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(54) **X-RAY GENERATION DEVICE AND METHOD, AND SAMPLE MEASUREMENT SYSTEM**

RÖNTGENERZEUGUNGSVORRICHTUNG UND -VERFAHREN SOWIE PROBENMESSSYSTEM

DISPOSITIF ET PROCÉDÉ DE GÉNÉRATION DE RAYONS X, ET SYSTÈME DE MESURE
D'ÉCHANTILLON

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Description

TECHNICAL FIELD

[0001] The present invention relates to an X-ray generating device and an X-ray generating method for generating X-rays using a so-called rotating anticathode style, and a sample measurement system including the X-ray generating device.

BACKGROUND ART

[0002] Conventionally, in the field of measurement, the method configured to generate selectively a linear or dot-like X-ray beam by irradiating an electron beam onto the outer circumferential surface of a rotating anticathode and forming long focal spots in a circumferential direction or a width direction has been known (See Patent Document 1). Document 2 describes a generic X-ray generating device as defined in the preamble part of claim 1.

PRIOR ART DOCUMENTS

Patent Documents

[0003]

[Patent Document 1] Japanese Patent Application Laid-Open No. 1994-020629 (FIG. 1, FIG. 6, etc.)

[Patent Document 2] JP S61 39351 A

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

[0004] From the viewpoint of usability at the time of measurement, it is desirable to realize improvement in output performance and improvement in working efficiency with a device that selectively generates a linear or dot-like X-ray beam with as simple a device configuration as possible.

[0005] The present disclosure has been made in view of the above problems, and an object of the present disclosure is to provide an X-ray generating device, an X-ray generating method, and a sample measurement system method which are capable of selectively generating a linear or dot-like X-ray beam while having an extremely simple device configuration.

Means for Solving the Problem

[0006] According to a first aspect of the present invention, there is provided an "X-ray generating device" comprising: an electron generator having an electron source for emitting a linear electron beam suitable for generating a focal spot of linear shape, and a switching mechanism switching an extending direction of the electron source to either one of a first direction and a second direction

perpendicular to the first direction while fixing a center position of the electron source; and a rotating anticathode with a disk shape or a columnar shape, having a circumferential surface portion being impinged by the electron beam from the electron source and emitting linear or dot-like X-ray beams and configured to be rotatable about a rotation axis; wherein the electron generator and the rotating anticathode are fixedly arranged in a positional relationship in which the electron source and the circumferential surface portion face each other and the rotation axis is tilted with respect to the first direction and the second direction, wherein the surface portion is geometrically designed as a circumferential surface portion, and the rotation axis is tilted with respect to the first direction and the second direction in a plane comprising the first direction and the second direction. According to the invention the rotation axis is tilted within a range of 30 to 60 degrees with respect to the first direction.

[0007] In this manner, since the switching mechanism is provided for switching the extension direction of the electron source to either one of the first direction and the second direction perpendicular to the first direction while fixing the center position of the electron source, and the electron generator and the rotating anticathode are fixedly arranged in the positional relationship in which the electron source and the circumferential surface portion face each other, a linear or dot-like X-ray beam can be selectively generated by simply switching the extending direction of the electron source without changing positions and attitudes of the electron generator and the rotating anticathode.

[0008] Further, since the rotating anticathode is in the positional relationship in which its rotation axis is tilted with respect to the first direction and the second direction, for two focal spots formed by emissions of the electron beams from the first direction and the second direction, a divergence amount of focal lengths traversing in a circumferential direction is smaller than when the rotation axis is not tilted. That is, instead of lowering the output efficiency on the highest side, by raising the output efficiency on the lowest side, the maximum amount (that is, the limit output amount of X-rays) that can be commonly output to both of the X-ray beams is raised.

[0009] Thus, it is possible to selectively generate a linear or dot-like X-ray beam while maintaining a very simple device configuration, and to improve the output performance of the entire device.

[0010] The rotation axis is tilted within a range of 30 to 60 degrees with respect to the first direction. This makes it possible to suppress the divergence amount of the focal lengths traversing in the circumferential direction, more specifically the ratio of the focal lengths to less than about twice in general, thereby further reducing the gap between the output performances of both.

[0011] In addition, it is preferable that the rotation axis be tilted by 45 degrees with respect to the first direction. Since the focal lengths traversing in the circumferential direction become equal, the limit output amount common

to both of the X-ray beams is maximized.

[0012] According to the first aspect of the present invention, there is also provided an "X-ray generation method" as defined in claim 9.

[0013] Preferred embodiments of the X-ray generating device and of a sample measurement system comprising the X-ray generating device according to the invention are defined in the dependent claims.

[0014] The sample measurement system comprises an X-ray detecting device for detecting X-ray beams generated from the X-ray generating device and transmitted through or reflected a sample; and a measuring means for measuring a physical quantity relating to the sample, based on a detected amount of the X-ray beams detected by the X-ray detecting device.

[0015] The X-ray generating device may further comprise a chamber housing the electron source and the rotating anticathode; wherein the electron generator and the rotating anticathode are fixedly arranged in the chamber in a positional relationship in which the electron source and the circumferential surface portion face each other, the electron generator comprising: a support base for supporting the electron source; and a rotation introducing mechanism being airtightly inserted and passed within the chamber and rotates the support base in accordance with an operation from the outside of the chamber.

[0016] In this manner, since the rotation introducing mechanism for rotating the support base for supporting the electron source in accordance with an operation from the outside of the chamber is provided, it is not necessary to replace the electron generator or the rotating anticathode and it is possible to change the extending direction of the electron source while maintaining the vacuum state within the chamber. Thus, it is possible to selectively generate a linear or dot-like X-ray beam with a simple device configuration, and to suppress deterioration of working efficiency due to this selection.

[0017] Further, it is preferable that the rotation introducing mechanism has a handle portion rotatably arranged outside the chamber, and the support base is rotated in accordance with an operation of rotating the handle portion. The operator can easily change the extending direction of the electron source by rotating the handle portion.

[0018] Also, it is preferable that the rotation introducing mechanism further includes an indication means for indicating rotating states of the handle portion in a visible way from the outside of the chamber. The operator can grasp the rotating state of the handle portion and the extending direction of the electron source at a glance by visually confirming a position indicated by the indicating means from the outside of the chamber.

[0019] In addition, it is preferable that the rotation introducing mechanism further includes rotation restricting means restricting a range of rotation of the handle portion. Thereby, it is possible to prevent the driven parts of the electron source from being excessively twisted and dam-

aged.

[0020] In addition, the rotation introducing mechanism is capable of changing the extending position of the electron source to a first direction and a second direction perpendicular to the first direction by an operation of rotating the support base, and a rotation axis of the rotating anticathode is tilted with respect to the first direction and the second direction. Regarding two focal spots formed by emissions of the electron beams from the first direction and the second direction, a divergence amount of focal lengths traversing in a circumferential direction is smaller than when the rotation axis is not tilted. That is, instead of lowering the output efficiency on the highest side, by raising the output efficiency on the lowest side, the maximum amount (that is, the limit output amount of X-rays) that can be outputted in common with both of the X-ray beams is raised.

[0021] According to a second aspect of the present invention, there is further provided a "sample measurement system" comprising: any one of the X-ray generating devices described above; an X-ray detecting device for detecting X-ray beams generated from the X-ray generating device and transmitted through or reflected by a sample; and a measuring means for measuring a physical quantity relating to the sample, based on a detected amount of the X-ray beams detected by the X-ray detecting device.

Effect of the Invention

[0022] According to the X-ray generating device and method and the sample measurement system of the present invention, it is possible to selectively generate a linear or dot-like X-ray beam while maintaining a very simple device configuration, and to improve the output performance and the work efficiency of the entire device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

FIG. 1 is a perspective view of an X-ray generating device according to this embodiment.

FIG. 2 is a cross-sectional view taken along line II - II of FIG. 1.

FIG. 3 is a cross-sectional view taken along line III - III in FIG. 1.

FIG. 4 is a schematic view showing shapes of X-ray beams according to a switching operation between a first direction and a second direction.

FIG. 5 is a schematic view showing a formation position of a focal spot at a tilt angle of 0 degrees.

FIG. 6 is a schematic view showing a formation position of a focal spot at a tilt angle of 45 degrees.

FIG. 7 is a graph showing a relationship between a tilt angle and a circumferential focal length.

FIG. 8 is an overall configuration view of a sample measurement system incorporating the X-ray gen-

erating device of FIG. 1.

FIG. 9 is a perspective view of an X-ray generating device according to a second embodiment.

FIG. 10 is a cross-sectional view taken along line II - II of FIG. 9.

FIG. 11 is a side view of the X-ray generating device shown in FIG. 9.

FIG. 12 is a cross-sectional view taken along line IV - IV of FIG. 9.

FIG. 13 is a schematic view showing shapes of X-ray beams according to a switching operation between a first direction and a second direction.

FIG. 14 is a graph showing a relationship between a tilt angle and a circumferential focal length.

FIG. 15 is an overall configuration view of a sample measurement system incorporating the X-ray generating device of FIG. 9.

DETAILED DESCRIPTION OF EMBODIMENTS

[0024] Embodiments of the claimed invention and comparative examples will be described below with reference to the accompanying drawings.

<First Embodiment>

[Configuration of X-ray Generating Device 10]

[0025] FIG. 1 is a perspective view of an X-ray generating device 10 according to a first embodiment, FIG. 2 is a sectional view taken along line II - II of FIG. 1, and FIG. 3 is a sectional view taken along line III - III of FIG. 1. For convenience of explanation, in these FIGS. 1 to 3, three axis directions (X direction, Y direction, and Z direction) indicating a three dimensional orthogonal coordinate system are defined.

[0026] As shown in FIG. 1, the X-ray generating device 10 is a device for generating X-rays using a so-called rotating anticathode system. The outward appearance is such that, the X-ray generating device 10 has a substantially rectangular chamber 12 made of a metal material having a low X-ray transmittance. In one corner portion on the side of one surface 14 of the chamber 12, a recessed portion 16 recessed in a triangular column shape is formed.

[0027] A circular opening portion 18 is provided on an tilted surface 17 forming the recessed portion 16 and a window portion 22 in which a beryllium thin film having a high X-ray transmittance is inserted is provided on an opposing surface 20 which faces the one surface 14. By mounting the lid portion 46 at a position covering the opening portion 18, an airtight state is maintained inside the chamber 12.

[0028] As shown in FIGS. 2 and 3, the X-ray generating device 10 includes an electron generator 24 configured to generate an linear electron beam B1, a rotating anticathode 26 having a disk shape or a columnar shape, and a cooling mechanism (not shown) configured to cool

the rotating anticathode 26. The electron generator 24 and the rotating anticathode 26 are housed in a fixed state in a room 28 of the chamber 12, respectively.

[0029] The electron generator 24 is a thermoelectron type, electric field emission type, or Schottky type electron gun, and will be described by taking as an example the thermoelectron type. Specifically, the electron generator 24 includes a main body 30 having a substantially rectangular shape, an electron source 32 made of tungsten filament or the like, and a switching mechanism 34 for switching an extending direction of the electron source 32 to a plurality of directions. For example, it is noted that the main body portion 30 has a floating structure (not shown), and the electron source 32 is electrically insulated from the chamber 12.

[0030] The switching mechanism 34 has a disc portion which is rotatable around a rotation axis along the Y direction and to which the electron source 32 is fixed. In other words, the switching mechanism 34 rotates the disk portion integrally with the electron source 32, thereby making it possible to switch the extending direction of the electron source 32 to the X direction or Z Direction while fixing a center position O (FIG. 2) of the electron source 32.

[0031] The rotating anticathode 26 is configured to be rotatable in the A direction around the rotating axis 36 at a speed of, for example, 5000 to 12000 rpm. The rotating anticathode 26 has a circumferential surface portion 38 covered with a metal layer of molybdenum (Mo), copper (Cu) or the like, and a side surface portion 40 to which a rotation mechanism 42 of the rotating anticathode 26 is mounted.

[0032] The rotation mechanism 42 is configured to include a cylindrical axis portion 44 configured to pivotally support the rotating anticathode 26 and a disk-shaped lid portion 46 provided on the side of one end of the axis portion 44. The lid portion 46 has a main surface with a diameter larger than the opening portion 18 and is detachable at a position covering the opening portion 18 from the outside of the chamber 12.

[0033] As understood from FIG. 2, the rotating anticathode 26 is fixedly arranged under a positional relationship in which the rotation axis 36 is tilted with respect to the X direction and the Z direction. That is, when an angle formed by the radial direction of the rotating anticathode 26 and the Z direction is defined as "tilt angle φ " ($0 \leq \varphi \leq 90$, unit: degree), the relationship $0 < \varphi < 90$ is satisfied. According to the claimed invention, the tilt angle is within a range of 30 to 60 degrees. In this embodiment, in particular, $\varphi = 45$ degrees is satisfied.

[0034] As understood from FIG. 3, since the electron source 32 and the circumferential surface portion 38 are in a positional relationship facing each other, a linear focal spot (first focal spot 51) by the electron beam B1 from the electron source 32 is formed on the circumferential surface portion 38. When a specific generation condition is satisfied at the time of collision of the electron beam B1, the circumferential surface portion 38 emits the X-

ray beam B2 from the position of the first focal spot 51 or a nearby position thereof. As will be described later, the shape of the X-ray beam B2 emitted to the outside of the chamber 12 changes in accordance with the geometric relationship between the linear focal spot and the window 22.

[Operation of X-ray Generating Device 10]

[0035] Subsequently, the operation of the X-ray generating device 10 according to the first embodiment will be described with reference to the respective views in FIGS. 1 to 3 and the schematic view in FIG. 4.

(1) Fixed-Arrangement Step

[0036] First, a user places the electron generator 24 and the rotating anticathode 26 within the room 28 of the chamber 12, and then mounts the lid portion 46 at a position covering the opening 18. Thereby, the electron generator 24 and the rotating anticathode 26 are fixedly arranged in the positional relationship in which the electron source 32 and the circumferential surface portion 38 face each other and the rotation axis 36 is tilted with respect to the first direction and the second direction.

[0037] The first direction and the second direction are orthogonal to each other and cross respectively with a direction (that is, the Y direction) separating the electron source 32 from the circumferential surface portion 38. Here, the first direction corresponds to the "Z direction" and the second direction corresponds to the "X direction."

(2) Switching Step

[0038] The switching mechanism 34 switches the extending direction of the electron source 32 according to the user's selection operation. Specifically, when it is desired to use a linear X-ray beam B2 (see FIG. 4), the extending direction of the electron source 32 is switched to the "first direction," and when it is desired to use a dot-like X-ray beam B3 (see FIG. 4), the extending direction of the electron source 32 is switched to the "second direction."

(3) Generating Step

[0039] A vacuum pump (not shown) is used to evacuate the interior of the chamber 28 and the rotating anticathode 26 is rotated in the A direction at a predetermined speed. After various preparations for satisfying the X-ray generation conditions are completed, the electron generator 24 generates the linear electron beam B1 according to the user's operation instruction. As a result, the X-ray beams B2, B3 are emitted to the outside of the X-ray generating device 10 via the window section 22.

[0040] FIG. 4 is a schematic view showing the shapes of the X-ray beams B2, B3 according to the switching operation between the first direction and the second di-

rection. According to the extending direction of the electron source 32 (FIGS. 2 and 3), the first focal spot 51 curved along the first direction or a second focal spot 52 curved along the second direction is selectively formed.

