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A MULTICHANNAL DETECTOR FOR THE VUV

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ABSTRACT

A 2000 channel intensified diode array detector has been developed for use with a 1 metre normal incidence spectrometer. Details of the detector's construction, the electronics associated with control of the array and data digitisation are presented. The detector has a spectral coverage of approximately 150Å, and has been operated over the wavelength region 300-1700Å, with an integration time of 20ms to survey the spectrum of the DITE tokamak. With this spectral coverage the spectral resolution is sufficient, ~0.1Å in 1st order, to monitor rotational shear from simultaneous observation of a range of ion species. Additionally, the detector has been used to examine details of individual line profiles at a faster rate (by restricting the number of channels recorded), allowing the observation of rapid (2ms) evolution of plasma mass motion effects[1]. We also report on the intensity calibration of the spectrometer and detector combination using a deuterium lamp over the range 1700-1100Å, with the possibility for extending the lower wavelength limit with charge exchange and branching ratio techniques.

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INTRODUCTION

We have developed a 2000 channel intensified diode array for use as a detector on a Rank Hilger model E766 1 metre normal incidence spectrograph. We present a description of the detector, its associated electronics and some examples of its performance on the DITE Tokamak[1].

A Rank Hilger model E766 1 metre normal incidence spectrograph has been in use for some time in the laboratory, operating both in a photographic mode, recording some 5 spectra on a 50mm strip of 35mm film, and in a photoelectric mode, with a single channel photomultiplier. There are clear shortcomings in both of these modes of operation, which provided the incentive to look at an alternative detector system.

The technology of microchannel plates is well proven, as is that of diode array detectors. In this application the EG and G. Reticon-SF series of devices with pixels of high aspect ratio (2.5mm x 25μm), to match the shape of the image of the spectrometer entrance slit, was the obvious choice for the array. The detector incorporates two 1024 element devices from this series to span the image plane of the spectrometer.

DETECTOR

The detector was designed to be a simple replacement on the exit plane mounting of the spectrometer, and was, in fact, built into a modified film cassette holder. Thus the instrument, which had already been aligned with some precision to a good focus at the film plane at all wavelengths, needed only the detector to be positioned to lie in the same plane as the film cassette, an adjustment easily achieved at any convenient wavelength using a lamp source.

This adjustment was carried out using a penning discharge lamp, and the Helium 584Å line in third order. The detector surface is flat, whilst the spectrometer focal plane has a curvature of radius 1 metre. The defocusing of the spectral image can be minimised by ensuring that the detector plane cuts the focal plane in two places rather than being at a tangent to it at its mid point. The focusing error is in any case not serious in relation to the detector's intrinsic resolution. The detector mounting incorporates a rocking adjustment of the detector plane to match the change in angle of the focal plane of the instrument at different wavelength settings. This adjustment would only be necessary to achieve the highest resolution from the instrument, and for all work done so far this has not been of concern so a compromise setting was adopted, and remained untouched for operation and calibration of the instrument. It is to be expected that the instrument sensitivity should change markedly when this setting is altered, leading to unnecessary complication.

A diagram of the detector is shown in figure 1 and a photograph appears in plate 1. It was manufactured by ITT Electro Optics (Type F1-112C) being assembled into a ceramic housing manufactured by Ferranti Electronics Ltd. A schematic of the layout of the spectrometer and detector is shown in figure 2. Input radiation falls on the front face of the first Microchannelplate (MCP) which is coated with 1000Å CuI.

Photoelectrons from this photocathode are collected and amplified in a chevron pair of MCP's, the channel bias angle of the MCP's being 5°. The amplified electron cloud is accelerated and proximity focused onto a P20 phosphor layer coated on a fibre optic plate that forms part of the vacuum envelope of the detector. The rear face of this fibre optic plate is coupled to two fibre bundles that bisect the spectral image, and conduct the two halves to two Reticon RL1024-SF fibre optic windowed diode arrays. There is a final fibre optic interface at the window of the arrays, before the light passes into the silicon of the diode array.

