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(54) **Charged particle energy analyzer.**

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NUCLEAR INSTRUMENTS & METHODS, vol. 172, no. 1,2, May 1980, pages 327-336, Amsterdam, NL. D.E. EASTMAN et al.: "Ellipsoidal mirror display analyzer system for electron energy and angular measurements"

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Description

The present invention relates to a charged particle energy analyzer such as for electron spectroscopy and ion spectroscopy, and, more particularly, to an energy analyzer of the type in which a low energy reflection filter and a high energy transmission filter are combined to measure the energy of charged particles generated from a sample.

Fig. 1 shows one of the conventional combinations of a low energy reflection filter and a high energy transmission filter provided in a conventional energy analyzer of the type comprising a spherical mirror and a spherical retarding grid as disclosed in U.S. Patent No. 3,749,926.

The geometry of Fig. 1 contains a low energy pass reflection filter and a high energy pass transmission filter. The low energy pass reflection filter selectively reflects charged particles having energy lower than a predetermined value. The high energy transmission filter selectively transmits electrons having energy higher than a predetermined value.

In Fig. 1, the low energy pass filter comprises a spherical mirror M having a curvature center O, and a spherical grid G_1, which are arranged to be concentric. The high energy transmission filter comprises the spherical grids G_2 and G_3 having the curvature center O. The mirror M has a potential V_1. The grid G_3 has another potential V_2. The grids G_1 and G_2 are at the same potential V_a and appropriate voltage are applied between the grid G_1, and the spherical mirror M, and the grids G_2 and G_3.

When charged particles are diverged from an injection points S adjacent the center O, the charged particles having energy lower than e $|V_1|$ are reflected by the mirror M, so that they are converged to a point adjacent the center O. They are diverged toward the high energy transmission filter. The charged particles having energy higher than e $|V_2|$ are transmitted through the grid G_3.

Finally, the charged particles having an energy higher than e $|V_2|$ and lower than e $|V_1|$ can be collected by a detector disposed behind the grid G_3. By selecting the potential of this grid, charged particles having a selected energy band width can be obtained.

However, since the low energy reflection filter and the high energy transmission filter must be disposed on opposite sides of the curvature center O, the energy analyzer must be large as such. Furthermore, a sample cannot be placed close to the point S, because there is not space to set an exciting source such as an X-ray source, an electron gun, near the sample, so it needs a complicated lens system to focus the charged particles from the excited surface of the sample to the point S.

Usually, the lens system reduces the transmission of the charged particles according to the particle energy.

Therefore, it is desired to provide a compact charged particle energy analyzer, which has no lens system.

Another conventional charged particle energy analyzer which has the features described in the pre-characterizing part of claim 1 is described by Eastman et al. in Nuclear Instruments & Methods, vol. 172 No. 1, 2, May 1980, pages 327—336, Amsterdam, NL. In this analyser, an elliposidal low energy reflection filter is employed, and the sample is disposed near one focus of the elliposoidal reflection filter.

Summary of the invention

It is an object of the invention to provide an improved charged particle energy analyzer of high sensitivity and compact construction.

According to the invention, this object is achieved by the features indicated in claim 1.

The charged particle analyzer according to the invention is a lensless device which provides a high luminosity and is adapted for electron spectroscopy for chemical analysis (ESCA), XPS, AES, and SIMS.

Further useful details of the device according to the invention are specified in the dependent claims.

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

Fig. 1 shows one of the conventional combinations of a low energy pass reflection filter and a high energy pass transmission filter for a conventional charged particles energy analyzer;

Fig. 2 shows a construction of a charged particle energy analyzer according to the present inventon;

Fig. 3 shows a graph representing characteristics of a filter means provided in the analyzer as shown in Fig. 2; and

Fig. 4 shows an enlarged view of a filter means for reflecting charged paticles according to the present invention.

