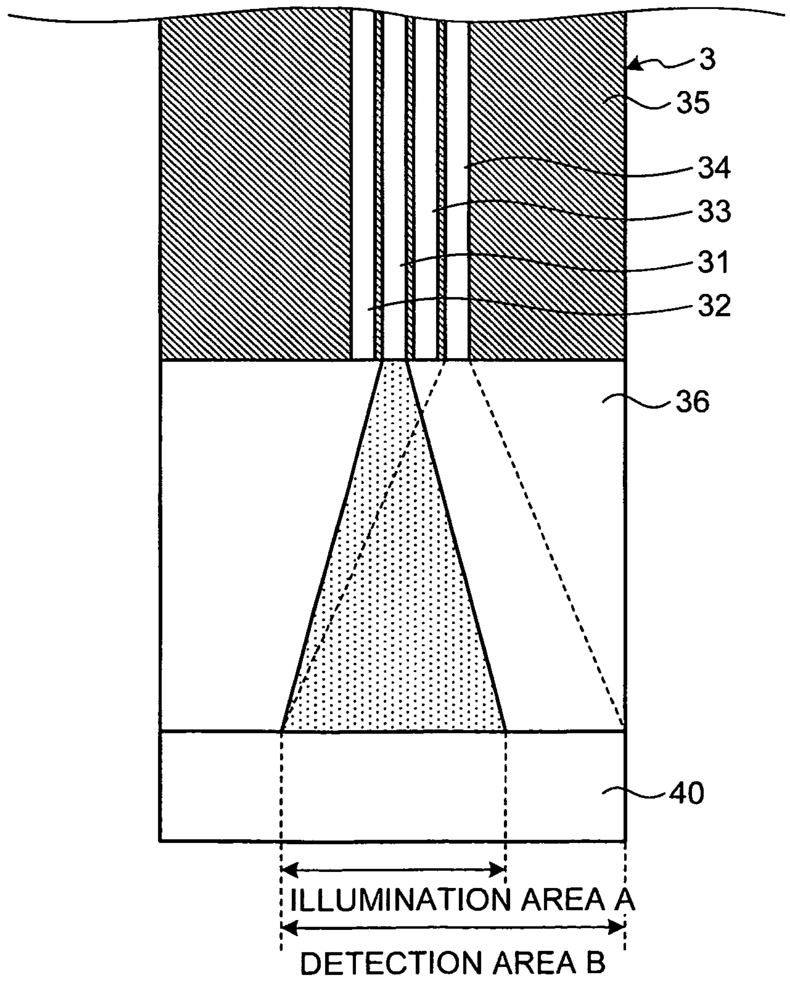
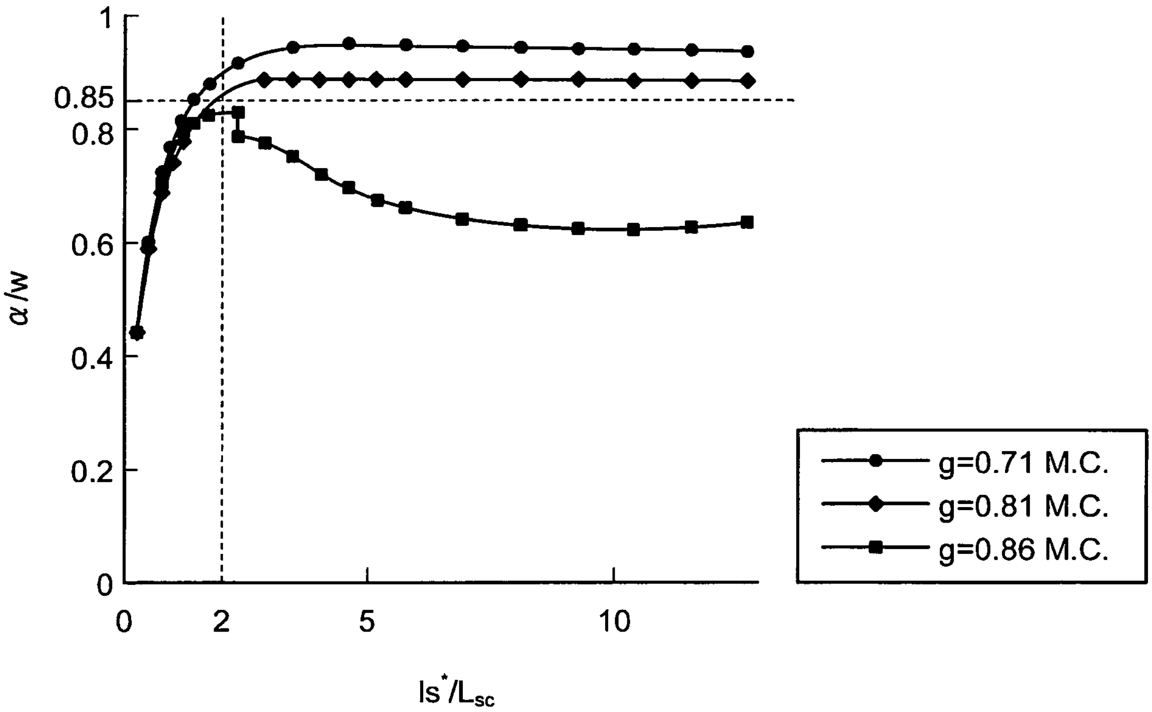
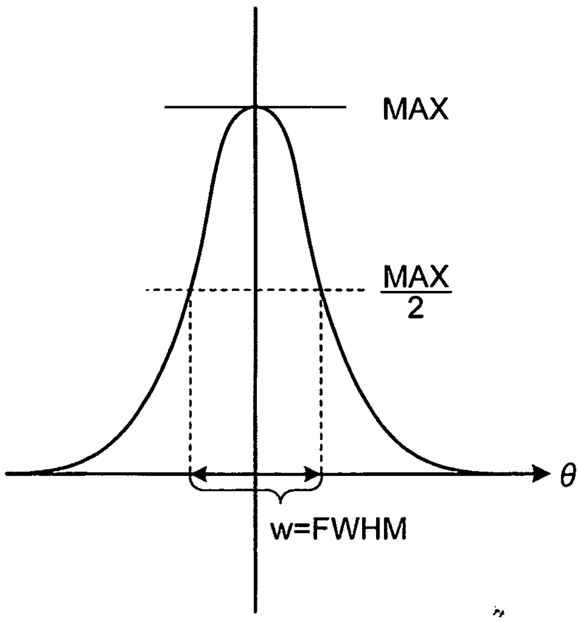