CuI was chosen as the photocathode to enhance the long wavelength response of the detector whilst also being stable to exposure to air[2].

The detector was chosen to have two diode arrays so as to span the entire spectral plane accessible to a photographic film. The alternative of using a fibre optic reducer to map the spectral image onto a single detector was not adopted because it was wished to preserve as much information on lineshape as conveniently possible, and the additional data aquisition required for a second array is much less than that required for the first.

The array scan control electronics is shown in figure 3. It is based around the Reticon RC1024-SA evaluation board, modified slightly to allow the injection of clocking and reset signals from an external source. The boards are interfaced to a PDP-11 microcomputer via the CAMAC standard interface. The CAMAC crate is situated on the spectrometer, some way distant from the computer. Light fibres link this, and other, diagnostics to the computer. The two arrays are operated in parallel from the same clock and reset sources. A simple module was designed to inject reset pulses to the boards under program control. Clocking signals are derived from two Culham model 8332 Time Sequence Generators (TSG's). The first TSG generates a pulse each time a scan is to be read out. This pulse triggers the second TSG which then generates the pattern of pulses necessary to clock out the arrays. This approach allows considerable flexibility in the readout mode of the arrays. Video data clocked out of the arrays is digitised and stored by a LeCroy model 8210 (1 μs, 10 bit) ADC and two 8800 memories. The array clock is used, via a divide by four circuit, to generate the ADC clock pulses. The 500 ns monostable inhibits the ADC when the clock rate is very high, allowing us to skip through unwanted parts of the array rapidly, without producing any data. This feature is exploited in the so-called 'monochromator mode' described below. A pair of preamplifiers is used between the video outputs and the ADC inputs with a gain of 2 to exploit the full dynamic range of the ADC.

Although the readout system is sufficiently flexible to allow access to almost any selected parts of the array, in practice only two distinct modes of operation are routinely used. These are refered to as 'survey' and 'monochromator' modes.

In survey mode, the whole of the arrays are clocked out. The memories can store 32 spectra in this mode, and readout takes around 12 ms, although the spectra can be spaced at convenient intervals to span a Tokamak discharge. In monochromator mode, data from a region of 100 diode array elements (pixels) can be read out at just under 2 ms. This mode has been used to study the line shape evolution of a spectral feature during Neutral Beam Injection into the DITE Tokamak[1].

The detector response to an isolated spectral line is shown in figure 4. It has a full width of approximately 4 pixels. As each pixel is 25 μm wide this corresponds to a detector full width of 100μm. The major contribution to the width of the detected line images is charge spreading between the output face of the second MCP and the phosphor screen. The spacing between the MCP and the screen is 1.3 ±0.05mm. At this separation the expected charge spreading in the detector amounts to 70 μm refs 3,4. This figure compares favourably with the measured value, when the effect of pore spacing (14.5 μm) and the entrance slitwidth (25 μm) is included.

OPERATION

Figure 5 (shot 28852) shows an example of the performance of the instrument in survey mode, in use on the DITE Tokamak. The part of the spectrum from 750 to 800 Å is shown. This data was taken during a neon impurity injection experiment, hence the presence of the neon lines. In figure 6 we show an example of the analysis of data taken with the instrument in monochromator mode. In this experiment the spectrometer viewed the plasma tangentially via a plane aluminium mirror at about a 20° grazing angle. The spectral line profiles were seen to become asymmetric and shifted in wavelength during the application of neutral beam heating due to the bulk toroidal rotation of the plasma. The data in figure 6 are the result of performing a least squares fit of a Gaussian (with height, width and central position as free parameters) to each successive scan. To fit a single Gaussian is obviously not appropriate where there are asymmetries in the line profiles. Ideally one would wish to use a series of nested Gaussians representing elements of the plasma with differing velocities, and to convolve these with the detector response, however such an approach is not justified unless extremely good signal to noise data is available. It is considered acceptable and computationally feasible to use here a single Gaussian. The variation of the parameters of the Gaussians are plotted as a function of time in the discharge, together with the neutral beam injection power. The results show clearly the beam induced plasma rotation as a shift in the apparent line centre position, and demonstrate the usefulness of this instrument.