Fig. 2 shows a construction of a charged particle energy analyzer applied for electron spectroscopy for chemical analysis (ESCA) according to the present invention. It is evident that the charged particle energy analyzer of Fig. 2 is adapted for XPS, AES, and SIMS.

The charged particle energy analyzer of Fig. 2 comprises an analyzer body 1, an inlet sleeve 2, an outlet sleeve 3 a first grid G_1, a second grid G_2, a third grid G_3, a fourth grid G_4, a fifth grid G_5, and a sixth grid G_6, a mirror 4 having a central axis, electrostatic shields 5, exhaustion ports 6, and an electron multiplier 7.

The above-constructed analyzer is shielded by a magnetic shield 20. An X-ray gun 8 with an X-ray filter 9 is provided adjacent the analyzer. A sample 10 is disposed under the inlet sleeve 2, being adjacent the X-ray gun 8. The analyzer, the X-ray gun 8, and the sample 10 are disposed within a vacuum chamber 11.

The X-ray gun 8 is provided for irradiating the sample 10 with a beam of characteristic X-rays, so that the charged particles, in this case, are emitted from the sample 10. The X-ray gun 8 may be replaced by an electron gun or an ion gun. The charged particles disperse toward the inlet sleeve 2. The outlet sleeve 3 receives the photoelectrons to be selected in accordance with the principle of the present inventions by the grids.

The mirror 4 has two focuses close to the center of the sample 10 and the center of the electron multiplier 7, which are symmetrical with respect to the central axis of the mirror 4. The analyzer body 1 covers the analyzer, wholly. The third grid G_3 is disposed in front of the mirror 4, so that the grid G_3 is parallel with the mirror 4. The third grid G_3 and the mirror 4 form a low energy reflection filter. The first grid G_1 is provided for preventing performance decrease resulting from static sample charging. The second grid G_2 is provided for making a retarding field. The first grid G_1 and the second grid G_2 are arranged at the inlet sleeve 2. These grids G_1 and G_2 are concentric with the center of the sample 10.

The fourth grid G_4, the fifth grid G_5 and the sixth grid G_6 are disposed at the outlet sleeve 3. The photo-electrons having high energy can pass through the fifth grid G_5. The sixth grid G_6 is provided to accelerate the photoelectrons. The fourth grid G_4, the fifth grid G_5 and the sixth grid G_6 are concentric with the center of the electron multiplier 7.

The ring 12 is provided for supporting the third grid G_3. The mirror 4 made of aluminium has a reflection surface having a central axis. On the surface of the mirror 4, carbon 14 is coated to give a surface having a better conductivity and to reduce emission of secondary electrons. The insulators 13 made of ceramic, whose surface is coated with a film having a high resistivity, are guard rings provided for preventing filed disturbance at the rand between the mirror 4 and the third grid G_3, the first grid G_1 and the second grid G_2, and the fourth grid G_4 and the fifth grid G_5.

The exhaustion ports 6 are provided, through which air can be evacuated from the analyzer body 1. The electrostatic shield 5 is provided to prevent the field effect through the ports from the outer part. The electron multiplier 7 is provided for detecting the photoelectrons and measuring their energy.

While the photoelectrons are emitted from the sample 10 in response to the irradiation of the X-rays characteristic of the X-ray gun 8, the emitted photoelectrons are received by the inlet sleeve 2. At this time, the respective parts have the following voltage.

The sample 10:
0 volt

The first grid G_1:
0 volt

The second grid G_2:
$-V_A$ volt

The third grid G_3:
$-V_A$ volt

The mirror 4:
$-V_A-(E_O'+\Delta E'/2)$ volt $(=V_1)$

The fourth grid G_4:
$-VA$ volt

The fifth grid G_5:
$-VA-(E_O-\Delta E/2)$ volt $(=V_2)$

The sixth grid G_6:
$[-VA-(E_O-\Delta E/2)+V_D]$ volt

where

ΔE=a half width volt,
V_D=100—200 volt

preferably

V_A=0—3000 volt
eEo (analyzer pass energy)=0—200 ev.
$eEo'=eEo\cdot\cos\theta$, $\Delta E'=\Delta E\cdot\cos\theta$