3
35
34
33
31
32
36
40
ILLUMINATION AREA A
DETECTION AREA B

FIG.11



1
0.85
0.8
0.6
0.4
0.2
0
α/w
0
2
5
10
ls*/Lsc
g=0.71 M.C.
g=0.81 M.C.
g=0.86 M.C.

FIG.12



MAX
MAX/2
θ
w=FWHM

FIG.13

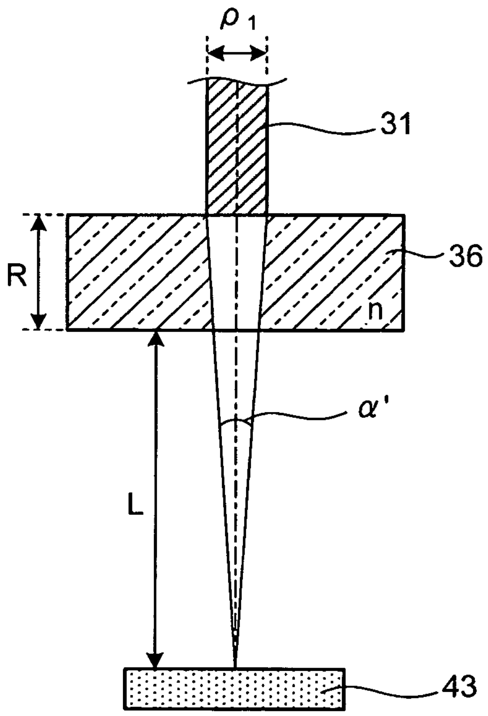


FIG.14

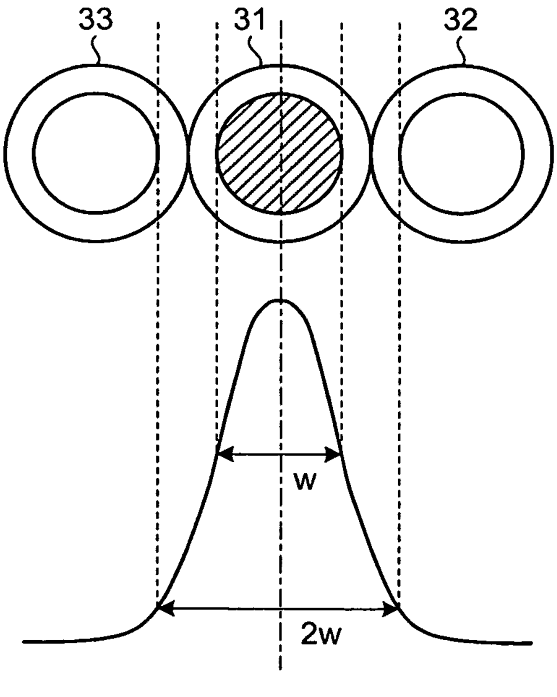


FIG.15

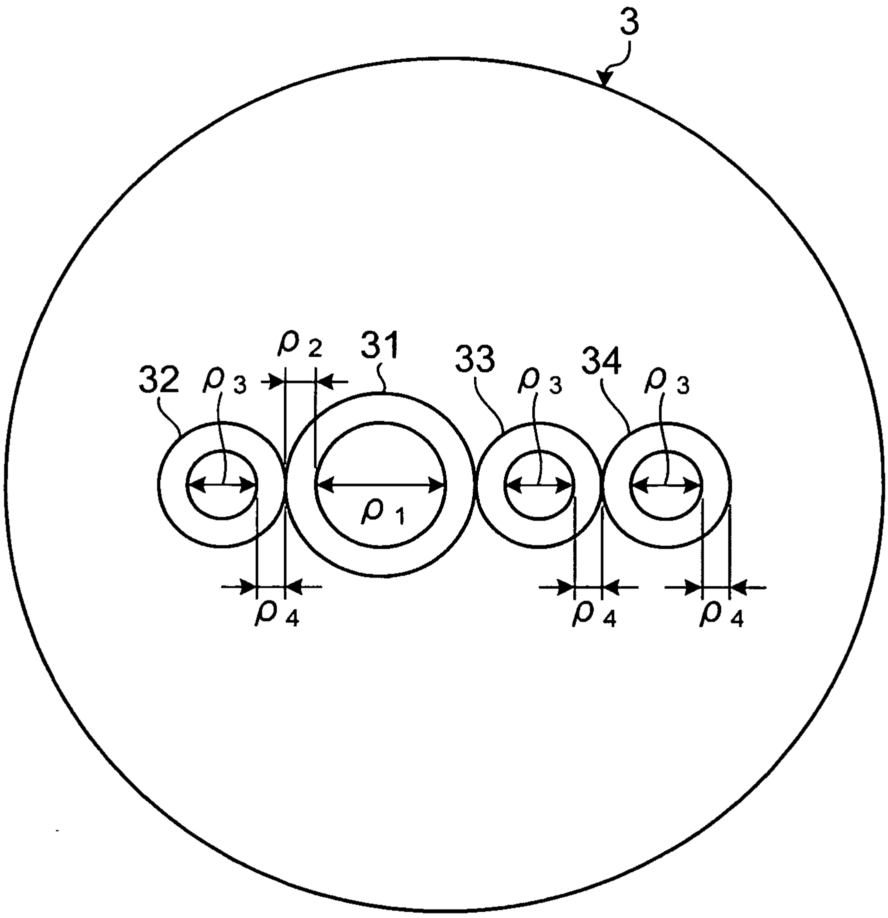


