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DL/SRF/TM 11
(Experimental)

# technical memorandum Daresbury Laboratory

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THE INSTALLATION OF AN SRF GRAZING INCIDENCE MONOCHROMATOR
AT THE WISCONSIN STORAGE RING

by

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## 1. INTRODUCTION

This report describes the installation of the SRF grazing incidence monochromator originally used by the group of universities studying photoemission from solids on the NINA synchrotron. On the closure of the SRF, most of the instrumentation was lying idle, and an inquiry was made by Professor G.J. Lapeyre's group from the Montana State University to ascertain whether it was suitable for use on the 250 MeV storage ring at the Physical Sciences Laboratory, University of Wisconsin (UWPSL). Some U.K. university groups, primarily Warwick and Ulster Physics Departments expressed an interest in using the spectrometer, and the Director of UWPSL gave his support to the installation of the instrument at the storage ring, agreeing to make the necessary modifications. The installation was completed during the period 2nd-12th November 1977 and this document is intended for those who wish to use the instrument for their own research, i.e. it is a users guide.

## 2. SPECTROMETER DESCRIPTION

Figure 1 shows the optical layout; the instrument is designed to reject higher spectral orders in its output by selective reflection on four different ranges. These are chosen by positioning a spherical mirror in one of the four focal positions shown on fig. 1, and tilting it until the light diffracted from the grating M passes through the exit slit S. Of course this is best done with the spectrometer set at zero order. Two mirrors of different radii of curvature are needed for the four ranges, a 3.25 m mirror for ranges 1 and 4, and a 4 m mirror for ranges 2 and 3. The changeover is carried out inside the instrument automatically. The diffraction grating is plane, 632 lines/mm and is of the phase type (square wave profile) manufactured by the National Physical Laboratory in the U.K.



It is described by Franks et al [1] and is a "master", i.e. it contains no replicating material, photoresist or any other hydrocarbon.

The instrument is housed in a stainless steel vacuum tank from which it may be withdrawn by using a cantilever frame attached to the main frame. It is constructed of stainless steel throughout, except for components where friction could cause "cold welding", where phosphor bronze is used as one of the components. Also, where high stability is required, cast steel is used, chromium plated. All rotary and linear drives into the vacuum are via stainless steel bellows, and thus the instrument is in principle of UHV standard, the only elastomer seal being on the valve sealing surface at the exit. This valve also has a window to aid alignment of the experiment following the spectrometer.

At the storage ring the spectrometer is pumped out with an ion pump of 200 litres/s capacity and a sublimation pump after roughing out with sorption pumps to $\sim 5 \times 10^{-4}$ torr. An ionisation gauge, Q4 mass spectrometer and pirani gauge, all of Vacuum Generators manufacture, are fitted. Because of the large surface area inside the instrument, some mild baking is necessary ($\leq 70^{\circ}$C) before pressures on the $10^{-9}$ torr range can be attained. The beam line to the mirror box is $\sim 4.5$ m long and provides a degree of differential pumping such that the spectrometer can be opened up to the ring when its pressure is $\sim 5 \times 10^{-8}$ torr. The 2 mm high aperture at the front of the spectrometer assists in this, although its main purpose is as a light baffle. A set of baffles with 1, 3 and 4 mm high apertures is provided in addition to the one presently fitted.

A premirror set at a grazing angle of $5^{\circ}$ interupts $\sim 10$ mrad beam horizontally, and this mirror is a "bent" triangle placed 1.5 m from the tangent point. It is thus cylindrical and focusses the horizontal dimension of the beam at a distance ∿ 5.5 m from the mirror, i.e. at a point just beyond the spectrometer exit slit, thereby magnifying it ∿ 3.7 times. Vertically, this mirror does not focus so the acceptance of the spectrometer is 2 mm at 6 m, i.e. 1/3 mrad. The bending of this mirror is preset and cannot be altered from outside the vacuum. Adjustments are provided on the mirror box however, for tilt and horizontal angular orientation, which can be operated while the mirror box and spectrometer are under vacuum. Figure 6 shows the instrument installed at the storage ring.

