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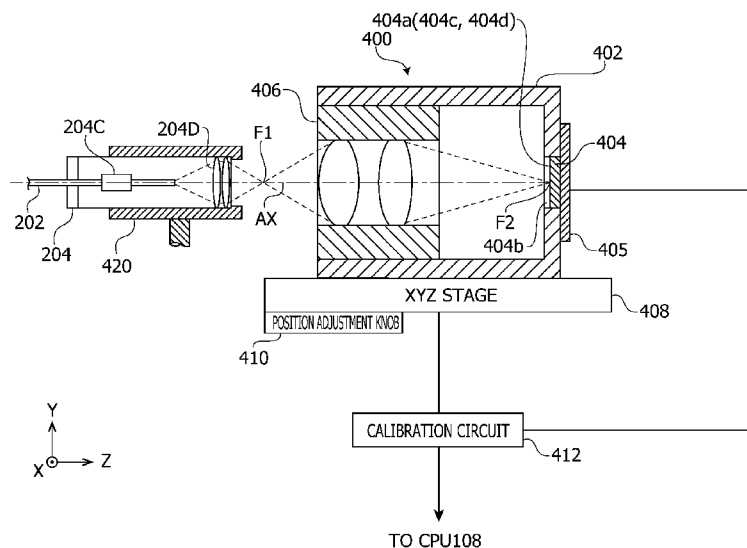
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(54) Title: CALIBRATION APPARATUS



(57) Abstract: A calibration apparatus comprising: a relay lens; a light detection means to detect a scanning trajectory of excitation light received on a light-receiving surface; a fluorescent material arranged at a position optically equivalent to the light-receiving surface; a moving means to move the relay lens and the light detection means relative to the light scanning device; and a correction means that corrects a scan parameter so that the scanning trajectory becomes a reference scanning trajectory, and wherein the relay lens is arranged so that a rear focal point of the relay lens substantially coincides with a center position of the light-receiving surface, and the moving means moves the relay lens and the light detection means so that a front focal point of the relay lens substantially coincides with a convergence point of the excitation light and that the scanning area of the excitation light falls within the light-receiving surface.



Description

Title of Invention: CALIBRATION APPARATUS

Technical Field

[0001] The present invention relates to a calibration apparatus for a scanning confocal endoscope system which has a light scanning device configured to emit excitation light with a predetermined wavelength and to cause the light to scan periodically within a predetermined scanning area and which is configured to display a confocal image by receiving fluorescence produced from a subject excited by the excitation light emitted by the light scanning device.

Background Art

[0002] Conventionally, a scanning endoscope system configured to cause light guided by an optical fiber to scan in a spiral form with respect to an observation portion, and to image the observation portion by receiving reflected light from the observation portion is known (e.g., Domestic Republication No. JP 2008-514342A1 of PCT international application (hereafter, referred to as "patent document 1")). The scanning endoscope system of this type includes a single mode optical fiber in an endoscope, and a proximal end of the optical fiber is held by a biaxial actuator in a state of a cantilever. The biaxial actuator vibrates (resonate) a tip of the optical fiber in two-dimension in accordance with a characteristic frequency while modulating and amplifying the amplitude of the vibration so that the tip of the optical fiber is driven in a spiral form. As a result, the illumination light guided by the optical fiber from the light source scans on the observation portion in a spiral form, and an image corresponding to an illumination range (a scanning area) is obtained based on returning light from the observation portion.

[0003] Recently, it has been proposed that the scanning endoscope system as shown in patent document 1 is applied to a scanning confocal endoscope system (e.g., Japanese Patent Provisional Publication No. 2011-255015A (hereafter, referred to as "patent document 2")). The scanning confocal endoscope system is configured to emit laser light to a living tissue to which a medical agent is administered and to extract only a component, obtained through a pin hole arranged at a position conjugate with a focal point of a confocal optical system, of fluorescence emitted from the living tissue so that observation can be achieved at a magnification higher than that of an observation image obtained by a normal endoscope optical system. The scanning confocal endoscope system described in patent document 2 is configured to be able to observe a minute subject which cannot be observed at a magnification of an observation image obtained by the normal endoscope optical system and to be able to observe a cross

section of a living tissue, by scanning in two dimension or three dimension with laser light for a particular narrow area of a living tissue.

[0004] In the system described in each of patent documents 1 and 2, the reflected light or the fluorescence from the scanning area is received at a predetermined period of timing (hereafter, referred to as a "sampling point"), intensity information at each sampling point is assigned to a display coordinate (a pixel position of the endoscope image), and a two-dimensional endoscopic image is displayed. Therefore, in order to generate an endoscopic image having a high degree of reproducibility with no distortion, it is necessary to precisely assign the scanning position of each sampling point to the display coordinate. For this reason, in the scanning endoscope system of this type, the calibration is performed by monitoring an actual scanning pattern (scanning trajectory) so that an ideal scanning pattern is obtained (patent document 1).

Summary of Invention

[0005] The scanning endoscope system described in patent document 1 is configured to perform calibration so as to obtain an ideal scanning pattern by receiving illumination light emitted from an optical fiber on a PSD (Position Sensitive Detector) and adjusting the amplitude, phase and frequency of voltages applied to the biaxial actuator while detecting the position of the illumination spot on the scanning pattern (scanning trajectory). Such a calibration manner is effective for a scanning endoscope system configured to scan within a relatively wide scanning area (e.g., a scanning area having the diameter of 10mm) as in the case of the scanning endoscope system described in patent document 1. However, for a scanning endoscope system configured to scan within a relatively small scanning area (e.g., a scanning area having the diameter of 500mm) as in the case of the scanning endoscope system described in patent document 2, there is a problem that the position of the illumination spot cannot be precisely detected due to limitation of resolution of the PSD sensor.

[0006] For the calibration for the scanning pattern, it is important to precisely position the optical fiber with respect to the PSD so that the illumination light scans on the light-receiving surface of the PSD (i.e., so that the scanning trajectory falls within the light-receiving surface of the PSD). It is possible to automatically adjust the positions of the optical fiber and the PSD, for example, based on position information of the illumination spot obtained by the PSD. However, there is a case where the position information of the illumination spot cannot be obtained precisely (e.g., when a part of the scanning trajectory deviates from the light-receiving surface during the position adjustment). Therefore, a configuration enabling visual checking is required.

[0007] The present invention is made in view of the above described circumstances. That is, the object of the present invention is to provide a calibration apparatus capable of

precisely detecting an illumination spot of the illumination light on a scanning pattern, performing calibration to obtain an ideal scanning pattern, and easily checking the illumination position of the illumination light, even for a scanning endoscope system configured to scan within a narrow scanning area.

[0008] To achieve the above described object, there is provided a calibration apparatus for a scanning confocal endoscope system configured to have a light scanning device which causes excitation light with a predetermined wavelength from a light source to periodically scan within a predetermined scanning area on a subject, to receive fluorescence from the subject excited by the excitation light emitted from the light scanning device and thereby to display a confocal image. The calibration apparatus comprises a relay lens to which the excitation light emitted from the light scanning device enters and which magnifies the predetermined scanning area, a light detection means configured to receive the excitation light emerging from the relay lens on a light-receiving surface of the light detection means perpendicularly arranged with respect to an optical axis of the relay lens and to detect a scanning trajectory of the received excitation light on the light-receiving surface, a fluorescent material that is arranged at a position optically equivalent to the light-receiving surface and emits fluorescence when the excitation light emerging from the relay lens is incident on the fluorescent material, a moving means configured to move the relay lens and the light detection means relative to the light scanning device, and a correction means that corrects a scan parameter for the excitation light emitted from the light scanning device so that the scanning trajectory detected by the light detection means becomes a reference scanning trajectory. In this configuration, the relay lens is arranged so that a rear focal point of the relay lens substantially coincides with a center position of the light-receiving surface, and the moving means moves the relay lens and the light detection means, based on the fluorescence of the fluorescent material displayed on the endoscopic image, so that a front focal point of the relay lens substantially coincides with a convergence point of the excitation light emitted from the light scanning device and that the scanning area of the excitation light emerging from the relay lens falls within the light-receiving surface.

[0009] According to the above described configuration, since the scanning trajectory of light emitted from the light scanning device is received in a state of being magnified on the light detection means to the extent that the calibration is not affected by the resolution of the light detection means, it becomes possible to detect the scanning trajectory with a high degree of precision, even for a scanning endoscope system configured to scan within a narrow scanning area. As a result, it becomes possible to perform the calibration to obtain an ideal scanning trajectory. Furthermore, by checking the fluorescence produced by the excitation light being incident on the fluorescent material, it

becomes possible to easily confirm whether the scanning area of the excitation light emerging from the relay lens falls within the light receiving surface.

- [0010] The fluorescent material may include an indicator part indicating a position equivalent to the center of the light-receiving surface, and the moving means may move the relay lens and the light detection means so that a center of the scanning area of the excitation light emerging from the relay lens substantially coincides with the center of the light-receiving surface. According to this configuration, it is possible to detect the scanning trajectory of the excitation light emitted from the relay lens with the central portion of the light receiving surface where the position detection precision is stable.
- [0011] The indicator part may be a cross-shaped indicator which is formed of two lines perpendicularly intersecting with each other and perpendicularly intersects with an optical axis of the relay lens at the position equivalent to the center of the light-receiving surface. In this case, the cross-shape indicator may be formed of a solid line or a dashed line. The indicator part may include a plurality of indicators arranged discretely on a plane equivalent to the light-receiving surface, and each of the plurality of indicators has a predetermined shape.
- [0012] The indicator part may include a distance indicator indicating distances from the center of the light-receiving surface. In this case, the distance indicator may include scales formed to perpendicularly intersect the cross-shaped indicator at positions respectively corresponding to the distances from the center of the light-receiving surface. The distance indicator may include indicators having shapes which differ depending on a distance from the center of the light-receiving surface. According to this configuration, it is possible to check the size of the scanning area of the excitation light emerging from the relay lens on a confocal image.
- [0013] The fluorescent material may include a frame part configured to surround a periphery of the light-receiving surface at a position equivalent to the light-receiving surface. The moving means may move the relay lens and the light detection means so that the scanning area of the excitation light emerging from the relay lens does not interfere with the frame part.
- [0014] The fluorescent material may be configured to cover the light-receiving surface and a periphery of the light-receiving surface at a position equivalent to the light-receiving surface, and to let a part of the excitation light incident thereon from the relay lens pass therethrough. The fluorescent material may include an indicator part which is formed of two straight lines perpendicularly intersecting with each other at the position equivalent to the center of the light-receiving surface and which does not emit fluorescence. The fluorescent material may be formed in a grid shape. According to this configuration, it is possible to observe the fluorescence regardless of the position of the

scanning area of the excitation light on the light receiving surface. Therefore, it becomes possible to perform positioning for the light scanning device and the light detection means extremely easily.

- [0015] The light detection means may include a cover glass on a front side of the light-receiving surface, and the fluorescent material may be provided to coat a surface of the cover glass facing the light-receiving surface. In this case, a fluorescence reflection coating which reflects fluorescence produced by the fluorescent material may be formed on the fluorescent material. According to this configuration, it is possible to prevent the fluorescence from the fluorescent material from entering to the light receiving surface of the light-receiving surface. Therefore, it is possible to detect the position of the excitation light incident on the light receiving surface with a high degree of precision.
- [0016] The calibration apparatus may further comprise a beam splitter which is arranged between the relay lens and the light detection means. The beam splitter divides the excitation light incident thereon through the relay lens, lets the divided excitation light proceed to the light detection means and the fluorescent material, and lets the fluorescence produced by the fluorescent material be reflected toward the relay lens.
- [0017] The scan parameter may include at least one of a first parameter to magnify or reduce the scanning area of scanning light, a second parameter to change a shape of the scanning area of the scanning light, and a third parameter to change a scanning speed of the scanning light.
- [0018] The calibration apparatus may further comprise a remapping table creation means which samples the scanning trajectory of the scanning light corrected by the correction means at a predetermined timing, and assigns a two dimensional raster coordinate to each sampling point.
- [0019] The relay lens, the light detection means and the fluorescent material may be accommodated in a single case. In this case, the case may shield at least the light detection means against external light. According to this configuration, since the effect of the external light can be excluded, it becomes possible to detect the scanning trajectory of the scanning light at a high SN ratio.
- [0020] According to the calibration apparatus of the present invention, it becomes possible to precisely detect an illumination spot of the illumination light on a scanning pattern, to perform calibration to obtain an ideal scanning pattern, and to easily check the illumination position of the illumination light, even for a scanning endoscope system configured to scan within a narrow scanning area.

Brief Description of Drawings

- [0021] [fig.1] Fig. 1 is a block diagram illustrating a configuration of a scanning confocal

endoscope system according to an embodiment of the invention.

[fig.2]Fig. 2 generally illustrates a configuration of a confocal optical unit included in the scanning confocal endoscope system according to the embodiment of the invention.

