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[54] **X-RAY SPECTROSCOPE**

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[52] **U.S. Cl.** **250/276;** 250/273; 250/399
[51] **Int. Cl.** **G01t 1/00**
[58] **Field of Search** 250/272, 273, 276, 278, 250/280, 399

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[57] **ABSTRACT**

In an X-ray spectrometer, an X-ray source which uses X-rays generated by irradiating a specimen with a primary electron beam, a curved dispersing crystal to diffract the X-rays and a slit device to take out desired components of the X-rays, are diposed on a Rowland's circle. The X-ray spectroscope is so designed that the crystal and the slit device may be rotated about the same crystal maintained in the center of rotation in such a manner that the radius of the Rowland's circle is varied while Bragg equation and the condition of convergence are satisfied, and that the radius of curvature of the curved crystal may be varied in accordance with the angle of rotation.

6 Claims, 7 Drawing Figures

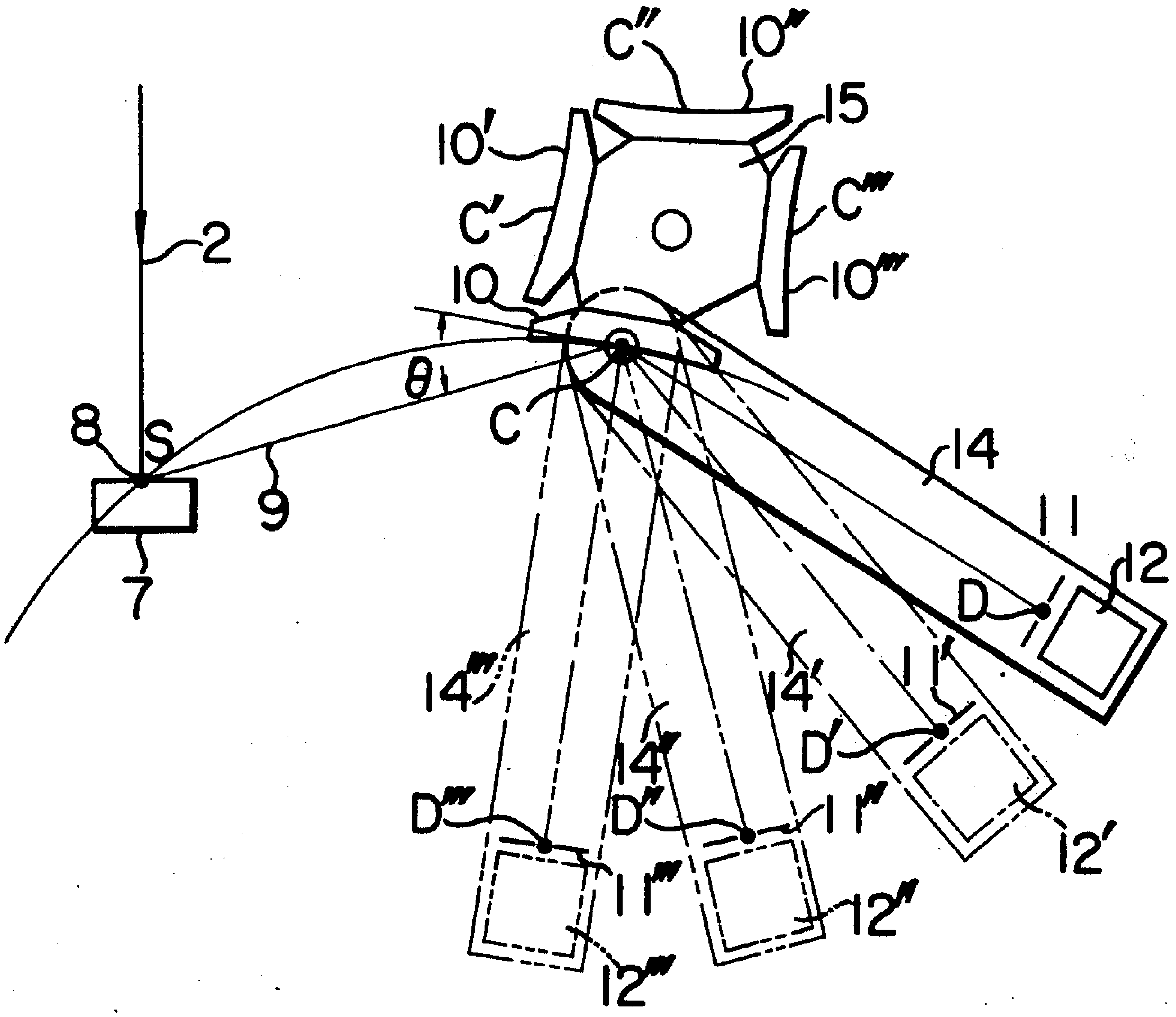


