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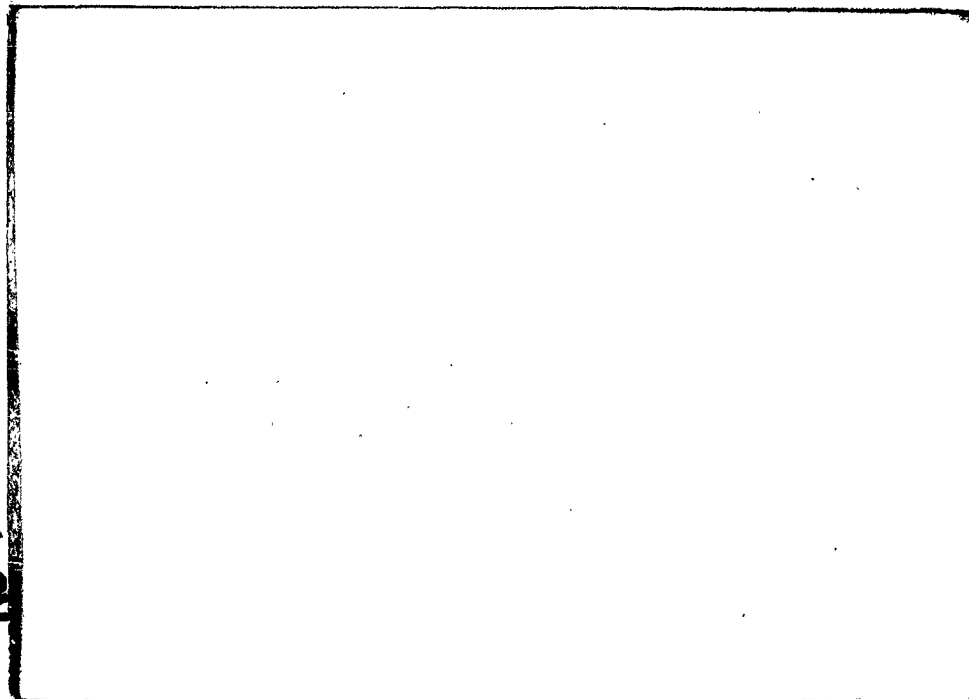
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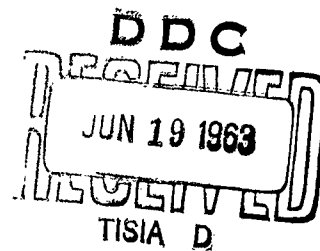
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DEPARTMENT OF PHYSICS
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TECHNICAL REPORT NO. 1

A VACUUM ULTRA-VIOLET SPECTROMETER

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A b s t r a c t

A grazing incidence vacuum spectrometer is described. It is based on a 2 m., 30,000 lines per inch, Siegbahn glass grating. Both plateholder and grating are hold on arms fastened to the axis of the Rowland circle. The wavelength range extends up to $2300 \text{ \AA}$. Instrumental considerations for obtaining high resolution in the short wavelength range are discussed.