[fig.3]Fig. 3 illustrates a rotational trajectory of a tip of an optical fiber on a XY approximate plane.

[fig.4]Fig. 4 illustrates a relationship between sampling and braking periods and a changing amount (amplitude) of the tip of the optical fiber in X (or Y) direction on the XY approximate plane.

[fig.5]Fig. 5 illustrates a relationship between a sampling point and a raster coordinate.

[fig.6]Fig. 6 schematically illustrates a calibration apparatus according to the embodiment of the invention.

[fig.7]Fig. 7 is a front view of a PSD according to the embodiment of the invention.

[fig.8]Fig. 8 is a flowchart of a calibration program executed by the scanning confocal endoscope system according to the embodiment of the invention.

[fig.9]Fig. 9 illustrates a relationship between a scanning area of excitation light and the PSD.

[fig.10]Fig. 10 illustrates a situation where the center of the scanning area moves to the center of the PSD.

[fig.11]Fig. 11 illustrates a variation of a fluorescent material according to the embodiment of the invention.

[fig.12]Fig. 12 illustrates a variation of a fluorescent material according to the embodiment of the invention.

[fig.13]Fig. 13 illustrates a variation of a fluorescent material according to the embodiment of the invention.

[fig.14]Fig. 14 illustrates a variation of a fluorescent material according to the embodiment of the invention.

[fig.15]Fig. 15 illustrates a variation of a fluorescent material according to the embodiment of the invention.

[fig.16]Fig. 16 illustrates a variation of the calibration apparatus according to the embodiment.

Description of Embodiments

[0022] Hereinafter, a scanning confocal endoscope system according to an embodiment of the present invention is described with reference to the accompanying drawings.

[0023] The scanning confocal endoscope system is a system designed by making use of a fundamental principle of a confocal microscope, and is configured suitable for observing a subject at a high magnification and a high resolution. Fig. 1 is a block diagram illustrating a configuration of a scanning confocal endoscope system 1

according to the embodiment of the invention. As shown in Fig. 1, the scanning confocal endoscope system 1 includes a system main body 100, a confocal endoscope 200, a monitor 300 and a calibration apparatus 400. Confocal observation using the scanning confocal endoscope system 1 is performed in a state where a tip face of the flexible confocal endoscope 200 having a tube-like shape is operated to contact a subject.

- [0024] The system main body 100 includes a light source 102, an optical coupler 104, a damper 106, a CPU 108, a CPU memory 110, an optical fiber 112, an optical receiver 114, a video signal processing circuit 116, an image memory 118 and a video signal output circuit 120. The confocal endoscope 200 includes an optical fiber 202, a confocal optical unit 204, a sub CPU 206, a sub memory 208 and a scan driver 210.
- [0025] The light source 102 emits excitation light which excites medical agents administered in a body cavity of a patient in accordance with driving control by the CPU 108. The excitation light enters the optical coupler 104. To one of ports of the optical coupler 104, an optical connector 152 is coupled. To a non-use port of the optical coupler 104, the damper 106 which terminates, without reflection, the excitation light emitted from the light source 102 is coupled. The excitation light which has entered the former port passes through the optical connector 152, and enters an optical system arranged in the confocal endoscope 200.
- [0026] A proximal end of the optical fiber 202 is optically coupled to the optical coupler 104 through the optical connector 152. A tip of the optical fiber 202 is accommodated in the confocal optical unit 204 which is installed in a tip portion of the confocal endoscope 200. The excitation light which has exited from the optical coupler 104 enters the proximal end of the optical fiber 202 after passing through the optical connector 152, passes through the optical fiber 202, and thereafter is emitted from the tip of the optical fiber 202.
- [0027] Fig. 2A generally illustrates a configuration of the confocal optical unit 204. In the following, for convenience of explanation, a direction of the longer side of the confocal optical unit 204 is defined as Z-direction, and the two directions which are perpendicular to the Z-direction and are perpendicular with respect to each other are defined as X-direction and Y-direction. As shown in Fig. 2A, the confocal optical unit 204 has a metal outer tube 204A which accommodates various components. The outer tube 204A holds, to be slidable in a coaxial direction, an inner tube 204B having an outer wall shape corresponding to an inner wall shape of the outer tube 204A. The tip (a reference symbol 202a is assigned hereafter) of the optical fiber 202 is accommodated and supported in the inner tube 204B through openings formed in proximal end faces of the outer tube 204A and the inner tube 204B, and functions as a secondary point source of the scanning confocal endoscope system 1. The position of

the tip 202a being the point source changes periodically under control by the CPU 108. In Fig. 2A, the center axis AX represents an axis of the optical fiber 202 arranged in the Z-direction, and when the tip 202a of the optical fiber 202 does not vibrate, the center axis AX coincides with an optical path of the optical fiber 202.

[0028] The sub memory 208 stores probe information, such as identification information and various properties of the confocal endoscope 200. The sub CPU 206 reads out the probe information from the sub memory 208 at a time of start-up, and transmits the probe information to the CPU 108 via an electric connector 154 which electrically connects the system main body 100 with the confocal endoscope 200. The CPU 108 stores the transmitted probe information in the CPU memory 110. The CPU 108 generates signals necessary for controlling the confocal endoscope 200 when necessary, and transmits the signals to the sub CPU 206. The sub CPU 206 designates setting values required for the scan driver 210 in accordance with the control signal from the CPU 108.

[0029] The scan driver 210 generates a drive signal corresponding to the designated setting value, and drives and controls a biaxial actuator 204C adhered and fixed to the outer surface of the optical fiber 202 close to the tip 202a. Fig. 2B generally illustrates a configuration of the biaxial actuator 204C. As shown in Fig. 2B, the biaxial actuator 204C is a piezoelectric actuator in which a pair of X-axis electrode (X and X' in the figure) and Y-axis electrode (Y and Y' in the figure) connected to the scan driver 210 are formed on a piezoelectric body.

[0030] The scan driver 210 applies an alternating voltage X between the electrodes for the X-axis of the biaxial actuator 204C so that the piezoelectric body is resonated in the X-direction, and applies an alternating voltage Y which has the same frequency as that of the alternating voltage X and has a phase orthogonal to the phase of the alternating voltage X, between the electrodes for the Y-axis so that the piezoelectric body is resonated in the Y-axis direction. The alternating voltage X and the alternating voltage Y are defined as voltages which linearly increase in amplitude in proportion to time and reach average root-mean-square values (X) and (Y) by taking times (X) and (Y), respectively. The tip 202a of the optical fiber 202 rotates to draw a spiral pattern having the center at the center axis AX on a plane (hereafter, referred to as a "XY approximate plane") which approximates the X-Y plane, due to combining of kinetic energies in the X-direction and Y-direction by the biaxial actuator 204C. A rotation trajectory of the tip 202a becomes larger in proportion to the applied voltage, and becomes a circle having the maximum diameter when the alternating voltages having the average root-mean squares (X) and (Y) are applied. In this embodiment, the amplitudes, the phases and the frequencies of the alternating voltages X and Y are adjusted through calibration which is described later so that the rotation trajectory of

the tip 202a becomes an ideal trajectory. Fig. 3 illustrates a rotation trajectory of the tip 202a on the XY approximate plane adjusted through the calibration.

[0031] Fig. 4 illustrates a relationship between various operation timings and the changing amount (amplitude) of the tip 202a of the optical fiber 202 in the X (or Y) direction on the XY approximate plane. The excitation light is continuous light (or pulse light), and is emitted from the tip 202a of the optical fiber 202 during a time period (hereafter, referred to as "sampling period" for convenience of explanation) from start of application of the alternating voltage to the biaxial actuator 204C to stop of application of the alternating voltage. As described above, when the alternating voltage is applied to the biaxial actuator 204C, the excitation light emitted from the tip 202a of the optical fiber 202 scans in a spiral form in a predetermined circular scanning area having the center at the center axis AX because the tip 202a of the optical fiber 202 rotates to draw a spiral pattern having the center at the center axis AX. When application of the alternating voltage to the biaxial actuator 204C is stopped after the sampling period has passed, the vibration of the optical fiber 202 is attenuated. The circular motion of the tip 202a on the XY approximate plane converges in accordance with attenuation of the vibration of the optical fiber 202, and the vibration of the optical fiber 202 becomes almost zero after a predetermined time has passed (i.e., the tip 202a becomes an almost stopped state on the center axis AX). In the following, the time period from an end of the sampling period to the time when the tip 202a becomes an almost stopped state on the center axis AX is referred to as a "braking period" for convenience of explanation. After the braking period has passed and further a predetermined time has passed, a next sampling period is started. In the following, a time period from an end of the braking period to start of the next sampling period is referred to as a "settling period". The settling period is a waiting time for completely stopping the tip 202a of the optical fiber 202 on the center axis AX, and by providing the settling period, it becomes possible to cause the tip 202a to precisely scan. Furthermore, a period corresponding to one frame is formed by one sampling period and one braking period, and by adjusting the settling period, it becomes possible to adjust the frame rate. That is, the settling period can be appropriately set based on the relationship between the frame rate and the time until when the tip 202a of the optical fiber 202 completely stops. To shorten the braking period, a reverse phase voltage may be applied to the biaxial actuator 204C at an initial stage of the braking period so as to positively apply a braking torque.

[0032] On the front side of the tip 202a of the optical fiber 202, an objective optical system 204D is arranged. The objective optical system 204D is formed by a plurality of optical lenses, and is held in the outer tube 204A via a lens frame (not shown). The lens frame is fixed and supported relative to the inner tube 204B in the outer tube 204A. Therefore, an optical lens group held on the lens frame slides together with the

inner tube 204B in the outer tube 204A. At the forefront of the outer tube 204A (i.e., on the front side of the objective optical system 204D), a cover glass (not shown) is held.

- [0033] Between a proximal end face of the inner tube 204B and the inner wall of the outer tube 204A, a helical compression spring 204E and a shape memory alloy 204F are attached. The helical compression spring 204E is initially compressed and sandwiched in the Z-direction from a natural length thereof. The shape memory alloy 204F has a rod-like shape elongated in the Z-direction, deforms when an external force is applied thereto under a room temperature condition, and is restored to a predetermined shape by the shape memory effect when heated to be higher than or equal to a predetermined temperature. The shape memory alloy 204F is designed such that the restoring force by the shape memory effect is larger than the restoring force of the helical compression coil 204E. The scan driver 210 generates a driving signal corresponding to the setting value designated by the sub CPU 206, and controls the expanding and contracting amount of the shape memory alloy 204F by electrifying and heating the shape memory alloy 204F. The shape memory alloy 204F causes the inner tube 204B to move forward or backward in the Z-direction in accordance with the expanding and contracting amount.
- [0034] The excitation light emitted from the tip 202a of the optical fiber 202 forms a spot on a surface or a surface layer of the subject through the objective optical system 204D. A spot formation position moves depending on movement of the tip 202a being the point source. That is, the confocal optical unit 204 performs the three dimensional scanning on the subject by combining the periodic circular motion of the tip 202a on the XY approximate plane by the biaxial actuator 204C and the movement in the Z-axis direction.
- [0035] Since the tip 202a of the optical fiber 202 is arranged at the front focal point of the objective optical system 204D, the tip 202a functions as a pin hole. Of the scattered component (fluorescence) of the subject excited by the excitation light, only fluorescence from the convergence point which is conjugate with the tip 202a is incident on the tip 202a. The fluorescence passes through the optical fiber 202, and then enters the optical coupler 104 through the optical connector 152. The optical coupler 104 separates the entered fluorescence from the excitation light emitted from the light source 102, and guides the fluorescence to the optical fiber 112. The fluorescence is transmitted through the optical fiber 112, and then is detected by the optical receiver 114. In order to detect feeble light with a low level of noise, the optical receiver 114 may be configured as a high-sensitivity optical detector, such as a photomultiplier.
- [0036] The detection signal detected by the optical receiver 114 is inputted to the video signal processing circuit 116. The video signal processing circuit 116 operates under

control of the CPU 108, and generates a digital detection signal by performing sampling-and-holding and AD conversion for the detection signal at a constant rate. When the position (trajectory) of the tip 202a of the optical fiber 202 during the sampling period is determined, the spot formation position in the observation area (the scanning area) corresponding to the determined position and the signal acquisition timing (i.e., the sampling point) for obtaining the digital detection signal by detecting the returning light (fluorescence) from the spot formation position are definitely defined. As described later, in this embodiment, the scanning trajectory of the tip 202a is measured in advance by using the calibration apparatus 400. Then, the amplitude, phase and frequency of the application voltage to the biaxial actuator 204C are adjusted so that the measured scanning trajectory becomes an ideal scanning pattern (i.e., an ideal spiral scanning pattern), and the sampling point and the position (a pixel position of the endoscopic image displayed on the monitor 300) on the image corresponding to the sampling point are determined. The relationship between the sampling point and the pixel position (a pixel address) of the endoscopic image is stored in the CPU memory 110 as a remapping table. For example, if the endoscopic image is formed by 15 pixels in the horizontal direction (X-direction) and 15 pixels in the vertical direction (Y-direction), the relationship between the position (sampling point) of the excitation light sampled sequentially and the pixel position (raster address) of the endoscopic image becomes a state shown in Fig. 5, and the CPU 108 creates the remapping table by obtaining the pixel position (raster coordinate) of the endoscopic image corresponding to each sampling point based on the relationship. In Fig. 5, for convenience of illustration, partial sampling points are shown in the central portion and the peripheral portion of the scanning area; however, actually a number of sampling points exist along the spiral scanning trajectory.