The sample 10 and the first grid G_1 are both grounded together with the inlet sleeve 2 at the interval between the sample 10 and the first grid G_1. As stated above, the second grid G_2 is provided for reflecting the photoelectrons having the energy lower than eV_A. The photoelectrons having the energy higher than eV_A can pass through the second grid G_2. The second grid G_2, the third grid G_3 and the fourth grid G_4 are all biased with the same voltage together with the analyzer body 1 surrounding these grids G_2, G_3 and G_4. Therefore, around the space surrounded by these grids G_2, G_3 and G_4, and the analyzer body 1, the same voltage is applied. The voltage V_A is to scan the energy.

The photoelectrons passing through the second grid G_2 go towards the third grid G_3 after straight passing through the above stated space. The mirror 4 having a central axis is provided for selectively reflecting the photoelectrons. Since the absolute value of the voltage at the mirror 4 is more than that of the voltage at the third grid G_3, namely,

$$-(V_A+Eo'+\Delta E'/2)$$

volt, the photoelectrons having the energy smaller than

$$e(V_A+EO+\Delta E/2)$$

are reflected by the mirror 4 and the photoelectrons having the energy larger than

$$e(V_A+Eo+\Delta E/2)$$

collide with the mirror 4 to thereby consume the energy. The analyser pass energy Eo is referred to pass energy of the photoelectrons in the analyzer.

Since the mirror 4 has two focuses close to the center of the sample 10 and the center of the electron multiplier 7, the photoelectrons reflected by the mirror 4 are directed straight toward the center of the outlet sleeve 3. The photoelectrons reflected by the mirror 4 can pass through the fourth grids G_4 having the voltage of $-V_A$. The fourth and fifth grid G_4 and G_5 are provided for selectively transmitting the photoelectrons as another high energy transmission filter. Therefore, the photoelectrons having an energy smaller than

$$e(V_A+Eo-\Delta E/2)$$

are reflected by the fifth grid G_5 and the photoelectrons having an energy larger than

$$e(V_A+Eo-\Delta E/2)$$

pass the fifth grid G_5. The voltage V_D applied between the fifth grid G_5 and the sixth grid G_6 is provided for accelerating the photoelectrons.

Thus, the photoelectrons are converged at the electron multiplier 7, the electrons having an energy larger than

$$e(V_A+Eo-\Delta E/2)$$

as selected by the fifth grid G_5 and smaller than

$$e(V_A+Eo+\Delta E/2)$$

as selected by the mirror 4. Namely, the electron multiplier detects the electrons having the band energy $e \cdot \Delta E$.

Fig. 3 shows a graph representing the voltages applied to the grids and the mirror 4 and the filter characteristic according to the present invention. With the help of the low energy reflection filter provided by the third grid G_3 and the mirror 4 and the high energy trnasmission filter provided by the fourth and fifth grids G_4 and G_5, the photoelectrons having an energy in a half width of the $e \cdot \Delta E$ can be selected which are detected by the electron multiplier 7.

In accordance with the above principle, the energy analysis is carried out by changing the value of V_A to be applied to the second, third, and fourth grids G_2, G_3 and G_4 while the voltages of the second, third and fourth grids G_2, G_3 and G_4 are made identical, and the voltage differences between the grids G_2, G_3, G_4 and the mirror 4, the third grid G_3, the fifth grid G_5 are constant.

The electron image of the sample 10 is formed on the electron multiplier 7. The photoelectrons passed through the fifth grid G_5 are so slow, as to be zero electron volt. The sixth grid G_6 is provided for accelerating the photoelectron passing through the fifth grid G_5.