FIG. 1

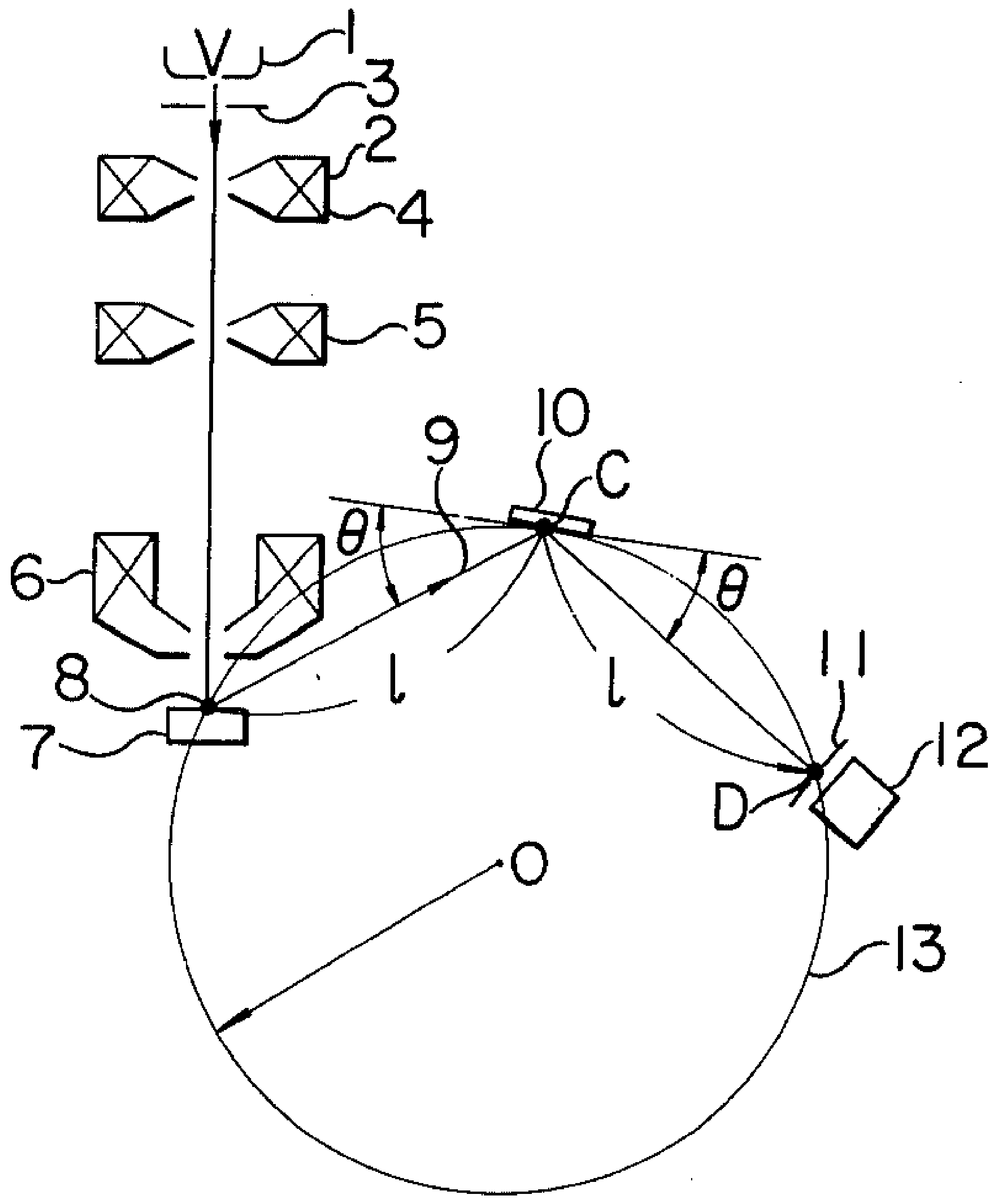


FIG. 2

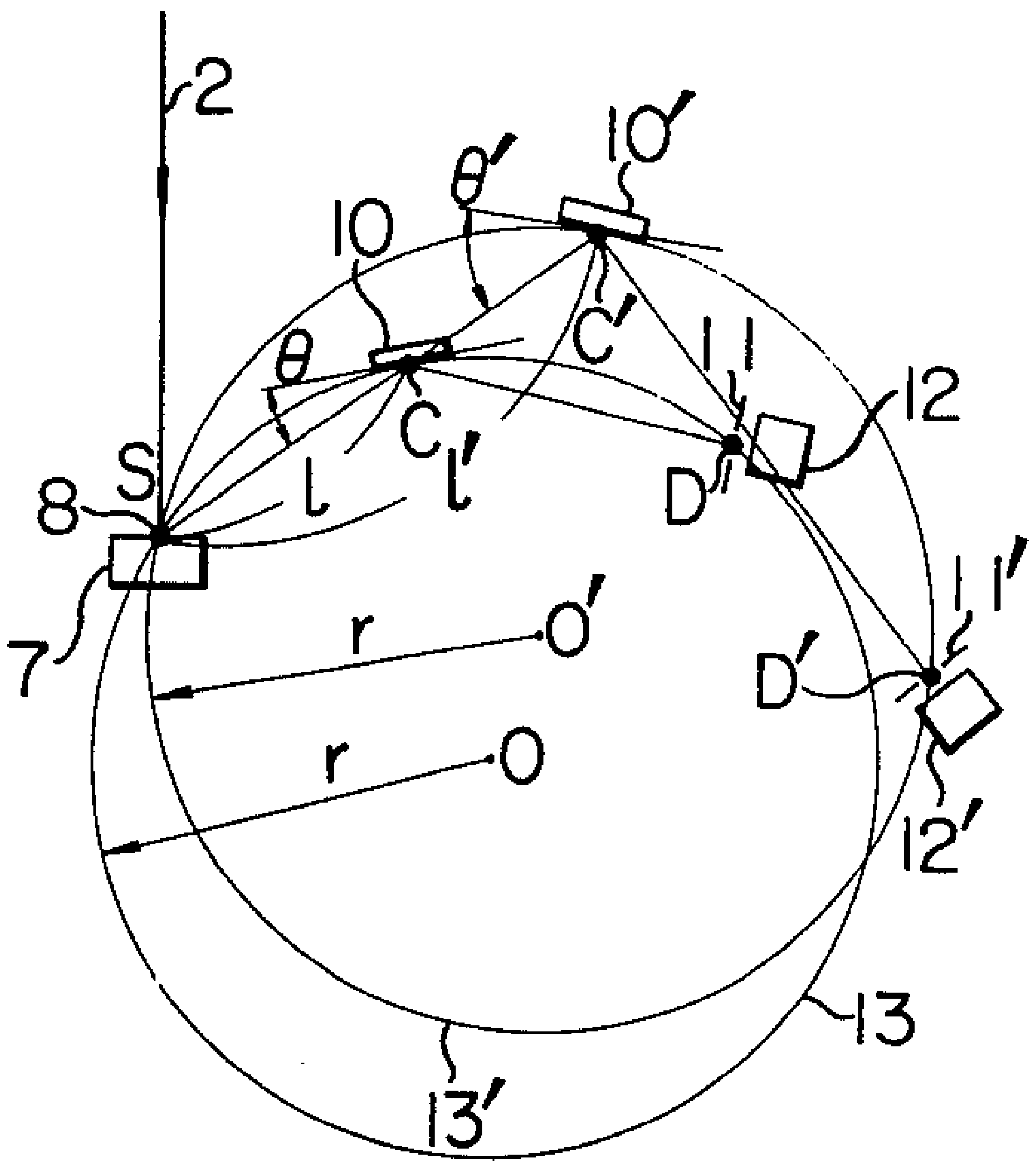


FIG. 3

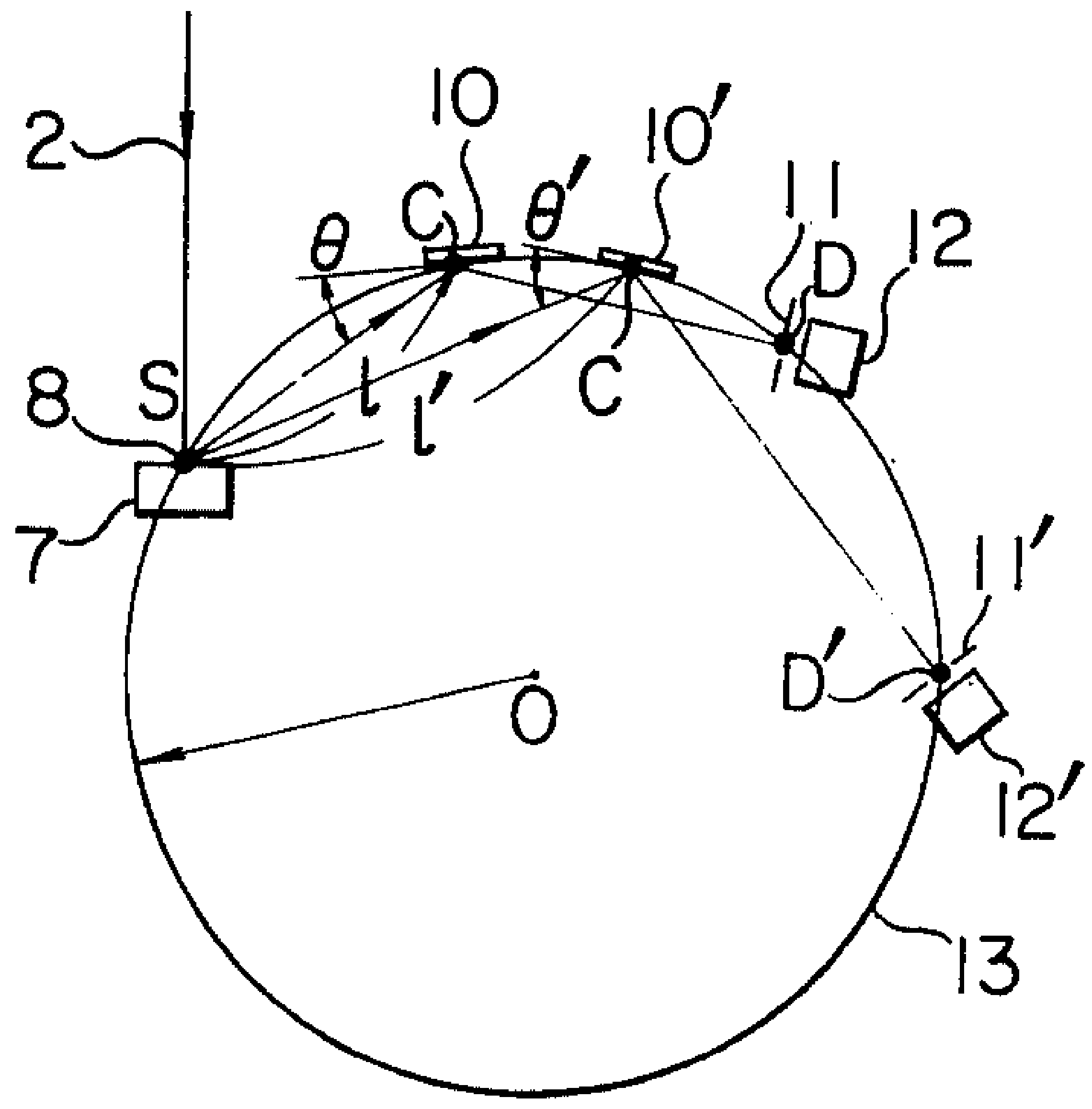


FIG. 4

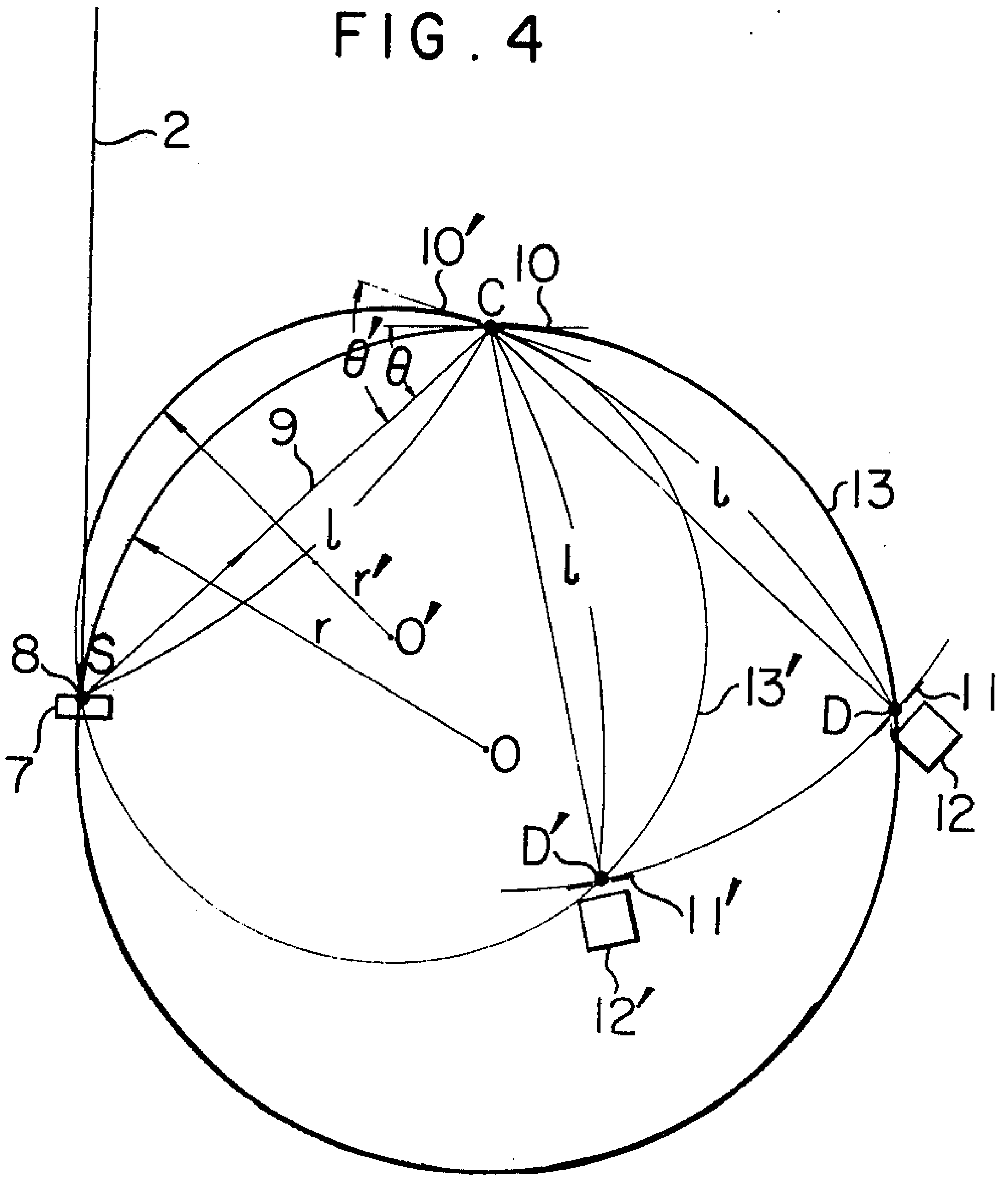


FIG. 5

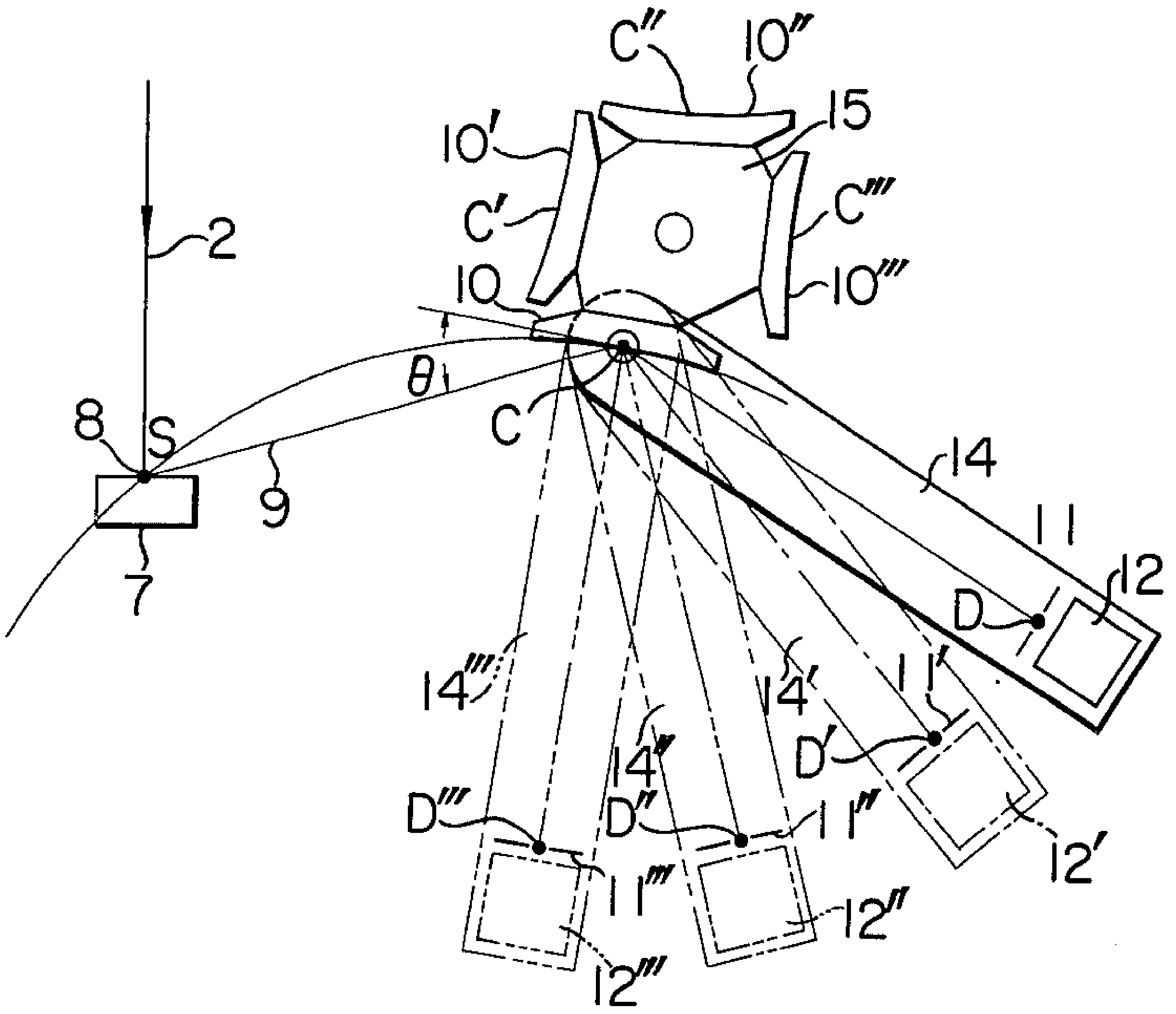


FIG. 6

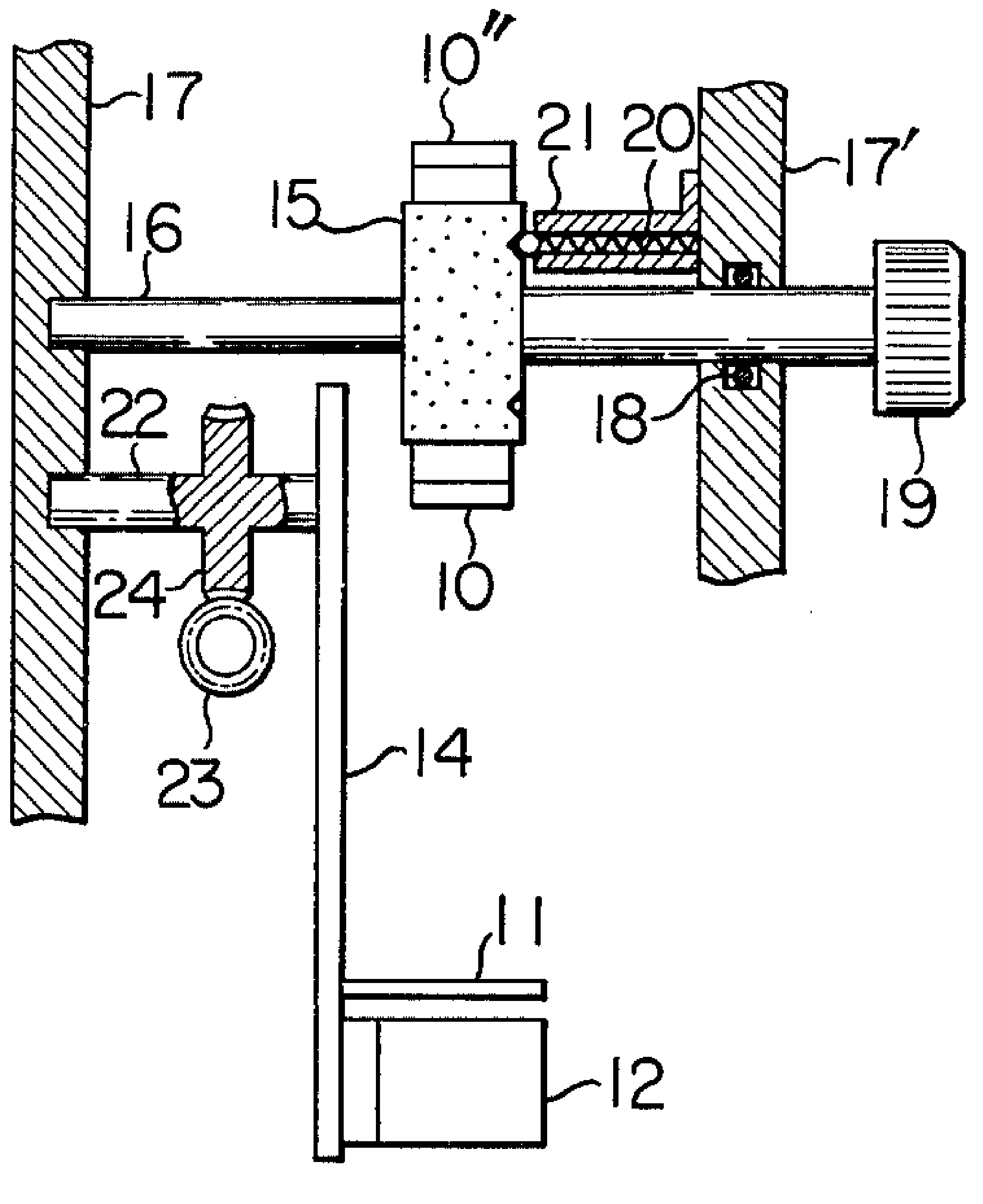
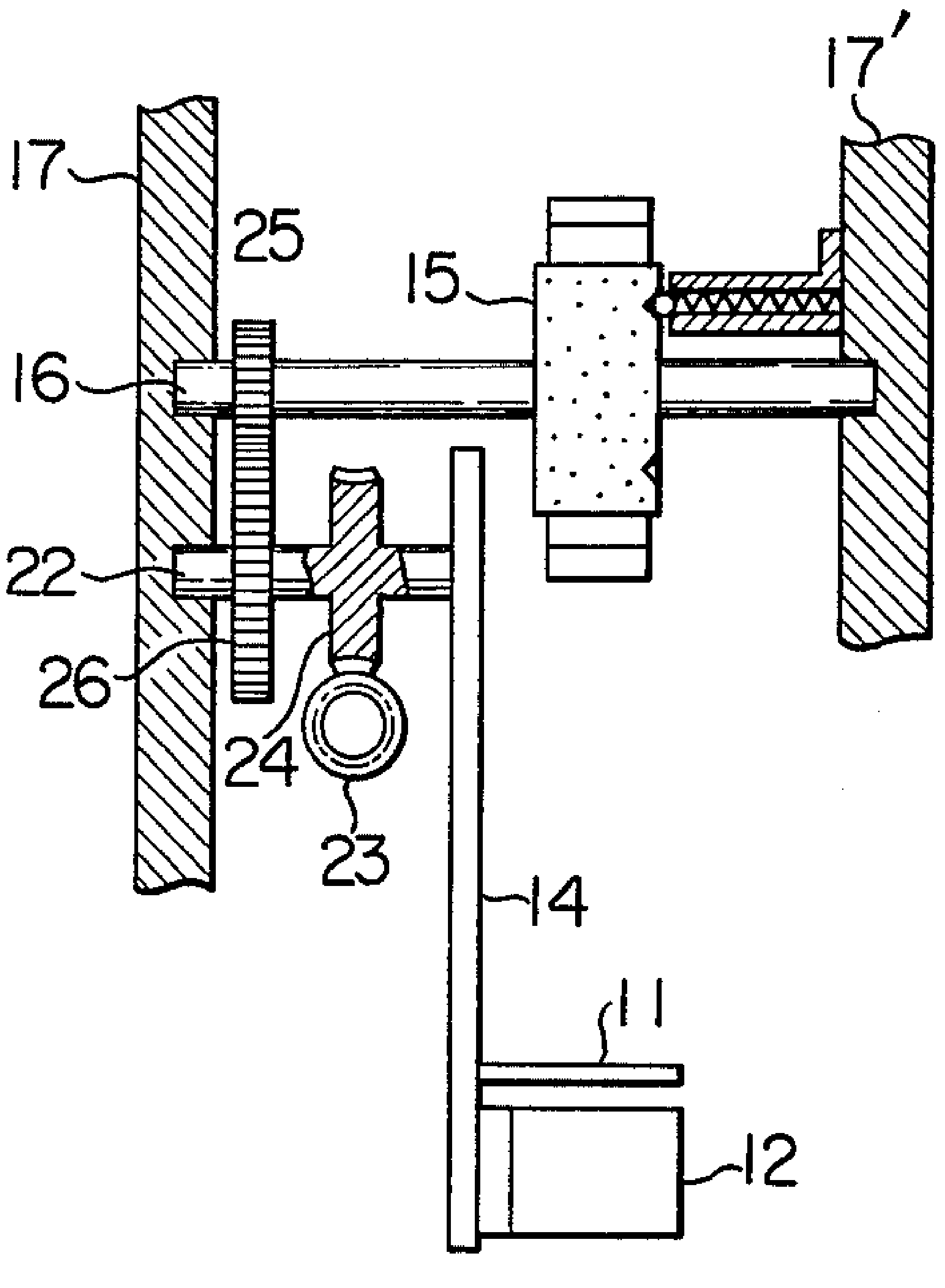