[0037] The video signal processing circuit 116 refers to the remapping table, and assigns the digital detection signal obtained at each sampling point as data of a corresponding pixel address data. In the following, the above described assigning work is referred to as remapping, for convenience of explanation. The video signal processing circuit 116 performs buffering by storing the signal of the image formed by the spatial arrangement of point images into the image memory 118 on a frame-by-frame manner. The buffered signal is swept out at a predetermined timing from the image memory 118 to the video signal output circuit 120, and is displayed on the monitor 300 after being converted into a video signal complying with a predetermined standard, such as NTSC (National Television System Committee) or PAL (Phase Alternating Line). On a display screen of the monitor 300, a three-dimensional confocal image (which may be simply referred to an "endoscopic image" in this specification) with a high magnification and a high resolution is displayed.

- [0038] As described above, since the subject image is formed through the remapping operation, the tip 202a needs to be rotated to draw an ideal spiral scanning pattern so that an endoscopic image without distortion can be obtained. However, typically the property of each of the components constituting the scanning confocal endoscope system 1 varies within a certain range, and therefore has a property specific to each product (product-specific property). Therefore, it is impossible to obtain an ideal scanning trajectory shown in Fig. 3 if the components are assembled simply. Therefore, in the scanning confocal endoscope system 1 according to the embodiment, the calibration described later is performed to cancel the product-specific property of this type.
- [0039] Fig. 6 illustrates the calibration apparatus 400 used for the calibration according to the embodiment. In the calibration, a rotational trajectory of the tip 202a of the optical fiber 202 is detected, and the amplitude, phase and frequency of each of the alternating voltages X and Y to be applied to the biaxial actuator 204C are adjusted so that the rotational trajectory becomes an ideal trajectory (i.e., so that the scanning trajectory of the excitation light emitted from the confocal optical unit 204 becomes a reference scanning trajectory), and a new remapping table is created. In the following, parameters to be adjusted in the calibration, including primarily the amplitude, phase and frequency, are collectively referred to as "adjustment parameters". It should be noted that, although the calibration apparatus 400 is explained as a configuration separately provided from the system main body 100, the calibration apparatus 400 may be incorporated in the system main body 100.
- [0040] As shown in Fig. 6, the calibration apparatus 400 includes a unit support member 420, a case 402, an XYZ stage 408, a position adjustment knob 410 and a calibration circuit 412.
- [0041] The unit support member 420 is a cylindrical member fixed to a main body of the calibration apparatus 400, and is configured such that an inner diameter thereof is slightly larger than the outer diameter of the confocal optical unit 204. During the calibration, the confocal optical unit 204 is inserted into the inside of the unit support member 420, and is positioned in X, Y and Z directions.
- [0042] In the case 402, a PSD 404, a PSD substrate 405 and a relay lens unit 406 are attached. The PSD 404 is mounted on the PSD substrate 405, and is arranged at the proximal side of the case 402 such that a light-receiving surface thereof is located in the XY plane (i.e., such that the light-receiving surface thereof is perpendicular to the Z-direction). The PSD 404 receives the excitation light emitted from the confocal optical unit 204, and detects the position of the excitation light (i.e., the position of the excitation light on the light-receiving surface 404a) (details are described later). The relay lens unit 406 is arranged at the tip end side of the case 402 (the confocal optical

unit 204 side) so that the optical axis thereof is directed to the Z direction. The relay lens unit 206 is a so-called magnifying optical system including a plurality of lenses therein, and is arranged such that the optical axis thereof passes through the center of the light-receiving surface 402a of the PSD 404, and a rear focal point F2 is located at the center of the light-receiving surface 402a of the PSD 404. Furthermore, the front focal point F1 of the relay lens unit 406 is adjusted by the calibration described later such that the front focal point F1 substantially coincides with the focal point of the objective optical system 204D of the confocal optical unit 204 (i.e., the convergence point of the excitation light). That is, the relay lens unit 406 serves to magnify a projected image at the convergence point of the excitation light emitted from the confocal optical unit 204 (i.e., the scanning area (a maximum swing width) of the excitation light). The magnification of the relay lens unit 406 is determined by totally considering various factors including the size of the scanning area of the excitation light and the size and the position detection resolution of the PSD 404. Assuming a PSD commercially available, it is desirable that, from the position detection resolution thereof, the magnification of the relay lens unit 406 is set so that the size of the scanning area magnified by the relay lens unit 406 has a size larger than or equal to 1mm on the light-receiving surface of the PSD 404. Furthermore, from the viewpoints of the device size and the response speed, it is desirable that the magnification of the relay lens unit 406 is set to approximately 2 to 20 magnifications while considering the position detection resolution and the device size because it is desirable to use the PSD 404 whose light-receiving surface is formed to be as small as possible. For this reason, in this embodiment, the diameter of the scanning area of the excitation light emitted from the confocal optical unit 204 (i.e., the maximum swing width at the convergence point of the excitation light) is set to 500 mm, and the magnification of the relay lens unit 10 is set to 10 magnifications assuming the size, the position detection resolution and the response speed of a commercially available PSD 404. Therefore, the scanning trajectory of the excitation light emitted from the confocal optical unit 204 is magnified by the relay lens unit 406, and scans on the light-receiving surface 404a of the PSD 404 to draw a circle having the diameter of 5mm at the maximum. The inside of the case 4 is shielded from the external light, and the PSD 404 detects the excitation light from the confocal optical unit 204 at a high SN ratio. When the excitation light is incident on the light-receiving surface 404a of the PSD 404, a detection current corresponding to the position of the excitation light is generated, and the detection current is outputted to the calibration circuit 412 via the PSD substrate 405.

[0043] Fig. 7 is a front view of the PSD 404 according to the embodiment. The PSD 404 includes the rectangular light-receiving surface 404a at a central portion thereof, and the light-receiving surface 404a is sealed by a cover glass 404b (Fig. 6). On the side of

the cover glass 404b facing the light-receiving surface 404a, a coating formed of fluorescent material 404c (e.g., SiAlON phosphor) which produces fluorescence by receiving the excitation light having the wavelength of 488nm and a fluorescence reflection coating 404d are provided in sequence. In this embodiment, each coating is sufficiently thin, and the light-receiving surface 404a, the fluorescent material 404c and the fluorescence reflection coating 404d are regarded as being on substantially the same plane.

[0044] As shown in Fig. 7, the fluorescent material 404c is formed of a frame part 404ca arranged to surround the periphery of the light-receiving surface 404a and a cross-shaped indicator part 404cb arranged at a central portion of the light-receiving surface 404a. When the excitation light is incident on the fluorescent material 404c during the calibration, produced fluorescence enters the tip 202a of the optical fiber 202 and is displayed as an endoscopic image on the monitor 300. The light-receiving surface 404a of the PSD 404 is sufficiently larger than the scanning area (the diameter of 5mm) of the excitation light, and, in this embodiment, the PSD 404 having a light-receiving surface size of 10mm x 10mm is used. The line width of each of vertical and horizontal lines constituting the indicator part 404cb is formed to be sufficiently thin so as not to affect the remapping, and is set to approximately 10mm in this embodiment.

[0045] The fluorescence reflection coating 404d is a coating for reflecting the fluorescence produced by the indicator part 404cb. As described above, the fluorescence reflection coating 404d is arranged between the fluorescent material 404c and the light-receiving surface 404a, and all the fluorescence produced by the indicator part 404cb is reflected toward the optical fiber 202 side. Therefore, the fluorescence produced by the indicator part 404cb does not enter the light-receiving surface 404a, and the PSD 404 detects the excitation light from the confocal optical unit 204 at a high SN ratio. Furthermore, as described above, since the frame part 404ca of the fluorescent material 404c is arranged to surround the periphery of the light-receiving surface 404a, fluorescence is produced by the frame part 404ca when the excitation light deviates from the light-receiving surface 404a. However, since all the fluorescence produced by the frame part 404ca is also reflected toward the optical fiber 202 side, the excitation light or the fluorescence does not enter an electrode arranged in the peripheral part of the PSD 404. Therefore, stray light from the electrode formed at the peripheral part of the PSD 404 does not enter the PSD 404, and the PSD 404 detects the position of the excitation light incident on the light-receiving surface 303a with a high degree of precision.

[0046] The case 402 is fixed to the XYZ stage 408 which is movable in each of X, Y and Z directions through operations to the position adjustment knob 410 by a user (Fig. 6). During the calibration described later, the user operates the position adjustment knob 410 to adjust the relative positional relationship between the case 402 (i.e., the relay

lens unit 406 and the PSD 404) and the confocal optical unit 204 fixed to the unit support member 420.

[0047] The calibration circuit 412 is a circuit capable of performing bidirectional communication with the CPU 108. During the calibration, the calibration circuit 412 converts a detection current by the PSD 404 into a voltage, and outputs the voltage, as a detection voltage, to the CPU 108.

[0048] Fig. 8 is a flowchart of a calibration program executed for the calibration. The calibration program is a subroutine executed by the CPU 108 when the user inserts the confocal optical unit 204 into the unit support member 420 and inputs a predetermined instruction to the system main body 100 through a user interface (not shown). For convenience of explanation, each processing step in the calibration is abbreviated as "S" in this specification and drawings.

[0049] As shown in Fig. 8, when the calibration program is started, the CPU 108 executes S11 to drive the confocal optical unit 204. Specifically, the CPU 108 controls the light source 102 so that the excitation light is emitted continuously, and controls the scan driver 210 to apply the predetermined alternating voltages X and Y to the biaxial actuator 204C. The predetermined alternating voltages X and Y mean the alternating voltages X and Y adjusted by the previous calibration when data of the previous calibration is available, and mean reference (default) alternating voltages X and Y when data of previous calibration is not available (e.g., for a calibration during assembling in a factory). When the predetermined alternating voltages X and Y are thus applied to the biaxial actuator 204C, the tip 202a of the optical fiber 202 rotates in response to the applied alternating voltages X and Y. The excitation light being emitted from the optical fiber 202 rotates and scans on the fluorescent material 404c or the light-receiving surface 404a of the PSD 404 through the relay lens unit 406. When the excitation light is incident on the fluorescent material 404c, the produced fluorescence enters the tip 202a of the optical fiber 202 and is detected by the optical receiver 114, and then the produced fluorescence is displayed on the monitor 300 as an endoscopic image. Then, the process proceeds to S12.

[0050] In S12, the CPU 108 judges whether the position adjustment of the PSD by the user has finished. In order to precisely detect the scanning trajectory of the excitation light emitted from the confocal optical unit 204 by the PSD 404, it is necessary that the scanning area of the excitation light falls within the light-receiving surface 404a of the PSD 404. However, the scanning area of the excitation light does not necessarily fall within the light-receiving surface 404a of the PSD 404 by merely attaching the confocal optical unit 204 to the unit support member 420, due to a product-specific property and a positional error caused when the confocal optical unit 204 is attached to the unit support member 420. For this reason, in this embodiment, the position of the

light-receiving surface 404a is made adjustable so that the user can visually check the scanning trajectory of the excitation light on the light-receiving surface 404a of the PSD 404 and that the scanning trajectory of the excitation light falls within the light-receiving surface 404a of the PSD 404.

[0051] Specifically, the user operates the position adjustment knob 410 to move the case 402 in Z-direction with respect to the confocal optical unit 204 while viewing the endoscopic image being displayed on the monitor 300. Then, the adjustment is conducted so that the fluorescence produced by the fluorescent material 404c is displayed on the monitor 300 as an endoscopic image. As described above, since the light-receiving surface 404a and the fluorescent material 404c are arranged to be on substantially the same plane, the tip 202a of the optical fiber 202 is precisely arranged at the front side focal point of the objective optical system 204D and becomes optically conjugate with the light-receiving surface 404a when the fluorescence produced by the fluorescent material 404c is displayed on the monitor 300 as an endoscopic image. Fig. 9 illustrates a positional relationship between a scanning area A of the excitation light and the PSD 404 when the tip 202a of the optical fiber 202 is arranged at the front focal point of the objective optical system 204D. As shown in Fig. 9, the scanning area A of the excitation light does not necessarily coincide with the center of the PSD 404 due to a product-specific property and a positional error caused when the confocal optical unit 204 is attached to the unit support member 420; however, when the tip 202a of the optical fiber 202 is arranged at the front focal point of the objective optical system 204D, fluorescence is produced from the fluorescent material 404c included in the scanning area A (the frame part 404ca in the upper right portion of the light-receiving surface 404a in Fig. 9), and is observed on the monitor 300.