[0041] In the former case, the circumferential surface portion 38 emits the X-ray beam B2 from the position of the first focal spot 51 of linear shape on which the electron beam B1 is incident. At this time, since the first focal spot 51 is in a relationship substantially parallel with the plane formed by the window section 22, the linear X-ray beam B2 is emitted.

[0042] In the latter case, the circumferential surface portion 38 emits the X-ray beam B3 from the position of the second focal spot 52 of linear shape on which the electron beam B1 is incident. At this time, since the second focal spot 52 is in a relationship substantially perpendicular to the plane formed by the window section 22, the dot-like X-ray beam B3 is emitted.

[0043] As described above, the electron generator 24 is provided with the switching mechanism 34 for switching the extending direction of the electron source 32, and the electron generator 24 and the rotating anticathode 26 are fixedly arranged in a positional relationship in which the electron source 32 and the circumferential surface portion 38 face each other. Thus, by simply switching the extension direction of the electron source 32 without changing the positions/attitudes of the electron generator 24 and the rotating anticathode 26 at all, the linear or dot-like X-ray beam B2, B3 can be selectively generated.

[Effects of X-Ray Generating Device 10]

[0044] Subsequently, the effect of the X-ray generating device 10 will be described in detail with reference to FIGS. 5 to 7.

[0045] FIG. 5 is a schematic view showing a formation position of a focal spot at a tilt angle φ of 0 degree ($\varphi = 0$), according to a comparative example. More specifically, FIG. 5 (a) is a projection view of the first focal spot 51 formed on the circumferential surface portion 38 as viewed from the Y direction, and FIG. 5 (b) is a projection view showing the second focal spot 52 formed on the circumferential surface portion 38 as viewed from the Y direction.

[0046] As shown in FIG. 5 (a), the first focal spot 51 has a rectangular shape having a width of W [mm] and a height of H [mm] ($H > W$) in a plan view from the Y direction. A line segment 53 shown by a broken line corresponds to a focal length traversed in a circumferential direction. Hereinafter, the length of the line segment 53 at the first focal spot 51 is referred to as "circumferential focal length L1." In the example of this figure, since the height direction of the first focal spot 51 coincides with the circumferential direction of the circumferential surface portion 38, $L1 = H$ [mm].

[0047] As shown in FIG. 5 (b), the second focal spot 52 has substantially the same shape as the first focal spot 51 shown in FIG. 5 (a) in a plan view from the Y

direction. Hereinafter, the length of the line segment 53 at the second focal spot 52 is referred to as "circumferential focal length L2." In the example of this figure, since a width direction of the second focal spot 52 coincides with the circumferential direction of the circumferential surface portion 38, $L2 = W$ [mm].

[0048] With respect to this X-ray generation method, as the circumferential focal lengths L1, L2 become larger, the thermal load received by the rotating anticathode 26 tends to increase. As the thermal load increases, the metal provided on the circumferential surface portion 38 becomes more difficult to cool, so there is a phenomenon whereby the output efficiency of the X-ray decreases. That is, in FIG. 5 (a), the output efficiency is relatively low because L1 is large, and in FIG. 5 (b), the output efficiency is relatively high since L2 is small. From the viewpoint of usability at the time of measurement, it is not preferable that a difference in output efficiency occurs due to the selection of the X-ray beams B2, B3.

[0049] FIG. 6 is a schematic view showing a formation position of a focal spot at a tilt angle φ of 45 degrees ($\varphi = 45$). More specifically, FIG. 6 (a) is a projection view of the first focal spot 51 formed on the circumferential surface portion 38 as viewed from the Y direction, and FIG. 6 (b) is a projection view showing the second focal spot 52 formed on the circumferential surface portion 38 as viewed from the Y direction.

[0050] As shown in FIG. 6 (a), the first focal spot 51 has substantially the same shape as the first focal spot 51 shown in FIG. 5 (a) in a plan view from the Y direction. In the embodiment of this figure, since the height direction of the first focal spot 51 is tilted by 45 degrees with respect to the circumferential direction of the circumferential surface portion 38, $L1 = \sqrt{2} \cdot W$ [mm].

[0051] As shown in FIG. 6 (b), the second focal spot 52 has substantially the same shape as the second focal spot 52 shown in FIG. 5 (a) in a plan view from the Y direction. In the embodiment of this figure, since the width direction of the second focal spot 52 is tilted by 45 degrees with respect to the circumferential direction of the circumferential surface portion 38, $L2 = \sqrt{2} \cdot W$ [mm].

[0052] FIG. 7 is a graph showing a relationship between the tilt angle φ and the circumferential focal lengths L1, L2. The horizontal axis of the graph is the tilt angle φ (unit: degree), and the vertical axis of the graph is the circumferential focal lengths L1, L2 (unit: mm). In addition, the solid line shows a function of L1 and the alternate long and short dash line shows a function of L2.

[0053] As understood from this figure, the circumferential focal length L1 satisfies $L1 = H$ [mm] when $\varphi = 0$ degree and $L1 = W$ [mm] when $\varphi = 90$ degrees and monotonically decreases as the tilt angle φ increases. On the other hand, the circumferential focal length L2 satisfies $L2 = W$ [mm] when $\varphi = 0$ degree and $L2 = H$ [mm] when $\varphi = 90$ degrees, and monotonically decreases as the tilt angle φ increases.

[0054] That is, when the tilt angle φ satisfies $\varphi = 0$ degree or $\varphi = 90$ degrees, the value of $|L1 - L2|$ is maximized

and when the tilt angle φ is set within the range of $0 < \varphi < 90$, the value of $|L1 - L2|$ becomes relatively small. It should be noted that the relationship of $L1 = W/\sin \varphi$ and $L2 = W/\cos \varphi$ holds in the vicinity of $\varphi = 45$ degrees.

[0055] If the rotating anticathode 26 is in the positional relationship ($0 < \varphi < 90$) in which the rotation axis 36 is tilted with respect to the first direction and the second direction, a divergence amount $|L1 - L2|$ of the circumferential focal lengths L1, L2 with respect to the first focal spot 51 and the second focal spot 52 formed by emissions of the electron beams B1 from the first direction and the second direction is smaller than when the rotation axis 36 is not tilted ($\varphi = 0, 90$). That is, by increasing the output efficiency on the lowest side instead of lowering the output efficiency on the highest side, the maximum amount (that is, the limit output amount of X-rays) that can be outputted in common to both of the X-ray beams B2, B3 is raised.

[0056] Further, the rotation axis 36 is, according to the claimed invention, in a positional relationship ($30 \leq \varphi \leq 60$) in which the rotation axis 36 is tilted within a range of 30 to 60 degrees with respect to the first direction. This makes it possible to suppress the ratio ($L1/L2$ or $L2/L1$) of the circumferential focal lengths L1, L2 to approximately less than twice in general, thereby further reducing the gap between the output performances of both.

[0057] In addition, the rotation axis 36 may be in a positional relationship ($\varphi = 45$) in which the rotation axis 36 is tilted by 45 degrees with respect to the first direction. In this case, since the circumferential focal lengths are equal as $L1 = L2 = \sqrt{2} \cdot W$ [mm], the limit output amount common to both of the X-ray beams B2, B3 is maximized.

[0058] As described above, the X-ray generating device 10 includes: [1] the electron generator 24 having the electron source 32 for emitting the linear electron beam B1, and the switching mechanism 34 for switching the extending direction of the electron source 32 to either one of the first direction (Z direction) or the second direction (X direction) while fixing the center position O of the electron source 32, [2] the rotating anticathode 26 which is a disk shape or a columnar shape, having the circumferential surface portion 38 for emitting the X-ray beams B2, B3 with the electron beam B1 impinged, and configured to be rotatable about the rotation axis 36. The electron generator 24 and the rotating anticathode 26 are fixedly arranged in the positional relationship in which the electron source 32 and the circumferential surface portion 38 face each other and the rotational axis 36 is tilted with respect to the first direction and the second direction.

[0059] The X-ray generating method using the X-ray generating device 10 includes the steps of: fixedly arranging the electron generator 24 and the rotating anticathode 26, and switching the extending direction of the electron source 32 to either one of the first direction or the second direction.

[0060] Thereby, it is possible to selectively generate the linear or dot-like X-ray beam B2, B3 while maintaining

a very simple device configuration, and to improve the output performance of the entire device. For example, when the aspect ratio of the electron source 32 is $H/W = 10$, assuming that the thermal load in the comparative example of FIG. 5 (a) is the reference (100%), the thermal loads in the comparative example of FIGS. 5 (b) and in the embodiments of figures 6 (a) and 6 (b) are estimated to be 32%, 84% and 84%, respectively. That is, by adopting the configuration of FIG. 6, although there is a loss of 16% compared to the maximum value, a similar high gain can be obtained.

[Configuration Example of Sample Measurement System 100]

[0061] Subsequently, a sample measurement system 100 incorporating the X-ray generating device 10 will be described with reference to FIG. 8. Here, an "X-ray diffraction apparatus" will be described as an example, but it is not limited to this configuration and measurement method.

[0062] The sample measurement system 100 includes the X-ray generating device 10 for generating the X-ray beams B2, B3, an X-ray detection device 102 for detecting the X-ray beams B2, B3 reflected from a sample S, a goniometer 104 for setting angles in θ_1 and θ_2 directions, and a controller 106 (measuring means) for controlling each portion.

[0063] The goniometer 104 includes a first arm 110 for grasping the X-ray generating device 10, a θ_1 rotation mechanism 112 for rotating the first arm 110 in the θ_1 direction, a second arm 114 for grasping a detector 126 of the X-ray detection device 102, and a rotation mechanism 116 for rotatingly driving the second arm 114 in the θ_2 direction.

[0064] A sample table 118 for placing the sample S to be measured is fixedly arranged at the center of rotation of the first arm 110 and the second arm 114. A divergence slit 120 and the X-ray generating device 10 are fixed to the first arm 110 sequentially outward from the center of rotation. To the second arm 114, a scattering slit 122, a light receiving slit 124, and the detector 126 are fixed in order from the center of rotation toward the outside. In the case of using a focusing method, the positions of the first focal spot 51 and the light receiving slit 124 are adjusted so as to exist on a single circular orbit C, as shown in the drawing.

[0065] The X-ray detection device 102 includes the detector 126 for outputting detection signals corresponding to intensities of the X-ray beams B2, B3, and a detection circuit 128 for obtaining detected amounts of the X-ray beams B2, B3 based on the detection signals from the detector 126. The detector 126 is configured to include a single X-ray detection element or an X-ray detection element array arranged in a linear or planar manner.

[0066] The controller 106 controls the θ_1 rotation mechanism 112 and θ_2 rotation mechanism 116 to place the X-ray generating device 10, the sample S and the

detector 126 under a proper positional relationship. In this measurement example, the first arm 110 and second arm 114 are set to the same angle ($\theta_1 = \theta_2$).

[0067] The controller 106 controls the X-ray generating device 10 to emit the electron beam B1 (FIG. 3) and to generate the X-ray beams B2, B3. The controller 106, based on the setting angle of the goniometer 104 and the detected amounts of the X-ray beams B2, B3 reflected by the sample S, measures a physical quantity related to the sample S. The output device 130, in response to an output instruction from the controller 106, outputs a measurement result of the sample S, including the lattice spacing, diffraction intensity, Miller indices, lamination cycle, stress, and identified material name.

[0068] Depending on a combination of type, property or physical quantity to be measured of the sample S, any one of the linear or dot-like X-ray beams B2, B3 is selected. The user adjusts the X-ray optical system which is suitable for the selected beam shape, in particular, replaces the divergence slit 120, the scattering slit 122 or the light receiving slit 124. Thereafter, the controller 106, in response to an operation of the user, transmits the instruction signal to rotate the electron source 32 to the switching mechanism 34. Accordingly, the extending direction of the electron source 32 is switched automatically and a desired X-ray measurement can be performed. Instead of the above configuration, the extending direction of the electron source 32 may be switched manually by a user.

[0069] As described above, the sample measurement system 100 includes the X-ray generating device 10 described above, the X-ray detection device for detecting the X-ray beams B2, B3 generated from the X-ray generating device 10 and transmitted through or reflected by the sample S, and the controller 106 (measuring means) for measuring a physical quantity relating to the sample S on the basis of the detected amounts of the detected X-ray beams B2, B3. Thus, without performing the adjustment on the X-ray generating device 10, the X-ray measurement of switching the shape of the X-ray beam B2, B3 in a timely manner can be performed.

<Second Embodiment>

[Configuration of X-ray Generating Device 1010]

[0070] FIG. 9 is a perspective view of an X-ray generating device 1010 according to a second embodiment, FIG. 10 is a sectional view taken along line II - II of FIG. 9, FIG. 11 is a side view of the X-ray generating device 1010 shown in FIG. 9, and FIG. 12 is a sectional view taken along line IV-IV of FIG. 9. For convenience of explanation, in these FIGS. 9 to 12, three axis directions (X direction, Y direction, and Z direction) indicating a three dimensional orthogonal coordinate system are defined.

[0071] As shown in FIG. 9, the X-ray generating device 1010 is a device for generating X-rays using a so-called rotating anticathode system. The X-ray generating de-

vice 1010 has a substantially rectangular chamber 1012 made of a metal material having a low X-ray transmittance.

[0072] A circular first opening portion 1016 is provided on the side of a first surface 1014 of the chamber 1012. In one corner portion on the side of a second surface 1018 of the chamber 1012, a recessed portion 1020 recessed in a triangular column shape is formed. A circular second opening portion 1024 is provided on an tilted surface 1022 forming the recessed portion 1020, and a window 1028 in which a beryllium thin film having a high X-ray transmittance is inserted is provided on a third surface 1026 which faces the second surface 1018.

[0073] By inserting an electron generator 1030 through the first opening portion 1016, and mounting a lid portion 1032 in a position to cover the second opening portion 1024, an airtight state is maintained inside a room 1034 (FIGS. 10 and 12) of the chamber 1012. The electron generator 1030 is a thermoelectron type, electric field emission type, or Schottky type electron gun, and will be described by taking as an example the thermoelectron type.

[0074] As shown in FIG. 10, the electron generator 1030 includes an electron source 1036 for emitting a linear electron beam B1, a columnar-shape supporting base 1038 for supporting the electron source 1036, a holding portion 1040 for holding the support base 1038, a rotation introducing mechanism 1042 for introducing a rotating movement from the outside of the chamber 1012, and a housing case 1044 for accommodating components required for various operations of the electron generator 1030. The necessary components include, for example, a power supply of a heater for heating the electron source 1036 and a high-pressure introducing portion for introducing a high voltage into the chamber 1012.

[0075] The electron source 1036 made of, for example, tungsten filament, has a coil shape extending in one direction. The holding portion 1040 which is substantially cylindrical is made of an insulating material comprising ceramic. Thus, the electron source 1036, in a state electrically insulated from the chamber 1012, is disposed within the room 1034.

[0076] The rotation introducing mechanism 1042 is a mechanism for introducing a rotating movement along a T direction, around an axis of the cathode side (hereinafter, cathode axis Ac), and is connected to the base end side of the holding portion 1040. Thus, the rotation introducing mechanism 1042 integrally rotates the holding portion 1040 and the supporting base 1038, and it is capable of changing the extending direction of the electron source 1036 while fixing a center position O (FIG. 4) of the electron source 1036.