FIG.16

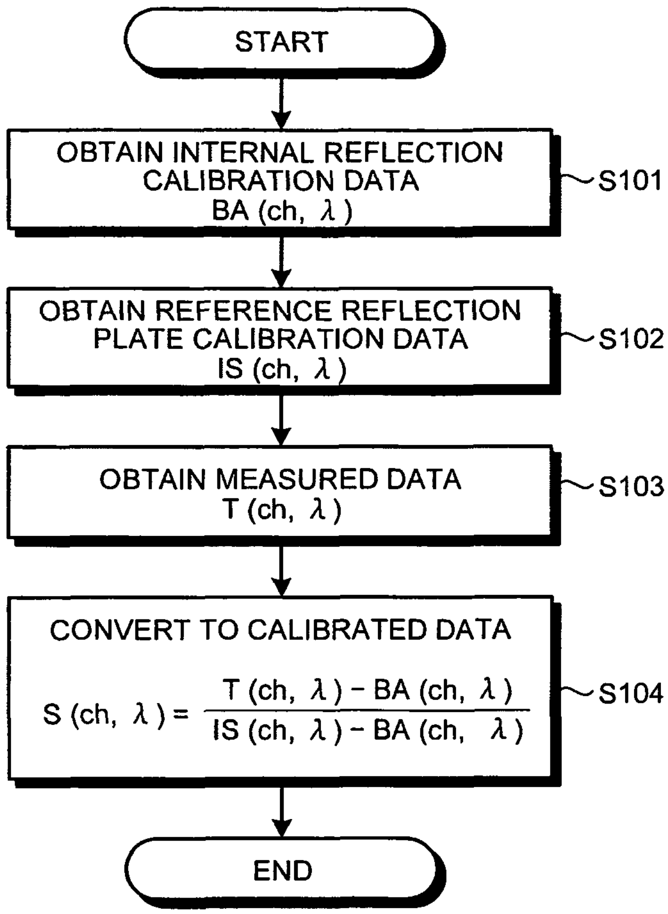

START
OBTAIN INTERNAL REFLECTION CALIBRATION DATA BA (ch, λ)
S101
OBTAIN REFERENCE REFLECTION PLATE CALIBRATION DATA IS (ch, λ)
S102
OBTAIN MEASURED DATA T (ch, λ)
S103
CONVERT TO CALIBRATED DATA
S (ch, λ) = (T (ch, λ) - BA (ch, λ)) / (IS (ch, λ) - BA (ch, λ))
S104
END

