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

(57) A charged particle energy analyzer comprises a source (8) for generating radiation to be incident on a sample (10) so as to emit charged particles from the sample, a low energy pass reflection filter for selectively reflecting the charged particles having energy lower than a first value, a high energy pass transmission filter (G^5) for selectively transmitting the charged particles having energy lower than a second value. The low energy pass filter comprises a reflector (4) and a first grid (G^3). The reflector (4) is a spheroid mirror having two complex focuses, in a symmetrical manner, at which the sample and a detector are disposed. The detector (7) detects the selected charged particles.

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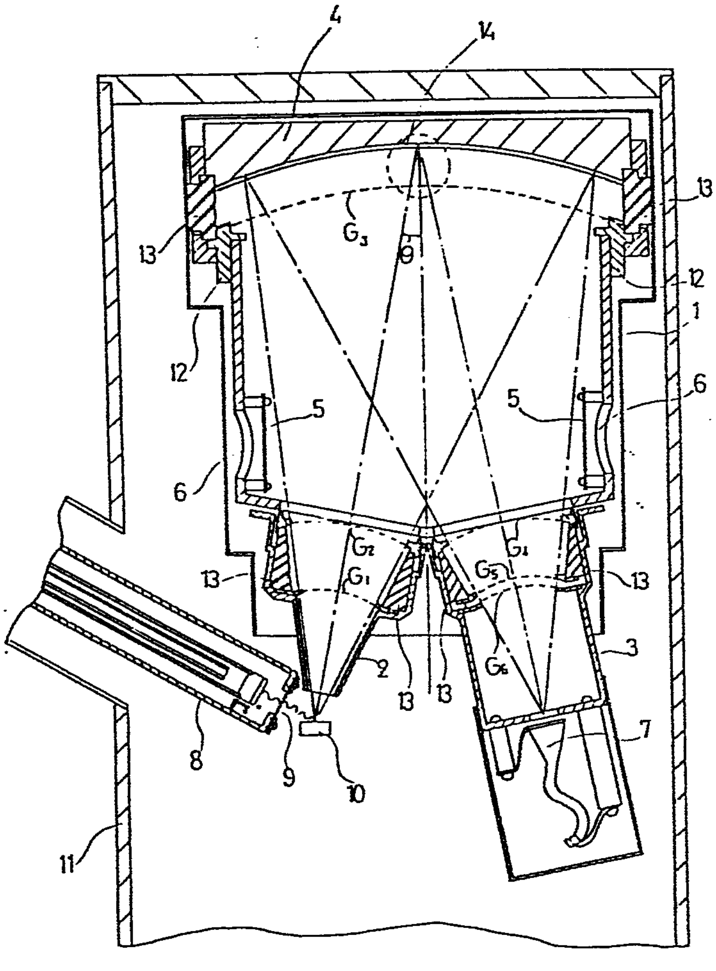
FIG. 2



TITLE OF THE INVENTION

CHARGED PARTICLE ENERGY ANALYZER

BACKGROUND OF THE INVENTION

The present invention relates to an charged particle energy analyzer for such as electron spectroscopy and ion spectroscopy, and , more particularly, to an energy analyzer of the type in which a low energy pass reflection filter and a high energy pass 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 pass reflection filter and a high energy pass transmission filter provided for a conventional energy analyzer of a spherical mirror-spherical grid retarding potential type, as disclosed in U.S. Patent No. 3,749,926 granted to Jerald D. Lee, issued on July 31, 1973, entitled "CHARGED PARTICLE ENERGY ANALYSIS".

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 is featured by selectively reflecting charged particles having energy lower than a predetermined value. The high energy pass transmission filter is featured by selectively transmitting electrons having energy higher than a predetermined value.

In FIG. 1, the low energy pass filter is provided with a spherical mirror M having a curvature center O, and a spherical grid G_1, which are arranged as a concentric circle. The high energy pass transmission filter is provided with double spherical grids G_2 and G_3 having the curvature center O. The mirror M has a potential of V_1. The grid G_3 has another potential of V_2. The grids G_1 and G_2 are placed in the same potential of 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 an injection point is disposed on a point S adjacent the center O from which charged particles are diverged, 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 pass transmission. The charged particles having energy higher than $e|V_2|$ are transmitted through the grid G_3.