[0052] Then, the user operates the position adjustment knob 410 while viewing the endoscopic image (i.e., the fluorescence image in the scanning area A) displayed on the monitor 300 so as to move the case 402 in X and Y directions with respect to the confocal optical unit 204. Then, the user moves the case 402 so that the fluorescence from the indicator part 404cb is displayed on the monitor 300, and makes adjustment so that the center of the scanning area A substantially coincides with the center of the PSD 404 (i.e., the center of the indicator part 404cb). Fig. 10 illustrates a situation where the center of the scanning area A moves to the center of the PSD 404. In the case of Fig. 10, the user moves the center of the scanning area A to the center of the PSD 404 by moving the confocal optical unit 204 in the upper right direction based on the fluorescence image displayed on the monitor 300. When the scanning area A is adjusted so that the center of the scanning area A substantially coincides with the center of the PSD 404, the center axis AX substantially coincides with the optical axis of the relay lens unit 406, and, on the monitor 300, a cross-shaped fluorescence

produced by the indicator part 404cb is observed.

[0053] As described above, in S12, the user operates the position adjustment knob 410 while viewing the endoscopic image displayed on the monitor 300 to move the case 402 in X, Y and Z directions with respect to the confocal optical unit 204. Then, the user makes adjustment so that the scanning trajectory of the excitation light is located at the center of the light-receiving surface 404a of the PSD 404, and, after the adjustment, the user inputs the predetermined instruction through the user interface (not shown) of the system main body 100. The CPU 108 waits until the predetermined input from the user is received (S12: NO). When the CPU 108 receives the predetermined input from the user, the CPU 108 judges that the position adjustment of the PSD by the user has finished (S12: YES), and the process proceeds to S15.

[0054] In S15, the CPU 108 detects the scanning trajectory of the excitation light scanning spirally on the light-receiving surface of the PSD 404. Specifically, the CPU 108 detects the current outputted from each electrode of the PSD 404 at a predetermined timing, and executes the calculation based on the detected current to obtain a spot formation point of the excitation light on the PSD 404. As described above, since the scanning confocal endoscope system 1 has a product-specific property, an ideal scanning trajectory cannot be achieved in the state where the predetermined alternating voltages X and Y by S11 are applied, and, for example, the scanning area A becomes larger than the diameter of 5mm or becomes smaller than the diameter of 5mm, or becomes an elliptically distorted scanning trajectory. Then, the process proceeds to S16.

[0055] In S16, the CPU 108 evaluates the scanning trajectory of the excitation light detected in S15, and judges whether the detected scanning trajectory is within a predetermined tolerance (i.e., whether the detected scanning trajectory is acceptable). The predetermined tolerance has been determined in advance based on an acceptable distortion amount of an image, and the CPU 108 evaluates the size and shape (circularity) of the scanning area and the scanning speed based on the scanning trajectory of the excitation light detected in S15. When it is judged that the scanning trajectory is within the tolerance in S16 (S16: YES), the process proceeds to S18. When it is judged that the scanning trajectory is not within the tolerance (S16: NO), the process proceeds to S17.

[0056] In S17, the CPU 108 changes the adjustment parameter (scan parameter) of the alternating voltages X and Y applied to the biaxial actuator 204C. Specifically, based on the evaluation result for the scanning trajectory of the excitation light in S16, the CPU 108 adjusts the amplitudes of the alternating voltages X and Y to magnify or reduce the scanning area when the size of the scanning area is not appropriate. When the shape of the scanning area is not appropriate, the CPU 108 adjusts the phases of the alternating voltages X and Y to change the shape of the scanning area. When the

scanning speed of the scanning area is not appropriate, the CPU 108 adjusts the frequencies of the alternating voltages X and Y to change the scanning speed of the excitation light. The CPU 108 repeatedly executes the process from S15 to S17 until the CPU 108 judges that the scanning trajectory is within the tolerance. As a result, the scanning trajectory detected in S15 is adjusted to become an ideal scanning trajectory.

[0057] In S18, for the scanning trajectory adjusted in S17, the CPU 108 obtains a relationship between each sampling point and the pixel address (pixel position) of the endoscopic image to create a new remapping table. Then, the CPU 108 stores the created remapping table adjusted in S17 into the CPU memory 110 together with the adjustment parameter (i.e., the amplitude, phase and frequency of the alternating voltages X and Y), and terminates the calibration program. The adjustment parameter and the remapping table stored in the CPU memory 110 at S18 are repeatedly used until a new calibration is executed.

[0058] As described above, in the calibration according to the embodiment, the scanning trajectory of the excitation light emitted from the confocal optical unit 204 is magnified by the relay lens unit 406 and is received by the PSD 404. The PSD 404 is coated with the fluorescent material 404c, and the user is able to make adjustment so that the scanning area A is located at the center of the light-receiving surface 404a of the PSD 404 while viewing the endoscopic image (i.e., the fluorescence image in the scanning area A displayed on the monitor 300). Therefore, the scanning trajectory of the excitation light emitted from the confocal optical unit 204 is magnified to the extent that the calibration is not affected by the resolution of the PSD 404, and is securely received on the light-receiving surface 404a of the PSD 404. That is, even for a scanning endoscope system configured to scan within a narrow scanning area, such as the scanning confocal endoscope system 1 according to the embodiment, it becomes possible to detect a scanning trajectory of scanning light precisely and reliably, and thereby it becomes possible to execute the calibration (adjustment) so that the detected scanning trajectory becomes an ideal scanning trajectory.

[0059] The foregoing is the embodiment of the present invention. However, the present invention is not limited to the above described embodiment, and can be varied within a technical concept of the invention. For example, in the above described embodiment, the CPU 108 executes the calibration. However, the invention is not limited to such a configuration, and the calibration may be executed in the calibration circuit 412. In this case, the calibration circuit 412 is configured to change the adjustment parameter through communication with the CPU 108.

[0060] The magnification of the relay lens unit 406 is set to 10 magnifications in the embodiment; however, the magnification of the relay lens unit 406 may be set to approximately 2 to 20 magnifications. By enlarging the scanning area of the excitation

light on the PSD 404 within the range in which the scanning trajectory falls within the light-receiving surface 40a of the PSD 404, it becomes possible to more precisely detect the scanning trajectory of the excitation light.

[0061] A system to which the present invention is applied is not limited to a scanning confocal endoscope system. For example, the present invention may be applied to a scanning endoscope system employing a raster scanning manner in which light horizontally scans on a scanning area to reciprocate or a Lissajous scanning manner in which light sinusoidally scans on a scanning area.

[0062] In the above described embodiment, the confocal optical unit 204 is installed in the tip of the confocal endoscope 200. However, the confocal optical unit 204 may be installed in a confocal probe inserted into an instrument insertion channel of an endoscope.

[0063] A position detection device to be installed in the calibration apparatus 400 is not limited to a PSD. The PSD 404 may be replaced with another device which is able to detect the position and the light amount, such as a CCD (Charge Coupled Device) and an array type PMT (Photomultiplier Tube).

[0064] In the calibration according to the above described embodiment, the user operates the position adjustment knob 410 while viewing the endoscopic image displayed on the monitor 300 to move the case 402 in X, Y and Z directions with respect to the confocal optical unit 204; however, the present invention is not limited to such a configuration. For example, the XYZ stage may be moved by a motor, and the CPU 108 may automatically execute the position adjustment so that the scanning trajectory of the excitation light is located at the center of the light-receiving surface 404a of the PSD 404 while processing the obtained fluorescence image.

[0065] The fluorescent material 404c according to the embodiment is formed as a coating applied to the back side (the light-receiving surface 404a side) of the cover glass 404b. However, the present invention is not limited to such a configuration. The fluorescent material 404c may be material that produces fluorescence by receiving excitation light having the wavelength of 488nm. Therefore, for example, the fluorescent material 404c may be formed by adhering yellow cloth (a fiber which produces yellow fluorescence) containing fluorescent paint to the cover glass 404b. The indicator part 404c may be formed by forming mark-off lines on the back side of the cover glass 404b and applying fluorescent paint to the mark-off lines.

[0066] In the above described embodiment, the frame part 404ca of the fluorescent material 404c is formed to surround the periphery of the light-receiving surface 404a of the PSD 404. However, when the position detection precision in the peripheral part of the light-receiving surface 404a is low and an effective detection area of the light-receiving surface 404a is set at the central part of the light-receiving surface 404a, a

part of the light-receiving surface 404a other than the effective detection area may be masked. Such a configuration makes it possible to perform the calibration more precisely because in this case the PSD 404 is used only in the part having the high degree of position detection precision.

[0067] In the above described embodiment, the fluorescence reflection coating 404d is provided on the coating of the fluorescent material 404c. However, when fluorescence produced by the indicator part 404cb does not affect the position detection by the PSD 404, the fluorescence reflection coating 404d may be omitted.

[0068] In the above described embodiment, the fluorescent material 404c is formed of the frame part 404ca and the indicator part 404cb. However, for example, when the light-receiving surface 404a of the PSD 404 is sufficiently large and the scanning trajectory of the excitation light surely falls within the light-receiving surface 404a of the PSD 404 even when a product-specific property and the positional error caused when the confocal optical unit 204 is attached to the unit support member 420 are considered, the indicator part 404cb is not necessarily required. In this case, as shown in Fig. 11, the user operates the position adjustment knob 410 to move the case 402 in X and Y directions while viewing the endoscopic image (i.e., the fluorescence image in the scanning area A) displayed on the monitor 300 so that the scanning trajectory A does not interfere with the frame part 440ca. However, in this case, when the adjustment is performed properly, the fluorescence from the fluorescent material 404c would never be observed on the monitor 300. Therefore, as shown in Fig. 12, the scanning trajectory A may be magnified by increasing the amplitudes of the alternating voltages X and Y so that the calibration can be performed after confirming the fluorescence of the frame part 404ca.

[0069] In the above described embodiment, the indicator part 404cb of the fluorescent material 404c is formed of the two vertical and horizontal lines; however, the present invention is not limited to such a configuration, and indicators having various types of shapes may be used. Fig. 13 illustrates variations of the indicator part 404cb of the fluorescent material 404c according to the embodiment. Fig. 13A illustrates a variation where the two vertical and horizontal lines forming the indicator part 404cb according to the embodiment is altered to a dashed indicator part 404cb1. Such a configuration makes it possible to check the diameter of the scanning area A on the endoscopic image displayed on the monitor 300 by counting divided dashed lines. As shown in Fig. 13B, the indicator part 404cb may be provided with scales (distance scales) formed to perpendicularly intersect with the lines at predetermined positions. Such a configuration makes it possible to easily know the diameter of the scanning area A from the endoscopic image displayed on the monitor 300. As shown in Fig. 13C, the indicator part 404cb may be formed, for example, by discretely arranging circular

marks. In this case, it is preferable that the marks include a mark indicating the center of the light-receiving surface 404a and a plurality of marks indicating distances from the center of the light-receiving surface 404a. Furthermore, it is preferable that the plurality of marks indicating the distances from the center of the light-receiving surface 404a may have different shapes depending on the distance from the center of the light-receiving surface 404a.

[0070] In the above described embodiment, the fluorescent material 404c includes the frame part 404ca and the indicator part 404cb; however, the present invention is not limited to such a configuration. Figs. 14 and 15 illustrate variations of the fluorescent material 404c according to the embodiment. As shown in Fig. 14, a coating (i.e., a semipermeable coating) which produces fluorescence by receiving excitation light and lets a part of the excitation light pass therethrough may be provided on the entire back surface of the cover glass 404b, in place of the fluorescent material 440c. In this case, by forming cross-shaped mark-off lines 404d (i.e., thin lines not emitting excitation light) at the central portion of the light-receiving surface to remove a part of the coating, the mark-off lines may be used as an indicator. As shown in Fig. 15, a coating of the fluorescent material 404c formed in a grid shape may be provided on the entire back surface of the cover glass 404b. In this case, a part of the coating corresponding to the indicator part 404cb may be removed so that the coating can serve as an indicator. With this configuration, by finishing the adjustment in Z direction of the case 402, the fluorescence in a grid shape can be observed regardless of the position of the scanning trajectory of the excitation light on the PSD 404. As a result, the positioning between the confocal optical unit 204 and the case 402 can be conducted easily.

[0071] In the above described embodiment, the fluorescent material 404c is formed in the inside of the PSD 404 (on the back side (the light-receiving surface 404a side) of the cover glass 404b; however, the present invention is not limited to such a configuration. Fig. 16 illustrates a variation of the calibration apparatus 400 according to the embodiment. A calibration apparatus 400M according to the variation is different from the calibration apparatus 400 according to the embodiment in that the calibration apparatus 400M includes a beam splitter 403, and includes a fluorescent material 407 on the outside of the PSD 404 in place of the fluorescent material 404c.