FIG.17

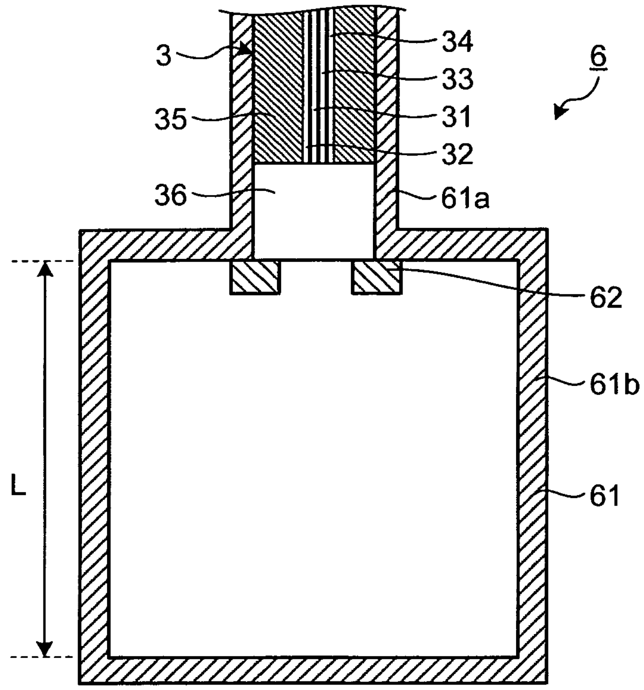

3
35
36
34
33
31
32
61a
6
62
61b
L
61

FIG.18

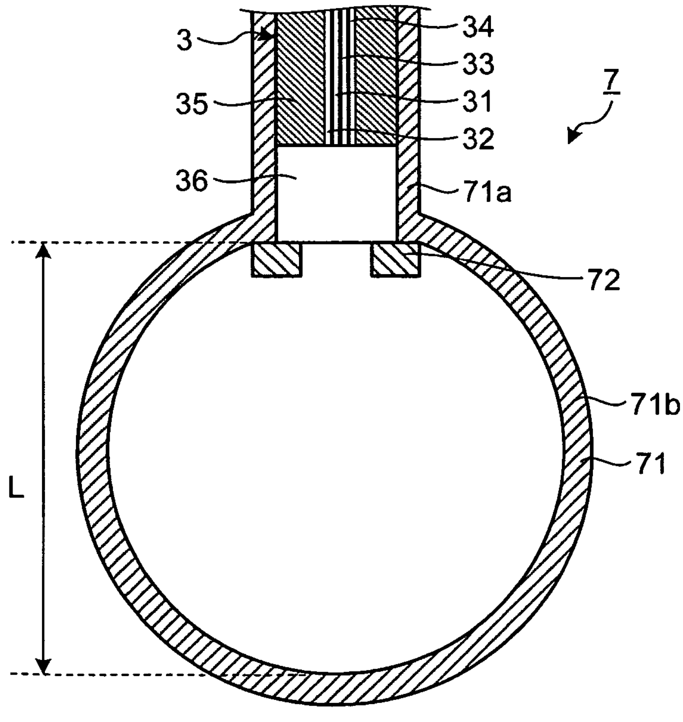

3
35
36
34
33
31
32
71a
7
72
71b
L
71

FIG.19