## 3. SPECTROMETER OPERATION

### 3.1 Motor drive units

There are three drives to the optics on the spectrometer: grating rotation, labelled "G"; mirror rotation, labelled "MR", and mirror translation, labelled "MT". Stepping motors are used for this purpose, and a manually operated control box is provided to drive them individually. The cables connecting the motors to this box are labelled and should not be interchanged. The position of any drive is recorded by a cyclometer which records a minimum of 1/10th of a motor revolution. The engraved drums can be used for finer settings. In the case of the grating drive, one cyclometer unit corresponds to 20 small divisions on the engraved drum; for the mirror drives, one cyclometer unit corresponds to 10 small divisions on the drum. A zero in the first figure on the cyclometer drive (i.e. the one which reads 1/10th revolutions) has been set to coincide with zero on the corresponding engraved drum. "Forward" on the drive unit corresponds to increasing numbers on the cyclometers. Micro switches are provided which stop the motors at the extreme limits of each drive; to restart, switch off the control box and rotate the motor back by



hand away from the tripped position. The control box may then be used to power the motor after reversing the direction switch. Any attempt to drive the motors beyond the extremes of the drives will result in serious damage to the spectrometer.

The cyclometer readings should be not allowed to go outside the following limits:

| | |
|---|---|
| Grating drive (G): | 0-4780 |
| Mirror Rotation drive (MR): | 527-8229 |
| Mirror Translation drive (MT): | 229-7213 |

### 3.2 Setting up the mirrors

The first stage in using the spectrometer is to decide on the wavelength range required, and table 1 with figs. 2-5 may assist in this respect. The mirror rotation drive (MR) should then be set to 2600 before the mirror translate drive (MT) is used. This is important to ensure that the mirror carriage does not obstruct the translation movement. The MT setting should then be adjusted to the desired value, always approaching the required number by increasing the cyclometer reading. The MR value can then be set, and the G value. The instrument will then be on zero order for the range concerned, and some small variation of the MR setting may be necessary for peak signal in zero order. It is to be noted that the backlash in this drive is ∿ 40 cyclometer units, so the final setting should always be approached from a value at least 40 cyclometer units less.

If the setting of the mirrors in some way becomes confusing, it is the MT drive which should not be varied at all. To find zero order, set the MT value as before, and then use the grating drive (G) to scan the zero order image onto the centre of the mirror. This can be seen through one of the instruments viewports, provided the background illumination has been reduced. Having done this, the mirror can be rotated using the MR drive so that the image comes through the exit slit. Again, this can be observed visually since there is a window valve at the rear of the instrument. This assumes that the users experiment does not obstruct access to the exit slit! In general, the mirror settings will not require adjustment unless there are large fluctuations in the source position, or the spectrometer is moved in any way.

It is possible to view the beam reflected from the premirror directly and thereby check the alignment of the whole spectrometer, by driving the (G) drive to 4770. This lifts the grating out of the way, and the direct beam should fall on the centre of the back viewport as far as horizontal direction is concerned. The correct vertical position is indicated by the scribe lines on the back flange of the spectrometer, and this also enables the horizontal focus to be checked. This has been set, but may alter because of premirror or spectrometer movements.

### 3.3 Wavelength scanning

This is achieved merely by operating the (G) drive, and table 1 gives the calibration for each of the ranges. The stepping motor has 200 steps/revolution, and can be driven via a computer if required. The drive box provided with the spectrometer is not really suitable for this purpose without a little modification.

### 3.4 Exit slit setting

A "black box" to the right of the exit port is used to adjust the slit, and the settings are viewed through a small hole in the box cover. A flashlight may be required to see the micrometer! The minimum slit width



is at a micrometer setting of 5.95 mm, and is ∿ 10 µm. To open the slit, the knob is turned anticlockwise. 1 mm movement of the micrometer corresponds to 400 µm opening of the slit. The instrument dispersion is approximately 6 Å/mm on all ranges, so there is little point in setting the slits to less than ∿ 100 µ.

## 4. SPECTROMETER OUTPUT

The output of the four ranges is shown on figs. 2-5, and was measured with an NBS calibrated photodiode receiving approximately 1/3 of the total output from the spectrometer. Thus the peak output is $3 \times 10^{10}$ photons/s for a stored beam current of 50 mA and a bandpass of 0.7 Å. At a distance of 200 mm from the exit slit, this will fall onto an area approximately 15 mm wide x 1 mm high, the height figure depending on the range used and being quoted here for ranges 2 and 3. To avoid loss of light where a small spot size is necessary on an experimental sample a post mirror is probably desirable. Without reducing the vertical dimension of the source the resolution cannot be better than 0.7 Å at all wavelengths, and in any event could not be better than 0.2 Å unless the entrance baffle before the grating is reduced from 2 mm to 1 mm. A baffle is available to do this, and 0.1 Å resolution would then be possible. At the grazing angles used on range 1 there is little point in increasing the vertical aperture of the instrument since this will merely result in the grating being overfilled.