[0072] The beam splitter 403 is arranged between the relay lens unit 406 and the PSD 404, and lets 50% of the excitation light proceeding from the relay lens unit 406 to the PSD 404 pass therethrough and lets the other 50% of the excitation light proceeding from the relay lens unit 406 to the PSD 404 be reflected therefrom. The excitation light which has passed through the beam splitter 403 is incident on the PSD 404 and the scanning trajectory thereof is detected as in the case of the embodiment. On the other

hand, the excitation light reflected by the beam splitter 403 is incident on the fluorescent material 407 to produce the fluorescence. A surface of the fluorescent material 407 is coated with a fluorescent material having the same pattern as the frame part 404ca and the indicator part 404cb according to the embodiment, and is arranged at a position which is optically equivalent to the position of the light-receiving surface 404a of the PSD 404. Therefore, the fluorescence produced in the fluorescent material 407 enters the tip 202a of the optical fiber 202 after proceeding along the same path for the excitation light, and then is displayed, as an endoscopic image, on the monitor 300. As in the case of the embodiment, when the position of the case 402 is adjusted so that the fluorescence at the central portion of the fluorescent material 406 is displayed on the monitor 300, the scanning trajectory of the excitation light moves to the central portion of the light-receiving surface 402a of the PSD 404. Thus, the configuration where the fluorescent material 407 is located on the outside of the PSD 404 also allows the user to conduct adjustment so that the scanning area A falls within the light-receiving surface 404a of the PSD 404 while viewing the endoscopic image (i.e., a fluorescent image in the scanning area A) displayed on the monitor 300.

Claims

[Claim 1]

A calibration apparatus for a scanning confocal endoscope system configured to have a light scanning device which causes excitation light with a predetermined wavelength from a light source to periodically scan within a predetermined scanning area on a subject, to receive fluorescence from the subject excited by the excitation light emitted from the light scanning device and thereby to display a confocal image, the calibration apparatus comprising:

a relay lens to which the excitation light emitted from the light scanning device enters and which magnifies the predetermined scanning area;

a light detection means configured to receive the excitation light emerging from the relay lens on a light-receiving surface of the light detection means perpendicularly arranged with respect to an optical axis of the relay lens and to detect a scanning trajectory of the received excitation light on the light-receiving surface;

a fluorescent material that is arranged at a position optically equivalent to the light-receiving surface and emits fluorescence when the excitation light emerging from the relay lens is incident on the fluorescent material;

a moving means configured to move the relay lens and the light detection means relative to the light scanning device; and

a correction means that corrects a scan parameter for the excitation light emitted from the light scanning device so that the scanning trajectory detected by the light detection means becomes a reference scanning trajectory,

wherein:

the relay lens is arranged so that a rear focal point of the relay lens substantially coincides with a center position of the light-receiving surface; and

the moving means moves the relay lens and the light detection means, based on the fluorescence of the fluorescent material displayed on the endoscopic image, so that a front focal point of the relay lens substantially coincides with a convergence point of the excitation light emitted from the light scanning device and that the scanning area of the excitation light emerging from the relay lens falls within the light-receiving surface.

- [Claim 2] The calibration apparatus according to claim 1,
wherein:
the fluorescent material includes an indicator part indicating a position equivalent to the center of the light-receiving surface; and
the moving means moves the relay lens and the light detection means so that a center of the scanning area of the excitation light emerging from the relay lens substantially coincides with the center of the light-receiving surface.
- [Claim 3] The calibration apparatus according to claim 2,
wherein the indicator part is a cross-shaped indicator which is formed of two lines perpendicularly intersecting with each other and perpendicularly intersects with an optical axis of the relay lens at the position equivalent to the center of the light-receiving surface.
- [Claim 4] The calibration apparatus according to claim 3, wherein the cross-shape indicator is formed of a solid line.
- [Claim 5] The calibration apparatus according to claim 3, wherein the cross-shape indicator is formed of a dashed line.
- [Claim 6] The calibration apparatus according to claim 2,
wherein the indicator part includes a plurality of indicators arranged discretely on a plane equivalent to the light-receiving surface, and each of the plurality of indicators has a predetermined shape.
- [Claim 7] The calibration apparatus according to claim any of claims 2 to 6,
wherein the indicator part includes a distance indicator indicating distances from the center of the light-receiving surface.
- [Claim 8] The calibration apparatus according to claim 7 referring to any of claims 3 to 5,
wherein the distance indicator includes scales formed to perpendicularly intersect the cross-shaped indicator at positions respectively corresponding to the distances from the center of the light-receiving surface.
- [Claim 9] The calibration apparatus according to claim 7 referring to claim 6,
wherein the distance indicator includes indicators having shapes which differ depending on a distance from the center of the light-receiving surface.
- [Claim 10] The calibration apparatus according to any of claims 1 to 9,
wherein:
the fluorescent material includes a frame part configured to surround a periphery of the light-receiving surface at a position equivalent to the

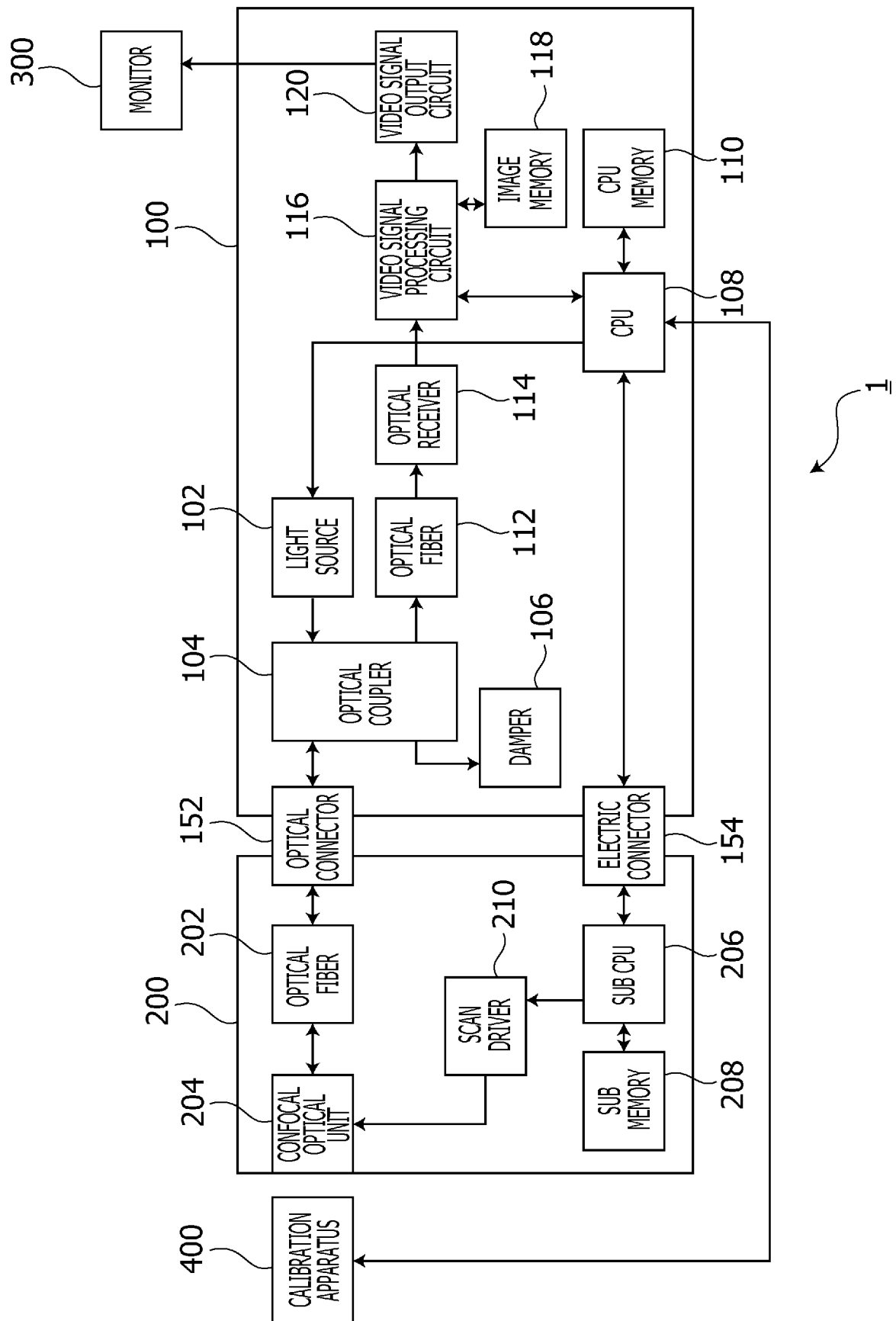
light-receiving surface; and

the moving means moves the relay lens and the light detection means so that the scanning area of the excitation light emerging from the relay lens does not interfere with the frame part.

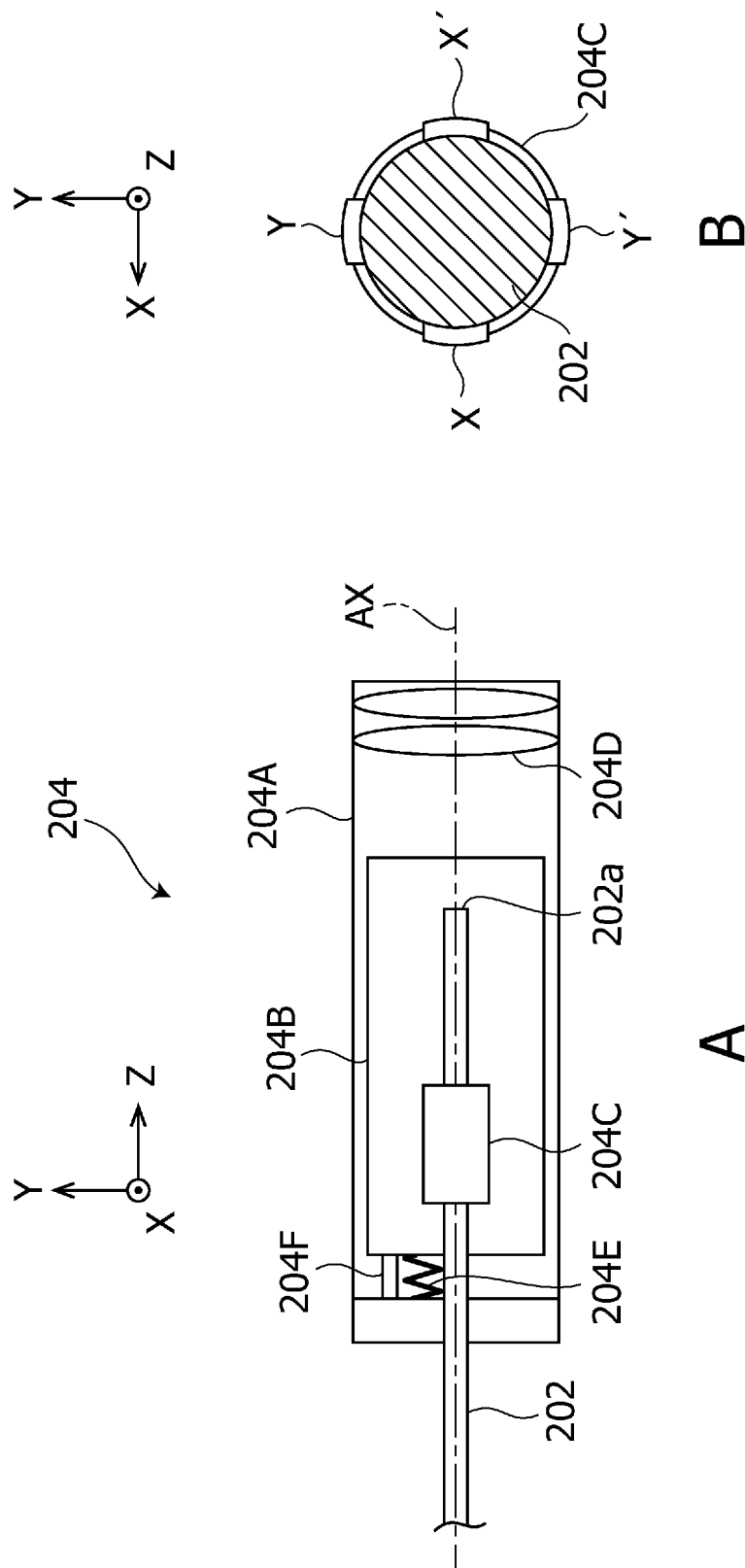
- [Claim 11] The calibration apparatus according to claim 1, wherein the fluorescent material is configured to cover the light-receiving surface and a periphery of the light-receiving surface at a position equivalent to the light-receiving surface, and to let a part of the excitation light incident thereon from the relay lens pass therethrough.
- [Claim 12] The calibration apparatus according to claim 11, wherein the fluorescent material includes an indicator part which is formed of two straight lines perpendicularly intersecting with each other at the position equivalent to the center of the light-receiving surface and which does not emit fluorescence.
- [Claim 13] The calibration apparatus according to claim 11 or 12, wherein the fluorescent material is formed in a grid shape.
- [Claim 14] The calibration apparatus according to any of claims 1 to 13, wherein:
the light detection means includes a cover glass on a front side of the light-receiving surface; and
the fluorescent material is provided to coat a surface of the cover glass facing the light-receiving surface.
- [Claim 15] The calibration apparatus according to claim 14, wherein a fluorescence reflection coating which reflects fluorescence produced by the fluorescent material is formed on the fluorescent material.
- [Claim 16] The calibration apparatus according to any of claims 1 to 13, further comprising a beam splitter which is arranged between the relay lens and the light detection means, wherein the beam splitter divides the excitation light incident thereon through the relay lens, lets the divided excitation light proceed to the light detection means and the fluorescent material, and lets the fluorescence produced by the fluorescent material be reflected toward the relay lens.
- [Claim 17] The calibration apparatus according to any of claims 1 to 16, wherein the scan parameter includes at least one of a first parameter to magnify or reduce the scanning area of scanning light, a second parameter to change a shape of the scanning area of the scanning light,