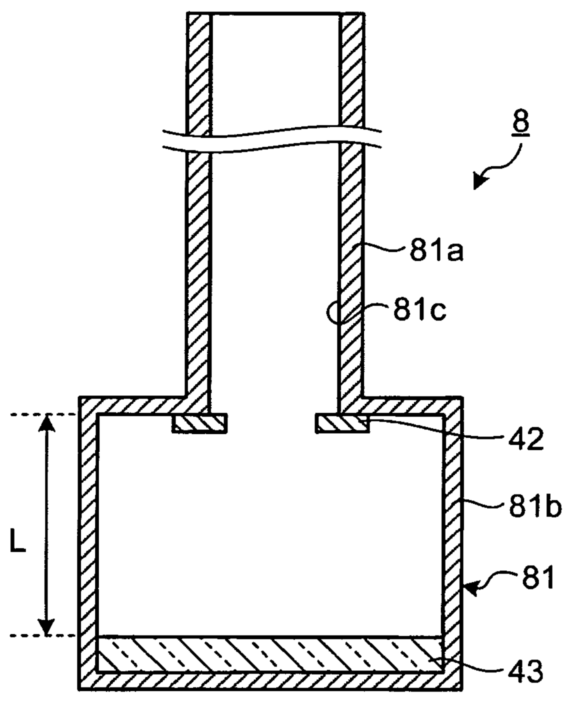


FIG.20

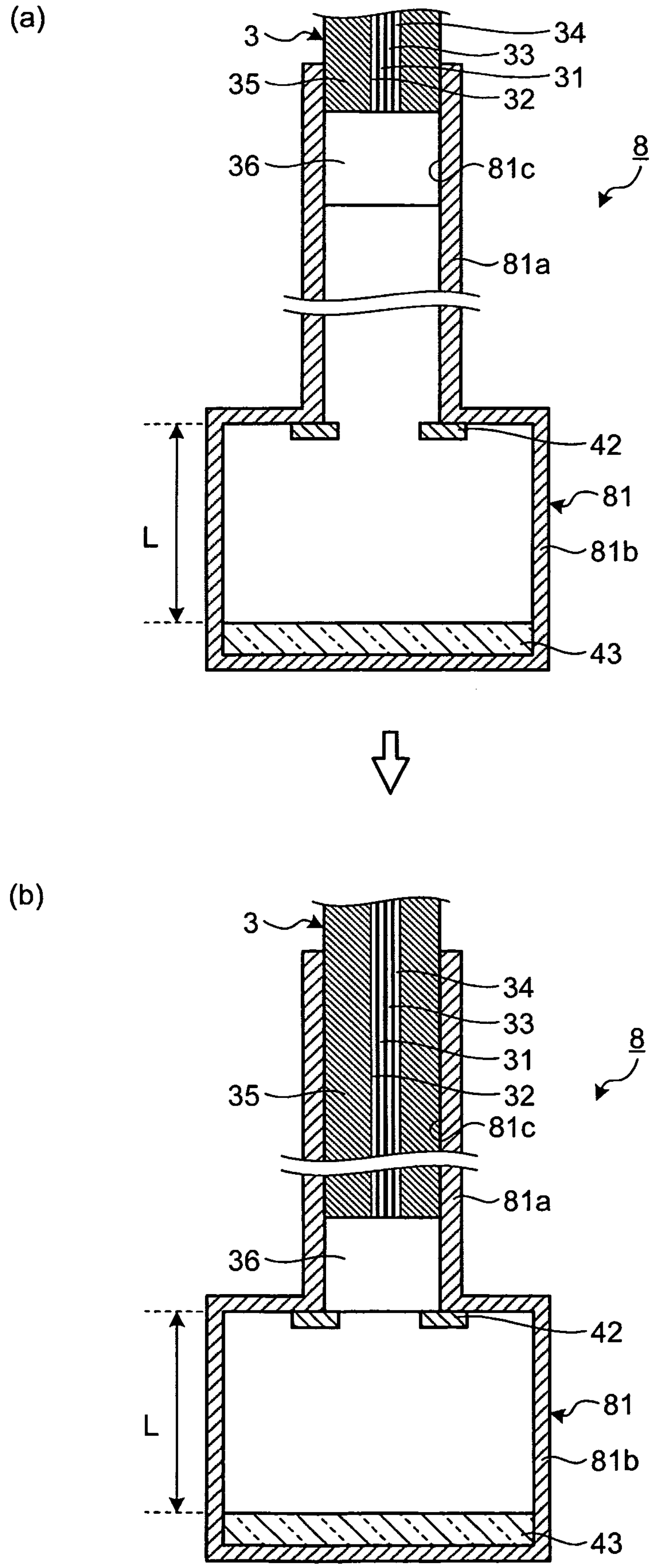

(a)
3
34
33
35
31
32
36
81c
8
81a
42
81
L
81b
43
(b)
3
34
33
31
35
32
81c
81a
36
42
81
L
81b
43