Finally, the charged particles having the energy higher than $e|V_2|$ and lower than $e|V_1|$ can be collected by a detector disposed behind the grid G_3. The charged particles diverged from the point S have energy of subtracting a potential applied to another grid from the energy of charged particles emitted from a sample, using a retarding field. By selecting the potential of this grid, the charged particles having a selected energy band width can be obtained.

However, since the low energy pass reflection filter and the high energy pass transmission filter must be disposed across 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 no 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 sany surface 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.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved charged particle energy analyzer of high sensitivity.

It is another object of the present invention to provide a compact, lensless and high luminosity charged particle energy analyzer comprising the energy analyzing elements disposed on one side of a curvature center of a reflective mirror.

It is a further object of the present invention to provide an improved arrangement of a charged particle energy analyzer in which a detector can be disposed at a focus position.

It is a further object of the present invention to provide an improved arrangement of a charged particle energy analyzer in which an exciting source element such as an X-ray gun, an electron gun and an ion gun is positioned at one side of the analyzer.

It is a further object of the present invention to provide an improved charged particle energy analyzer in which a spheroid mirror is provided for reflecting charged charticles.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a charged particle energy analyzer comprises a source or a gun for generating radiation to be incident on a sample so as to emit charged particles from the sample, a low energy pass reflection filter means for selectively reflecting the charged particles having energy lower than a first value, the low energy pass reflection filter means comprising a reflector and a first grid means, and a high energy pass transmission filter means for selectively transmitting the charged particles having energy higher than a second value.

The reflector has two complex focuses, in a symmetric relation, at which the sample and a detector means are disposed. The detector detects the charged particles selected.

The charged particle energy analyzer is adapted for electron spectroscopy for chemical analysis (ESCA), XPS, AES, and SIMS.

BRIEF DESCRIPTION OF THE DRAWINGS

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 invention;

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 particles according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

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 may be 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, and inlet sleeve 2, an outlet sleeve 3, a first grid G1, a second grid G2, a third grid G3, a fourth grid G_4, a fifth grid G_5, and a sixth grid G_6, a spheroid mirror 4, electrostatic shields 5, exhaustion ports 6, and an electron multiplier 7.

The above-constructed analyzer is shielded by a magnetic shield 8. 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 8, and the sample 10 are disposed within a vacuum chamber 11 for vacuum pumping.

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

The spheroid mirror 4 has two focuses close to the central surface of the sample 10 and the central surface of the electron multiplier 7, which are symmetrical as 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 spheroid mirror 4, so that the grid G_3 is parallel with the mirror 4. The third grid G_3 and the spheroid mirror 4 form a low energy pass reflection filter. The first grid G_1 is provided for preventing performance decrease 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 from aluminum has a spheroidal reflection surface. On the surface of the mirror 4, carbon 14 is coated to have better conductivity and to reduce secondary electrons. The insulator 13 made from ceramic whose surface is coated with film having high resistivity is a guard ring provided for preventing field disturbance at the ends between the spheroid 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 easily 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 to measure the energy of them.

While the photoelectrons are emitted from the sample 10 in response to the irradiation of the characteristic X-rays by the X-ray gun 8, the irradiated 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 spheroid mirror 4: $-V_A-(E_0' + \frac{\Delta E'}{2})$ volt $(=V_1)$
The fourth grid G_4: $-VA$ volt
The fifth grid G_5: $-VA-(E_0- \frac{\Delta E}{2})$ volt $(=V_2)$
The sixth grid G_6: $[-VA-(E_0- \frac{\Delta E}{2}) + V_D]$ 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 transmitting the second grid G_2 go towards the third grid G_3 after straight passing through the above-stated space. The spheroid mirror 4 is provided for selectively reflecting the photoelectrons. Since the absolute value of the voltage at the spheroid mirror 4 is more than that of the voltage at the third grid G_3, namely, $-(V_A + Eo' + \frac{\Delta E'}{2})$ volt, the photoelectrons having the energy smaller than $e(V_A+Eo+\frac{\Delta E}{2})$ are reflected by the mirror 4 and the photoelectrons having the energy larger than $e(V_A+Eo+\frac{\Delta E}{2})$ collide with the mirror 4 to thereby consume the energy. The analyzer pass energy Eo is referred to pass energy of the photoelectrons in the analyzer.