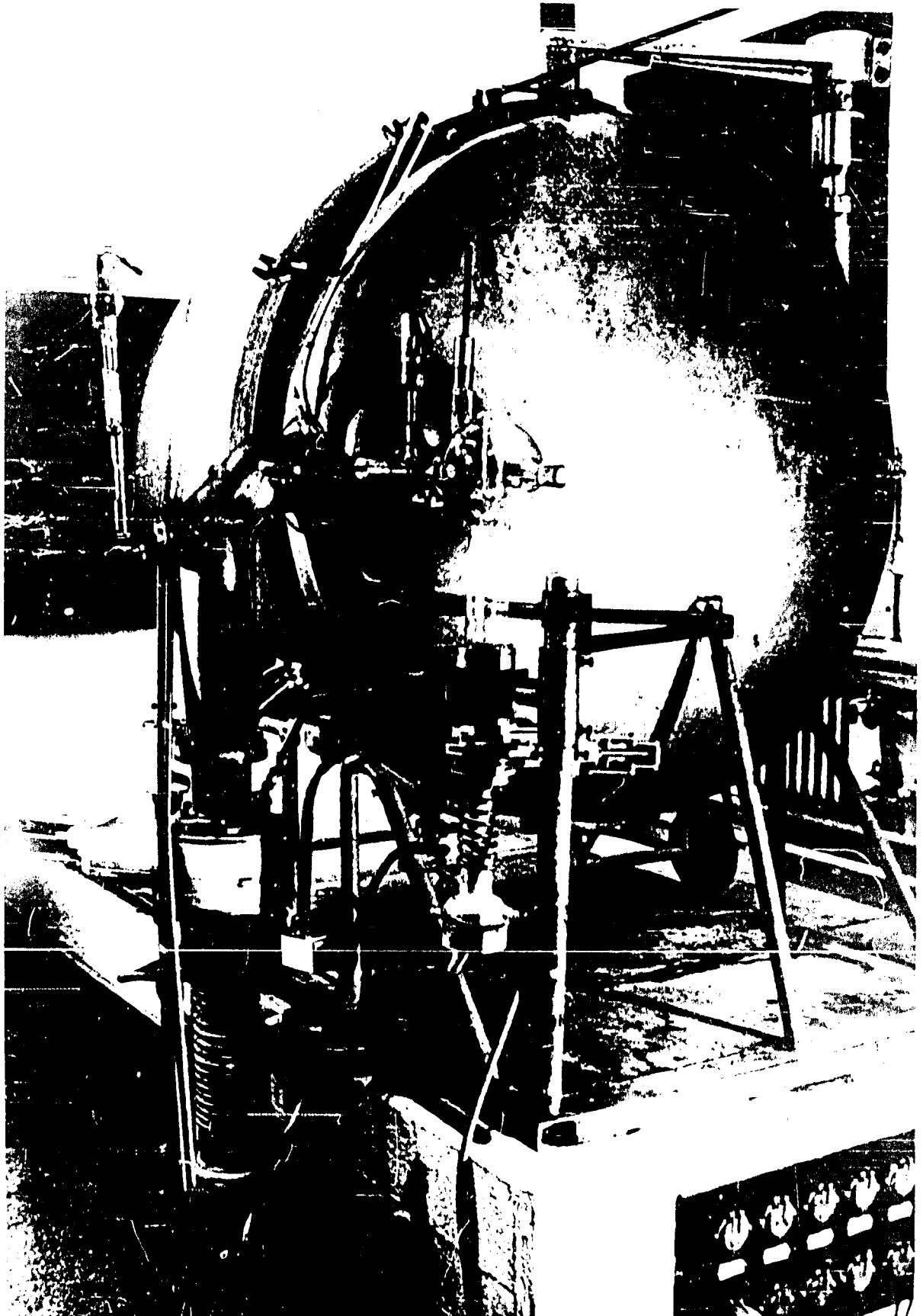


FIG. 4

I Introduction

The grazing incidence vacuum spectrometer described here is based on a grating of 2 m curvature, with 30,000 lines per inch. The spectrometer covers the wavelength up to 2300 Å. Spectra may be recorded on a photographic plate or by an electronic multiplier. An instrument of this type achieves higher resolution of short wavelength in its high order spectra than an instrument with a grating of greater radius of curvature, e.g., a 7 m curvature instrument, of the same instrumental dimensions. Also, e.g. absorption spectroscopy of gases, in the 30 to 500 Å range, is simplified by allowing comparison, under the same experimental conditions, of the absorption data with those in the range over 1000 Å. Thus, the wide range of the instrument is advantageous in a variety of problems.

II Description of the Spectrometer

a. General Description

The vacuum container of the spectrometer is made of two parts, the fixed part F and a removable lid L (Fig. 1). The centre of the Rowland circle lies on the vertical axis A defined by the rotating cone C. The female part of this cone supports at its lower end a horizontal arm H, to which the grating holder G and the slit system S (Fig. 2) are attached.

The plateholder P (or the multiplier) is attached to the male part of the cone C by means of a second horizontal arm I, allowing a movement of 90° .

b. The Container of the Spectrometer

The container of the spectrometer is made of welded 4 mm stainless steel plates, polished on the inside. It is a horizontal cylinder of 130 cm. diam., closed on both sides by spherical surfaces according to the A.S.M.E. code, resulting in an overall length of 130 cm. The two parts of this container are joined vacuumtight by an "O" ring O in a vertical plane at 40 cm distance from the end of the fixed part of the container. At each side a stainless steel rim R (at the fixed side holding the "O" ring) is supported by an iron ring of cross-section 5 x 5 cm. The spectrometer is opened by horizontal movement of the lid L on wheels W along the track T. When closing for vacuum pumping, the lid L has to be tightened to the fixed part F of the container by three screws M. There are three openings in the fixed part of the body, each provided with a sleeve containing an "O" ring, and screw holes for tightening. X holds the spectrometer axis C. Y is the opening for the slit system, and holds the spark-chamber or the soft X-ray tube. The opening Z at the end of a 40 cm long tube leads to a 4 inch diffusion pump. This tube contains a liquid air trap made of this stainless steel tubing.