FIG.21

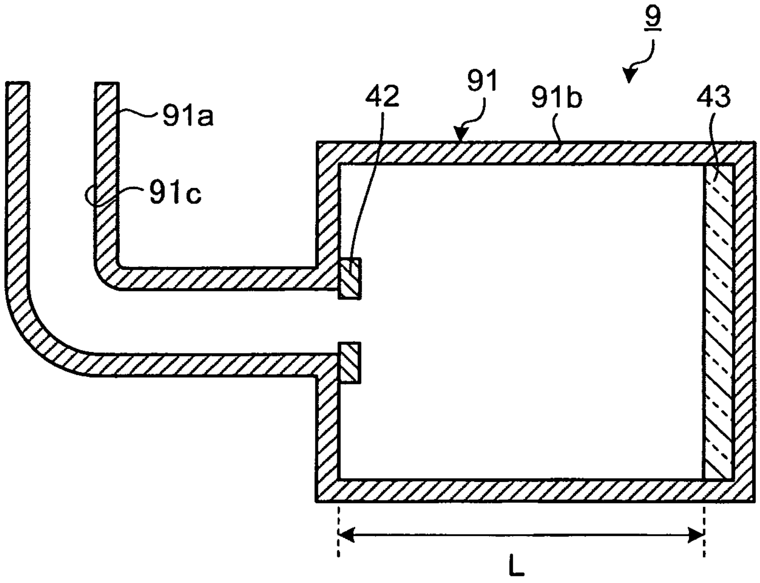

9
91
42
91b
43
91a
91c
L

FIG.22

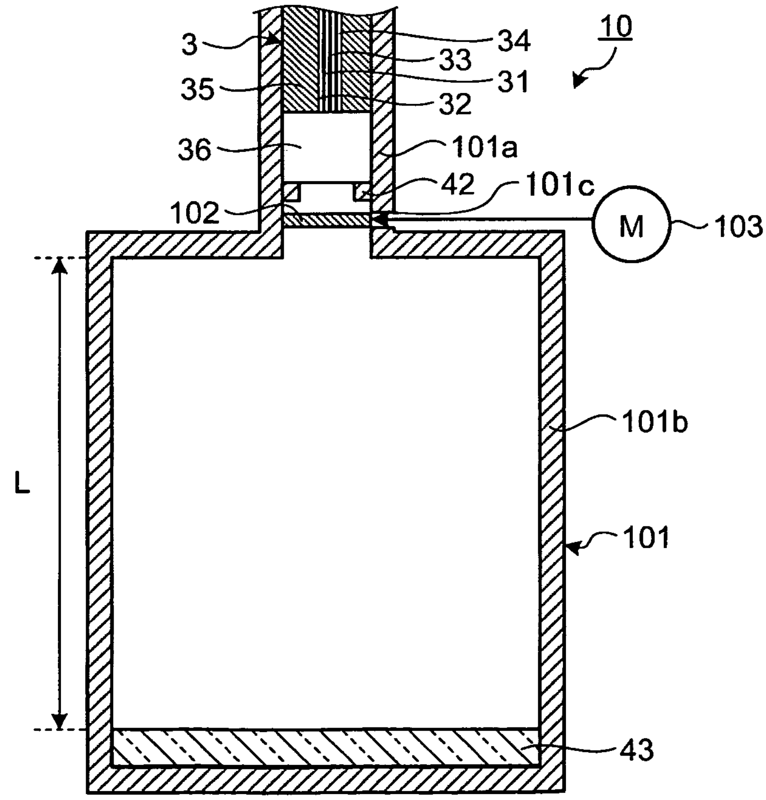

3
35
36
102
34
33
31
32
10
101a
42
101c