To observe the sample image of the photoelectrons selected in accordance with the above filtering operation, the sixth grid G_6 is needed between the fifth grid G_5 and the electron multiplier 7 for obtaining the good image, because the orbits of the electrons having very low energy are easily disturbed by the undesired outer electrostatic and magnetic fields. Usually, the detector to obtain the information of the image is a position sensitive one such as a channel plate or a fluorecent screen followed by a video camera.

The mirror 4 may be spherical when the distance between the sample 10 and the multiplier 7 is small enough as compared with the distance between the mirror surface and the sample 10, and the distance between the mirror surface and the multiplier 7.

Such a spherical mirror is disposed at a central point between the optical distance between the sample 10 and the multiplier 7.

Fig. 4 shows an enlarged view of a filter means such as the third grid G_3 and the mirror 4. It is now described that strictly speaking, the principal ray in the analyser in Fig. 2 is reflected by the mirror 4 as shown in Fig. 4. Before the photoelectrons pass through the third grid G_3, they run straight. After the photoelectrons pass through the third grid G_3, they run showing a parabola trace to thereby be reflected by the mirror 4 and be emitted out of the third grid G_3.

When the distance between the mirror 4 and the third grid G_3 is d, a virtual reflection surface is a spheroid surface separated at the distance d from the mirror 4. Therefore, the focuses of the center of the mirror 4 and the detector 7 are not the focus of the mirror 4, but one of a spheroid surface 4'.

As stated above, in accordance with the present invention, a mirror having a central axis is provided which has two complex focuses. On the two complex focuses, the sample and the electron multiplier are disposed. Therefore, the photoelectrons irradiated from the sample are introduced directly into the analyzer. In addition, the sample, the X-ray gun, and the electron multiplier are disposed outside the analyzer, so that the photoelectrons in the analyser are not prevented from raying. The photoelectrons emitted from the sample with wide solid angles are not lost.

Therefore, the system of the present invention provides high sensitivity concerning the photoelectrons as compared with the system of Fig. 1. Since the energy analyzing elements are gathered at the side of the curve surface of the reflected mirror, the size of the system of Fig. 2 can be half that of the system of Fig. 1.

The advantages of the present invention are summarized as follows:

1. No lens system for focusing the charged particles emitted from the sample is required. The gun is positioned only one side of the analyzer. A mirror having a central axis is used. Therefore, high sensitivity of the analyzer is attained with a compact system.

2. The detector is positioned at the image point of the sample. Therefore, a position sensitive analysis can be performed.

Claims

1. A charged particle energy analyzer comprising means (8) for generating radiation or charged particles which impinge on the surface of a sample (10) for emitting charged particles from said sample, a low energy reflection filter comprising a reflector (4) having a central axis and a grid means (G_3) located in front of said reflector with respect to the sample (10) for selectively reflecting the charged particles emitted by the sample and having an energy lower than a first value, detector means (7) for detecting the charged particles that have been reflected, and a high energy transmission filter (G_5) for selectively transmitting to the detector (7) the charged particles having an energy higher than a second value, characterized in that the sample (10) and the detector (7) are located at points which are conjugated with respect to the reflector and symmetrical with respect to the central axis thereof.

2. The analyzer according to claim 1, characterized in that the reflector (4) is a spherical mirror.

3. The analyzer according to claim 1, characterized by additional grid means (G_6) disposed between the high energy transmission filter (G_5) and the detector (7), the additional grid means (G_6) accelerating the charged particles.

4. The analyzer according to claim 1, characterized in that the detector (7) is a position sensitive detector for obtaining information of the image of the sample.

5. The analyzer according to claim 1, characterized in that the high energy transmission filter comprises first filter means (G_2) and second filter means (G_5), the first filter means (G_2) being disposed between the sample (10) and the reflector (4), and the second filter means (G_5) being disposed between the reflector (4) and the detector (7).