FIG. 7



X-RAY SPECTROSCOPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an X-ray spectrometer used in, for example, the electron probe microanalysis.

2. Description of the Prior Art

In general, as electronic apparatuses which are used to analyze the constituent elements of a specimen by the use of X-rays, are known an electron probe microanalyzer and a scanning electron microscope. The principle of operation of these apparatuses is as follows. Namely, a primary electron beam emitted from an electron gun in vacuum is energized by an anode structure up to a level of 1 – 50 KeV, the high-energy electron beam is then focussed through a plurality of electron lenses to have a tiny diameter of 50 – 5000 A, the very thin electron beam is bombarded on a specimen, and the elemental analysis in an infinitensimal region of the specimen is performed by detecting with a detector the X-rays emitted from the region.

In order to detect the secondary X-rays produced from the specimen as a result of impact by the primary electron beam, a detector having an energy proportionality, e.g. a scintillation counter or a semiconductor X-ray detector recently developed, may be used. Moreover, as the method for detecting X-rays are the non-dispersion type spectrometry and the dispersion type spectrometry. The former is to detect with such detectors as mentioned above the X-rays emitted directly from a specimen and to electrically measure the pulse height value of the detected output while the latter uses such a dispersion element as a diffraction grating or a single crystal. According to the non-dispersion type spectrometric method, the devices like detectors etc. have only to be fixedly placed near the specimen and therefore there is no need for that mechanism to put the devices in motion which are necessarily provided in the dispersion type spectrometric method. This may be said to be a great advantage. In this method, however, even if a semiconductor X-ray detector is used, the wavelength resolution is lower by a digit than in the dispersion type spectrometric method and therefore there is a drawback that the discrimination between elements whose atomic numbers are near one another is impossible. On the other hand, the dispersion type spectrometric method has an excellence of wavelength resolution over the non-dispersion type method, but it needs a driving mechanism to move the dispersion element and the X-ray detector along the Rowland's circle. Accordingly, the mechanical structure of the dispersion type method is complicated and the volume of the X-ray spectrometer accommodating the driving mechanism is large, so that it is hardly possible from the structural point of view to provide the X-ray spectrometer within a limited space near the specimen chamber of the X-ray analyzer.

SUMMARY OF THE INVENTION

One object of the present invention is to provide an X-ray spectrometer for an X-ray analyzer, having a simple mechanical structure.

Another object of the present invention is to provide an X-ray spectrometer for an X-ray analyzer, which is small in size.

An additional object of the present invention is to provide an X-ray spectrometer for an X-ray analyzer, which is low in cost.

A further object of the present invention is to provide an X-ray spectrometer .for an X-ray analyzer, which can cover the whole range of wavelengths of X-rays used in the X-ray analysis.

According to the present invention, which has been made to attain the objects mentioned above, there is provided an X-ray spectrometer wherein an X-ray source which is the surface of a specimen and emits X-rays when the primary electron beam bombards the surface, a curved diffraction crystal to diffract the X-rays and a slit device through which the desired components of the scattered X-rays are taken out, are disposed on a Rowland's circle, wherein the slit device can be rotated about an axis of rotation which passes through the center of the curved crystal and wherein the curved diffraction crystal can be replaced by any one of other plural curved diffraction crystals having different radii of curvature, according to the angle of rotation.

The above and other objects features and advantages of the present invention will be apparent when the following description of this specification will be read in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** schematically illustrates the principle of a dispersion type X-ray spectrometric method.

FIG. **2** schematically illustrates the principle of an X-ray spectrometric method with straight-forward system for curved crystal as one of the dispersion type X-ray spectrometric methods.

FIG. **3** schematically illustrates the principle of an X-ray spectrometric method with rotating system for curved crystal as one of the dispersion type X-ray spectrometric method.

FIG. **4** schematically illustrates the principle of an X-ray spectrometer according to the present invention.

FIG. **5** shows a one embodiment of an X-ray spectrometer according to the present invention.

FIG. **6** is a longitudinal cross section of a spectrometer as shown in FIG. **4.**

FIG. **7** is a modification of the spectrometer shown in FIG. **6.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before the description of an embodiment of the present invention, the principle of the dispersion type X-ray spectrometric method will be explained with the aid of FIGS. **1, 2** and **3.**

FIG. **1** diagrammatically illustrates the principle of a dispersion type X-ray spectrometric method using an electron probe microanalyzer (EPMA) or a scanning electron microscope (SEM).

An electron gun **1** emits primary electron beam **2,** which is energized by an anode **3** up to an energy level of 1 – 50 KeV. The energized electron beam **2** is then focussed by electronic lenes **4, 5** and **6** to have a very small diameter of 50 – 5000 A and the very thin electron beam serving as probe bombards a specimen **7.** Thereby, secondary X-ray are emitted from the specimen **7** over a solid angle of 2π steradians. Namely, the point to be analyzed on the surface of the specimen **7** forms an X-ray source **8** and some parts of all the generated X-rays **9** having a great number of wavelengths are diffracted by a dispersion element, i.e. a diffraction crystal **10.**

The diffracted X-rays are the characteristic X-rays which have wavelength proper to each of elements constituting the specimem **7** and the characteristic X-rays are detected, after having been passed through an exit slit **11** for X-rays, by a detector **12** to be converted to the corresponding electric signals.