c. The Grating Holder and the Slit System

The hollow horizontal arm H extending from the male part of the cone C holds near its end an adjustable sleeve U. This sleeve supports the slit system S and the grating holder G. The grating holder is built so that the grating is adjustable about the three perpendicular axes crossing the central point of the surface of the grating, and is also moveable along 3 perpendicular directions. The distance of the main slit MS (Fig. 3) from the centre of the grating, for a grazing incidence angle of 5 degrees and a Rowland circle of 1 m radius, is about 17.5 cm. A second slit, SS, 3 cm from the centre of the grating, is incorporated with the main slit into a slit system, held together by a 12 mm. diam. stainless steel tube, about 14.5 cm. length. This second slit is interchangeable with similar slits of various breadths. The breadth of the second slit determines the width of the area of the grating participating in reflection. This width may therefore be changed according to the "optimal width"¹⁾ correlated to the wavelength range investigated. The

1) J.E. Mack, J.R. Stehn and Bengt Edlén, J.O.S.A. 22, 245 (1932)

opening Y in the body of the spectrometer leaves room for changing the grazing incidence angle from 1° to 10° . This change can be performed by rotating the slit system about an axis through the central point of the grating, parallel to the main axis of the instrument. Another axis allows

the slit system to be adjusted to point to the centre of the grating.

The distance of the grating from the main axis A and the angular position of the grating are adjustable up to a linear accuracy of ± 0.01 mm and up to an angular accuracy of one minute.

d. The Plateholder

The plateholder P is essentially a stainless steel frame, ground to a curvature of 1 m, built to hold a 10 x 2 inch thin glass plate. It is mounted on the moveable arm I extending from the axle C. The plateholder may be elevated, in a direction parallel to the axis, so that 7 different exposures may be taken on the film, each about 5 mm wide. Also, the plateholder may be moved on the Rowland circle from a position adjoining the grating to a position making an angle of about 90 degrees with the grating (Fig. 1, view from above). Both movements may be put into operation from outside the body of the spectrometer, by rotating the axle C at its protruding upper end. The motion of elevation is made with the help of a ratched lever, which is acting on the dove tail D (Fig. 2) supporting the plateholder. This lever is put into action by swinging the plateholder arm against a fixed stop at its end position. Thus different exposures at different wavelength ranges may be made without breaking the vacuum in the instrument. When such a multiple exposure is **desired**, a suitable mask is mounted in front of the filmholder.

The plate is pressed by screws to the frame, at both ends, through a bronze plate having the same dimensions as the glass plate. This arrangement has been found sufficient in aligning the plate onto the ground surface of the plateholder. A suitable multiplier may be mounted on the moving arm in place of the plateholder.

The plateholder is adjustable to lie on the Rowland circle within 0.01 mm. Also, it is adjustable to be parallel to the main axis in its short edge, within one min. of a degree.

e. The Soft X-ray Tube and the Spark Chamber

The soft X-ray tube SX or the spark chamber (Figs. 3 and 4) is made of a 2 lt Pyrex flask with six openings. A tube E leads to a 2 inch diffusion pump, and a ground glass flange FL connects the tube to the opening Y of the spectrometer through an adjustable bellow system AB (Fig. 4). Both connections are made by "O" rings, instead of using in the usual way piece of wax for this purpose. The 4 other openings are female ground cones FC, which hold the electrodes, and the ionization gauge for vacuum measurement. In case of soft X-rays the electrodes are replaced by a cathode - usually a tungsten filament set in a Pyrex glass holder, an anode which is cooled on the cone and near the surface of emission, and an evaporator, also set in a Pyrex glass "pinch". Two liquid air traps LA are cooling the space near the anode and the cathode,

and the space above the diffusion pumps. This tube is similar to the one designed by H.W.B. Skinner²⁾. The slit system is protruding through

2) H.W.B. Skinner; Phil. Trans. Roy. Soc. A239 , 95 (1940)

the opening Y into the glass tube (Fig. 3). It is connected through an elastic bellow EB to the opening, ensuring that the vacuum gradient from the spark-chamber to the spectrometer goes through the slit system, and not through the whole area of the opening Y.