By selective reflection the instrument achieves a degree of order sorting, and the wavelength ranges shown in table 1 indicate the ranges over which the spectrometer can be used with less than 2% of higher order components present in the output. This order sorting capability is further assisted by the output of the storage ring at wavelengths shorter than 200 Å, since the second and higher order components enter the spectrometer at lower intensity than first order. Further details on the construction of this spectrometer, and the theoretical ideas behind its performance, are to be found in the publications by Howells et al[2] and West et al[3].

Acknowledgements

We are indebted to the UWPSL staff, in particular Lynwood Thomas, Charles Pruett, Roger Otte and Fred Middleton, for the excellent service and support they gave us while putting this spectrometer on line. We are also grateful to Ed Rowe without whose agreement and encouragement this project would never have taken place, and to the Science Research Council in the U.K. for its agreement to finance the operation.



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2. M.R. Howells, D. Norman, G.P. Williams and J.B. West, J. Phys. E: Sci. Instrum. to be published.

3. J.B. West, K. Codling and G.V. Marr, J. Phys. E: Sci. Instrum. 7 (1974) 137.

TABLE 1

| Range | Wavelengths covered (Å) | Energies covered (eV) | Mirror translation setting (MT) | Mirror rotation setting (MR) | Grating setting (G) |
|---|---|---|---|---|---|
| 1 | 65 - 130 | 95 - 190 | 7032 | 5900 | 1110 |
| 2 | 75 - 140 | 90 - 165 | 5722 | 5574 | 1295 |
| 3 | 80 - 160 | 77.5 - 155 | 2153 | 3677 | 2349 |
| 4 | 150 - 400 | 30 - 82.5 | 593 | 1570 | 3512 |

The above wavelength ranges indicate the regions over which the spectrometer output should contain very little (≤ 2%) second order radiation in the output. Useful output extends to longer wavelengths on each of the ranges, but may be contaminated with higher order radiation, particularly on range (4).



FIGURE CAPTIONS

Fig. 1 The optical layout of the spectrometer

G - diffraction grating, plane 632 lines/mm

$M_1$ - position of 3.25 m mirror on range 1

$M_2$ - " " 4.0 m " " " 2

$M_3$ - " " 4.0 m " " " 3

$M_4$ - " " 3.25 m " " " 4

S - exit slit

Fig. 2 The spectrometer output on R(1); the 2p edges of silicon and aluminium were used for calibration.

Fig. 3 The spectrometer output on R(2); the 2p edges of silicon and aluminium were used for calibration.

Fig. 4 The spectrometer output on R(3); the 2p edges of silicon and aluminium were used for calibration.

Fig. 5 The spectrometer output on R(4); the 2p edge of aluminium was used for calibration.

Fig. 6 The spectrometer in position at the storage ring

A - approximate position of tangent point

B - pre-mirror chamber

C - beam line from mirror box to spectrometer

D - "straight through" view port

E - exit slit.