In the X-ray diffraction, the Bragg equation such that $n\lambda = 2d \sin \theta$, must be satisfied, where n is the order of diffraction, λ the wavelength of incident X-ray radiation, d the interplanar spacing of lattice planes of the diffracting crystal, and θ the angle of diffraction. In order to obtain a high L-B ratio (Line to Background Ratio), a curved crystal must be used as diffraction element and moreover the condition of convergence such that $l = 2r \sin \theta$ must also be satisfied. In this case, it is needless to say that the X-ray source **8,** the center C of the diffraction crystal **10** and the center D of the exit slit are all situated on a Rowland's circle having a radius r. In the above-mentioned equation, l is the distance from the X-ray source **8** to the center of the diffraction crystal **10** and from the center of the crystal **10** to the center of the exit slit **11,** r is the radius of Rowland's circle and θ is the angle of diffraction. Usually, as such a curved diffraction element is used a Johann type curved crystal in which radius of curvature of the diffracting surface is $2r$, or a Johansson type curved crystal which is produced by bending a crystal so that it may have a radius of curvature of $2r$ and then by cutting the crystal in such a manner that the radius of curvature of the crystal surface is reduced to r.

In general, the range of wavelengths of X-rays used in the X-ray analysis is 0.7 to 120 A. In order to diffract X-rays having such a wide range of wavelengths, a large number of diffraction crystals need to be used in a change-over manner so that a range of wavelengths may be allotted to each crystals. For example, to a diffraction crystal of LiF (Lithium fluoride) is allotted a range of wavelengths 0.7 – 3.5 A, and, in like manner, wavelengths 2.4 – 9.7 A to ADP (Ammonium dihydrogen phosphate), 5.8 – 24 A to RAP (Rubidium acid phthalate), 22 – 92 A to STE (Stearate), and 29 – 120 A to LIG (Lignocerate), these allotments being rough.

FIG. 2 shows only principal portions in FIG. **1,** in which is illustrated how the range of the wavelengths allotted to each crystal is covered. Throughout the figures, the same reference numerals and characters are applied like parts and items as in FIG. **1.** Now, suppose that the center **0** of the Rowland's circle **13** is rotated through an arbitrary angle about the X-ray source **8** defined as the center of rotation and that a new Roland's circle formed as a result of the rotation is indicated at **13'** with a center **0'**. The straight line is drawn from the position S of the X-ray source **8** to the center C of the crystal **10** and let the intersection of the Rowland's circle **13'** and the extension of the straight line be indicated by C'. The center C of the crystal **10** is moved to the point C' and the crystal **10** after displacement is labeled with a new reference numeral **10'**. The distance between the points S and C' is also assumed to be l'. Further, another point D' is selected on the Rowland's circle **13'** in such a manner that the distance from the point C' to the point D' is l'. The center D of the slit **11** is moved to the point D' and the slit **11** after displacement is labeled with a new reference numeral **11'**.

In this way, the points C and D on the Rowland's circle **13** are transferred through the rotation respectively to the points C' and D' on the Rowland's circle **13'** while the point S remains stationary. In this case, also, the above mentioned Bragg equation and condition of convergence are both satisfied. As apparent from the Bragg equation, the wavelengths of the characteristic X-rays obtained from the Bragg equation depend upon the angles of incidence of the X-rays falling upon the diffraction crystal, or diffraction angle θ, so that the wavelength λ of the characteristic X-rays obtained before the rotation of the Rowland's circle is such that $n\lambda = 2d \sin \theta$ while the wavelength λ' of the characteristic X-rays obtained after the rotation is such that $n \lambda' = 2d \sin \theta'$.

This means that if the angle θ of diffraction of a single diffraction crystal is changed, under the above mentioned conditions, by rotating the Rowland's circle, then the X-rays within the range of wavelengths allotted to the crystal can be continuously diffracted. This way of operation is called wavelength scanning and used as one of analyzing methods of detecting the existence of certain elements in a specimen.

The foregoing lines have been given to the description of the principle of the X-ray analysis based on the X-ray spectrometric method with straightforward system for curved crystal. As a similar spectrometric method is known the X-ray spectrometric method with rotating system for curved crystal. The principle of the method will be described with reference to FIG. **3.** The Rowland's circle **13** having a radius r passes through the point S of the X-ray source **8** on the specimen **7** and is fixed stationary. In order to satisfy Bragg equation, the center C of the diffraction crystal **10** and the center D of the exit slit **11** near the X-ray detector **12** are located on the Rowland's circle **13** in such a manner that $SC = CD = l$. In this case, the diffraction angle of the crystal is θ. If it is required to change the diffraction wavelength λ, the points C and D have only to be transferred, as shown in FIG. **3,** to new points C' and D' on the fixed Rowland's circle **13** in such a manner that $SC' = C'D' = l'$. Namely, since, even after the displacement, the respective points satisfy the Bragg equation and simultaneously the diffraction angle changes from θ to θ', then the wavelength λ' of the characteristic X-rays obtained as a result of this displacement is such that $\lambda' = 2d \sin \theta'$.

In the two dispersion type spectrometric methods described above, the wavelength λ is changed by changing the distance l between the points S and C or C and D, that is, by moving the Rowland's circle itself or the diffraction crystal and the exit slit along the Rowland's circle in such a manner that the Bragg equation and the condition of convergence are both satisfied. This can be recognized also from the expression $\lambda = l \cdot (d/r)$ (here $n = 1$) which can be obtained from $n \lambda = 2d \sin \theta$ and $l = 2r \sin \theta$.

Of the two dispersion type spectrometric methods described above, the method with rotating system for curved crystal has a drawback that as the angle θ of diffraction is changed, the angle of derivation of the X-rays directed from the specimen to the diffraction crystal may be rendered so small, depending upon the direction of the change, that the X-rays tend to be blocked by the microscopic protrusions existing in the rough surface of the specimen with the result that the intensity of the produced X-rays are sometimes too low for actual analysis. On the other hand, according to the method with straightforward system for curved crystal, as shown in FIG. **2**, the angle of the X-rays leaving the specimen is kept constant and therefore this method may be claimed to be an effective spectrometric method which eliminates such a drawback as inherent to the previous method.

In these methods, however, the radius of the Rowland's circle is kept stationary and there is a merit that a diffraction crystal having the same radius of curvature can be used while there is needed a driving mechanism to move the diffraction crystal and the exit slit in such a manner that the Bragg equation and the condition of convergence are both satisfied since the crystal and the slit (inclusive of the X-ray detector) are moved on the Rowland's circle or the Rowland's circle itself is rotated. Accordingly, the driving mechanism needs to have a wide range of movement and a high accuracy so that the structure is complicated, large and costly. Moreover, it is very difficult from the technical standpoint to install a large spectrometer including such a driving mechanism within a limited space in the vicinity of the small specimen chamber of an X-ray analyzer. The reproducibility of the X-ray analyzer is largely affected by the mechanical precision of the driving mechanism and nowadays users require a reproducibility such as producing a wavelength difference less than 5/**10,000** A between detected wavelengths of a characteristic X-ray so that it is of technical difficulty to attain a reproducibility corresponding to a wavelength difference less than 5/**10,000** A with the spectrometer having such a complicated mechanism as described above. It is needless to say that since the inside of the spectrometer is kept in high vacuum it is very essential to reduce the size of the spectrometer.