- and a third parameter to change a scanning speed of the scanning light.
- [Claim 18] The calibration apparatus according to any of claims 1 to 17, further comprising a remapping table creation means which samples the scanning trajectory of the scanning light corrected by the correction means at a predetermined timing, and assigns a two dimensional raster coordinate to each sampling point.
- [Claim 19] The calibration apparatus according to any of claims 1 to 18, wherein the relay lens, the light detection means and the fluorescent material are accommodated in a single case.
- [Claim 20] The calibration apparatus according to claim 19, wherein the case shields at least the light detection means against external light.

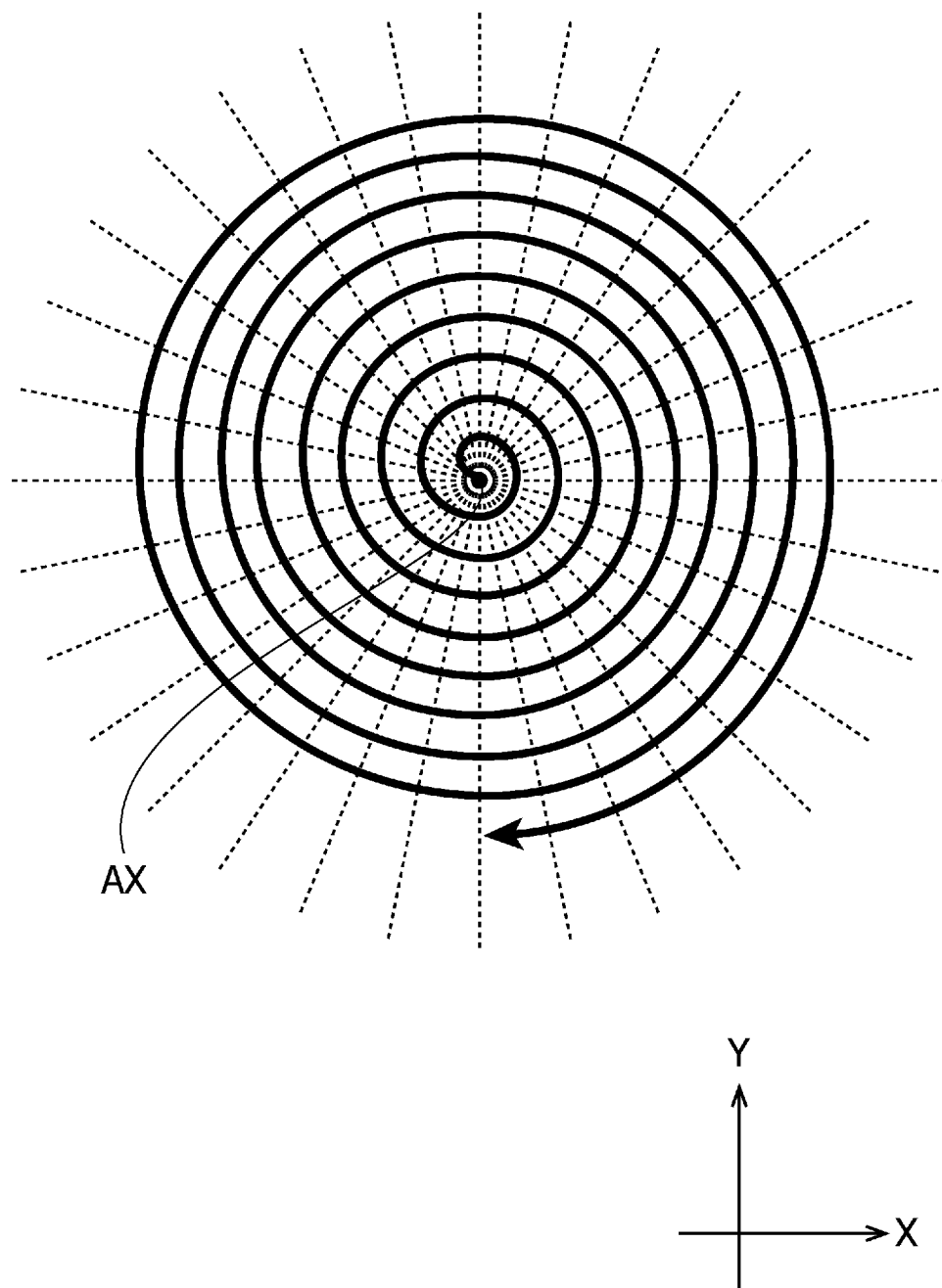
[Fig. 1]



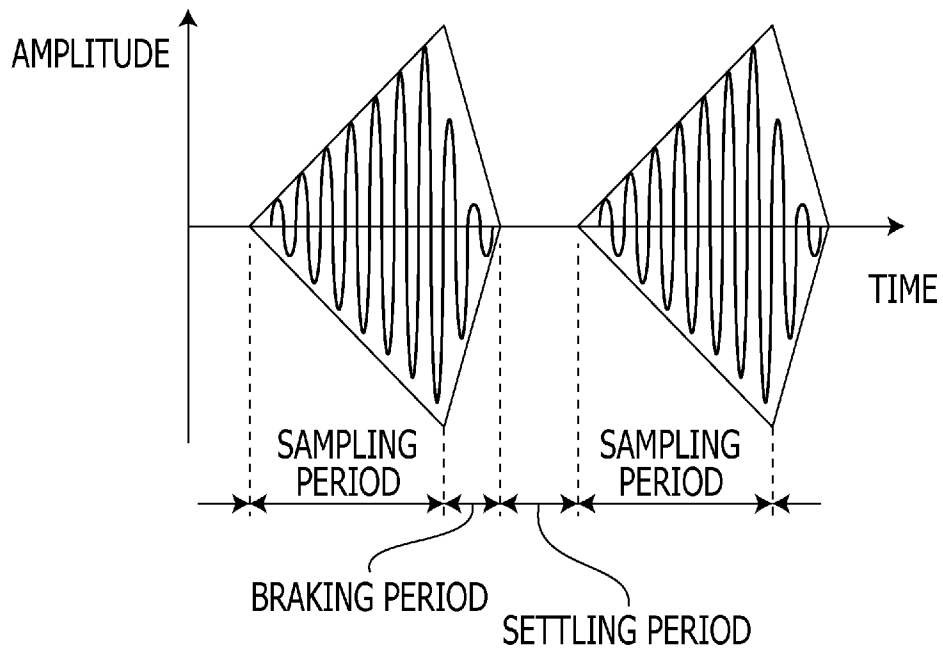
[Fig. 2]



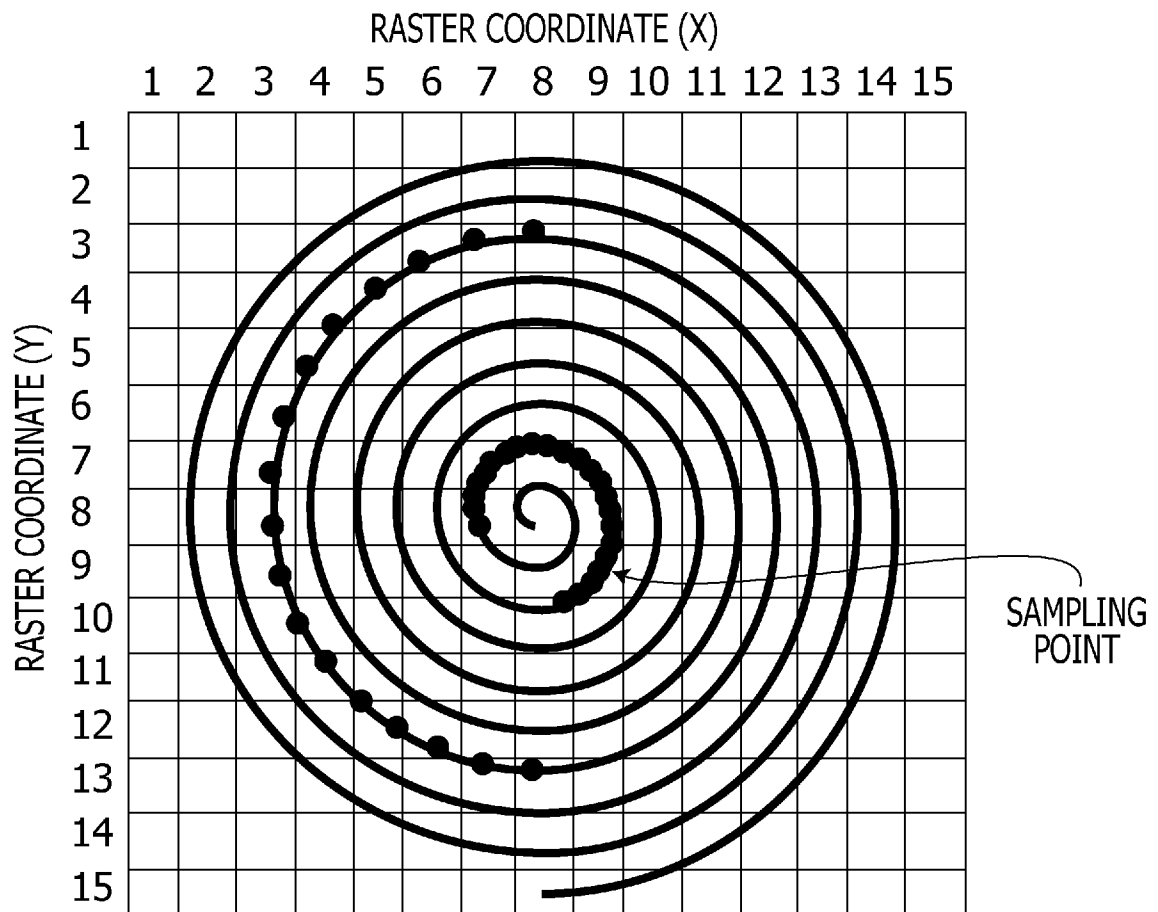
[Fig. 3]