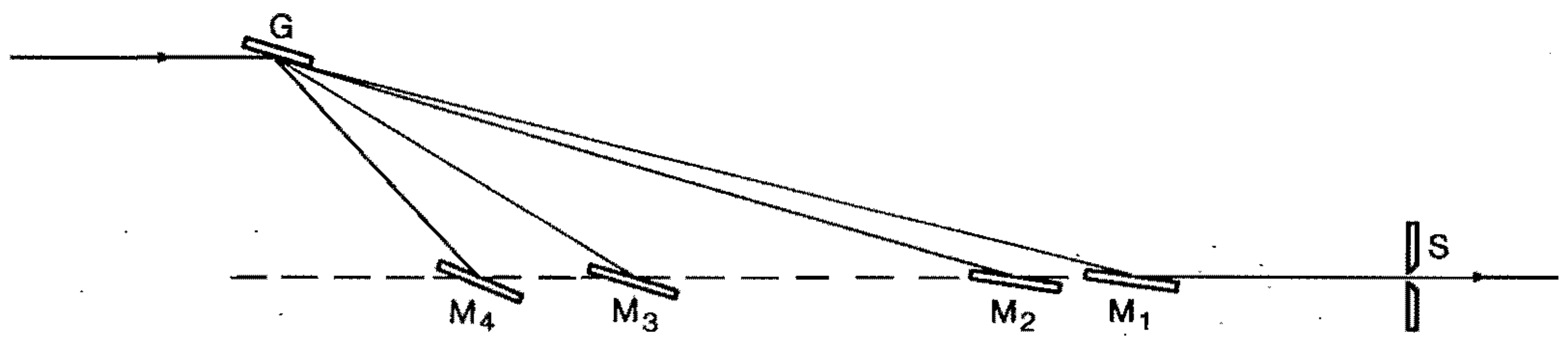



Fig. 1

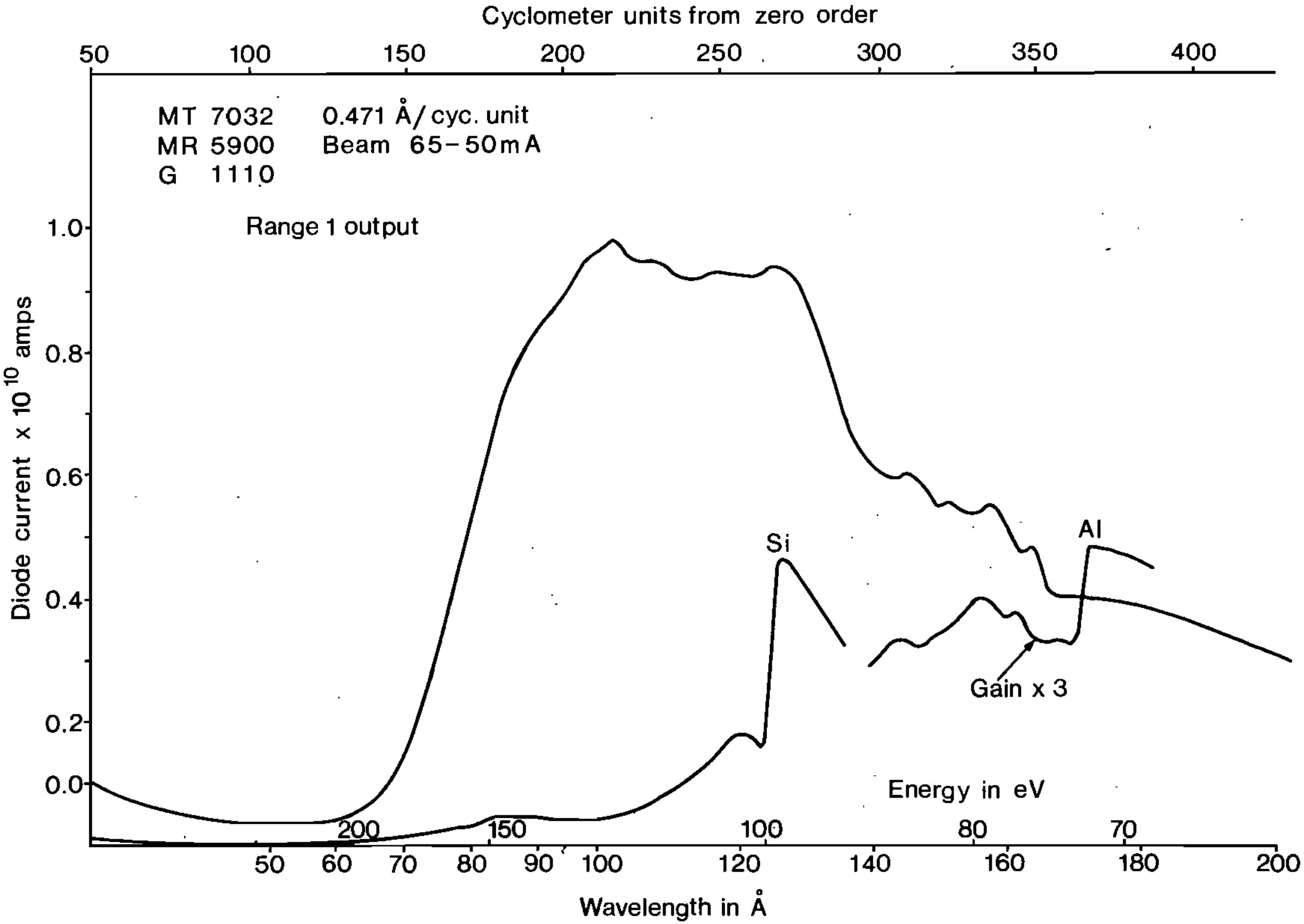

Cyclometer units from zero order
50
100
150
200
250
300
350
400
MT 7032
MR 5900
G 1110
0.471 Å/ cyc. unit
Beam 65–50mA
Range 1 output
Diode current x 10^10 amps
1.0
0.8
0.6
0.4
0.2
0.0
Si
Al
Gain x 3
Energy in eV
200
150
100
80
70
50
60
70
80
90
100
120
140
160
180
200
Wavelength in Å