[0077] Here, the rotation introducing mechanism 1042 is capable of changing the extending direction of the electron source 1036 by an operation of rotating the support base 1038 to either one of the first and second directions. While the first direction corresponds to the "Z direction," the second direction corresponds to the "X direction." In

this case, the first and second directions are orthogonal to each other and also perpendicular to the cathode axis Ac (Y-direction), respectively.

[0078] Specifically, the rotation introducing mechanism 1042 includes a rotating axis portion 1046 of which one end side is connected to the holding portion 1040, a columnar-shape sealing portion 1047 which seals the first opening portion 1016, a connecting flange 1048 for connecting the chamber 1012, and a handle portion 1050 engaged with the other end of the rotating axis portion 1046.

[0079] At the outer circumferential wall of the sealing portion 1047 is provided an O-ring (not shown), and low pressure air in chamber 1034 is prevented from flowing out by the O-ring. The connecting flange 1048 which has a main surface of a large diameter compared to the first opening portion 1016, is detachable at a position covering the first opening portion 1016 from the outside of the chamber 1012. The handle portion 1050, according to the rotating movement along the T direction, gives a rotating force with respect to the rotating axis portion 1046 by a bellows or magnetic coupling.

[0080] As shown in FIG. 11, as viewed from the side of the first surface 1014, in order from those having a smaller diameter, the housing case 1044, the handle portion 1050 and the connecting flange 1048 are coaxially arranged. On the side surface of the handle portion 1050 which is an annular shape, a linear first protrusion 1052 (indicating means) that extends and protrudes radially is formed. On the side of the connecting flange 1048 which is an annular shape, two marks 1054, 1055 are formed.

[0081] The mark 1054 comprises "L" in the alphabet, and a single short line arranged on the lower side of the "L." The mark 1055 comprises "P" in the alphabet, and a single short line arranged on the left side of the "P." Further, on the outer circumferential surface of the housing case 1044, a second protrusion 1056 (rotation restricting means) in the vicinity of the marks 1054, and a second protrusion 1057 in the vicinity of the mark 1055 (rotation restricting means) are formed, respectively.

[0082] As shown in FIGS. 10 and 12, the X-ray generating device 1010, in addition to the chamber 1012 and the electron generator 1030, further includes a rotating anticathode 1060 which is a disk shape or a columnar shape, and a cooling mechanism (not shown) for cooling the rotating anticathode 1060.

[0083] The rotating anticathode 1060 is configured to be rotatable in a R direction around an axis of the anode side (hereinafter, anode axis Aa) at a speed of, for example, 5000 to 12000 rpm. The rotating anticathode 1060 has a circumferential surface portion 1062 covered with a metal layer of molybdenum (Mo), copper (Cu) or the like, and a side surface portion 1064 to which a rotation mechanism 1066 of the rotating anticathode 1060 is mounted.

[0084] The rotation mechanism 1066 is configured to include a cylindrical rotation axis portion 1068 for axially supporting the rotating anticathode 1060 and a disk-

shaped lid portion 1032 provided on the side of one end of the rotation axis portion 1068 (FIG. 9). The lid portion 1032 has a main surface with a diameter larger than the second opening portion 1024 and is detachable at a position covering the second opening portion 1024 from the outside of the chamber 1012.

[0085] As understood from FIG. 12, the rotating anticathode 1060 is fixedly arranged under a positional relationship in which the anode axis Aa is tilted with respect to the X direction and the Z direction. That is, when an angle formed by the radial direction of the rotating anticathode 1060 and the Z direction is defined as "tilt angle φ " ($0 \leq \varphi \leq 90$, unit: degree), according to the claimed invention the rotation axis is tilted within a range of 30 to 60 degrees with respect to the z direction, which is the first direction. In this embodiment, in particular, $\varphi = 45$ degrees is satisfied.

[0086] As understood from FIG. 10 and FIG. 12, since the electron source 1036 and the circumferential surface portion 1062 are in a positional relationship in which they face each other, a linear focal spot (first focal spot 1071) is formed on the circumferential surface portion 1062 by the electron beam B1 from the electron source 1036. When a specific generation condition is satisfied at the time of collision of the electron beam B1, the circumferential surface portion 1062 emits the X-ray beam B2 from the position of the first focal spot 1071 or a nearby position thereof. As will be described later, the shape of the X-ray beam B2 emitted to the outside of the chamber 1012 varies in accordance with the geometric relationship between the linear focal spot and the window 1028.

[Operation of X-ray Generating Device 1010]

[0087] Subsequently, the operation of the X-ray generating device 1010 according to the second embodiment will be described with reference to the respective views in FIGS. 9 to 12 and the schematic view in FIG. 13.

(1) Fixed-Arrangement Step

[0088] The user, while grasping the connecting flange 1048 of the electron generator 1030, inserts the electron source 1036 through the first opening portion 1016 into the chamber 1012. Then, the user mounts the connecting flange 1048 at a predetermined position on the first surface 1014 (that is, a position for covering the first opening portion 1016). Thereby, the electron source 1036 is fixedly arranged in the chamber 1012.

[0089] In addition, the user, while grasping the lid portion 1032, inserts the rotating anticathode 1060 through the second opening portion 1024 into the chamber 1012. Then, the user mounts the lid portion 1032 at a predetermined position on the tilted surface 1022 (that is, a position for covering the second opening portion 1024). Thereby, the rotating anticathode 1060 is fixedly arranged in the chamber 1012.

[0090] Thus, the airtight state is maintained in the room

1034 of the chamber 1012. Further, it is noted that the electron source 1036 and the circumferential surface portion 1062 face each other, and that the anode axis Aa is in a positional relationship in which it is tilted with respect to the first direction (Z direction) and second direction (X direction).

(2) Setting Step

[0091] The user sets the shape of the X-ray beam B2, B3 by rotating the handle portion 1050 along the T direction. More specifically, by aligning the first protrusion 1052 on the position of the mark 1054 ("L" means "Line"), with the support base 1038 interlocked with the handle portion 1050, the extending direction of the electron source 1036 is set to "the first direction." In contrast, by aligning the first protrusion 1052 on the position of the mark 1055 ("P" means "Point"), with the support base 1038 interlocked with the handle portion 1050, the extending direction of the electron source 1036 is set to "the second direction."

[0092] Thus, the rotation introducing mechanism 1042 may adopt a structure in which it has the handle portion 1050 that is disposed rotatably in the outside of the chamber 1012, and in which the support base 1038 is rotated in accordance with an operation of rotating the handle portion 1050. By rotating the handle portion 1050, it is possible for an operator to easily change the extending direction of the electron source 1036.

[0093] Further, an indicating means (specifically, the first protrusion 1052) for indicating the rotating state of the handle portion 1050 to be visible from the outside of the chamber 1012 may be provided on the rotation introducing mechanism 1042. By viewing a position indicated by the first protrusion 1052 from the outside of the chamber 1012, the rotating state of the handle portion 1050 and the extending direction of the electron source 1036 can be grasped at a glance by the operator.

[0094] Further, the marks 1054, 1055 indicating the relationship between the rotating position of the handle portion 1050 and the shape of the X-ray beam B2, B3 may be provided to a member (the connecting flange 1048 or the housing case 1044) different from the handle portion 1050. Accordingly, a target position of the rotating operation becomes clear, and it is convenient for the operator.

(3) Generating Step

[0095] A purging operation by a vacuum pump (not shown) is performed to evacuate the interior of the chamber 1034 and the rotating anticathode 1060 is rotated in the R direction at a predetermined speed. After various preparations for satisfying the X-ray generation conditions are completed, the electron generator 1030 generates a linear electron beam B1 according to the operation indicated by the user.

[0096] FIG. 13 is a schematic view showing the shapes

of the X-ray beams B2, B3 according to the switching operation between the first direction and the second direction. According to the extending direction of the electron source 1036 (FIGS. 10 and 12), the first focal spot 1071 curved along the first direction or a second focal spot 1072 curved along the second direction is selectively formed.

[0097] In the former case, the circumferential surface portion 1062 emits the X-ray beam B2 from the position of the first focal spot 1071 of linear shape on which the electron beam B1 is incident. At this time, since the first focal spot 1071 is in a relationship substantially parallel with the plane formed by the window 1028, the linear X-ray beam B2 is emitted.

[0098] In the latter case, the circumferential surface portion 1062 emits the X-ray beam B3 from the position of the second focal spot 1072 of linear shape on which the electron beam B1 is incident. At this time, since the second focal spot 1072 is in a relationship substantially perpendicular to the plane formed by the window 1028, the dot-like X-ray beam B3 is emitted.

(4) Changing Step

[0099] According to the same operating procedure as the above "setting step," the user changes the shape of the X-ray beam B2, B3 to "the linear shape from the dot-like shape" or "the dot-like shape from the linear shape." By adopting the configuration in which the support base 1038 can be rotated in accordance with the operation (specifically, the operation of the handle portion 1050) from the outside of the chamber 1012, the extending direction of the electron source 1036 can be changed without replacing the electron generator 1030 or the rotating anticathode 1060.

[0100] Since the second protrusions 1056, 1057 are arranged on an orbit of the first protrusion 1052, an operation of rotating the first protrusion 1052 is permitted only within the interval of the second protrusions 1056, 1057 (here, within the rotation range of 90 degrees). Thus, the rotation restricting means (specifically, the second protrusions 1056, 1057) for restricting the rotation range of the handle portion 1050 may be provided on the rotation introducing mechanism 1042. Thus, the driven parts of the electron source 1036 can be prevented from being damaged excessively twisted.

[Effects of X-ray Generating Device 1010]

[0101] As described above, the X-ray generating device 1010 includes [1] the electron generator 1030 configured to include the electron source 1036 which emits the linear electron beam B1, [2] the rotating anticathode 1060 configured to include the circumferential surface portion 1062 which emits the X-ray beams B2, B3 with the electron beam B1 from the electron source 1036 impinged, and [3] the chamber 1012 housing the electron source 1036 and the rotating anticathode 1060.

[0102] Further, the electron generator 1030 and the rotating anticathode 1060 are fixedly arranged in the chamber 1012 in a position relationship in which the electron source 1036 and the circumferential surface portion 1062 face each other, and the electron generator 1030 includes the support base 1038 which supports the electron source 1036 and the rotation introducing mechanism 1042 which is airtightly inserted and passed within the chamber 1012, and which rotates the support base 1038 in response to an operation from outside the chamber 1012.

[0103] Thus, since the rotation introducing mechanism 1042 to rotate the support base 1038 supporting the electron source 1036 in accordance with an operation from the outside of the chamber 1012 is provided, it is not necessary to replace the electron generator 1030 or the rotating anticathode 1060, so that the extending direction (first direction/second direction) of the electron source 1036 can be switched while maintaining the vacuum state within the chamber 1012. Thus, it is possible to selectively generate a linear or dot-like X-ray beam B2, B3 with an extremely simple device configuration, and to suppress deterioration of working efficiency due to this selection.

[0104] Further, the rotation introducing mechanism 1042 is capable of changing the extending direction of the electron source 1036 by the operation of rotating the support base 1038 in first and second directions, and the anode axis Aa of the rotating anticathode 1060 may be tilted with respect to the first direction and the second direction. The effects obtained by this configuration will be described. Hereinafter, it is assumed that each of the first focal spot 1071 and the second focal spot 1072 (FIG. 13) has, in a plan view, a rectangular shape having a width of W [mm] and a height of H [mm] ($H > W$). Also, if a focal length across the circumferential direction of the circumferential surface portion 1062 is defined as a "circumferential focal length," circumferential focal lengths of the first focal spot 1071 and the second focal spot 1072 are L1 and L2, respectively.

[0105] Figure 14 is a graph showing a relationship between the tilt angle φ and the circumferential focal lengths L1, L2. The horizontal axis of the graph is the tilt angle φ : (unit: degree), and the vertical axis of the graph is the circumferential focal length L1, L2 (unit: mm). In addition, the solid line shows a function of L1 and the alternate long and short dash line shows a function of L2.

[0106] As understood from this figure, the circumferential focal length L1 satisfies $L1 = H$ [mm] when $\varphi = 0$ degree and $L1 = W$ [mm] when $\varphi = 90$ degrees and monotonously decreases as the tilt angle φ increases. On the other hand, the circumferential focal length L2 satisfies $L2 = W$ [mm] when $\varphi = 0$ degree and $L2 = H$ [mm] when $\varphi = 90$ degrees, and monotonically increases as the tilt angle φ increases.

[0107] That is, when the tilt angle φ satisfies $\varphi = 0$ degree or $\varphi = 90$ degrees, the value of $|L1 - L2|$ is maximized and when the tilt angle φ is set within the range of $0 < \varphi < 90$, the value of $|L1 - L2|$ becomes relatively small. It

should be noted that the relationship of $L1 = W/\sin \varphi$ and $L2 = W/\cos \varphi$ holds in the vicinity of $\varphi = 45$ degrees. According to the claimed invention, the tilt angle is within a range of 30 to 60 degrees.

[0108] In the second embodiment, since the rotating anticathode 1060 is in the positional relationship ($0 < \varphi < 90$) in which the anode axis Aa is tilted with respect to the first direction and the second direction, a divergence amount $|L1-L2|$ of the circumferential focal lengths L1, L2 with respect to the first focal spot 1071 and the second focal spot 1072 formed by emissions of the electron beams B1 from the first direction and the second direction is smaller than when the anode axis Aa is not tilted ($\varphi = 0, 90$).

[0109] That is, by increasing the output efficiency on the lowest side instead of lowering the output efficiency on the highest side, the maximum amount (that is, the limit output amount of X-rays) that can be outputted in common to both of the X-ray beams B2, B3 is raised. In particular, if the anode axis Aa is tilted by 45 degrees with respect to the first direction ($\varphi = 45$), since the circumferential focal lengths are equal as $L1 = L2 = \sqrt{2} \cdot W$ [mm], the limit output amount common to both of the X-ray beams B2, B3 is maximized.

[0110] [Configuration Example of Sample Measurement System 1100] Subsequently, a sample measurement system 1100 incorporating the above X-ray generating device 1010 will be described with reference to FIG. 15. Here, an "X-ray diffraction apparatus" will be described as an example, but is not limited to this configuration and measurement method.

[0111] The sample measurement system 1100 includes the X-ray generating device 1010 generating the X-ray beams B2, B3, an X-ray detection device 1102 detecting the X-ray beams B2, B3 reflected from a sample S, a goniometer 1104 setting angles in $\theta 1$ and $\theta 2$ directions, and a controller 1106 (measuring means) controlling each portion.

[0112] The goniometer 1104 includes a first arm 1110 grasping the X-ray generating device 1010, a $\theta 1$ rotation mechanism 1112 rotatably driving the first arm 1110 in the $\theta 1$ direction, a second arm 1114 grasping a detector 1126 of the X-ray detection device 1102, and a rotation mechanism 1116 rotatably driving the second arm 1114 in the $\theta 2$ direction.

[0113] A sample table 1118 placing the sample S to be measured is fixedly arranged at the center of rotation of the first arm 1110 and the second arm 1114. A divergence slit 1120 and the X-ray generating device 1010 are fixed to the first arm 1110 sequentially outward from the center of rotation. In the second arm 1114, a scattering slit 1122, a light receiving slit 1124, and the detector 1126 are fixed in order from the center of rotation toward the outside. When using a Bragg-Brentano parafocusing method, the positions of the first focal spot 1051 and the light receiving slit 1124 are adjusted so as to exist on a single circular orbit C, as shown in the drawing.