Patentansprüche

1. Energieanalysator für geladene Teilchen, mit Mitteln (8) zur Erzeugung von Strahlung oder geladenen Teilchen, die auf die Oberfläche einer Probe (10) auftreffen, so daß geladene Teilchen von der Probe emittiert werden, einem Niederenergie-Reflexionsfilter mit einem eine Mittelachse aufweisenden Reflektor (4) und einem in Bezug auf die Probe (10) vor dem Reflektor angeordneten Gitter (G_3), zur selektiven Reflexion der von der Probe emittierten geladenen Teilchen, die eine Energie unterhalb eines ersten Wertes aufweisen, Detektormitteln (7) zum Nachweis der reflektierten geladenen Teilchen und einem Hochenergie-Transmissionsfilter (G_5), der selektiv die geladenen Teilchen, deren Energie höher ist als ein zweiter Wert, zu dem Detektor (7) durchläßt, dadurch gekennzeichnet, daß die Probe (10) und der Detektor (7) an konjugierten Punkten in Bezug auf den Reflektor und symmetrisch zu dessen Mittelachse angeordnet sind.

2. Energieanalysator nach Anspruch 1, dadurch gekennzeichnet, daß der Reflektor (4) ein sphärischer Spiegel ist.

3. Energieanalysator nach Anspruch 1, gekennzeichnet durch ein zwischen dem Hochenergie-Transmissionsfilter (G_5) und dem Detektor (7) angeordnetes zusätzliches Gitter (G_6) zur Beschleunigung der geladenen Teilchen.

4. Energieanalysator nach Anspruch 1, dadurch gekennzeichnet, daß der Detektor (7) ein positionsempfindlicher Detektor zur Erfassung von Informationen über das Bild der Probe ist.

5. Energieanalysator nach Anspruch 1, dadurch gekennzeichnet, daß der Hochenergie-Transmissionsfilter eine erste Filtereinrichtung (G_2) und eine zweite Filtereinrichtung (G_5) umfaßt und daß die erste Filtereinrichtung (G_2) zwischen der Probe (10) und dem Reflektor (4) angeordnet ist, während die zweite Filtereinrichtung (G_5) zwischen dem Reflektor (4) und dem Detektor (7) angeordnet ist.

Revendications

1. Analyseur d'énergie de particules chargées, comprenant un moyen (8) pour produire un rayonnement de particules chargées qui frappe la surface d'un échantillon (10) pour émettre des particules chargées depuis cet échantillon, un filtre de réflexion des basses énergies comportant un réflecteur (4) ayant un axe central et un moyen formant grille (G_3) situé en face dudit réflecteur par rapport à l'échantillon (10) pour réfléchir sélectivement les particules chargées émises par l'échantillon et ayant une énergie inférieure à une première valeur, un moyen formant détecteur (7) pour détecter les particules chargées qui ont été réfléchies, et un filtre (G_5) de transmission des hautes énergies pour transmettre sélectivement au détecteur (7) les particules chargées ayant une énergie supérieure à une seconde valeur, caractérisé en ce que l'échantillon (10) et le détecteur (7) se trouvent en des points conjugués par rapport au réflecteur et symétriques par rapport à l'axe central de celui-ci.

2. Analyseur selon la revendication 1, caractérisé en ce que le réflecteur (4) est un miroir sphérique.

3. Analyseur selon la revendication 1, caractérisé par une grille supplémentaire (G_6) disposée entre le filtre de transmission des hautes énergies (G_5) et le détecteur (7), la grille supplémentaire (G_6) accélérant les particules chargées.

4. Analyseur selon la revendication 1, caractérisé en ce que le détecteur (7) est un détecteur sensible aux positions pour obtenir des informations sur l'image de l'échantillon.

5. Analyseur selon la revendication 1, caractérisée en ce que le filtre de transmission des hautes énergies comprend un premier moyen de filtrage (G_2) et un second moyen de filtrage (G_5), le premier moyen de filtrage (G_2) étant disposé entre l'échantillon (10) et le réflecteur (4), et le second moyen de filtrage (G_5) étant disposé entre le réflecteur (4) et le détecteur (7).