f. The Vacuum System

A 450 l/min single stage rotary vacuum pump ("Speedivac" LSC450) is used as forepump. A 300 lt/sec 4 inch diffusion pump (Type MCF-300) is used on the spectrometer. The spectrometer serves as a forevacuum container to the tube, which is pumped additionally by a 60 l/sec 2 inch diffusion pump (Type MCF-60). Two gate valves (Type VST) make isolation of the diffusion pumps possible. A system of valves allow separate fore-pumping of diffusion pumps and of spectrometer, making it possible to keep the diffusion pumps hot when letting air into the spectrometer. The vacuum obtained after 45 min. pumping, without liquid air, is about 10^{-5} mm Hg in the spectrometer and about 10^{-6} mm Hg in the tube. With liquid air and degassing by some sparks, a vacuum of 10^{-7} mm Hg is obtained in the tube.

g. The Grating

A Siegbahn glass grating of 2 m curvature and about 30,000 grooves per inch, made by Prof. M. Siegbahn, is used. Its dimensions are 5 cm. diam., and 8 mm. thickness. The ruled area is 4 x 1 cm. It has the anomaly that it does not reflect, in one grazing incidence direction, in the second order. This is true regardless to wavelength or angle. In most problems, however, this anomaly helps in identification of lines and diminishes "overlap" problems. The grating does not reflect very well above 500 Å. Thus most of the lines seen in the long wavelength region, at grazing incidence of 5 degrees, are higher orders of short wave lengths. For instance, the line O V at 192.906 Å is easily observed in the eleventh order.

III Discussion

The purpose of the described construction was mainly to obtain a spectrometer of high resolution for the wavelength range up to 250 Å. While the first order spectra are obtainable with a considerable resolution, enabling the determination of wavelengths up to an accuracy better than one hundredth of one Angström, there are cases where a much better resolution is needed. Thus the highly ionized elements of the iron group show already very dense spectra in this region in their ground state transitions, e.g., the eighth, ninth and tenth spectra of Ni, and the seventh, eighth, ninth and tenth spectra of Cu. If necessary, therefore,

exposures may be taken in a higher order, with a considerable rise in the resolving power. The advantage of using higher order spectra instead of gratings of greater radius of curvature is demonstrated in Fig. 5 for gratings of 1,000 lines per mm, with radii of curvature of 2 m and 7 m. Theoretical resolution, calculated according to Mack, Stehn and Edlén are compared in the different orders for 100 Å and 200 Å, with distance from centre of grating as abscissa. It shows that one may easily obtain with high order spectra a resolution which is considerably higher than the resolution obtained with similar gratings of a greater radius of curvature in low order spectra, when using instruments of the same dimensions. The instrument described is of medium size. The resolution which may be obtained with an e.g. 7 m curvature grating in an instrument of the same size is considerably smaller. Thus, at a distance of 120 cm from the centre of a 2 m curvature grating, and with 1000 lines per mm on the grating, a resolution of 450000 is obtained in the 20th order of 100 Å and of about 270000 in the 10th order of 200 Å. With a similar grating, having however a radius of curvature of 7 m, a resolution of about 110,000 only is obtained in the second order of 100 Å, and about 75,000 in the first order of 200 Å, at about the same distance of 120 cm from the centre of the grating.

The properties of our grating are described above (§ II g).

Overlap problems may be simplified easily in high orders by comparing two adjoining orders of the spectrum, and excluding lines not appearing in

both orders. The high demands on resolution call for a accuracy and rigidity in the instrument. This is ensured by the fact that all optical parts of the spectrometer, namely the filmholder, the grating and the slit system are supported by the cone C and therefore are connected rigidly to one point on the container - the opening X. Any change of dimension of the container, e.g., by outside pressure during evacuation will thus have no effect on the geometry of the spectrometer.

The filmholder is a light part, easily adjustable to its correct position. This is in contrast to the conventional heavy instruments of similar resolving power, where mechanical parts of considerable sizes must be ruggedly constructed and machined to precise tolerances.

Multiple exposures are possible on the same plate. This is made possible, as described above, by moving the plateholder in its own plane to different elevations. A mask in front of the plate allows radiation of line length of several mm to pass on to the plate. In some similar instruments this mask is moved and the film is kept in a fixed position. The method used here, however, ensures that the different expositions on the plate "see" the source of radiation from the same fixed angle. Comparison between spectra, not seeing the source of radiation from the same angle, is very often unreliable. We found this true both for spark spectra and for soft X-ray spectra.