[0114] The X-ray detection device 1102 includes the

detector 1126 outputting detection signals corresponding to intensities of the X-ray beams B2, B3, and a detection circuit 1128 obtaining detected amounts of the X-ray beams B2, B3 based on the detection signals from the detector 1126. The detector 1126 is configured to include a single X-ray detection element or an X-ray detection element array arranged in a linear or planar manner.

[0115] The controller 1106 controls the $\theta 1$ rotation mechanism 1112 and $\theta 2$ rotation mechanism 1116 to place the X-ray generating device 1010, the sample S and the detector 1126 under a proper positional relationship. In this measurement example, the first arm 1110 and second arm 1114 are set to the same angle ($\theta 1 = \theta 2$).

[0116] The controller 1106 controls the X-ray generating device 1010 to emit the electron beam B1 (FIG. 3) and to generate the X-ray beams B2, B3. The controller 1106, based on the setting angle of the goniometer 1104 and the detected amounts of the X-ray beams B2, B3 reflected by the sample S, measures a physical quantity related to the sample S. The output device 1130, in response to an output instruction from the controller 1106, outputs a measurement result of the sample S, including the lattice spacing, diffraction intensity, Miller indices, lamination cycle, stress, and identified material name.

[0117] Depending on a combination of type, property or physical quantity to be measured of the sample S, any one of the linear or dot-like X-ray beams B2, B3 is selected. The user adjusts the X-ray optical system which is suitable for the selected beam shape, in particular, replaces the divergence slit 1120, the scattering slit 1122 or the light receiving slit 1124. The user further rotates the handle portion 1050 in the T direction. Accordingly, the extending direction of the electron source 1036 is switched manually, and the desired X-ray measurement can be performed. Instead of the above configuration, it may be configured that the controller 1106 transmits an instruction signal toward the X-ray generating device 1010, and the handle portion 1050 is driven by using an actuator not shown to switch the extending direction of the electron source 1036 automatically.

[0118] As described above, the sample measurement system 1100 includes the X-ray generating device 1010 described above, the X-ray detection device 1102 detecting the X-ray beams B2, B3 generated from the X-ray generating device 1010 and transmitted through or reflected by the sample S, and the controller 1106 (measuring means) measuring a physical quantity relating to the sample S on the basis of the detected amounts of the detected X-ray beams B2, B3. Thus, while maintaining the vacuum state in the chamber 1012, the X-ray measurement of switching the shape of the X-ray beam B2, B3 in a timely manner can be performed.

[0119] Further, in the second embodiment, the handle portion 1050 (FIG. 11) is constituted by a rotating handle, but, instead of this, it may be a crank handle which is arranged rotatably at the outside of the chamber 1012.

[0120] In the second embodiment, the indicating means is constituted by one first protrusion 1052 (Fig.

11), but if it has a configuration in which the extending direction of the electron source 1036 which is not visible can be grasped from the outside of the chamber 1012, it does not matter what the form of the indicating means is. For example, an indication line may be printed on the side of the handle portion 1050 or the indicating means may be provided in a separate component from the handle portion 1050.

[0121] In the second embodiment, the rotation restricting means is constituted by two second protrusions 1056, 1057 (FIG. 11), but if it has a configuration in which a rotating range of less than 360 degrees can be arbitrarily set, it does not matter what the form of the rotation restricting means is. For example, the number of members constituting the rotation restricting means may be one, or the rotation restricting means may be provided in a separate component from the housing case 1044.

[Note]

[0122] The present invention is not intended to be limited to the embodiments described above, and it is obvious that various changes and modifications may be made without departing from the scope of the invention.

DESCRIPTION OF REFERENCE NUMERALS

[0123]

10, 1010 X-ray generating device
 12, 1012 chamber
 22, 1028 window
 24, 1030 electron generator
 26, 1060 rotating anticathode
 28, 1034 room
 32, 1036 electron source
 34 switching mechanism
 36 rotation axis
 38, 1062 circumferential surface portion
 42 rotation mechanism
 51, 1071 first focal spot
 52, 1072 second focal spot
 53 line segment
 100, 1100 sample measurement system
 102, 1102 X-ray detection device
 104, 1104 goniometer
 106, 1106 controller (measuring means)
 1016 first opening portion
 1024 second opening portion
 1038 support base
 1040 holding portion
 1042 rotation introducing mechanism
 1044 housing case
 1046 rotating axis portion
 1047 sealing portion
 1048 connecting flange
 1050 handle portion
 1052 first protrusion (instruction unit)

1054, 1055 mark
 1056, 1057 second protrusion (rotation restricting means)
 1064 side surface portion
 Aa anode axis (rotation axis)
 Ac cathode axis (rotation axis)
 B1 electron beam
 B2, B3 X-ray beam
 L1, L2 circumferential focal length
 S sample

Claims

1. An X-ray generating device (10) comprising:
 - an electron generator (24) having an electron source (32) emitting a linear electron beam (B) suitable for generating a focal spot of linear shape,
 - and a switching mechanism (34) switching an extending direction of the electron source (32) to either one of a first direction and a second direction perpendicular to the first direction while fixing a center position of the electron source (32); and
 - a rotating anticathode (26) with a disk shape or a columnar shape, having a circumferential surface portion (38) suitable for being impinged by the electron beam (B1) from the electron source (32) and emitting linear or dot-like X-ray beams (B2; B3), and configured to be rotatable about a rotation axis (36);
 - wherein the electron generator (24) and the rotating anticathode (26) are fixedly arranged in a positional relationship in which the electron source (32) and the surface portion (38) face each other and the rotation axis (36) is tilted with respect to the first direction and the second direction,
 - characterized in that** the rotation axis (36) is tilted within a range of 30 to 60 degrees with respect to the first direction in a plane comprising the first direction and the second direction.
2. The X-ray generating device (10) according to claim 1, wherein the rotation axis (36) is tilted by 45 degrees with respect to the first direction.
3. A sample measurement system (100) comprising:
 - an X-ray generating device (10) according to claim 1 or 2;
 - an X-ray detecting device (102) detecting X-ray beams (B2, B3) generated from the X-ray generating device (10) and transmitted through or reflected by a sample; and
 - a measuring means measuring a physical quan-

- tity relating to the sample, based on detected amounts of the X-ray beams (B2, B3) detected by the X-ray detecting device (102).
4. An X-ray generating device (1010) as described in claim 1 comprising:
- a chamber (1012) housing the electron source (1036) and the rotating anticathode (1060); wherein the electron generator (1030) and the rotating anticathode (1060) are fixedly arranged in the chamber (1012) in the positional relationship in which the electron source and the surface portion (1062) face each other, the electron generator (1030) comprising:
- a support base (1038) supporting the electron source (1036); and
- a rotation introducing mechanism (1042) being airtightly inserted and passed within the chamber (1012) and rotates the support base (1038) in accordance with an operation from the outside of the chamber (1012), wherein the rotation introducing mechanism (1042) is capable of changing the extension direction of the electron source to the first direction and the second direction perpendicular to the first direction by an operation of rotating the support base (1038).
5. The X-ray generating device (1010) according to claim 4, wherein the rotation introducing mechanism (1042) includes a handle portion (1050) rotatably arranged outside the chamber (1012), and rotates the support base (1038) in accordance with an operation of rotating the handle portion (1050).
6. The X-ray generating device (1010) according to claim 5, wherein the rotation introducing mechanism (1042) further includes an indication means (1052) indicating rotating states of the handle portion (1050) in a visible way from the outside of the chamber (1012).
7. The X-ray generating device (1010) according to claim 5 or 6 2. wherein the rotation introducing mechanism (1042) further includes a rotation restricting means (1056, 1057) restricting a rotation range of the handle portion (1050).
8. A sample measurement system (1100) comprising:
- an X-ray generating device (1010) according to any one of claims 4 to 7;
- an X-ray detecting device (1102) detecting X-ray beams (B2, B3) generated from the X-ray generating device (1010) and transmitted

through or reflected by a sample (S); and

a measuring means (1106) measuring a physical quantity relating to the sample (S), based on detected amounts of the X-ray beams (B2, B3) detected by the X-ray detecting device (1102).

9. An X-ray generating method using a device (10), the device (10) comprising:

an electron generator (24) having an electron source (32) emitting a linear electron beam (B) suitable for generating a focal spot of linear shape; and

a rotating anticathode with a disk shape or a columnar shape, having a circumferential surface portion (38) being impinged by the electron beam (B1) from the electron source (32) and emitting linear or dot-like X-ray beams (B2, B3) and configured to be rotatable about a rotation axis (36);

the method comprising the steps of:

fixedly arranging the electron generator (24) and the rotating anticathode (26) in a positional relationship in which the electron source (32) and the surface portion (38) face each other and the rotation axis (36) is tilted with respect to a first direction and a second direction perpendicular to the first direction; and

switching an extending direction of the electron source (32) to either one of the first direction and the second direction while fixing a center position of the electron source (32), **characterized in that** the rotation axis (36) is tilted within a range of 30 to 60 degrees with respect to the first direction and the second direction in a plane comprising the first direction and the second direction.

Patentansprüche

1. Röntgenstrahl-Erzeugungsvorrichtung (10), umfassend:

einen Elektronengenerator (24) mit einer Elektronenquelle (32), die einen linearen Elektronenstrahl (B) aussendet, der geeignet ist, einen Brennfleck von linearer Form zu erzeugen, und einen Schaltmechanismus (34) zum Schalten einer Ausdehnungsrichtung der Elektronenquelle (32) in eine erste Richtung oder eine zweite Richtung senkrecht zur ersten Richtung während eine Mittelposition der Elektronenquelle (32) festgelegt wird; und

eine rotierende scheiben- oder säulenförmige Antikathode (26) mit einem Umfangsflächenab-

schnitt (38), der geeignet ist, von dem Elektronenstrahl (B1) von der Elektronenquelle (32) getroffen zu werden und lineare oder punktförmige Röntgenstrahlen (B2; B3) aussendet und so konfiguriert ist, dass er um eine Rotationsachse (36) rotieren kann;
wobei der Elektronengenerator (24) und die rotierende Antikathode (26) fest in einem Positionsverhältnis angeordnet sind, in welchem die Elektronenquelle (32) und der Oberflächenabschnitt (38) einander zugewandt sind und die Rotationsachse (36) in Bezug auf die erste Richtung und die zweite Richtung gekippt ist,

dadurch gekennzeichnet,

dass die Rotationsachse (36) innerhalb eines Bereichs von 30 bis 60 Grad in Bezug auf die erste Richtung in einer Ebene gekippt ist, welche die erste Richtung und die zweite Richtung umfasst.

2. Röntgen-Erzeugungsvorrichtung (10) nach Anspruch 1, wobei die Rotationsachse (36) um 45 Grad in Bezug auf die erste Richtung gekippt ist.

3. Probenmesssystem (100) umfassend:

eine Röntgenstrahl-Erzeugungsvorrichtung (10) nach Anspruch 1 oder 2,
eine Röntgenstrahl-Detektionsvorrichtung (102), die Röntgenstrahlen (B2, B3) detektiert, die von der Röntgenstrahl-Erzeugungsvorrichtung (10) erzeugt werden und durch eine Probe übertragen oder von einer Probe reflektiert werden; und
eine Messeinrichtung, die eine physikalische Größe in Bezug auf die Probe auf der Basis von detektierten Mengen der von der Röntgenstrahl-Detektionsvorrichtung (102) detektierten Röntgenstrahlen (B2, B3) misst.

4. Röntgenstrahl-Erzeugungsvorrichtung (1010) nach Anspruch 1, umfassend:

eine Kammer (1012), in der die Elektronenquelle (1036) und die rotierende Antikathode (1060) untergebracht sind;
wobei der Elektronengenerator (1030) und die rotierende Antikathode (1060) fest in der Kammer (1012) in dem Positionsverhältnis angeordnet sind, in dem die Elektronenquelle und der Oberflächenabschnitt (1062) einander zugewandt sind,
wobei der Elektronengenerator (1030) umfasst:

eine Trägerbasis (1038), welche die Elektronenquelle (1036) trägt; und
einen Rotationseinführungsmechanismus

(1042), der luftdicht in die Kammer (1012) eingeführt ist und innerhalb der Kammer verläuft, und die Trägerbasis (1038) entsprechend eines Betriebs von außerhalb der Kammer (1012) rotiert, wobei der Rotationseinführungsmechanismus (1042) die Erstreckungsrichtung der Elektronenquelle in die erste Richtung und die zweite Richtung senkrecht zur ersten Richtung durch einen Rotationsbetrieb der Trägerbasis (1038) ändern kann.

5. Röntgenstrahl-Erzeugungsvorrichtung (1010) nach Anspruch 4, wobei der Rotationseinführungsmechanismus (1042) einen Griffabschnitt (1050) beinhaltet, der rotierbar außerhalb der Kammer (1012) angeordnet ist und die Trägerbasis (1038) entsprechend eines Rotationsbetriebs des Griffabschnitts (1050) rotiert.

6. Röntgenstrahl-Erzeugungsvorrichtung (1010) nach Anspruch 5, wobei der Rotationseinführungsmechanismus (1042) weiterhin eine Anzeigeeinrichtung (1052) beinhaltet, welche die Rotationszustände des Griffabschnitts (1050) von der Außenseite der Kammer (1012) sichtbar anzeigt.

7. Röntgenstrahl-Erzeugungsvorrichtung (1010) nach Anspruch 5 oder 6, wobei der Rotationseinführungsmechanismus (1042) weiterhin eine Rotationsbegrenzungseinrichtung (1056, 1057) beinhaltet, die einen Rotationsbereich des Griffabschnitts (1050) begrenzt.

8. Probenmesssystem (1100) umfassend:

eine Röntgenstrahl-Erzeugungsvorrichtung (1010) nach einem der Ansprüche 4 bis 7,
eine Röntgenstrahl-Detektionsvorrichtung (1102), die Röntgenstrahlen (B2, B3) detektiert, die von der Röntgenstrahl-Erzeugungsvorrichtung (1010) erzeugt werden und von einer Probe (S) übertragen oder reflektiert werden; und
eine Messeinrichtung (1106), die eine physikalische Größe, die sich auf die Probe (S) bezieht, auf der Basis von den von der Röntgenstrahl-Detektionsvorrichtung (1102) detektierten Mengen von Röntgenstrahlen (B2, B3) misst.

9. Verfahren zum Erzeugen von Röntgenstrahlen unter Verwendung einer Vorrichtung (10), wobei die Vorrichtung (10) umfasst:

einen Elektronengenerator (24) mit einer Elektronenquelle (32), die einen linearen Elektronenstrahl (B) aussendet, der geeignet ist, einen Brennfleck von linearer Form zu erzeugen, und eine rotierende scheiben- oder säulenförmige

Antikathode mit einem Umfangsflächenabschnitt (38), der von dem Elektronenstrahl (B1) von der Elektronenquelle (32) getroffen wird und lineare oder punktförmige Röntgenstrahlen (B2; B3) aussendet und so konfiguriert ist, dass er um eine Rotationsachse (36) rotieren kann; wobei das Verfahren die folgenden Schritte umfasst:

festes Anordnen des Elektronengenerators (24) und der rotierenden Antikathode (26) in einem Positionsverhältnis, in welchem die Elektronenquelle (32) und der Oberflächenabschnitt (38) einander zugewandt sind und die Rotationsachse (36) in Bezug auf eine erste Richtung und eine zweite Richtung senkrecht zur ersten Richtung gekippt ist, und

Schalten einer Ausdehnungsrichtung der Elektronenquelle (32) in eine erste Richtung oder eine zweite Richtung während eine Mittelposition der Elektronenquelle (32) festgelegt wird,

dadurch gekennzeichnet,

dass die Rotationsachse (36) innerhalb eines Bereichs von 30 bis 60 Grad in Bezug auf die erste Richtung und die zweite Richtung in einer Ebene gekippt ist, welche die erste Richtung und die zweite Richtung umfasst.