CALIBRATION

The spectrometer, equipped with a 2400 line.mm^{-1} osmium coated grating and the detector system have been intensity calibrated over the waveband 1750-1100 Å. The calibration was carried out using a deuterium lamp calibrated by the National Physical Laboratory as a transfer standard source. The spectrometer aperture was filled using a 1 metre radius of curvature aluminium mirror. The reflectance of the mirror was taken to be equal to that of a similar mirror that had been calibrated, but which had subsequently been damaged. It is planned to calibrate the actual mirror used in these measurements.

The sensitivity of the instrument is found to vary significantly over the length the detector, and this variation is found to be sensitive to wavelength. This variation is shown in figure 7. The set of curves shown in figure 8 indicate the wavelength dependence of the instrument sensitivity at various positions across the detector. The variation across the detector arises as a result of the different angles that the different parts of the detector subtend at the grating[5]: the mean angle changes by some 3° between the extreme ends of the detector. The peak in sensitivity at 1570Å is not due to the quantum efficiency of the photocathode[2], nor to the grating blaze (peak at 1350 Å). Rather it is thought to be due to changes in the angle between the grating and detector. The long wavelength limit of this calibration is set by the longest wavelength the spectrometer can reach. The short wavelength limit is determined jointly by the reflectivity of the aluminium mirror, and the transmission of the magnesium fluoride window of the deuterium lamp, both of which fall dramatically below 1100Å. There exists the possibility of extending the calibration to wavelengths below 1100Å by using charge exchange excited lines in the DITE Tokamak, but at present we are using the instrument to view the plasma tangentially, via a plane aluminised mirror and so have not had the opportunity to attempt this procedure with this instrument.

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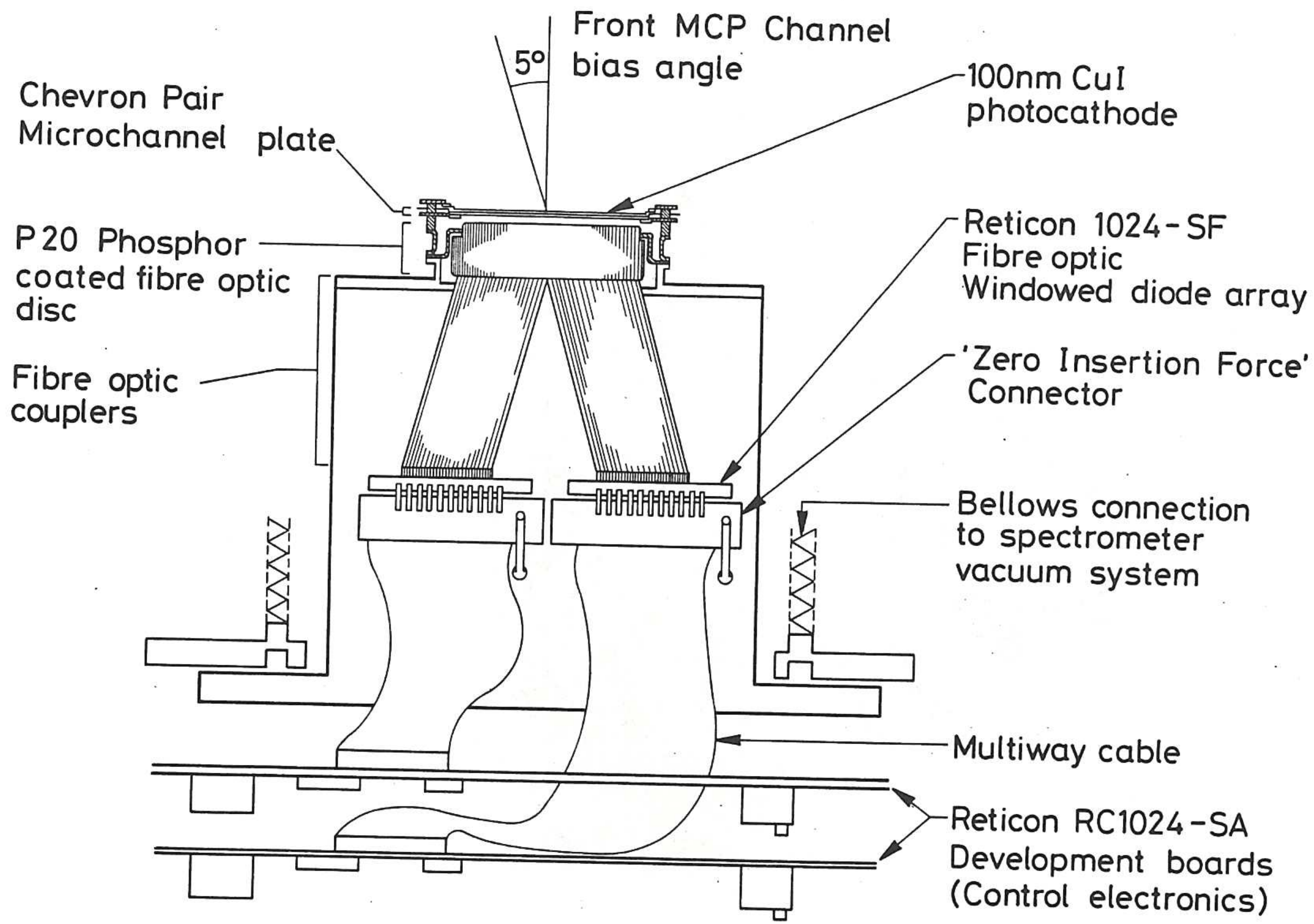