Finally, the range of the instrument is useful in the rather unexplored field of gas absorption spectroscopy, in the region below 500 Å. The density of the gas is not easily determinable. Data on gas absorption are however obtainable in the 1000 to 2000 Å region. The easiest way to determine the mass of gas which absorbed the radiation in the short wave-length range is to measure, with the same instrument and under the same experimental conditions, also the absorption coefficients of the gas in the long wavelength region, where the absolute absorption data are known from measurements with instruments not necessitating windowless spectroscopy.

Acknowledgements

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The director of the fine-mechanical workshop of this department Mr. B. Loewinson, Mr. I. Katzir and Mr. J. Barak are thanked for the great effort they put into the construction of this instrument.

Caption to Figures

Fig. 1

Mechanical and optical layout of the spectrometer

Fig. 2

The Spectrometer from inside

Fig. 3

Slit system and spark chamber

Fig. 4

View of the spectrometer with spark-chamber and pumping system

Fig 5

The resolution of lines at $100 \text{ \AA}$ and $200 \text{ \AA}$, for different orders of reflection. Orders of reflection are indicated by numbers. Resolution is given for gratings of 1000 lines per mm., having radius of curvature of 7 m., and 2m. The angle of grazing incidence is 5° . Resolution is plotted against distance from centre of grating.