Since the spheroid 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 spheroid mirror 4 are directed straight toward the center of the outlet sleeve 3. The photoelectrons reflected by the spheroid mirror 4 can transmit the fourth grid G_4 having the voltage of $-V_A$. The fifth grid G_5 is provided for selectively transmitting the photoelectrons as the high energy pass transmission filter. Therefore, the photoelectrons having the energy smaller than $e(V_A+Eo-\frac{\Delta E}{2})$ are reflected by the fifth grid G_5 and the photoelectrons having the energy larger than $e(V_A+Eo-\frac{\Delta E}{2})$ pass the fifth grid G_5. The sixth grid G_6 applied the voltage V_D is provided for accelerating the photoelectrons.

Thus, the photoelectrons are converged at the electron multiplier 7, the electrons having the energy larger than $e(V_A+Eo-\frac{\Delta E}{2})$ as selected by the fifth grid G_5 and smaller than $e(V_A+Eo+\frac{\Delta E}{2})$ as selected by the spheroid 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 spheroid mirror 4 and the filter characteristic according to the present invention. With the help of the low energy pass reflection provided by the third grid G_3 and the spheroid mirror 4 and the high energy pass transmission filter provided by the fifth grid G_5, the photoelectrons having the energy in a half width of $e \cdot \Delta E$ can be selected which are detected by the electron multiplier 7.

In accordance with the above principle, the energy analysis are 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 difference between the grids G_2, G_3, G_4 and the spheroid mirror 4, the third grid G_3, the fifth grid G_5 is constant.

On the position of the electron multiplier 7, the electron image of the sample 10 is made. The photoelectrons passed through the fifth grid G5 are so slow, as to be zero electron volt. The sixth grid G_6 is provided for accelerating the photoelectron pass through the fifth grid G_5.

To observe the 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 orbit of the electrons having very low energy are easily disturbed by the outer undesired electrostatic potential and magnetic field. Usually, the detector to obtain the information of the image is a position sensitive one such as a channel plate or the fluorescent screen followed by a video camera.

In the above preferred embodiment, the reflector is a spheroid mirror. However, it may be possible that a spherical mirror replaces the spheroid mirror 4 when the distance between the sample 10 and the multiplier 7 is enough small 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 spheroid mirror 4. It is now described that strictly speaking, the principal ray in the analyzer in FIG. 2 is reflected by the spheroid 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 spheroid mirror 4 and be emitted out of the third grid G_3.

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

As stated above, in accordance with the present invention, the spheroid mirror 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 analyzer are not prevented from raying. The photoelectrons irradiated 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 one side of the curve surface of the reflected mirror, the size of the system of FIG. 2 can be half of that of 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. The mirror having a spheroidal reflection surface 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, the position sensitive analysis can be performed.
3. Totally, the analyzer is highly sensitive and superior.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A charged particle energy analyzer characterized by:

a source means (8) for generating radiation to be incident on a sample (10) so as to emit charged particles from the sample;

a low energy pass reflection filter means for selectively reflecting the charged particles having energy lower than a first value, the low energy pass reflection filter means comprising a reflector (4) and first grid means (G_3),

the reflector (4) having two complex focuses, in a symmetric manner, at which the sample (10) and a detector means (7) are disposed, the detector means (7) detecting the charged particles, and

a high energy pass transmission filter means (G_5) for selectively transmitting the photoelectrons having energy higher than a second value.

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

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

4. The analyzer according to claim 1, characterized in that the source means (8), the low energy pass reflection filter means (4, G_3) and the high energy pass transmission filter means (G_5) are positioned at one side of a curvature center of the reflector (4).