FiG 1

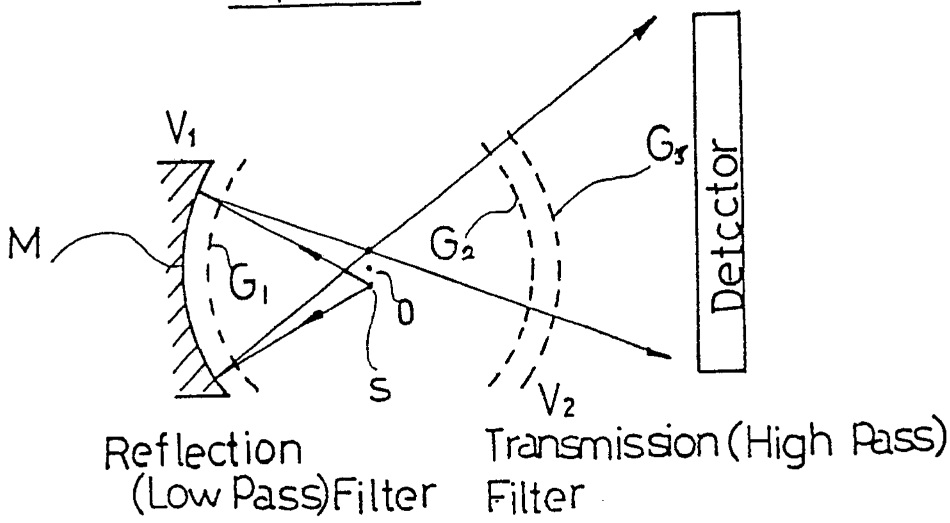


FiG 3

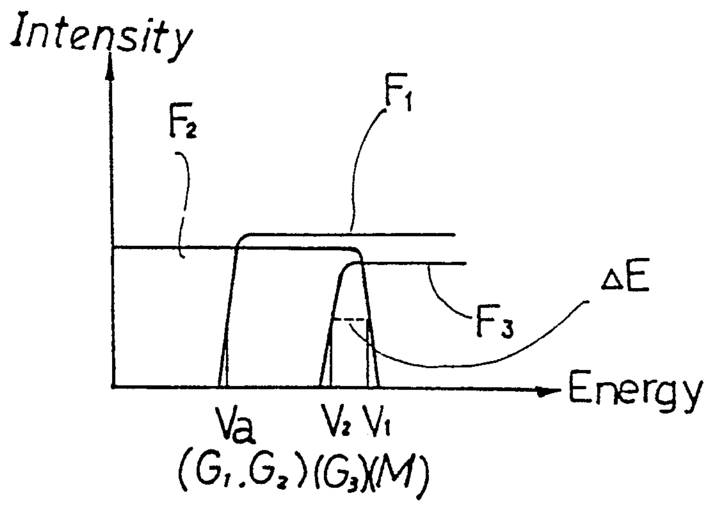


FiG 4