FIG. **4** is a diagram useful to explain the principle of an X-ray spectrometer according to the present invention. The basic conception of the conventional X-ray spectrometric methods described with FIGS. **2** and **3** is that the characteristic X-rays having different wavelengths are diffracted by changing l in the formula $\lambda = l \times d/r$ obtained from the Bragg equation and the condition of convergence and by maintaining the radius r of the Rowland's circle constant. On the other hand, the fundamental feature of the present invention is that the characteristic X-rays having desired wavelengths are obtained by changing the radius of the Rowland's circle and maintaining the quantity l constant. Reference should now be had to FIG. **4**. A primary electron beam **2** bombards a specimen **7** to emit X-rays from the portion serving as an X-ray source **8** (represented by a point S). Some part **9** of the X-rays emitted from the source S is diffracted by a diffraction crystal **10** (its center point is represented by C) placed at a distance l from the source S, the angle of diffraction being θ. The diffracted characteristic X-rays are passed through the center D of an exit slit **11** placed at a distance l from the center C of the diffraction crystal **10** and detected by a detector **12**. Here, the points S, C and D are all situated on the Rowland's circle **13** having a radius r. Therefore, the wavelength λ of the thus diffracted X-rays is such that $n\lambda = 2d \sin\theta$. Next, the slit **11** and the detector **12** are rotated through an arbitrary angle about the point C of the diffraction crystal as the center of rotation and the slit **11** and the detector **12** after the rotation are labeled with new reference numerals **11′** and **12 ′**, respectively, and the center of the slit **11′** is indicated by the point D′. Further, the diffraction crystal **10** is so rotated about its center point C that the X-rays diffracted may be exactly directed to the slit **11′** and the detector **12′** and the crystal **10** after rotation is also labeled with a new reference numeral **10′** with a new angle θ' of diffraction. It follows, therefore, thast before the rotation of the slit **11′** the points S, C and D are situated on the Rowland's circle having the center **0** and the radius r in such a manner that $SC = CD = l$ while after the rotation the points S, C and D′ lie on the Rowland's circle having the center **0′** and the radius r' in such a manner that $SC = CD' = l$. This means that the characteristic X-rays having a range of wavelengths covered by a single diffraction crystal can be obtained also in the case where the radius r of the Rowland's circle is changed while d and l are kept constant, as is seen from the expression $\lambda = l \times (d/r)$ ($n = 1$). In other words, in order to obtain characteristic X-rays having different wavelengths, the slit **11** is rotated about the point C of the diffraction crystal **10** while the crystal is so rotated about its center C to exhibit desired angles of diffraction.

On the other hand, in order to detect the X-rays obtained through the rotation of the slit **11** at as high a sensitivity as possible, the diffracting surface of the crystal must be bent, as described before. The degree of the bend of the diffraction crystal is given by the condition of convergence: $l = 2r \sin\theta$. Therefore, as described with FIG. **4**, the radius of Rowland's circle is determined by rotating the slit **11** so that the radius of curvature of the diffraction crystal is uniquely given. Accordingly, for example, in the case where the X-ray analysis is performed to reveal the elements constituting a part of a specimen, a specific diffraction crystal must be chosen to obtain the characteristic X-rays having the wavelengths proper to the elements, that is, the diffraction crystal is so chosen as to cover the wavelengths proper to the elements, and the slit is so moved as to detect the X-rays having the required wavelengths, so that the radius of the Rowland's circle determined depending upon the position of the slit will give a suitable radius of curvature of the crystal.

The above described facts will now be explained through concrete examples. The explanation will be concentrated on the analysis of extra-light elements such as beryllium (Be), boron (B), carbon (C), nitrogen (N) and oxygen (O). The diffraction crystal used in this analysis is a laminated crystal such as stearite having an interplanar spacing d of 50 A. for lattice plane or lignocerate having an interplanar spacing d of 65 A. Each of the elements has its proper diffracting wavelength λ. Namely, oxygen **0** has a characteristic wavelength λ of 23.62 A, nitrogen N of **31.6** A, carbon C of 44.7 A, boron B of 67 A, and beryllium Be of 144 A. Accordingly, the radius R of curvature of the diffracting crystal for each of the elements can be obtained from the formula $\lambda = l \cdot (d/r)$ Now, suppose that, in FIG. **4**, $SC = CD = l = 120$ mm. Then, it follows that

1. in the case of detecting oxygen O, the radius r_o of curvature of a Rowland's circle = **120** × (50/**23.62**) = 254 mm, hence
   $R_o = 2r_o = 508$ mm,
2. in the case of detecting nitrogen N,
   $r_n = 120 \times (50/31.6) = 190$ mm,
   $\therefore R_N = 2r_N = 380$ mm,
3. in the case of detecting carbon C,
   $r_C = 120 \times (50/\mathbf{44.7}) = 134.2$ mm,
   $\therefore R_C = \mathbf{2r_C} = \mathbf{268.4}$ mm,

4. in the case of detecting boron B,
   $r_B = 120 \times (50/67) = 89.5$ mm,
   $\therefore R_B = 2r_B = 179.0$ mm, and
5. in the case of detecting beryllium Be,
   $r_{Be} = 120 \times (65/114) = 68.4$ mm
   $\therefore R_{Be} = 2r_{Be} = 136.9$ mm

Thus, the radius of curvature of each crystal may be determined. The X-ray analysis of a specimen can be easily performed according to the process as follows. A plurality of diffraction crystals whose radii of curvature were determined according to such a manner as described above, are mounted previously on a base shown in FIGS. **5**, **6** and **7**. The slit is moved to obtain the wavelength proper to the element to be analyzed and the angle θ of diffraction is so determined as to direct the X-rays having the characteristic wavelengths toward the slit. At the same time, one of the diffraction crystals mounted on the base is selected corresponding to the characteristic wavelength and the selected crystal is fixedly placed at the point C in FIG. **4**.

As described above, if a mechanism is employed in which the center of the diffraction crystals is fixed with the slit and the detector rotated about the center and in which the crystals are selectively changed over depending upon the wavelength proper to the element to be analyzed, then this mechanism is by far simpler than that used in the spectrometer with straightforward system for curved crystal, or the spectrometer with rotating system for curved crystal described with FIGS. **2** and **3**. The simplification of the mechanism leads to the reduction in size of the spectrometer itself and moreover to the improvements in the mechanical precision and the speed of evacuating the spectrometer.

Now, concrete embodiments of the present invention will be described.

FIG. **5** shows the principal part of an X-ray spectrometer as one embodiment of the present invention. When the specimen **7** is bombarded by the primary electron beam **2**, as seen in FIG. **5**, the portion **8** of the specimen **7** emits X-rays. Some part **9** of the X-rays falls upon the diffraction crystal **10** at an angle θ and then the characteristic X-rays diffracted by the crystal **10** impinge through the slit **11** onto the detector **12**. In this embodiment, four diffraction crystals **10**, **10'**, **10''** and **10'''** are used and they are fixedly mounted on a base **15**. The base **15** is rotated by a click-stop mechanism described later. The click-stop mechanism is so designed that the centers C', c'' and C''' of the crystals may be successively brought into the position coincident with the center C of the crystal **10** shown in FIG. **5** as the base **15** is rotated. The four planar surfaces of the base **15** on which the four crystals are attached are previously inclined so that when a desired crystal is set in its operating position by rotating the base **15**, the angle of diffraction may be equal to one determined by the desired crystal.