Revendications

1. Dispositif de génération de rayons X (10) comprenant :

un générateur d'électrons (24) qui comporte une source d'électrons (32) qui émet un faisceau d'électrons linéaire (B1) qui convient pour générer un point focal de forme linéaire, et un mécanisme de commutation (34) qui commute une direction d'extension de la source d'électrons (32) selon l'une ou l'autre direction prise parmi une première direction et une seconde direction qui est perpendiculaire à la première direction tandis qu'une position centrale de la source d'électrons (32) est fixée ; et

une anticathode rotative (26) qui présente une forme de disque ou une forme de colonne, laquelle comporte une partie de surface circonferentielle (38) qui convient pour l'arrivée en incidence dessus du faisceau d'électrons (B1) en provenance de la source d'électrons (32) et laquelle émet des faisceaux de rayons X linéaires ou en forme de point (B2, B3) et est configurée pour être entraînée en rotation autour d'un axe de rotation (36) ;

dans lequel le générateur d'électrons (24) et l'anticathode rotative (26) sont agencés de fa-

çon fixe selon une relation positionnelle selon laquelle la source d'électrons (32) et la partie de surface circonferentielle (38) se font face l'une l'autre et l'axe de rotation (36) est incliné par rapport à la première direction et à la seconde direction ;

caractérisé en ce que l'axe de rotation (36) est incliné à l'intérieur d'une plage de 30 à 60 degrés par rapport à la première direction dans un plan qui comprend la première direction et la seconde direction.

2. Dispositif de génération de rayons X (10) selon la revendication 1, dans lequel l'axe de rotation (36) est incliné de 45 degrés par rapport à la première direction.
3. Système de mesure d'échantillon (100) comprenant :

un dispositif de génération de rayons X (10) selon la revendication 1 ou 2;

un dispositif de détection de rayons X (102) qui détecte des faisceaux de rayons X (B2, B3) qui sont générés depuis le dispositif de génération de rayons X (10) et qui sont transmis au travers d'un échantillon ou qui sont réfléchis par l'échantillon ; et

un moyen de mesure qui mesure une quantité physique qui est en relation avec l'échantillon, sur la base de quantités détectées des faisceaux de rayons X (B2, B3) qui sont détectés par le dispositif de détection de rayons X (102).

4. Dispositif de génération de rayons X (1010) tel que décrit selon la revendication 1, comprenant :

une chambre (1012) qui loge la source d'électrons (1036) et l'anticathode rotative (1060) ; dans lequel le générateur d'électrons (1030) et l'anticathode rotative (1060) sont agencés de façon fixe à l'intérieur de la chambre (1012) selon la relation positionnelle selon laquelle la source d'électrons et la partie de surface circonferentielle (1062) se font face l'une l'autre ; le générateur d'électrons (1030) comprenant :

une base de support (1038) qui supporte la source d'électrons (1036) ; et

un mécanisme d'introduction de rotation (1042) qui est inséré de façon étanche à l'air et qui est passé à l'intérieur de la chambre (1012) et qui entraîne en rotation la base de support (1038) conformément à une opération en provenance de l'extérieur de la chambre (1012) ;

dans lequel le mécanisme d'introduction de rotation (1042) dispose de la capacité de

- modifier la direction d'extension de la source d'électrons selon la première direction et selon la seconde direction qui est perpendiculaire à la première direction au moyen d'une opération d'entraînement en rotation de la base de support (1038). 5
5. Dispositif de génération de rayons X (1010) selon la revendication 4, dans lequel le mécanisme d'introduction de rotation (1042) inclut une partie de manche ou de poignée (1050) qui est agencée à rotation à l'extérieur de la chambre (1012) et il entraîne en rotation la base de support (1038) conformément à une opération d'entraînement en rotation de la partie de manche ou de poignée (1050). 10 15
6. Dispositif de génération de rayons X (1010) selon la revendication 5, dans lequel le mécanisme d'introduction de rotation (1042) inclut en outre un moyen d'indication (1052) qui indique des états de rotation de la partie de manche ou de poignée (1050) d'une façon visible depuis l'extérieur de la chambre (1012). 20
7. Dispositif de génération de rayons X (1010) selon la revendication 5 ou 6, dans lequel le mécanisme d'introduction de rotation (1042) inclut en outre un moyen de restriction de rotation (1056, 1057) qui restreint une plage de rotation de la partie de manche ou de poignée (1050). 25 30
8. Système de mesure d'échantillon (1100) comprenant :
- un dispositif de génération de rayons X (1010) selon l'une quelconque des revendications 4 à 7 ; 35
- un dispositif de détection de rayons X (1102) qui détecte des faisceaux de rayons X (B2, B3) qui sont générés depuis le dispositif de génération de rayons X (1010) et qui sont transmis au travers d'un échantillon (S) ou qui sont réfléchis par l'échantillon ; et 40
- un moyen de mesure (1106) qui mesure une quantité physique qui est en relation avec l'échantillon (S), sur la base de quantités détectées des faisceaux de rayons X (B2, B3) qui sont détectés par le dispositif de détection de rayons X (1102). 45
9. Procédé de génération de rayons X en utilisant un dispositif (10), le dispositif (10) comprenant :
- un générateur d'électrons (24) qui comporte une source d'électrons (32) qui émet un faisceau d'électrons linéaire (B1) qui convient pour générer un point focal de forme linéaire ; et 50 55
- une anticathode rotative qui présente une forme de disque ou une forme de colonne, laquelle

comporte une partie de surface circonférentielle (38) pour l'arrivée en incidence dessus du faisceau d'électrons (B1) en provenance de la source d'électrons (32) et laquelle émet des faisceaux de rayons X linéaires ou en forme de point (B2, B3) et est configurée pour être entraînée en rotation autour d'un axe de rotation (36) ; le procédé comprenant les étapes constituées par :

l'agencement de façon fixe du générateur d'électrons (24) et de l'anticathode rotative (26) selon une relation positionnelle selon laquelle la source d'électrons (32) et la partie de surface circonférentielle (38) se font face l'une l'autre et l'axe de rotation (36) est incliné par rapport à une première direction et à seconde direction qui est perpendiculaire à la première direction ; et la commutation d'une direction d'extension de la source d'électrons (32) selon l'une ou l'autre direction prise parmi la première direction et la seconde direction tandis qu'une position centrale de la source d'électrons (32) est fixée ; **caractérisé en ce que** l'axe de rotation (36) est incliné à l'intérieur d'une plage de 30 à 60 degrés par rapport à la première direction et à la seconde direction dans un plan qui comprend la première direction et la seconde direction.