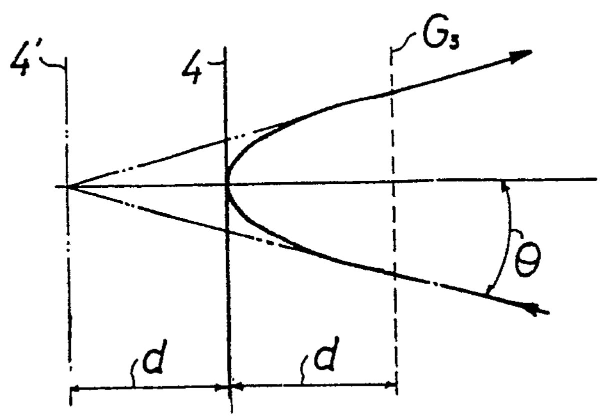
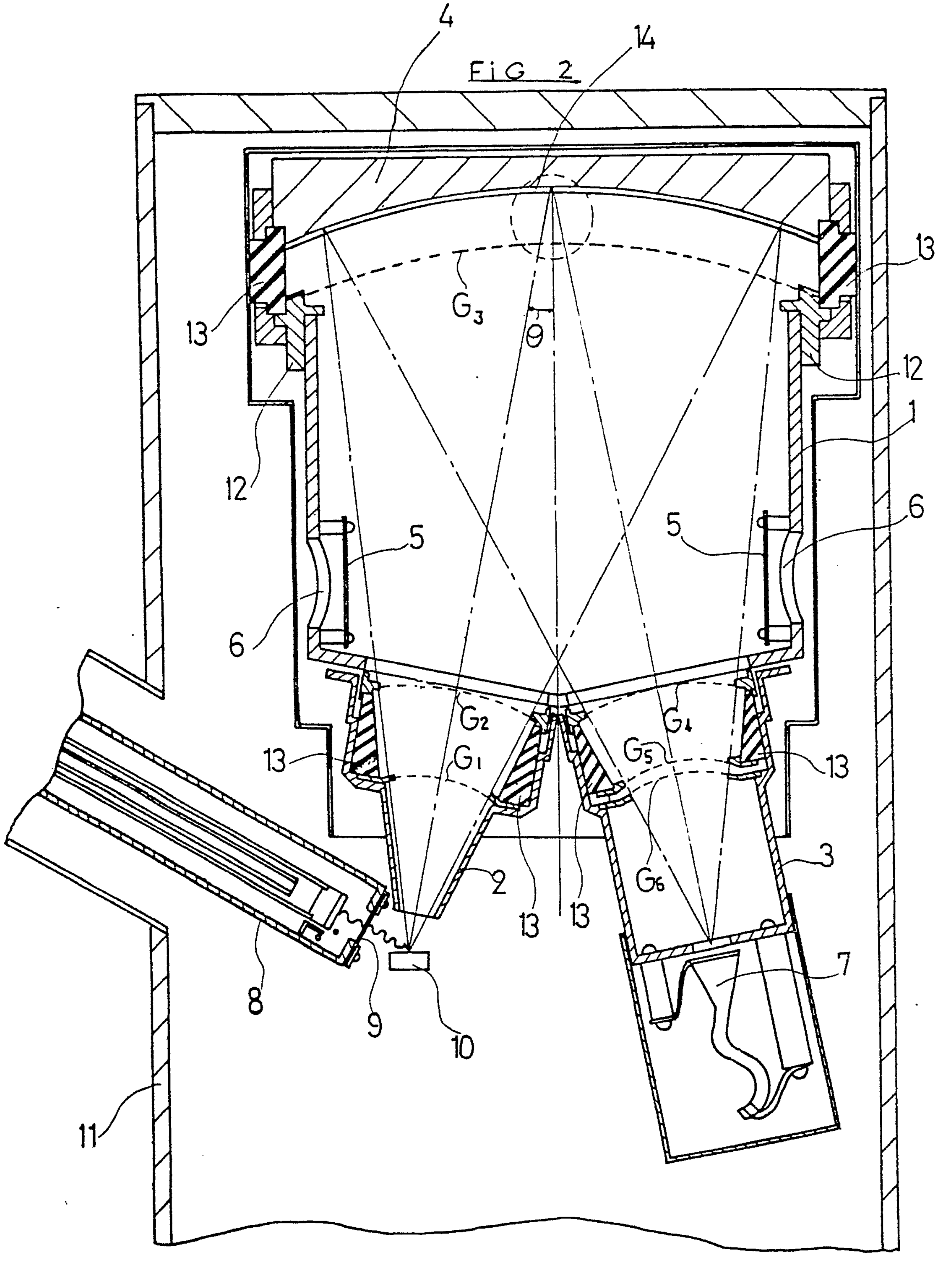


FiG 2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