Fig. 2

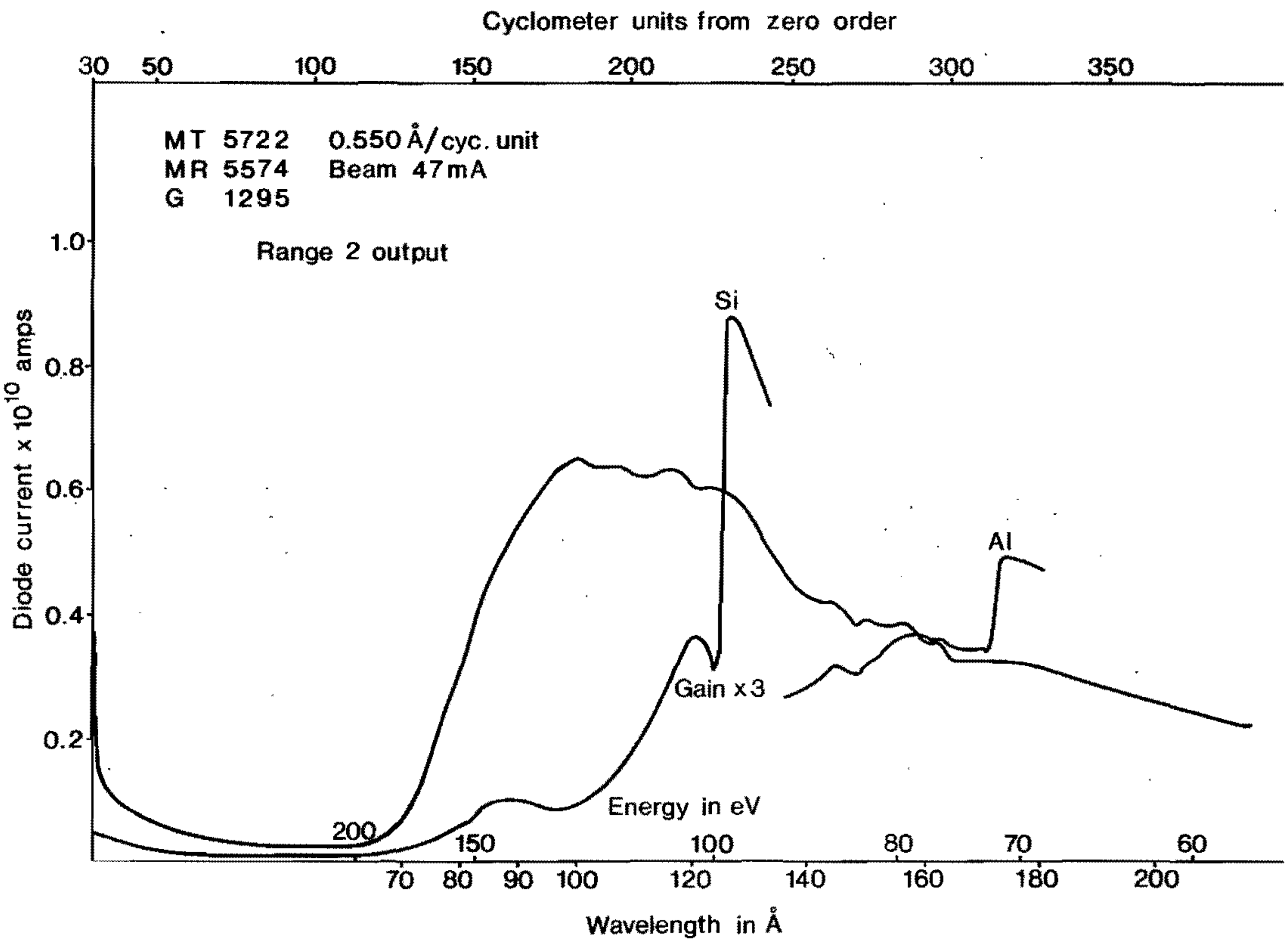