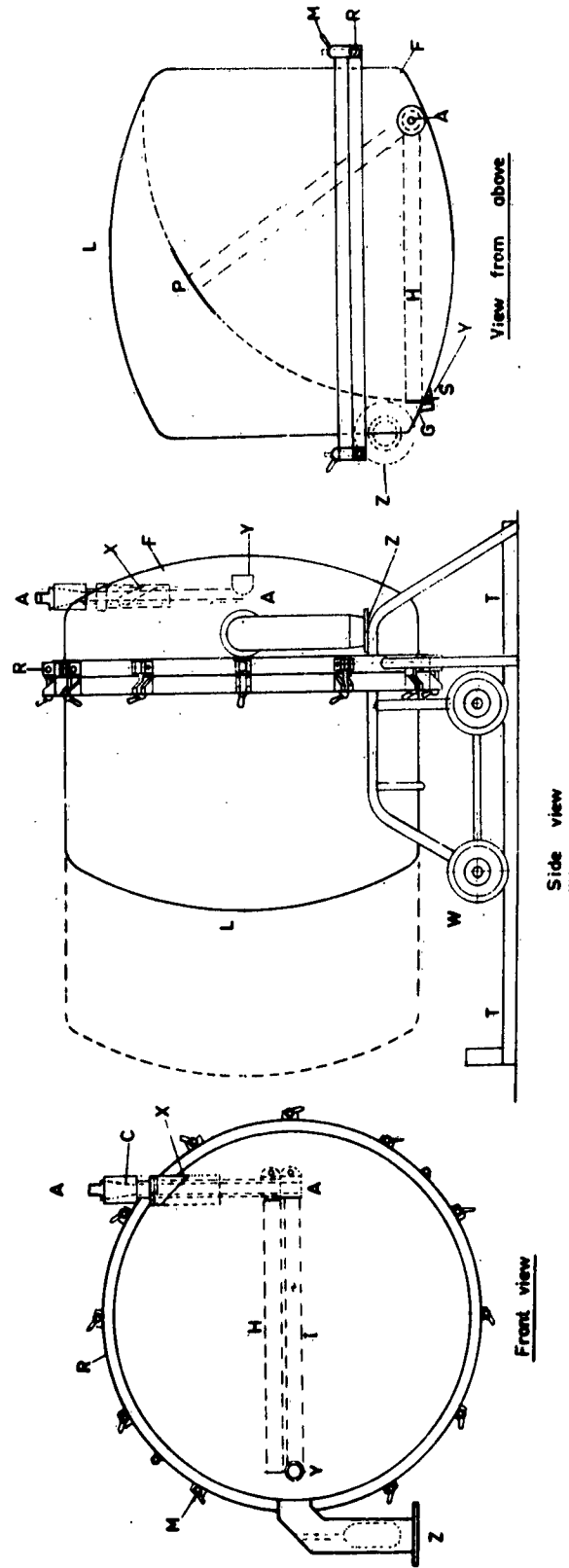


Fig. 1

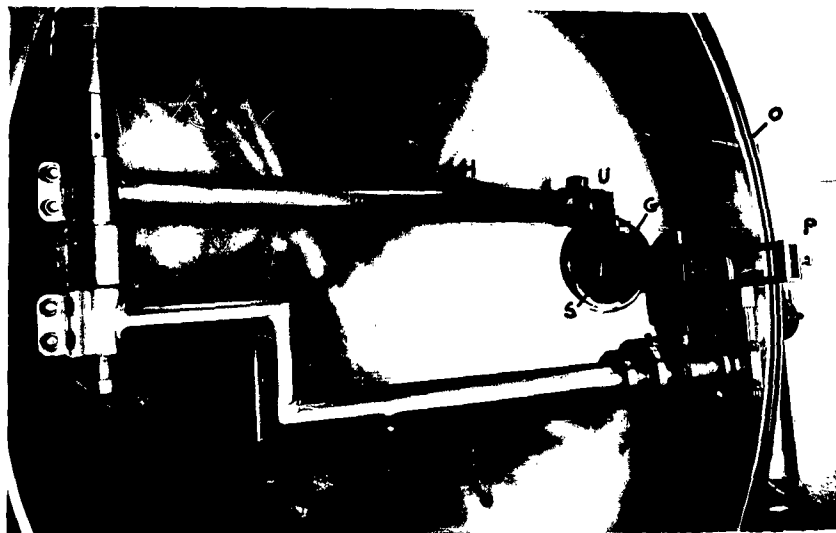


Fig. 2

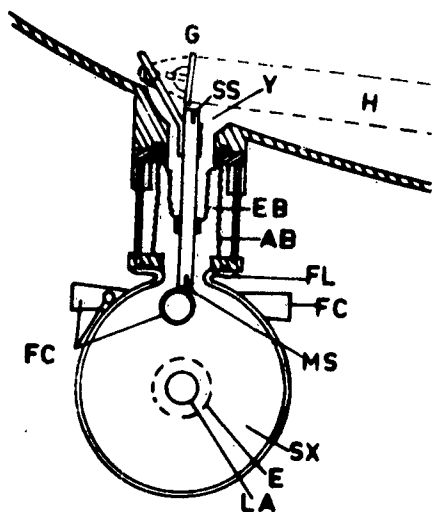


Fig. 3

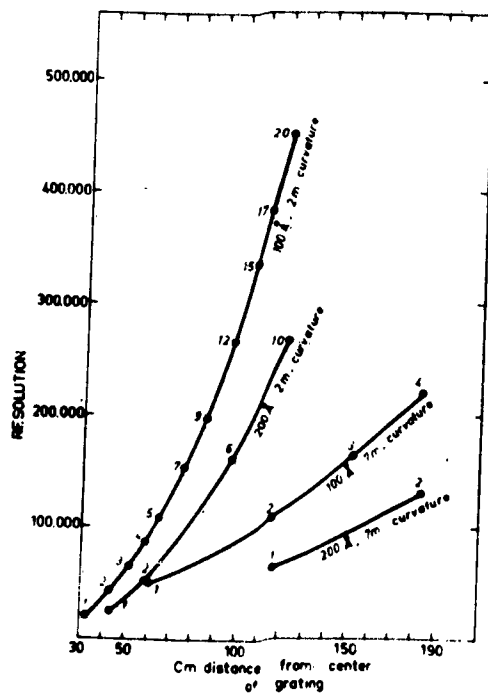


Fig. 5

DEPARTMENT OF PHYSICS AF EOAR 62-33 HEBREW UNIVERSITY _____ ATR JERUSALEM ISRAEL _____ SOLID STATE PHYSICS TECHNICAL REPORT NO. 1 February 1962 A VACUUM ULTRA-VIOLET SPECTROMETER E. Alexander and B.S. Fraenkel ABSTRACT: A grazing incidence vacuum spectrometer is described. It is based on a 2 m., 30,000 lines per inch, Siegbahn glass grating. Both plate-holder and grating are hold on arms fastened to the axis of the Rowland circle. The wavelength range extends up to 2300 Å. Instrumental considerations for obtaining high resolution in the short wavelength range are discussed.	DEPARTMENT OF PHYSICS AF EOAR 62-33 HEBREW UNIVERSITY _____ ATR JERUSALEM ISRAEL _____ SOLID STATE PHYSICS TECHNICAL REPORT NO. 1 February 1962 A VACUUM ULTRA-VIOLET SPECTROMETER E. Alexander and B.S. Fraenkel ABSTRACT: A grazing incidence vacuum spectrometer is described. It is based on a 2 m., 30,000 lines per inch, Siegbahn glass grating. Both plate-holder and grating are hold on arms fastened to the axis of the Rowland circle. The wavelength range extends up to 2300 Å. Instrumental considerations for obtaining high resolution in the short wavelength range are discussed.
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