The slit **11** and the detector **12** are fixedly mounted on an arm **14** which can be rotated about the point C. If the specimen **7** and the slit **11** are so arranged that the analyzed point S of the X-ray source **8** in the specimen **7** and the center D of the slit **11** may satisfy a condition: SC = CD, and if the center of the slit **11**, when the arm **14** is rotated as indicated at **14'**, **14''** and **14'''** in FIG. **5**, is represented successively by the points D', D'' and D''', then the conditions are attained such that SC = CD = CD' = CD'' = CD''', this arrangement

being a preferable embodiment of the method described with FIG. **4**.

FIG. **6** is a cross section of the structure shown in FIG. **5**. One end of the rotary shaft **16** of the base **15** is rotatably supported in the recess in the inner wall **17** of the casing of the spectrometer while the other end is journaled in the aperture in the casing wall **17'** by means of an O-shaped vacuum seal **18** and capped with a manipulating knob **19** outside the casing. By rotating the knob **19** is rotated the base **15**. On the inner side of the casing wall **17'** is fixed a hollow cylinder **21** having a spring **20** therein, recesses are cut at the predetermined positions in the base **15** opposite to the cylinder **21**, and a protuberance provided at the top of the cylinder **21** is urged by means of the spring **20** into the recess. This arrangement forms the click-stop mechanism. The locations of the recesses are so chosen that the base **15** in rotation may be stopped with the center of each crystal maintained at the predetermined position. The arm **14** has a rotary shaft **22** supported in the recess in the casing wall **17** and the center axis of rotation of the shaft **22** is in alignment with the center C of the crystal **10** on the base **15**. The rotary shaft **22** of the arm **14** on which the slit **11** and the detector **12** are mounted, also has worm wheel **24** fixed to the shaft which is engaged with a worm gear **23** driven by an external driving mechanism (not shown) placed outside the hermetical casing of the spectrometer. The arm **14** is rotated by the driving mechanism and accordingly the slit **11** and the detector **12** attached thereto are also rotated, so that the characteristic X-rays diffracted by the crystal **10** can be detected. The rotation of the base **15** and the arm **14** is so performed as to satisfy all the conditions described with FIG. **4**. Especially, *l* is kept constant so that the linear movement of the diffraction crystals, which is essential in the conventional spectrometer, can be avoided. Moreover, since the center of rotation of the arm carrying the detector thereon is fixed at a stationary point, the structure of the movable part of the spectrometer is much simplified and therefore advantageously conducive to the reduction of the size of the spectrometer. For example, the volume of the conventional X-ray spectrometer is **14***l* while the X-ray spectrometer having a mechanism according to the present invention has a volume of about 4 *l*. This means that the ratio of size reduction is less than one-third. Further, if the size is reduced, the evacuation of the vacuum chamber of the spectrometer is facilitated and the structure of the mechanism to determine the positions of the points S, C and D shown in FIG. **4** is simplified. Accordingly, the mechanical error is reduced and particularly the reproducibility attained by the spectrometer according to the present invention corresponds to a wavelength difference equal to or less than **5/10,000** A.

In FIGS. **5** and **6** is shown an embodiment in which the base **15** and the arm **14** are independently rotated but it is also possible to rotate them in an interlocked relation to each other. An interlocking mechanism to rotate them together will be described with the aid of FIG. **7**.

In FIG. **7**, the rotary shaft **16** of the base **15** is supported at its ends in the recesses in the casing walls **17** and **17'** and a cogged wheel **25** is fixedly attached to the shaft **16** near its one end. On the other hand, the rotary shaft **22** of the arm **14** has a cogged wheel **26** attached fixedly thereto, the cogged wheel being coaxial with the worm wheel **24** and engaged with the cogged wheel **25.** Therefore, the shaft **16** of the base **15** is rotated as the shaft **22** is rotated. The worm gear **23** is rotated by the external driving mechanism so that the arm **14** is rotated, and if the numbers of the teeth of the wheels **25** and **26** are kept in a predetermined ratio, the base **15** and the arm **14** will be rotated with the angles of rotation of the base **15** and the arm **14** maintained in a desired relationship.

In the embodiment shown in FIG. **5,** four diffraction crystals are used and attached onto the rotary base. However, the number of the used crystals is not limited to four. For example, if a spectrometer in which five diffraction crystals are mounted on the base is constructed, the entire range of wavelengths, i.e. a range of 0.7 – 120 A, necessary for the X-ray analysis of elements can be covered by the spectrometer alone. In view of the fact that only two or three diffraction crystals can be used in a conventional spectrometer and that at least two conventional spectrometers must be used to cover the entire range of the X-ray wavelengths, the spectrometer according to the present invention may be said to eliminate a problem of economy due to the use of plural spectrometers and a problem of wasted time required in the operation of changing over the spectrometers and the diffraction crystals and in the associated evacuation of the vacuum chamber of each spectroscope.

Further, in the embodiment shown in FIG. **7,** the arm **14** and the base **15** interlocked to the arm **14** are rotated by an external driving mechanism (not shown), e.g. a manipulating knob in its simplest form, coupled to the worm gear **23.** However, a modfication can be easily thought of by those skilled in the art, in which, for example, the external mechanism and the worm gear modification as shown in FIG. **7** are not used but in which one end of the rotary shaft of the base penetrates the casing wall to serve as a driving end so that the arm is rotated by rotating the driving end.

As described above, according to the present invention, there can be provided a spectrometer in which the structure of its movable parts is simplified and reduced in size and which enjoys the functions of a conventional spectrometer to its full extent. Therefore, the present invention will be considered to have a great practical merit in the field of the art.

I claim:

1. An X-ray spectrometer comprising,

an X-ray source;

a plurality of curved crystals for diffracting an X-ray beam emitted from said X-ray source, said curved crystals having radius of curvature different from each other, one of said curved crystals being disposed at a diffracting position where said X-ray beam is diffracted;

a slit means for taking out said diffracted X-ray beam;

a vacuum chamber for arranging therein said X-ray source, said curved crystals and said slit means which are situated on a Rowland's circle;

a first rotating means for rotating said slit means by means of a first rotary shaft, said first rotary shaft having an axis of rotation passing through the center of the curved surface of said curved crystal disposed at said diffracting position, and

a second rotating means including a second rotary shaft for rotating one of said curved crystals onto said diffracting position in accordance with the rotation of said slit means.

2. An X-ray spectrometer as claimed in claim **1,** wherein said first rotary shaft is coupled with a second rotary shaft penetrating a wall of said vacuum chamber, and a portion of said first rotary shaft protruding from said vacuum chamber is provided with a rotation driving means.

3. An X-ray spectrometer as claimed in claim **1,** wherein said second rotating means includes said second rotary shaft and a rotor fixed thereto, said rotor having on the surface thereof said curved crystals arranged in such a manner that said curved crystals are disposed on the same circle having as the center thereof said second rotary shaft.

4. An X-ray spectrometer as claimed in claim **1,** wherein said second rotary shaft penetrates a wall of said vacuum chamber, and a portion of said second rotary shaft protruding from said vacuum chamber is provided with a second rotation driving means for rotating said rotor.

5. An X-ray spectrometer as claimed in claim **1,** wherein said first rotating means is rotated by a first rotation driving means, and said spectrometer further comprises an interlocking means for rotating said second rotary shaft in accordance with the rotation of said first rotating means.

6. An X-ray spectrometer as claimed in claim **1,** wherein said second rotating means is rotated by a second rotation driving means, and said spectrometer further comprises an interlocking means for rotating said first rotary shaft in accordance with the rotation of said second rotating means.

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