Figure 1. Diagram of the Detector

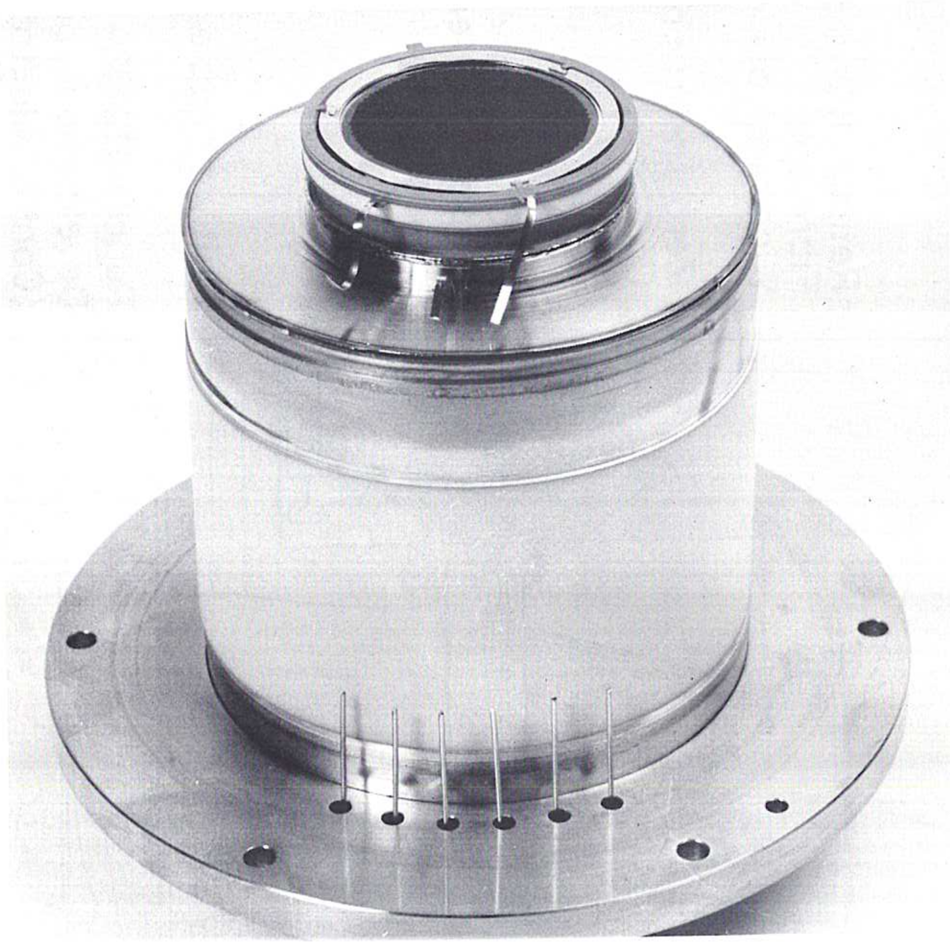

Plate 1. Photograph of the detector

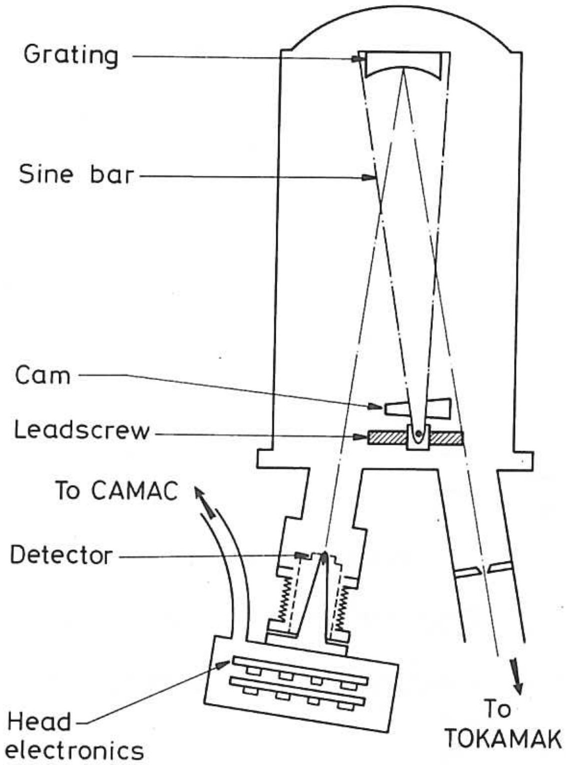