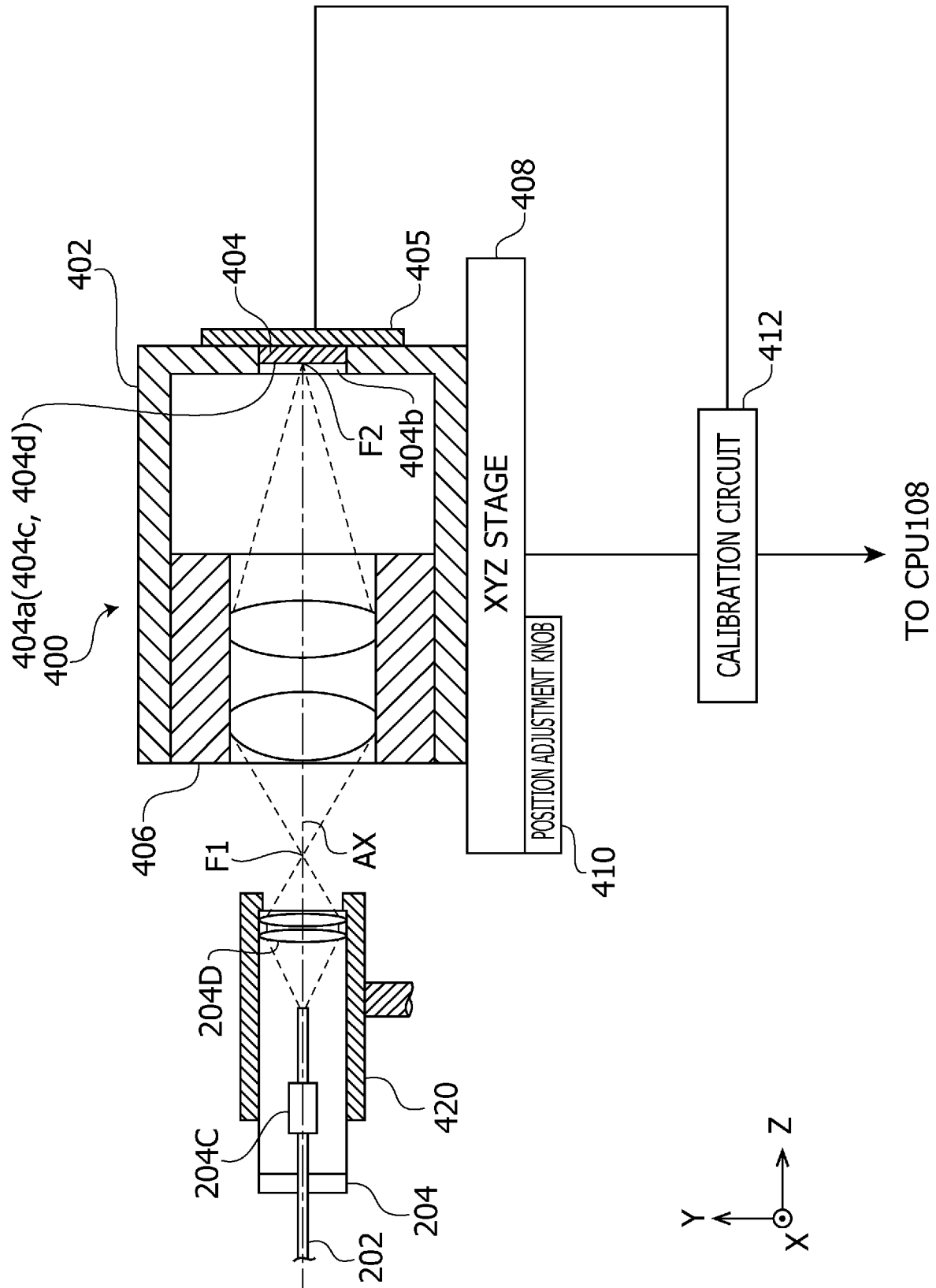
[Fig. 4]



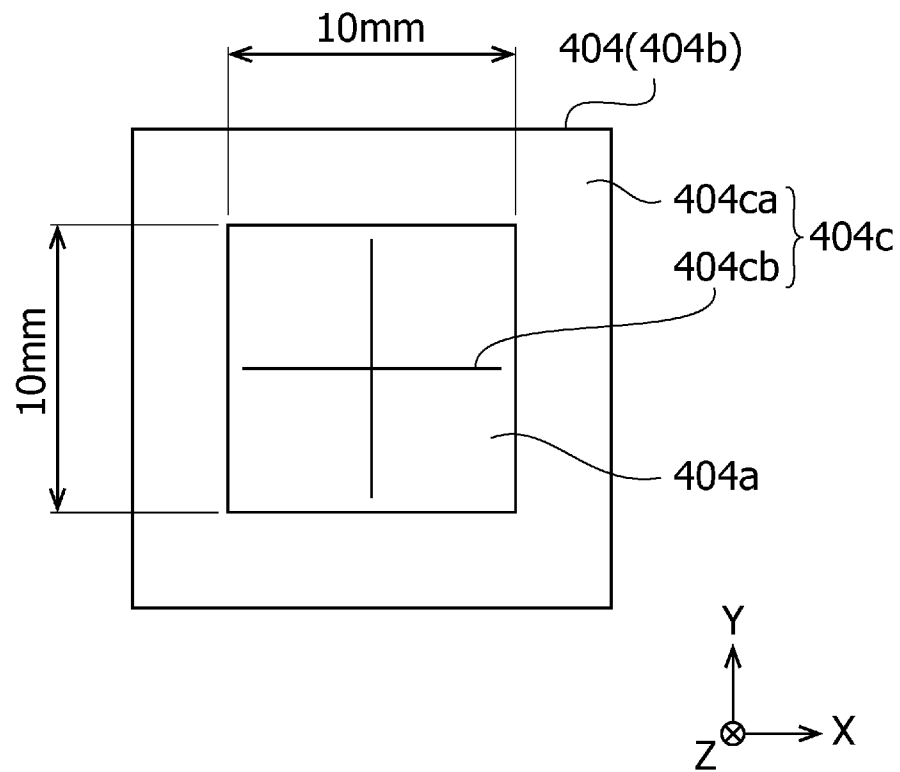
[Fig. 5]



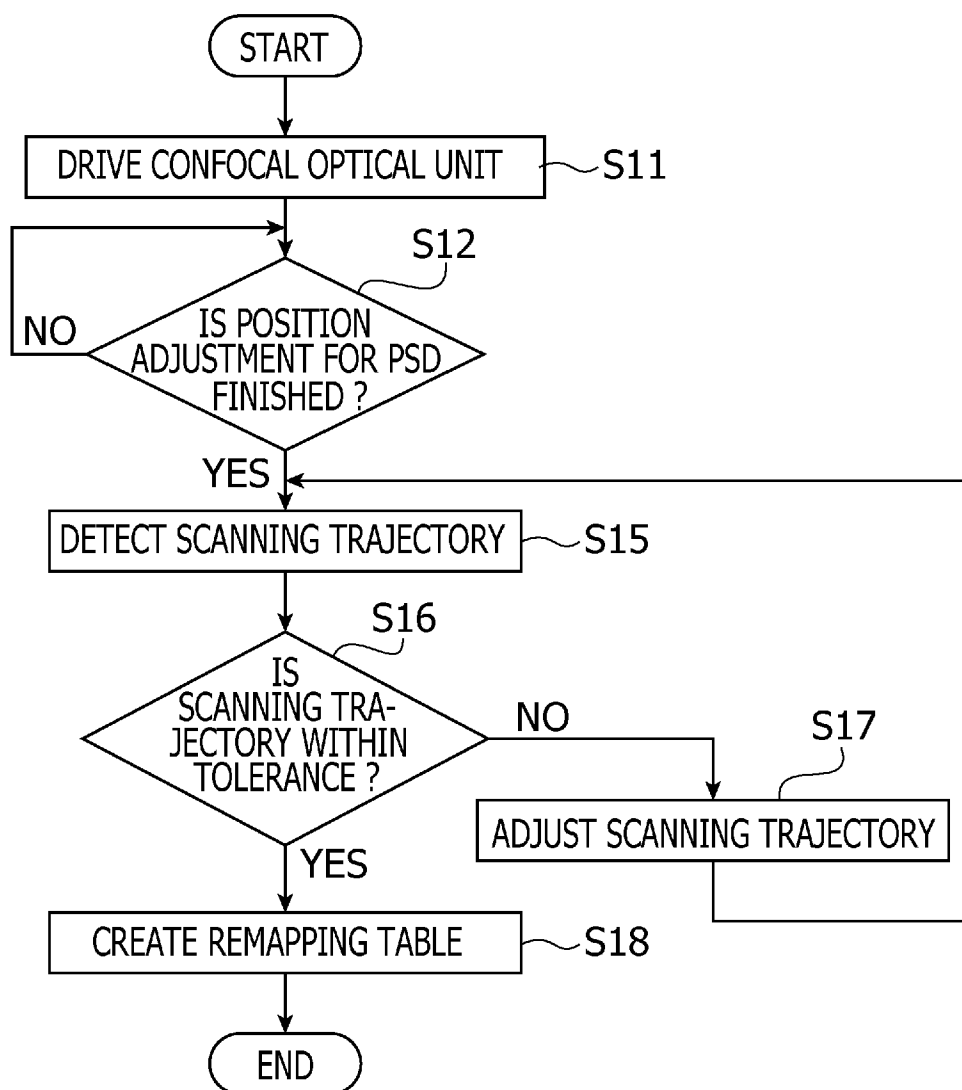
[Fig. 6]



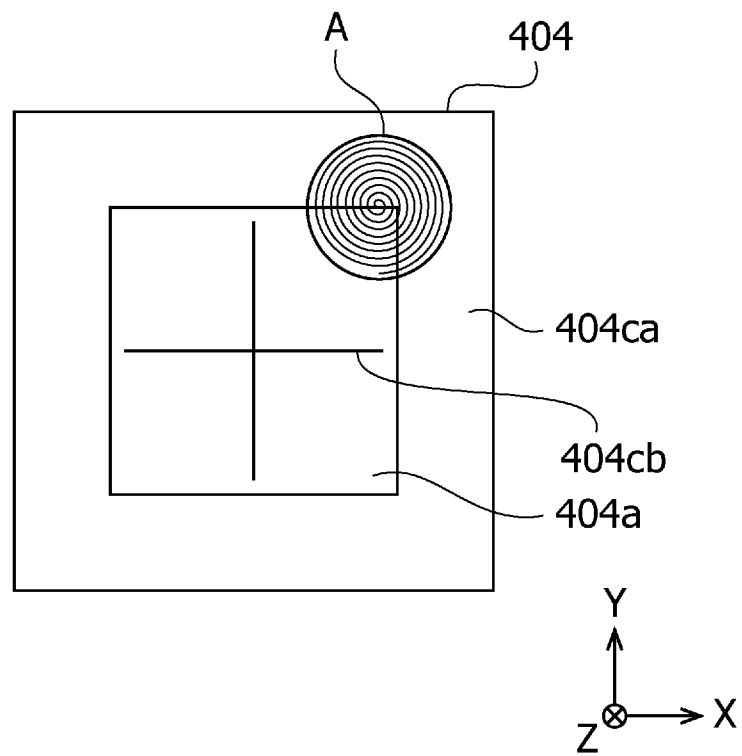
[Fig. 7]



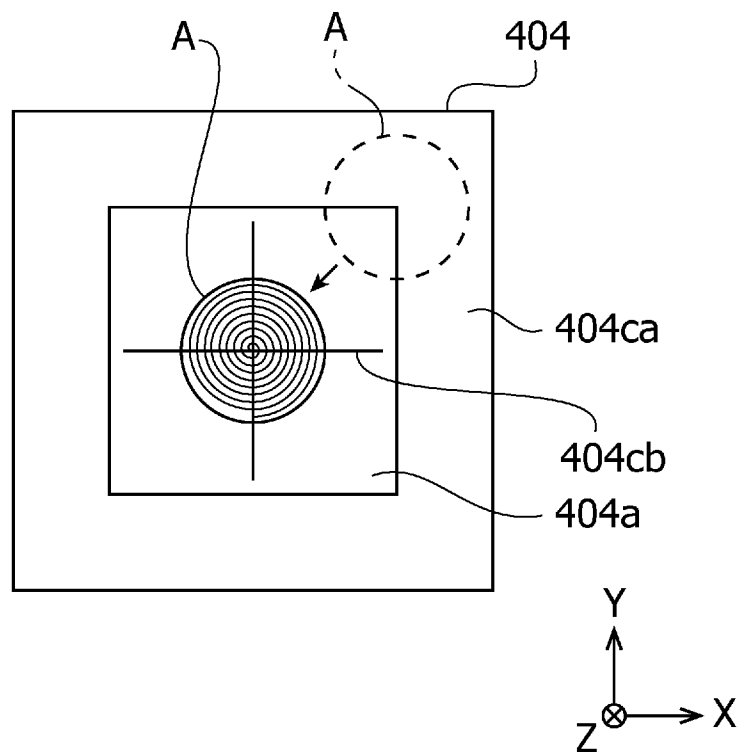
[Fig. 8]



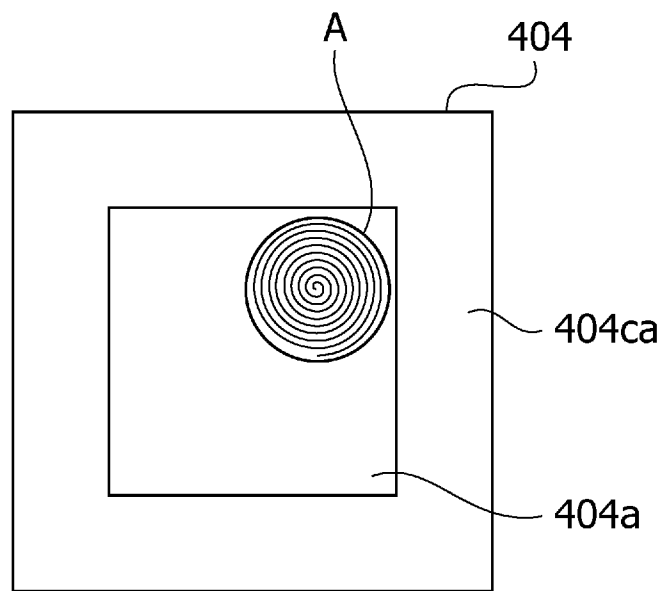
[Fig. 9]