M
103
L
101b
101
43

FIG.23

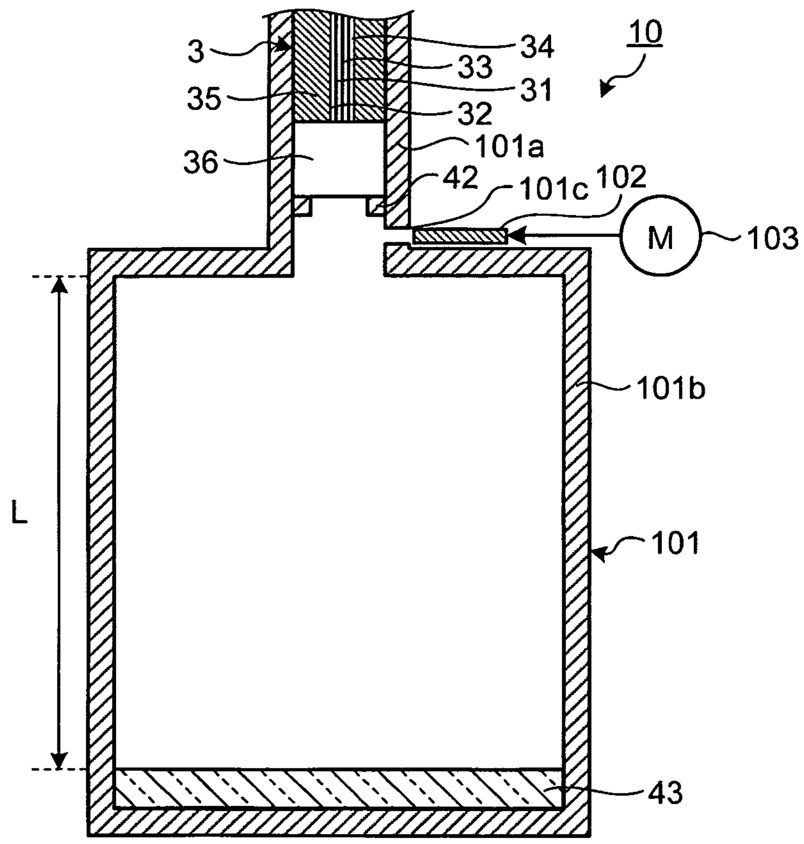


FIG.24

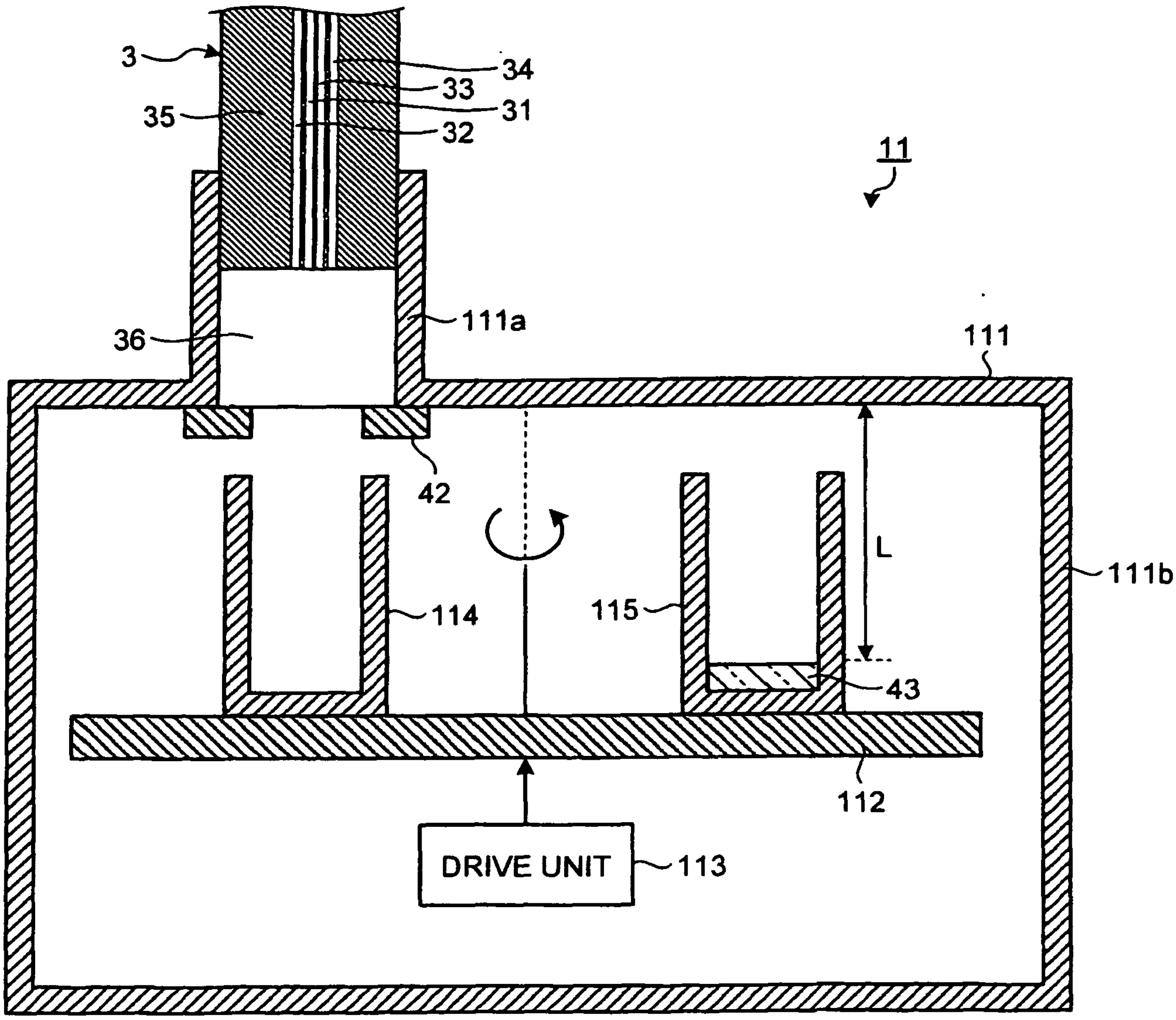
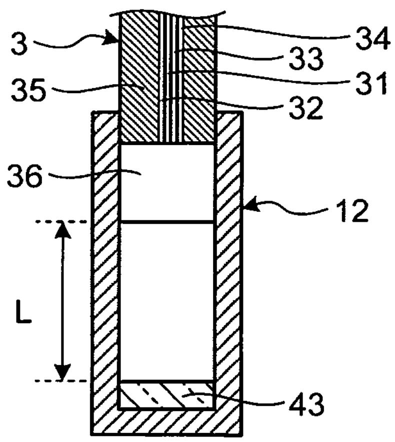