FIG. 1

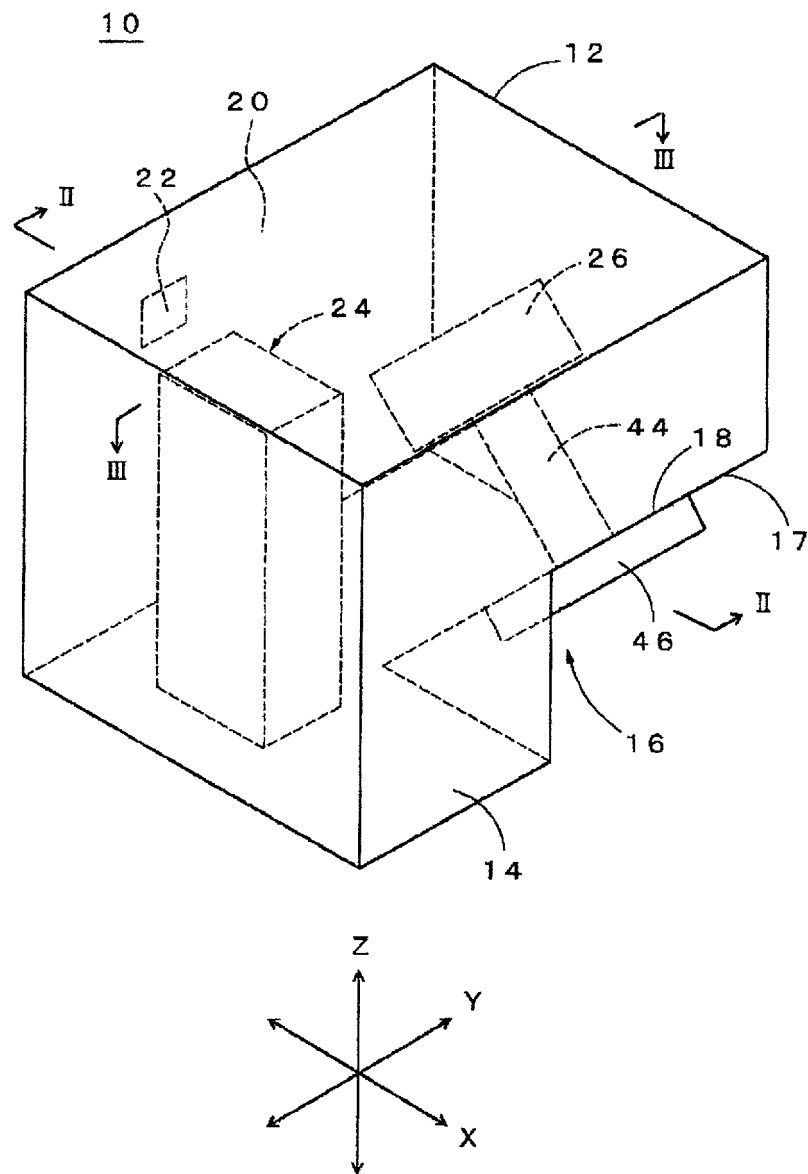


FIG. 2

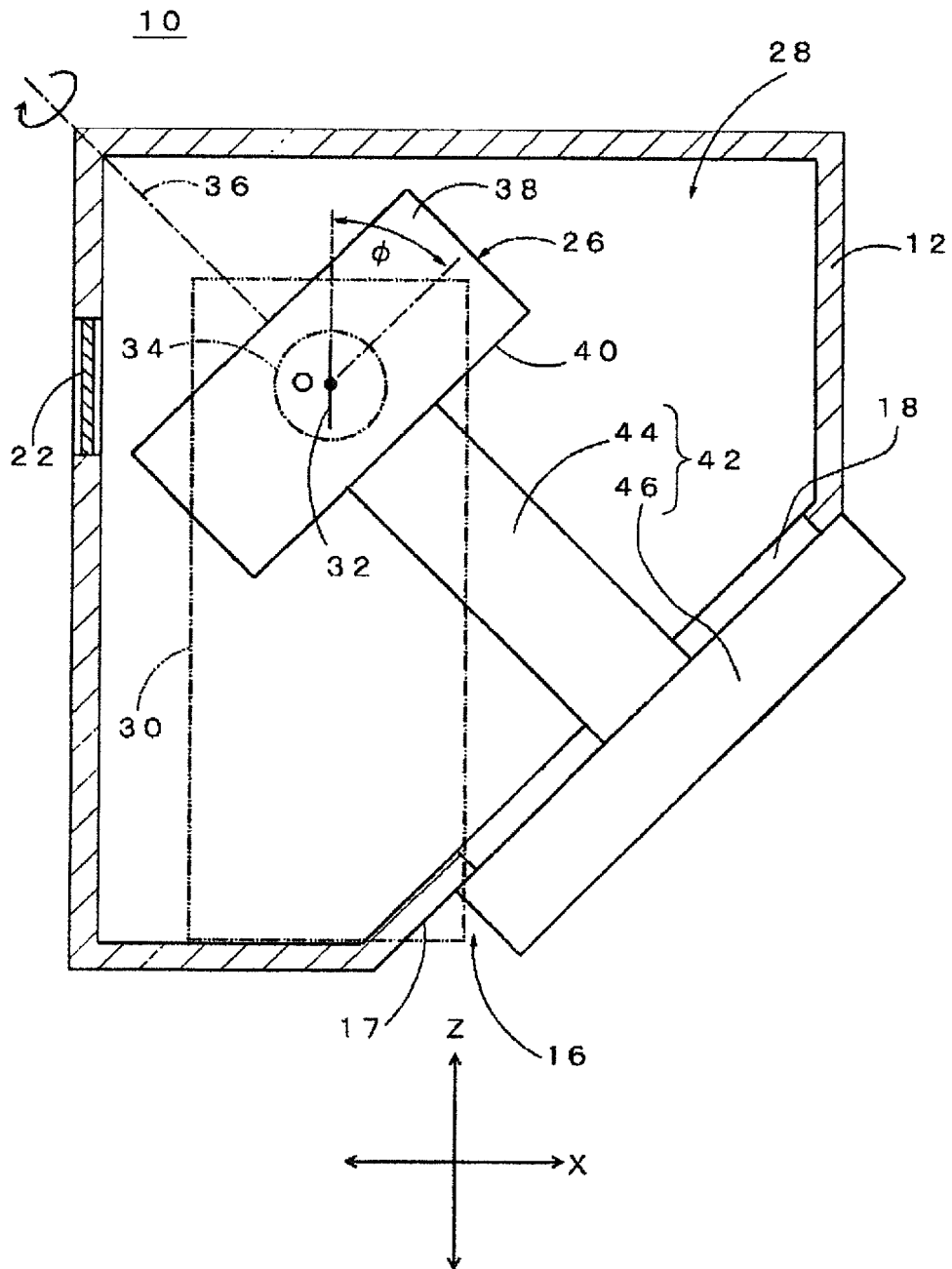


FIG. 3

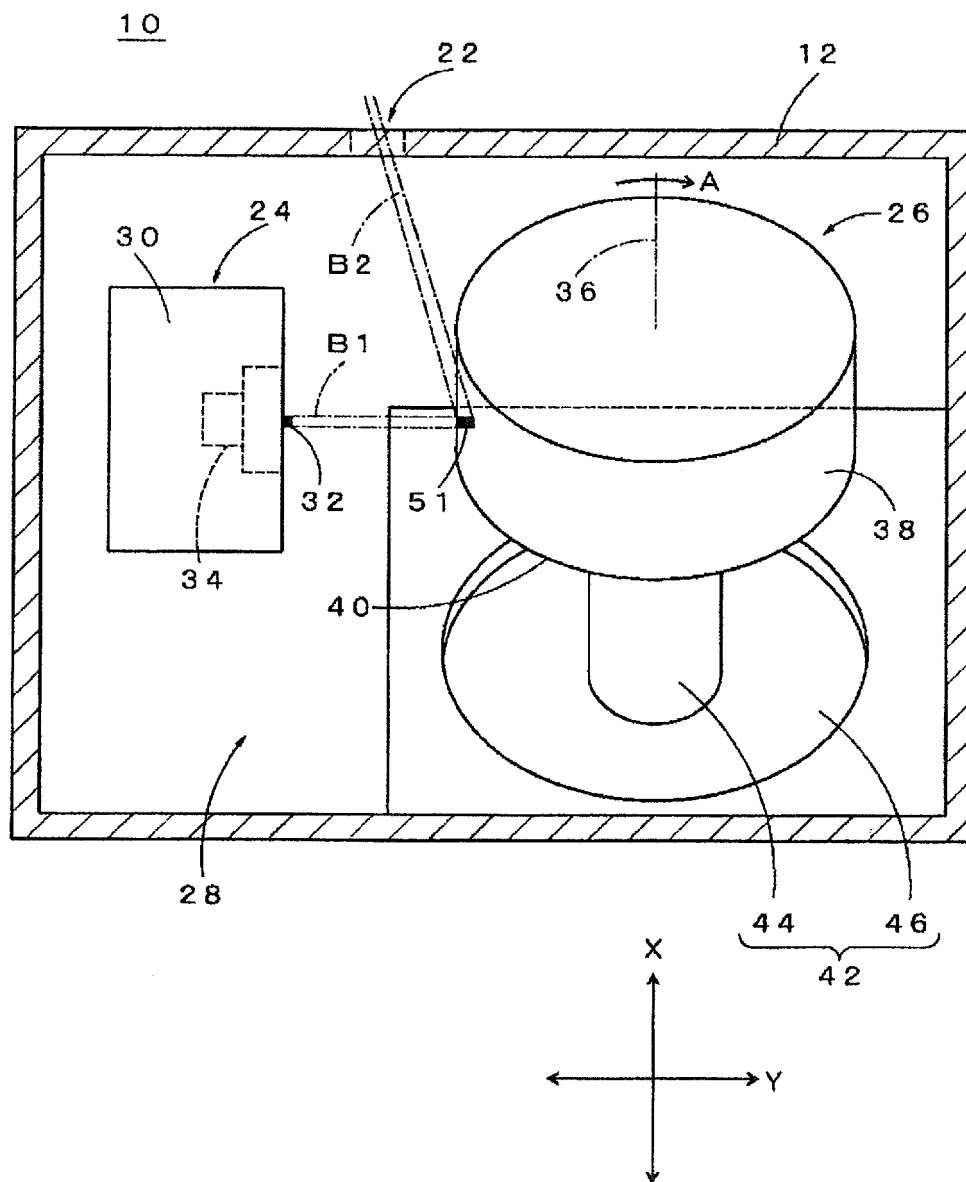


FIG. 4

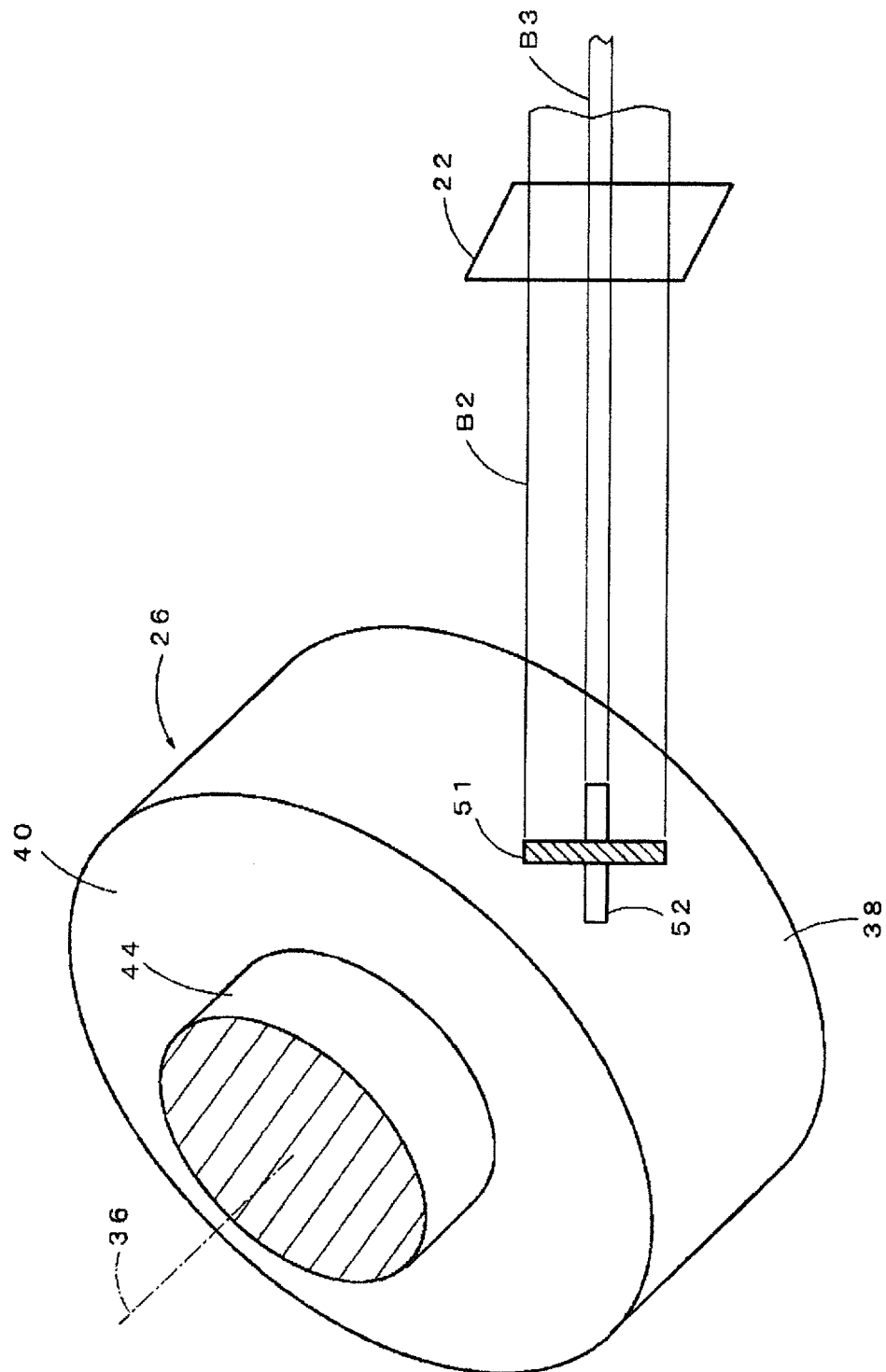
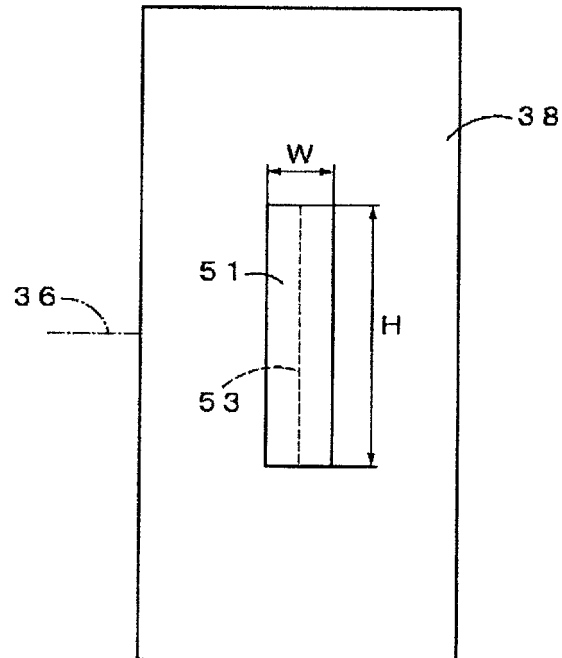


FIG. 5

(a)
(COMPARATIVE EXAMPLE / $\phi = 0$)



(b)
(COMPARATIVE EXAMPLE / $\phi = 0$)

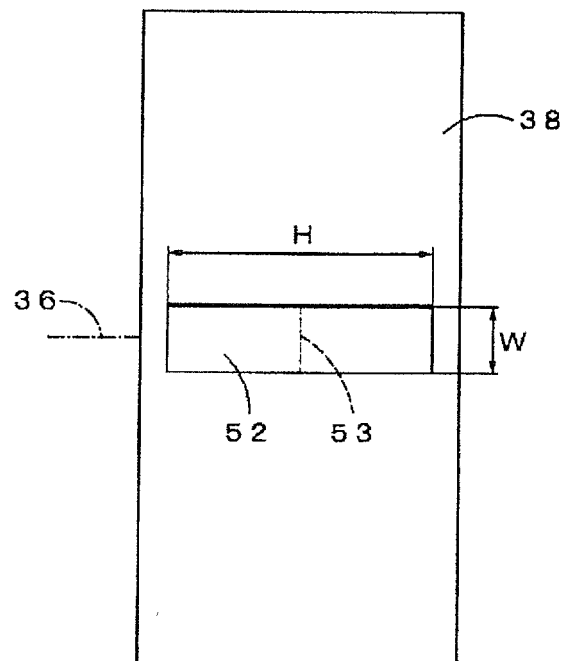


FIG. 6

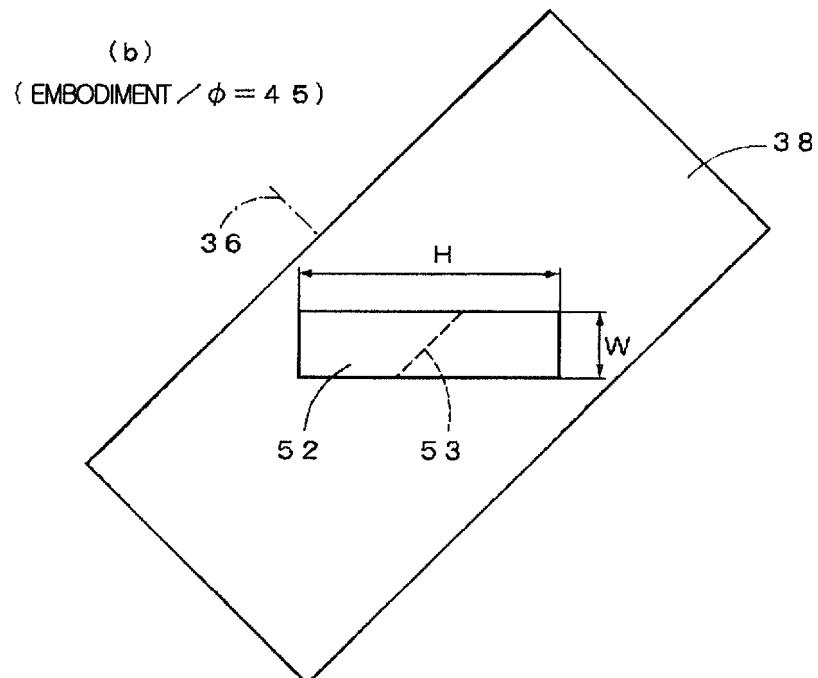
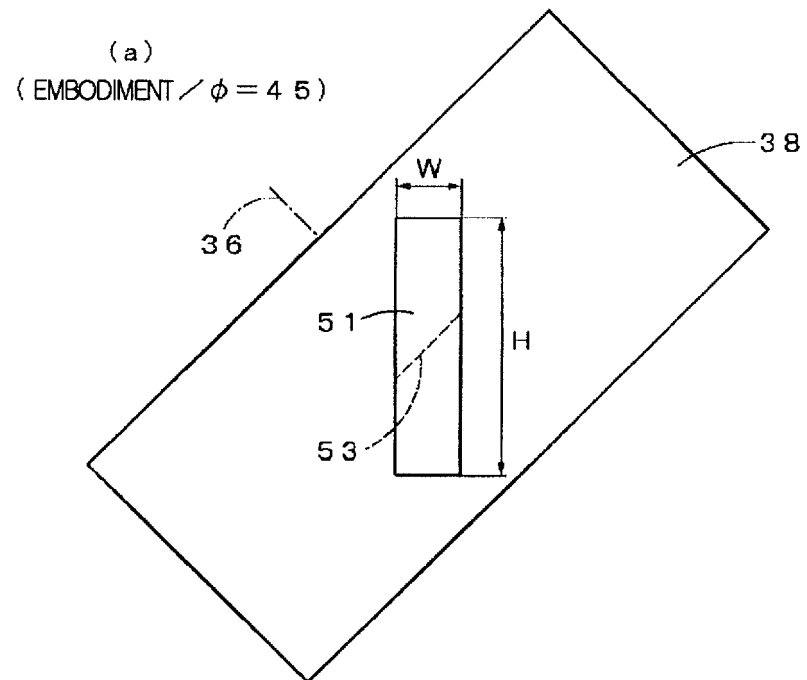