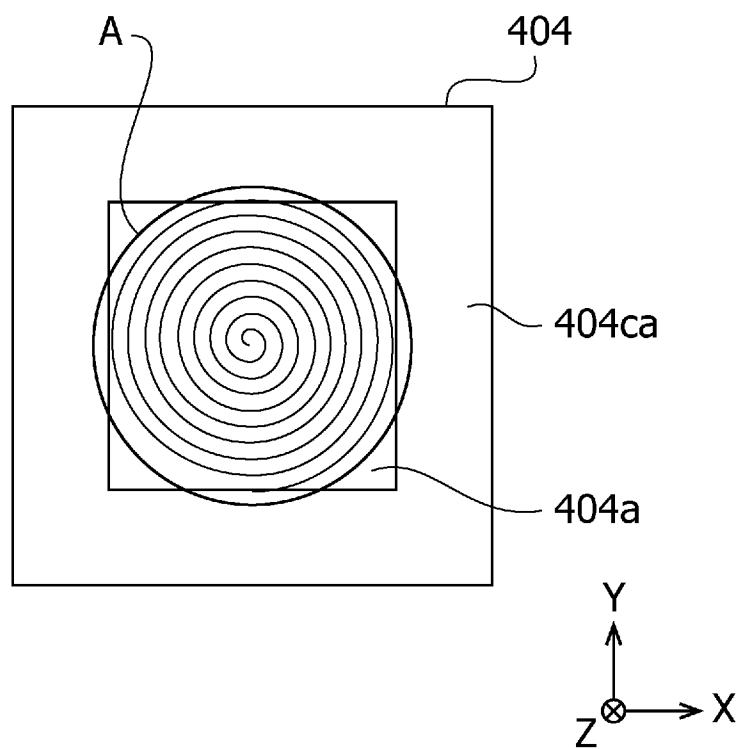
[Fig. 10]



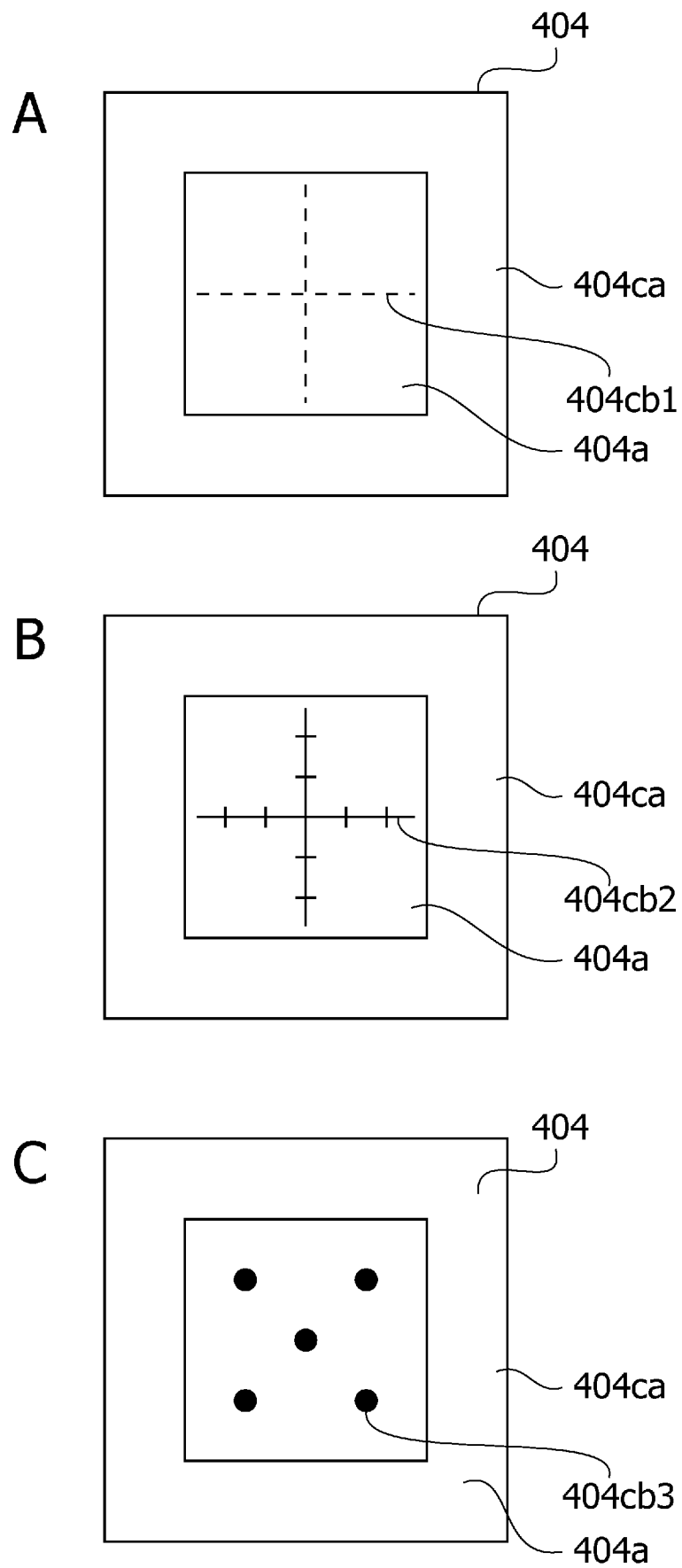
[Fig. 11]



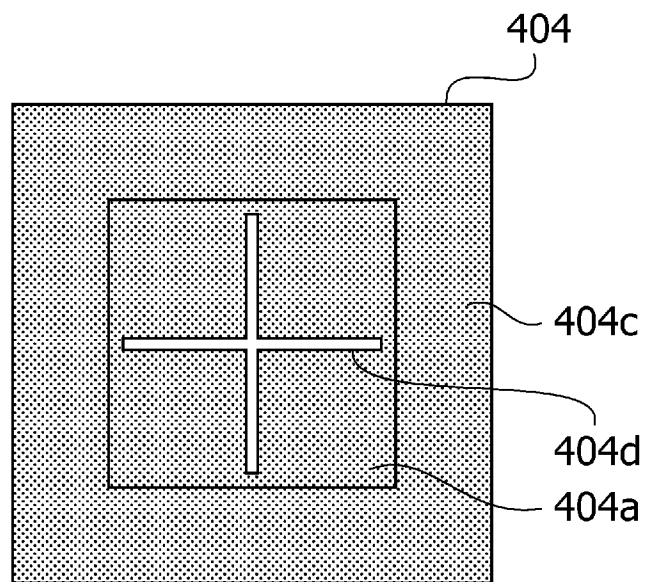
[Fig. 12]



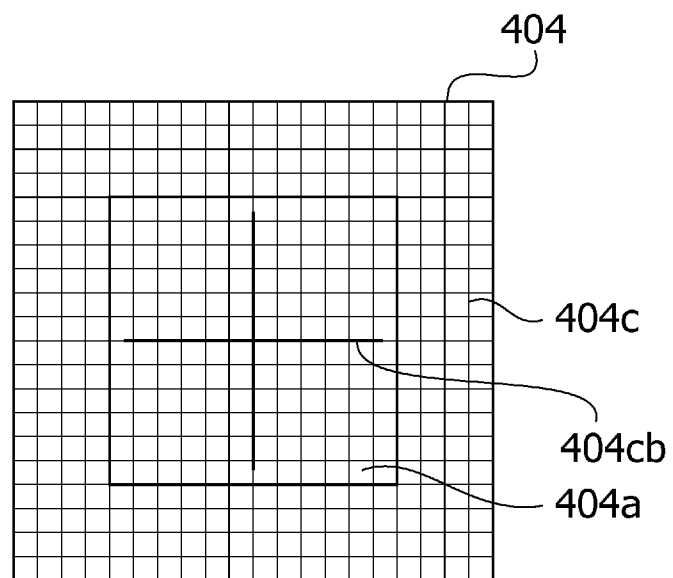
[Fig. 13]



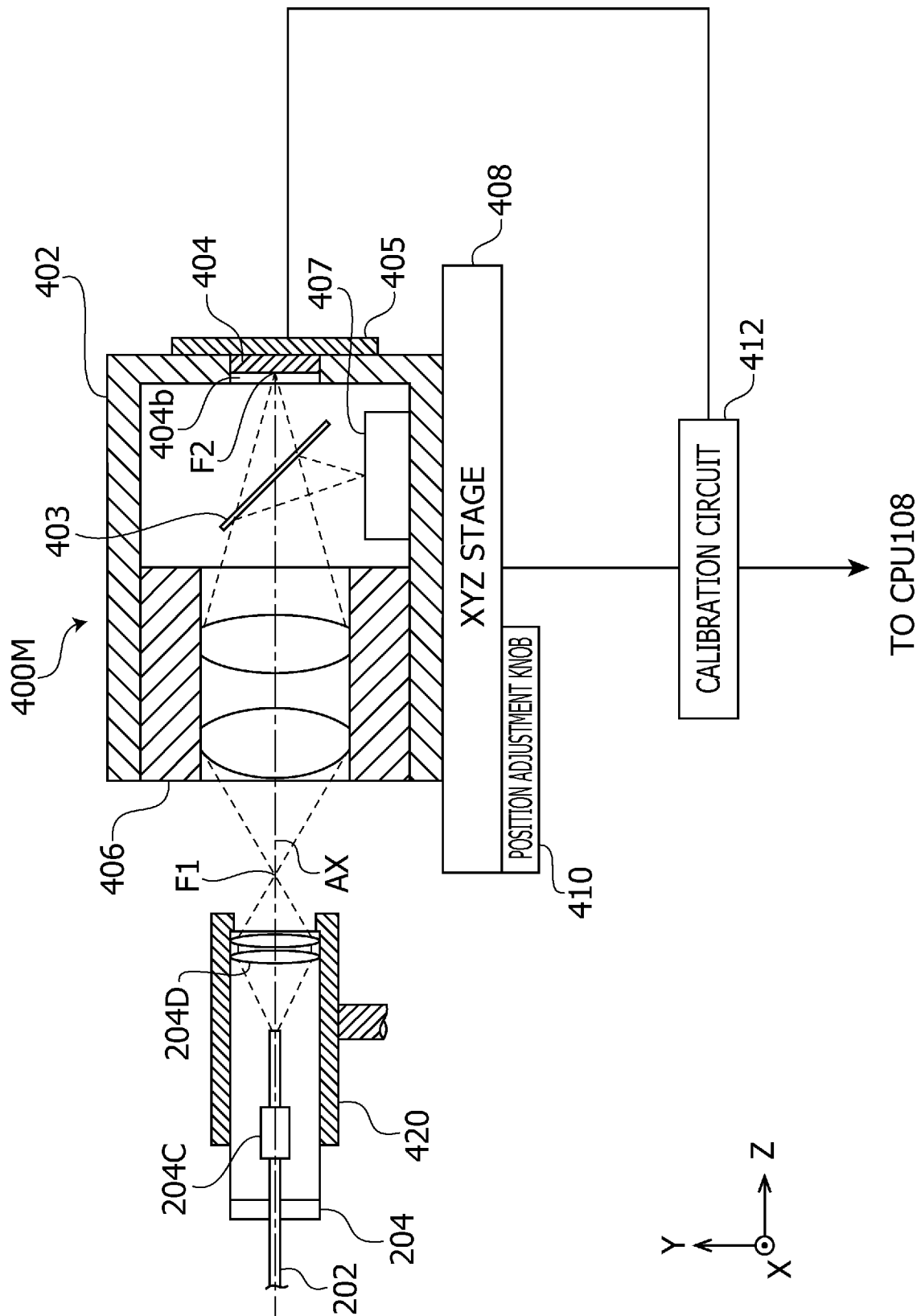
[Fig. 14]



[Fig. 15]



[Fig. 16]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/004442

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl. A61B1/00 (2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Int.Cl. A61B1/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2013 Registered utility model specifications of Japan 1996-2013 Published registered utility model applications of Japan 1994-2013		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/57152 A1 (OLYMPUS MEDICAL SYSTEMS CORP.) 2012.05.03, FIG. 3 (No Family)	1 - 2 0
A	JP 2005-6854 A (OLYMPUS CORP.) 2005.01.13, (No Family)	1 - 2 0
A	US 2007/0035797 A1 (PENTAX CORP.) 2007.02.15, & JP 2007-44221 A	1 - 2 0
A	JP 2011-24891 A (HOYA CORP.) 2011.02.10, FIG. 3 (No Family)	1 - 2 0
A	JP 2011-255015 A (HOYA CORP.) 2011.12.22, (No Family)	1 - 2 0
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 09.08.2013		Date of mailing of the international search report 20.08.2013
Name and mailing address of the ISA/JP Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan		Authorized officer NAOHITO ODAKURA Telephone No. +81-3-3581-1101 Ext. 3292