3
34
33
31
35
32
11
36
111a
111
42
L
111b
114
115
43
112
DRIVE UNIT
113

FIG.25



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20090009759 A **[0004]**
- US 2002097400 A1 **[0006]**

Non-patent literature cited in the description

- **YOUNG L. KIM.** Low-Coherence Enhanced Backscattering; Review of Principles and Applications for Colon Cancer Screening. *Journal of Biomedical Optics,* 2006, vol. 11 (4), 041125 **[0005]**
- **V, TURZHITSKY.** Characterization of Light Transport in Scattering Media at Subdiffusion Length Scales with Low-Coherence Enhanced Backscattering. *IEEE journal of selected topics in quantum electronics,* 2010, vol. 16 (3), 619 **[0005]**
- **HEMANT K. ROY.** Association Between Rectal Optical Signatures and Colonic Neoplasia: Potential Applications for Screening. *Cancer Research,* 2009, vol. 69 (10), 4476 **[0005]**

patsnap

专利名称(译)	校准装置和校准方法		
公开(公告)号	EP2759246B1	公开(公告)日	2016-02-03
申请号	EP2012833882	申请日	2012-09-20
[标]申请(专利权)人(译)	奥林巴斯株式会社		
申请(专利权)人(译)	OLYMPUS CORPORATION		
当前申请(专利权)人(译)	OLYMPUS CORPORATION		
[标]发明人	ITO RYOSUKE		
发明人	ITO, RYOSUKE		
IPC分类号	A61B1/00 G01N21/27 A61B5/00		
CPC分类号	G01N21/17 A61B1/00057 A61B1/00165 A61B5/0075 A61B2560/0238 G01N21/274		
优先权	61/536736 2011-09-20 US		
其他公开文献	EP2759246A1 EP2759246A4		
外部链接	Espacenet		

摘要(译)

提供了一种能够在一次操作中执行多个校准项的校准装置和校准方法。在测量探针3已插入插入部分41a的状态下布置在远离测量探针3的远端部分预定距离L的位置处的参考反射板43具有均匀的反射率包括在照射平面中测量的并且具有稳定反射特性的波长范围，并且形成参考反射板43的材料的散射平均自由程大于使用预定距离确定的空间相干长度Lsc L为参考反射板43。

$$(1):\ Ls^{2} \geq 2Lsc,\ AND\ g \leq 0.85$$