Figure 2. Diagram of the spectrometer and detector

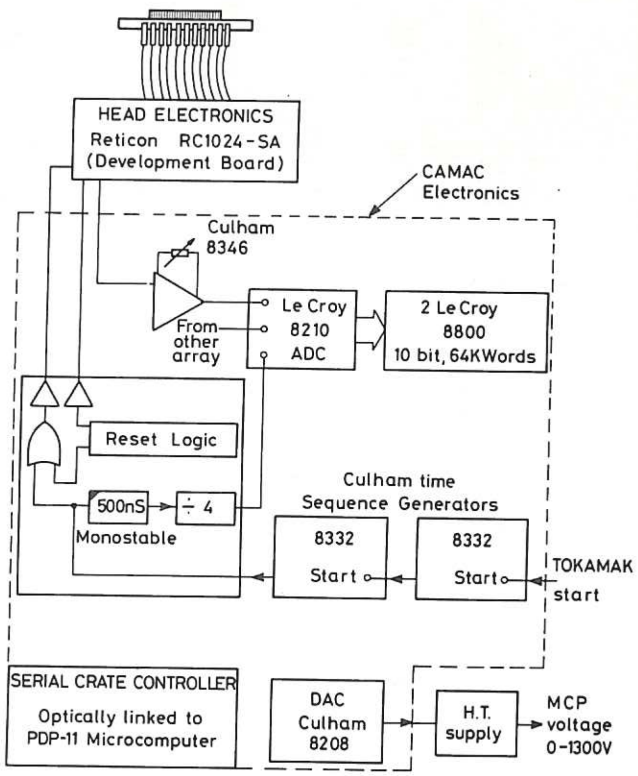

Figure 3. Readout electronics

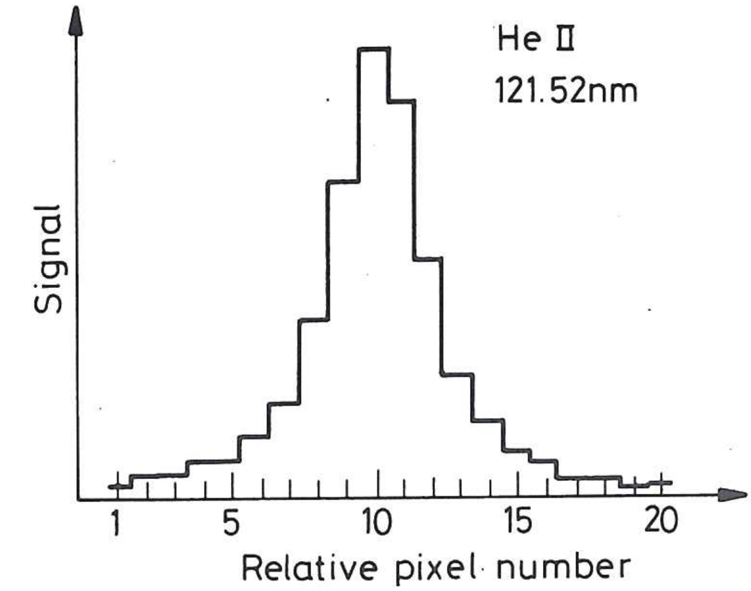