FiG 1

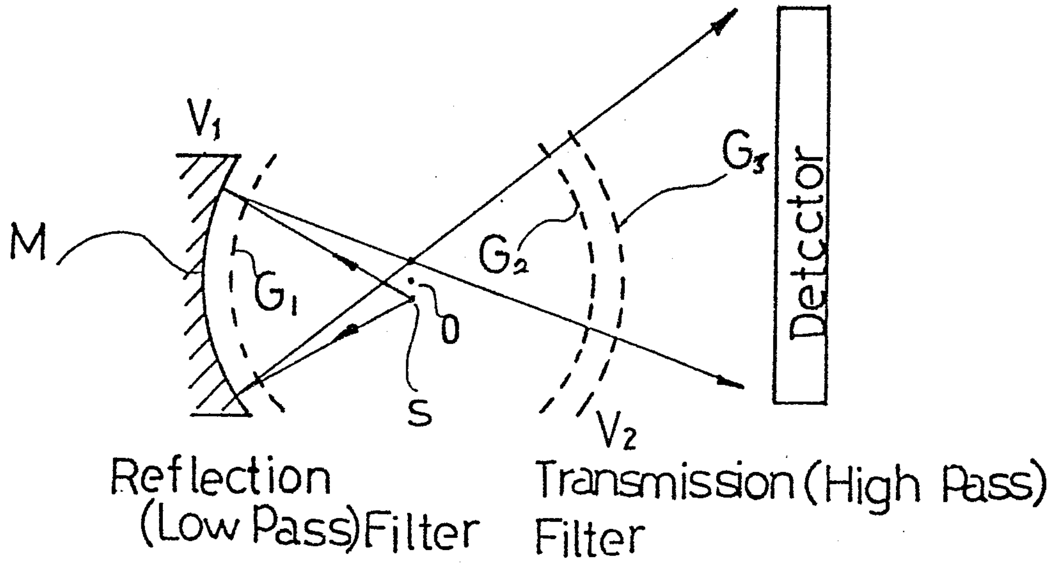


FiG 3

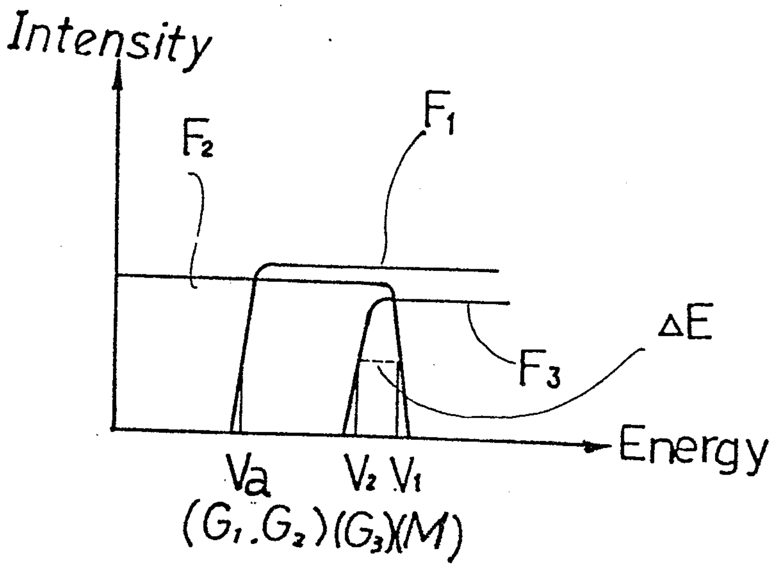


FiG 4

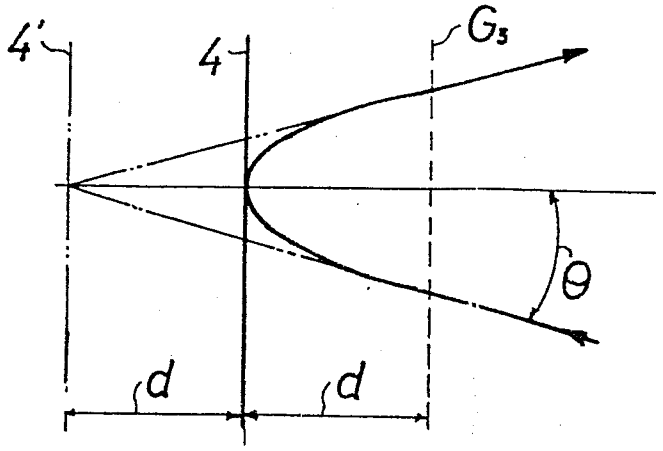
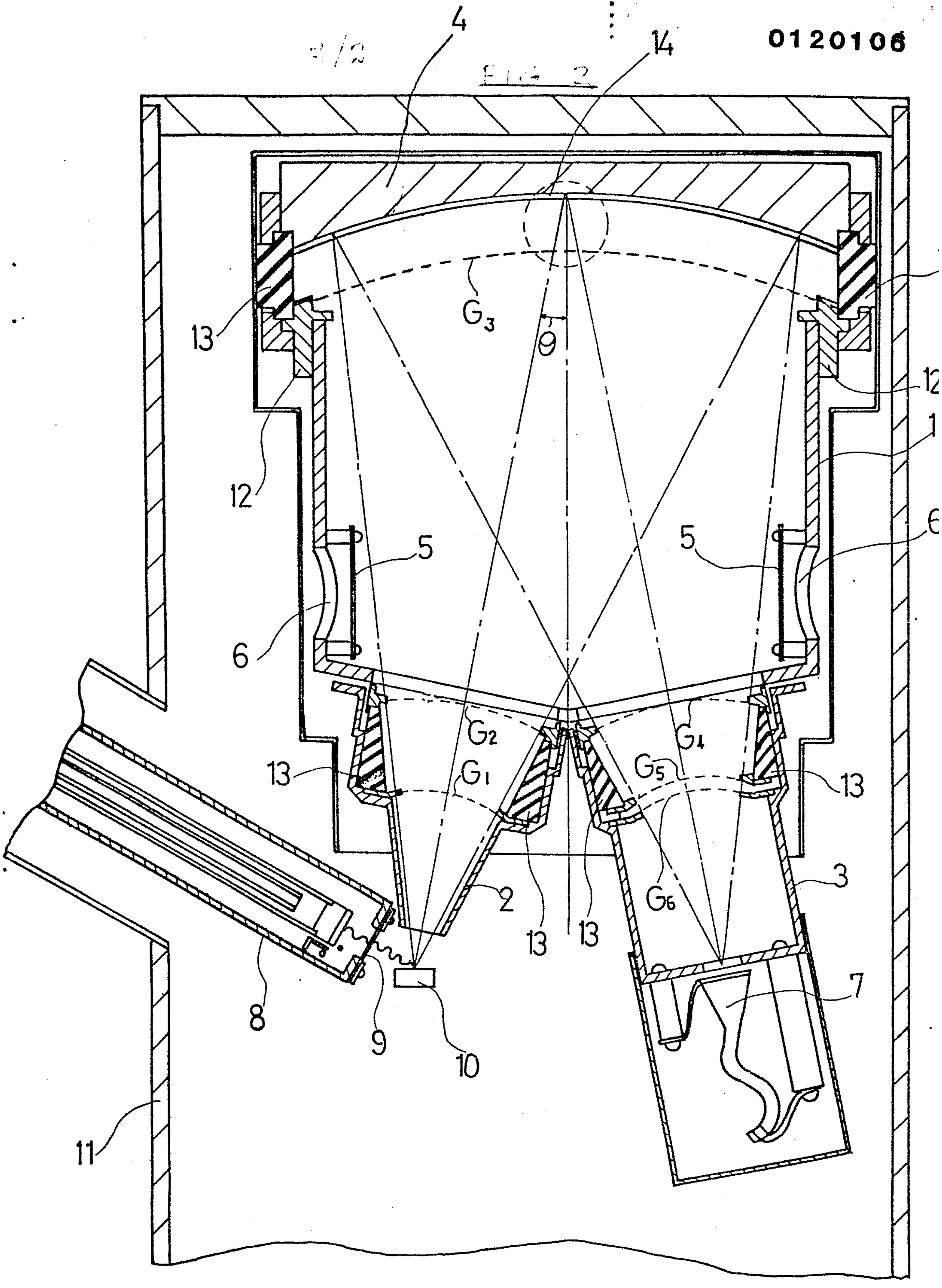


FIG 2



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EUROPEAN SEARCH REPORT

0120106
Application number

EP 83 10 2947

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	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" * Page 330, column 1, line 43 - column 2, line 5; lines 34-36; page 331, column 1, line 38 - column 2, line 2; figures 1-3,6 *	1,3,4	H 01 J 49/48

A	US-A-3 935 454 (J.D. LEE) * Claim 1; figure 1 *	1-3	

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

H 01 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30-11-1983	GALANTI M.

CATEGORY OF CITED DOCUMENTS

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