FIG. 7

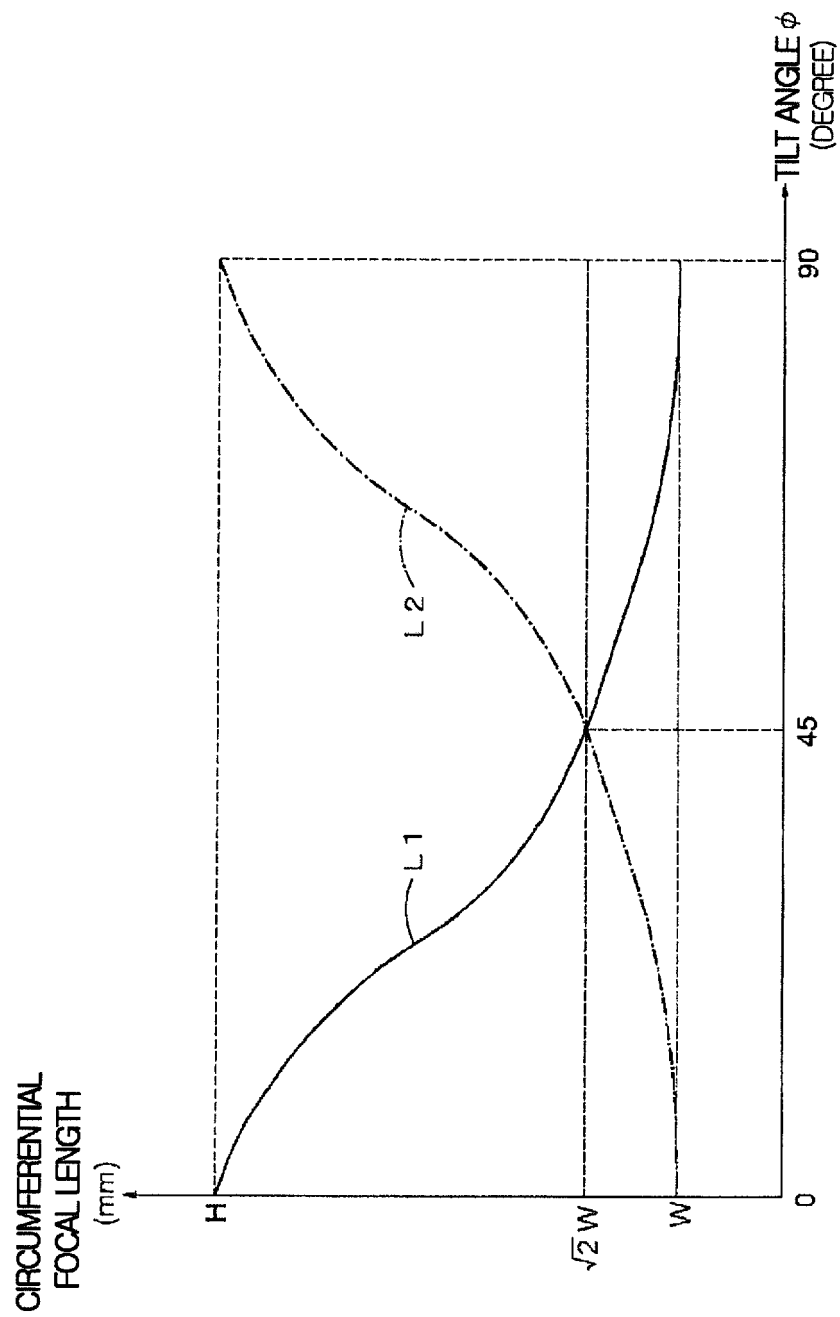


FIG. 8

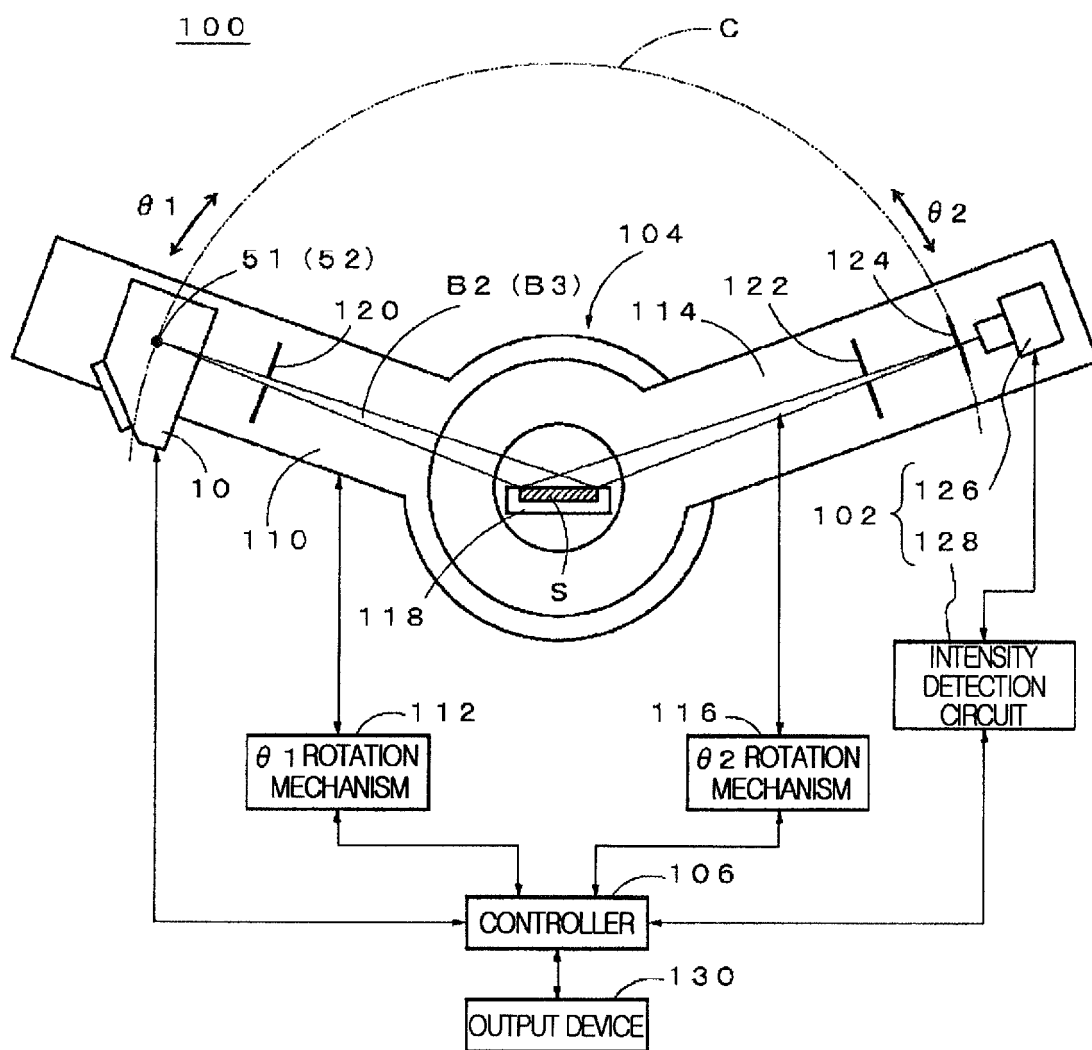


FIG. 9

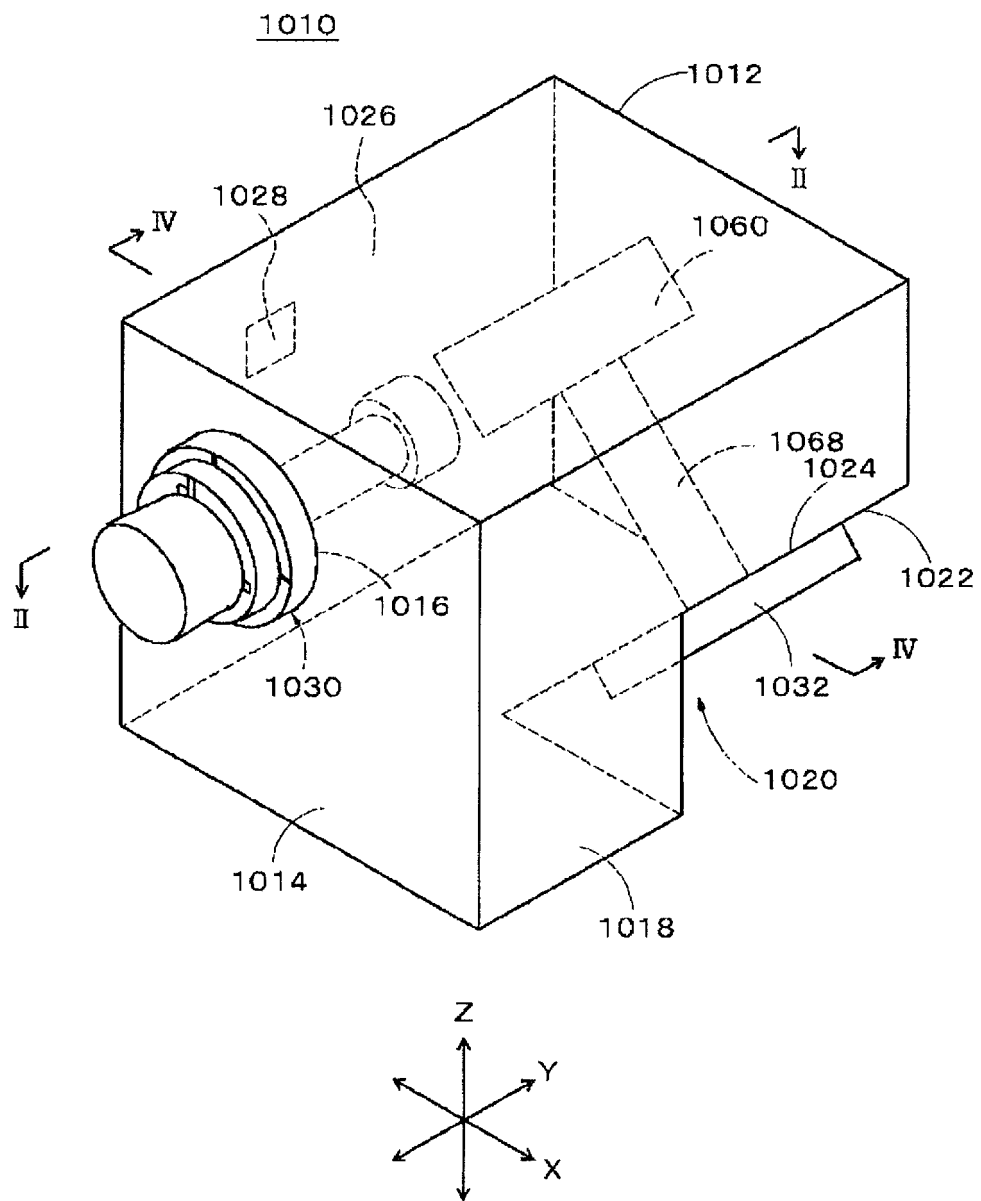


FIG. 10

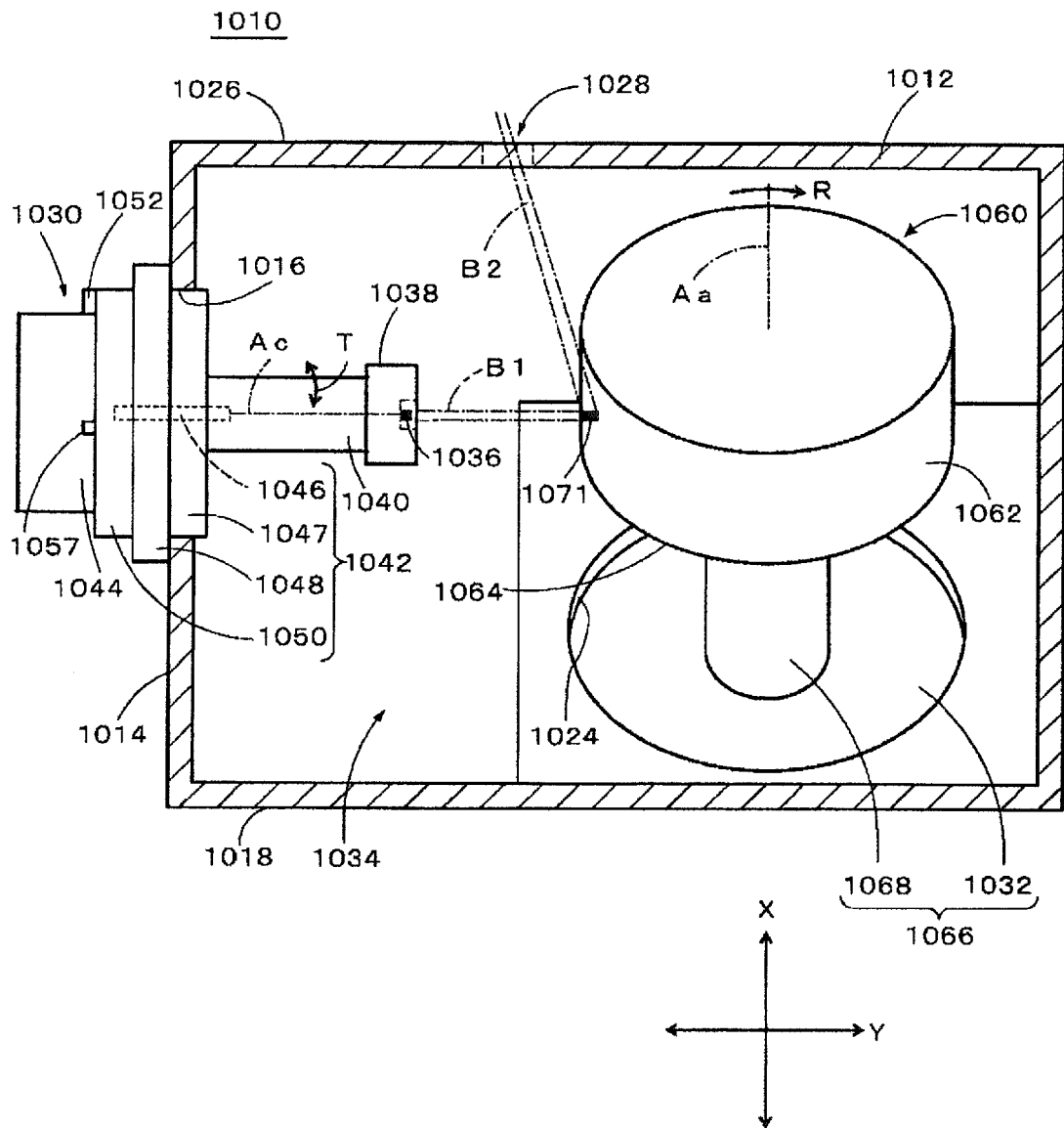


FIG. 11

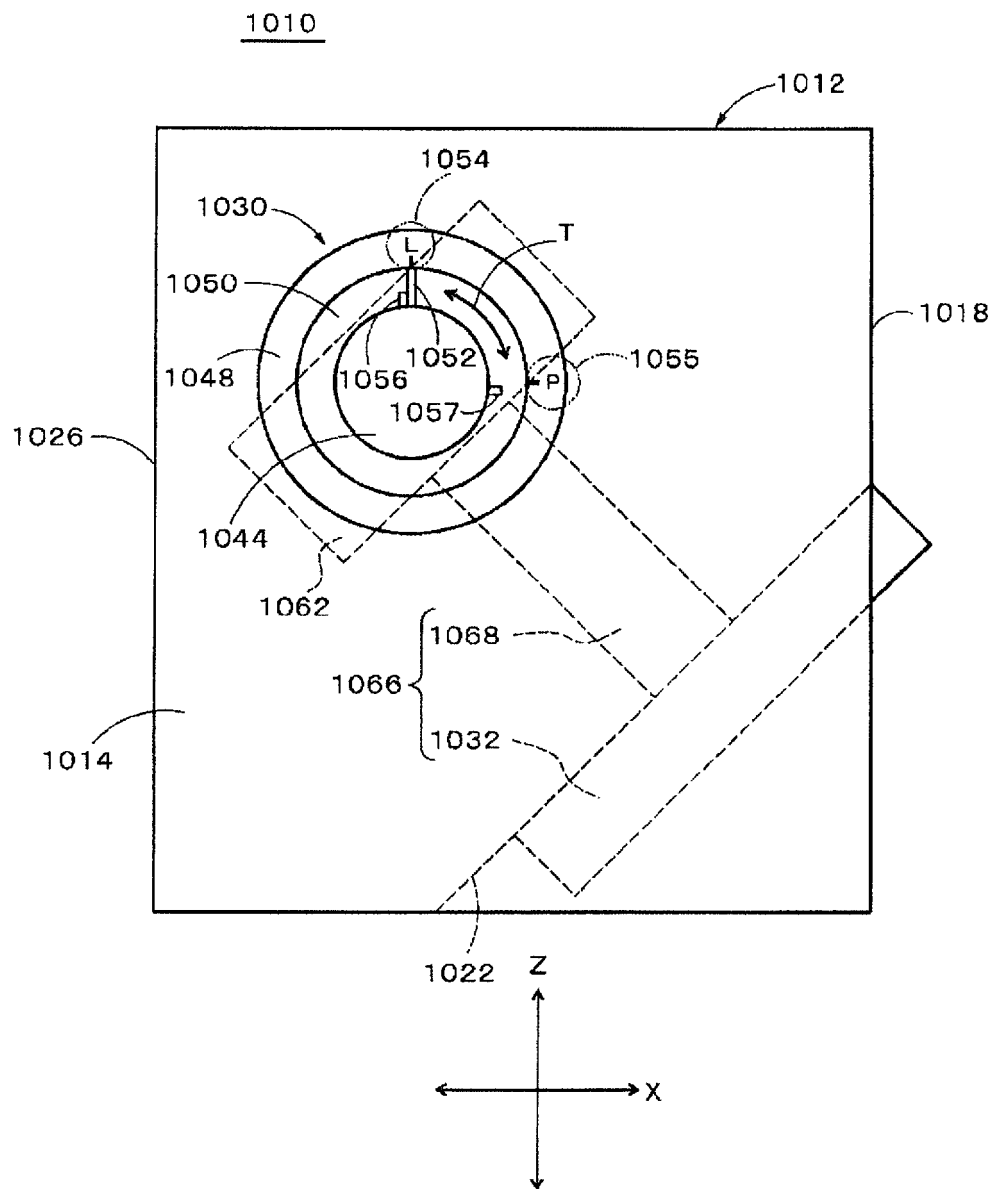


FIG. 12