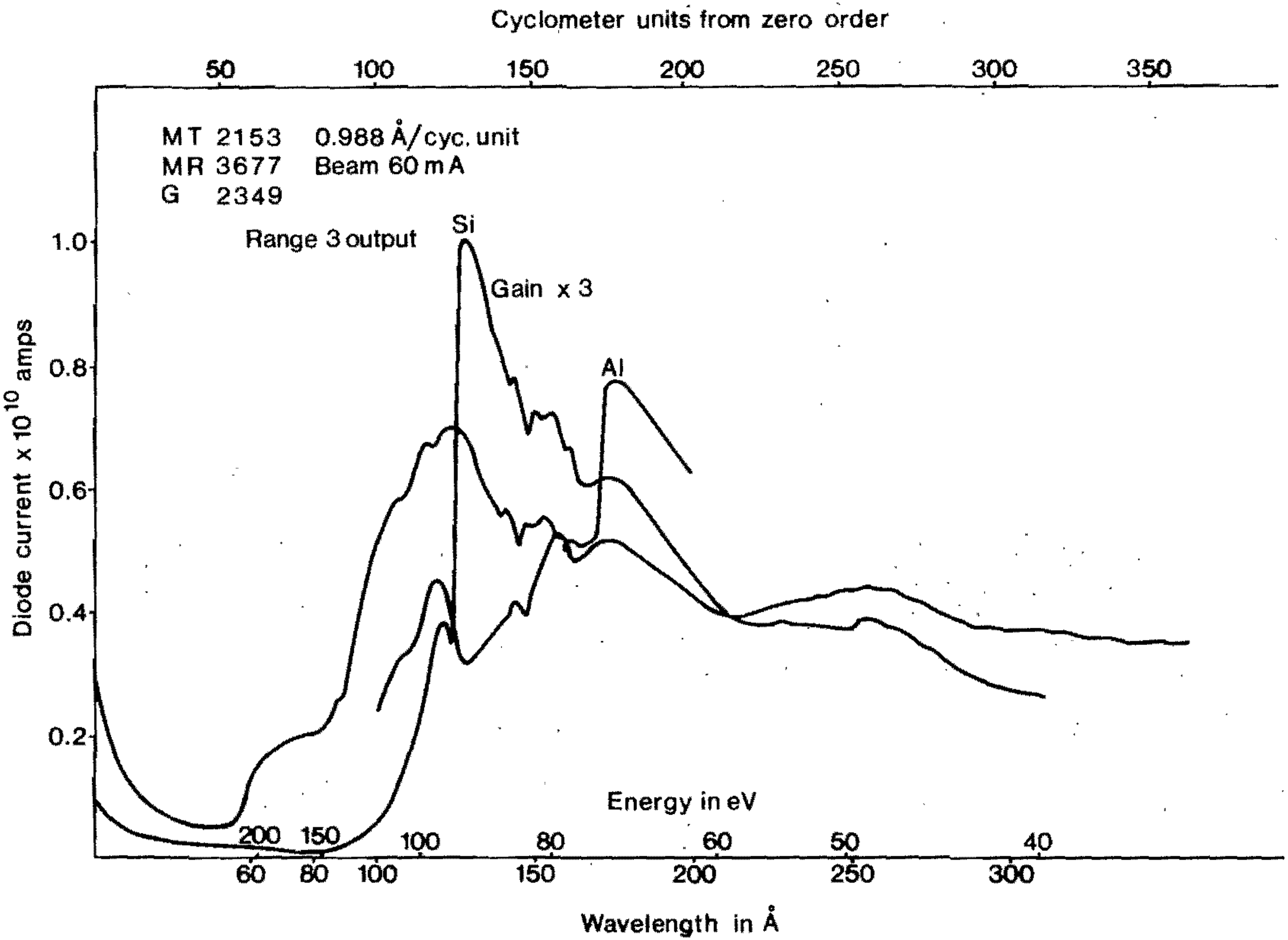

Cyclometer units from zero order
30
50
100
150
200
250
300
350
MT 5722 0.550 Å/cyc. unit
MR 5574 Beam 47 mA
G 1295
Range 2 output
1.0
0.8
0.6
0.4
0.2
Diode current x 10^10 amps
Si
Al
Gain x3
Energy in eV
200
150
100
80
70
60
70
80
90
100
120
140
160
180
200
Wavelength in Å

Fig. 3



Cyclometer units from zero order
50
100
150
200
250
300
350
MT 2153 0.988 Å/cyc. unit
MR 3677 Beam 60 mA
G 2349
Range 3 output
Si
Gain x 3
Al
1.0
0.8
0.6
0.4
0.2
Diode current x 10^10 amps
Energy in eV
200
150
100
80
60
50
40
60
80
100
150
200
250
300
Wavelength in Å


Fig. 4

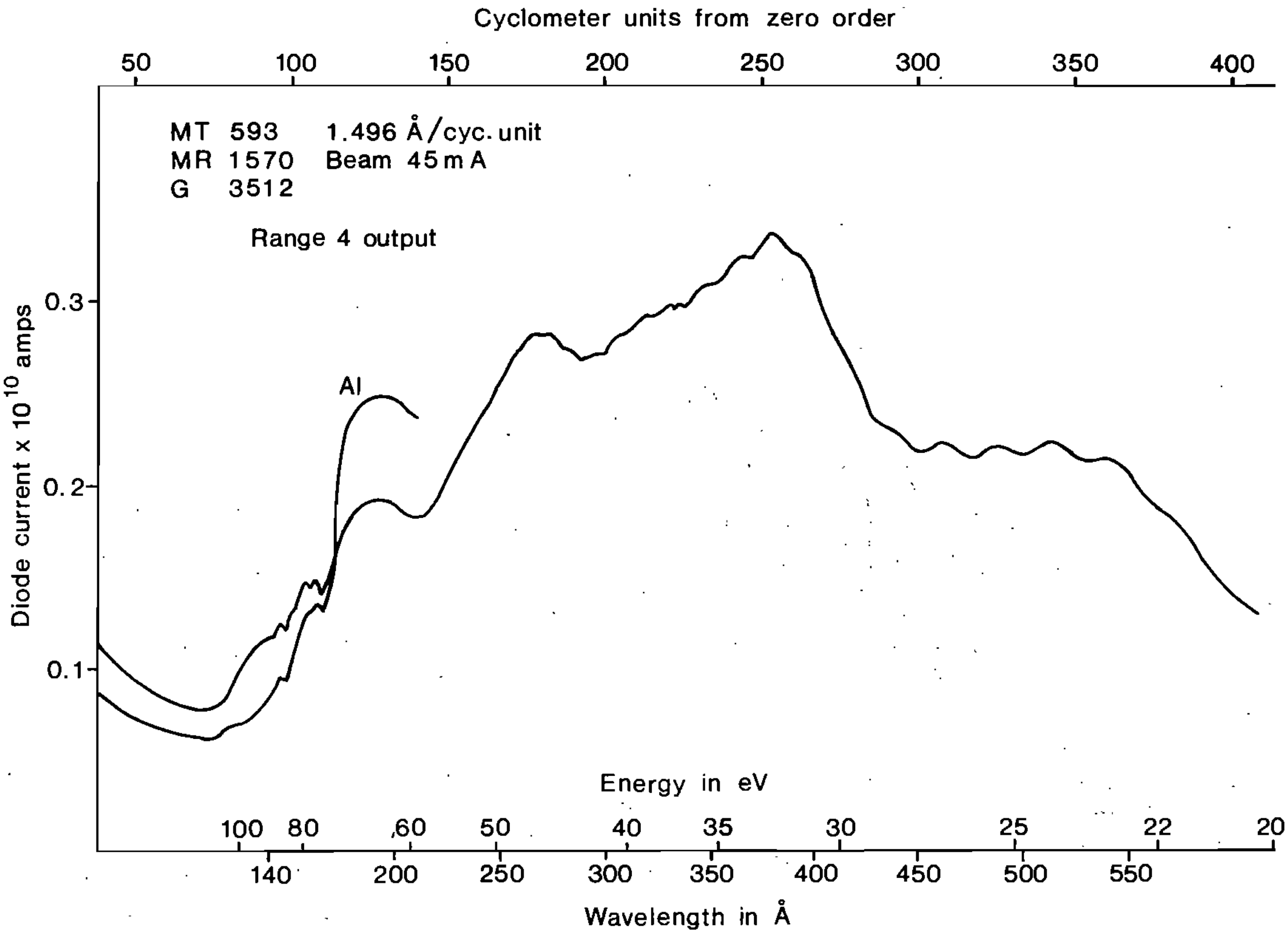

Cyclometer units from zero order
50 100 150 200 250 300 350 400
MT 593 1.496 Å/cyc. unit
MR 1570 Beam 45 m A
G 3512
Range 4 output
Al
Diode current x 10^10 amps
0.3
0.2
0.1
Energy in eV
100 80 60 50 40 35 30 25 22 20
140 200 250 300 350 400 450 500 550
Wavelength in Å

Fig. 5

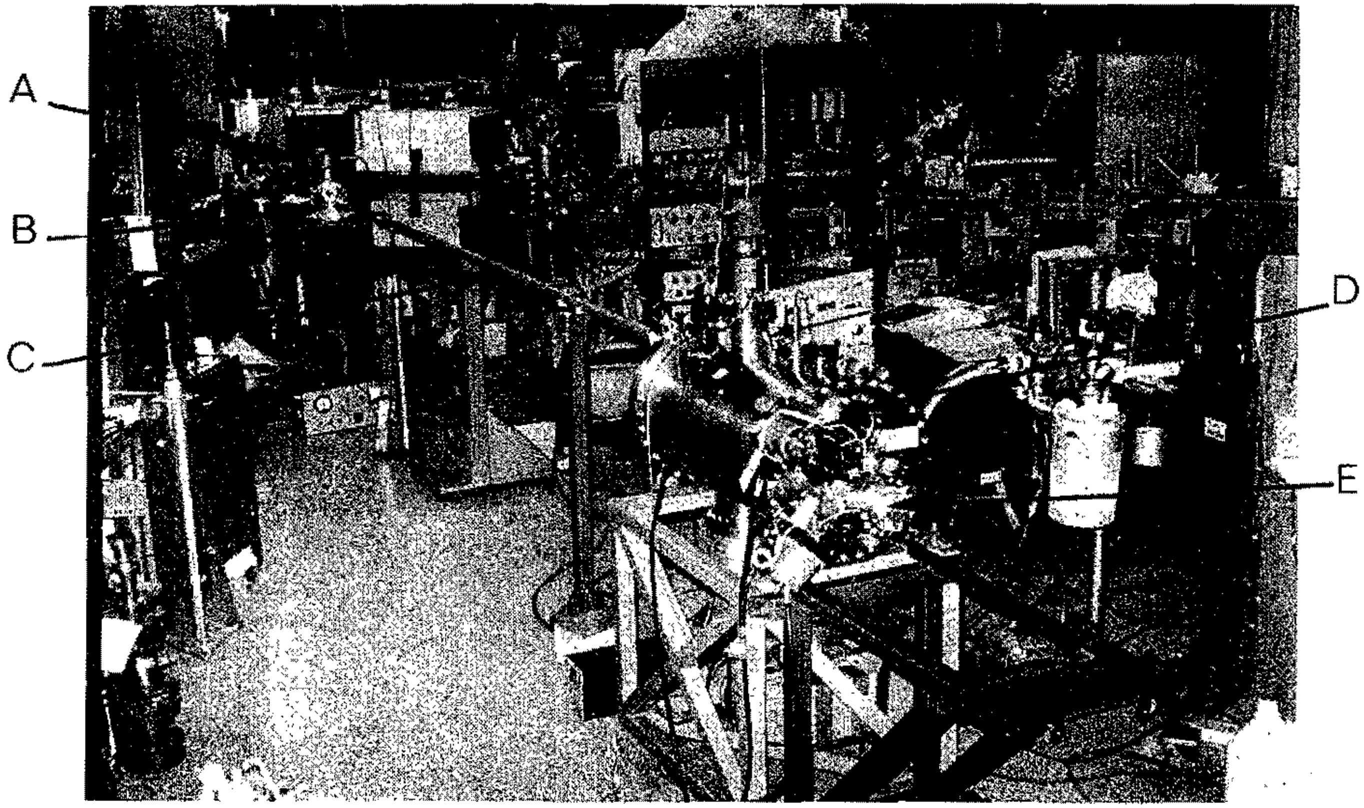



Fig.6