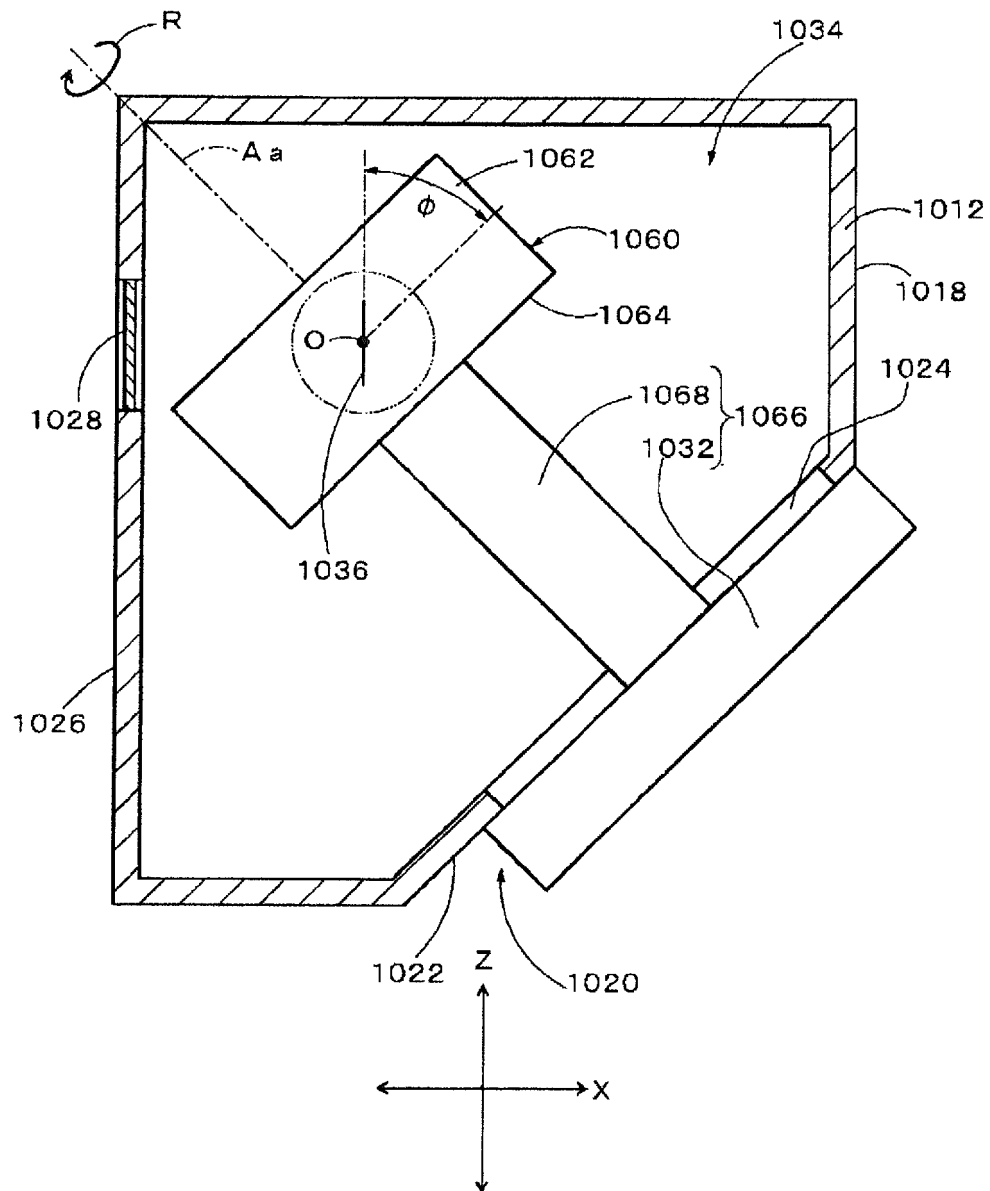


FIG. 13

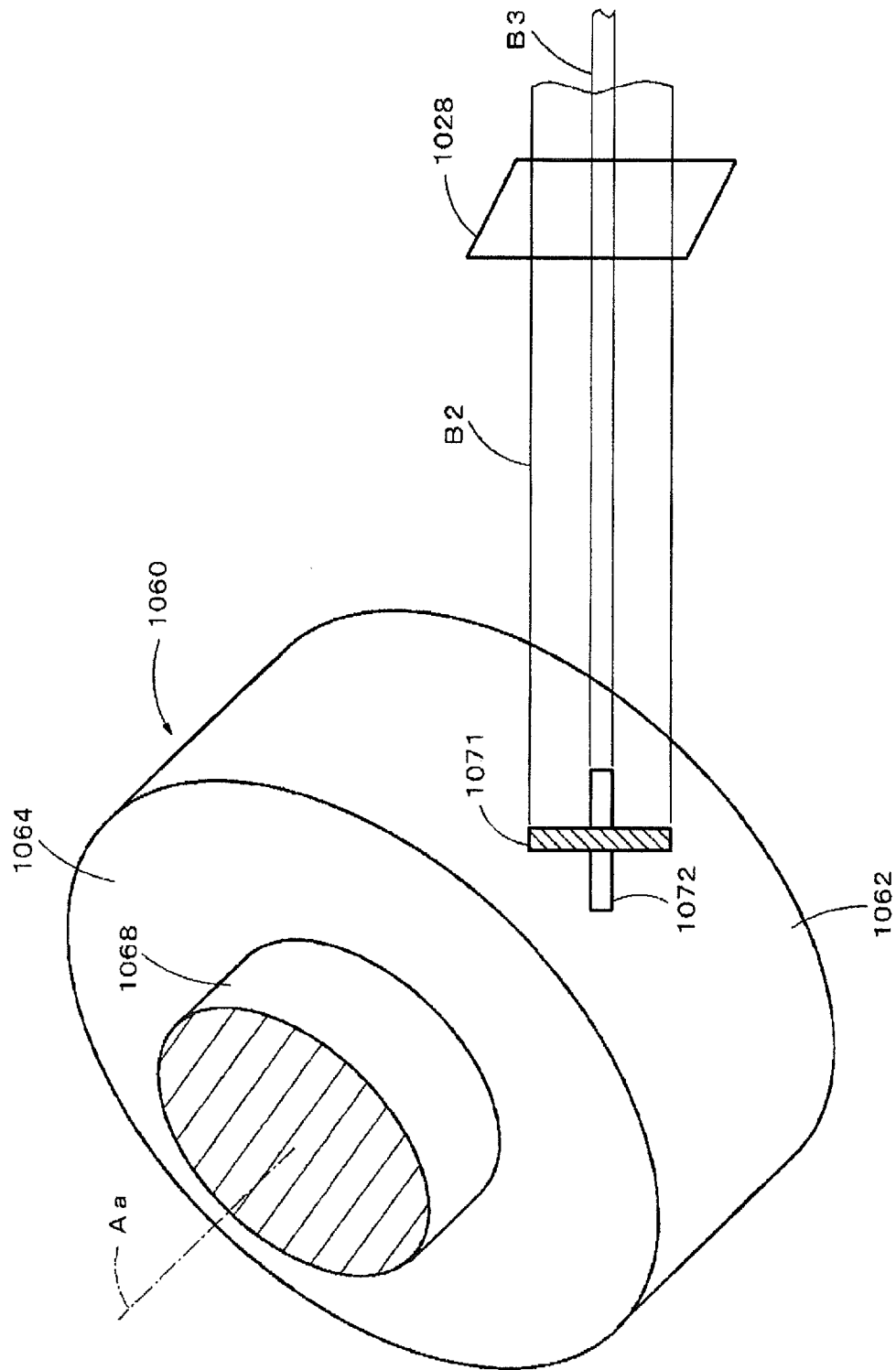


FIG. 14

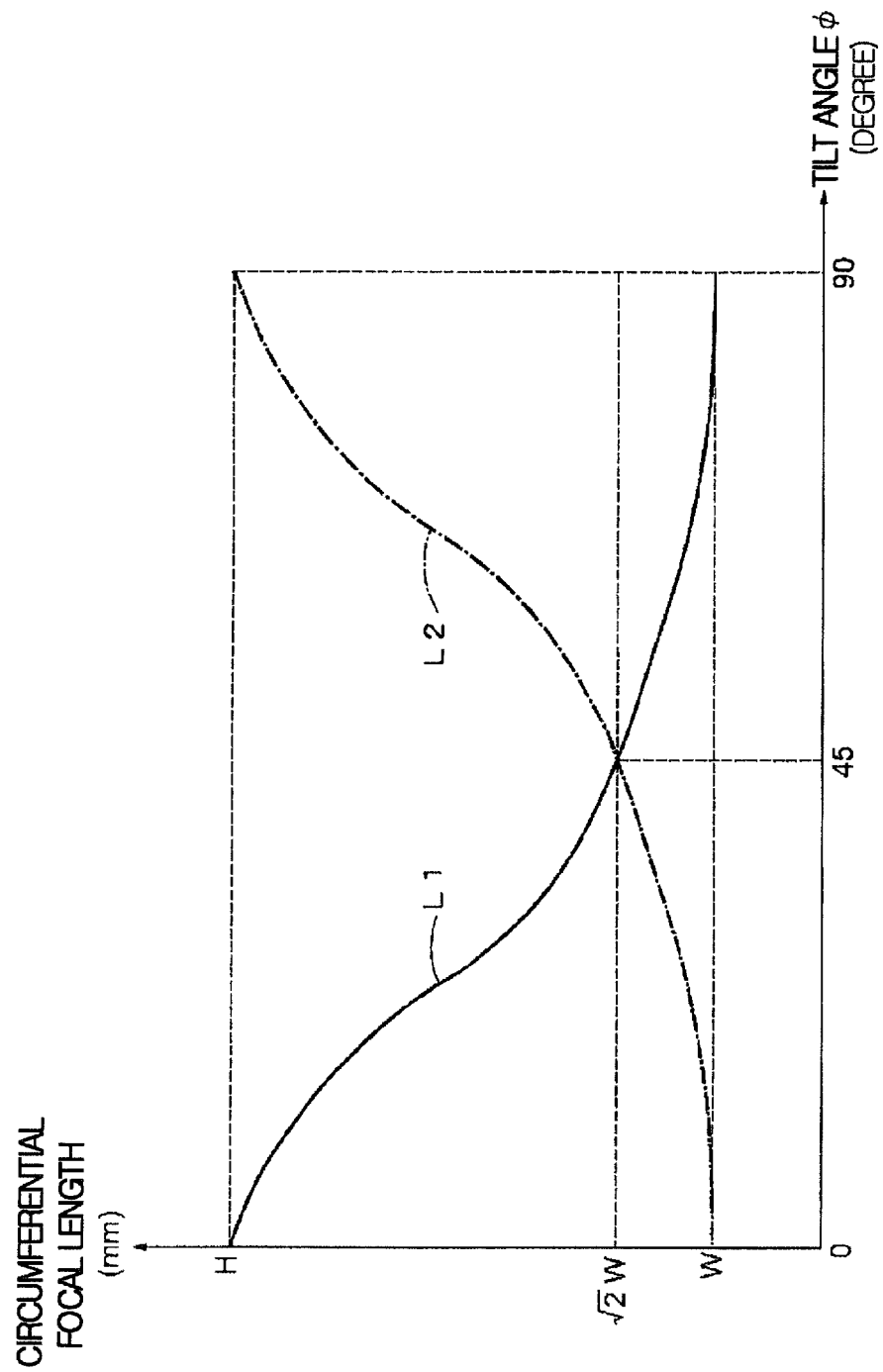
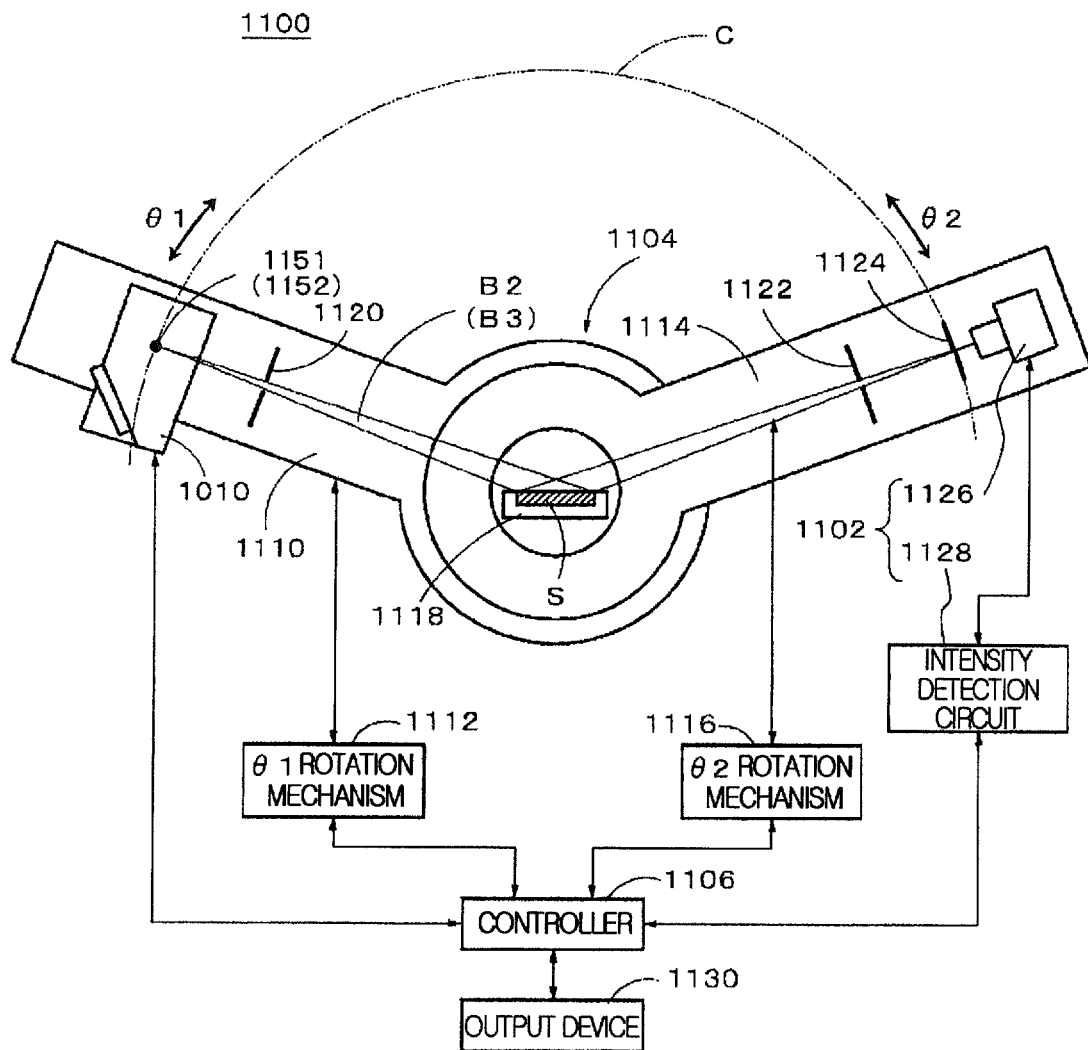


FIG. 15



REFERENCES CITED IN THE DESCRIPTION

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