Figure 4. Response of the detector to an isolated spectral line. Penning lamp He II 1215.1Å

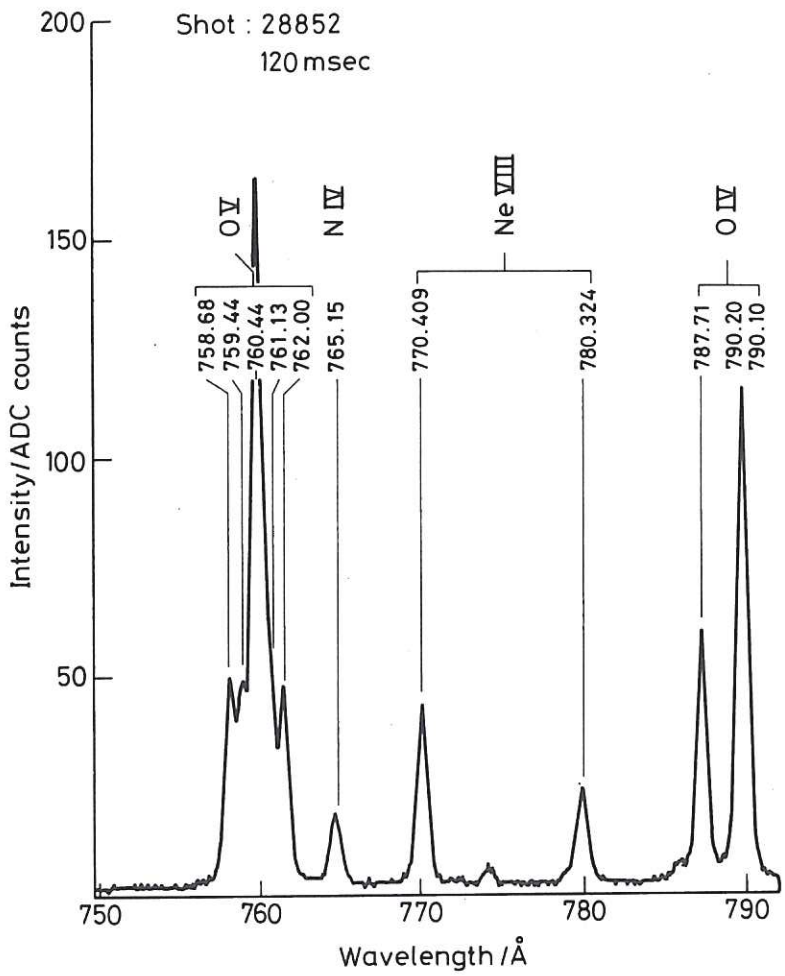

Figure 5. Survey mode data, Neon injection experiment

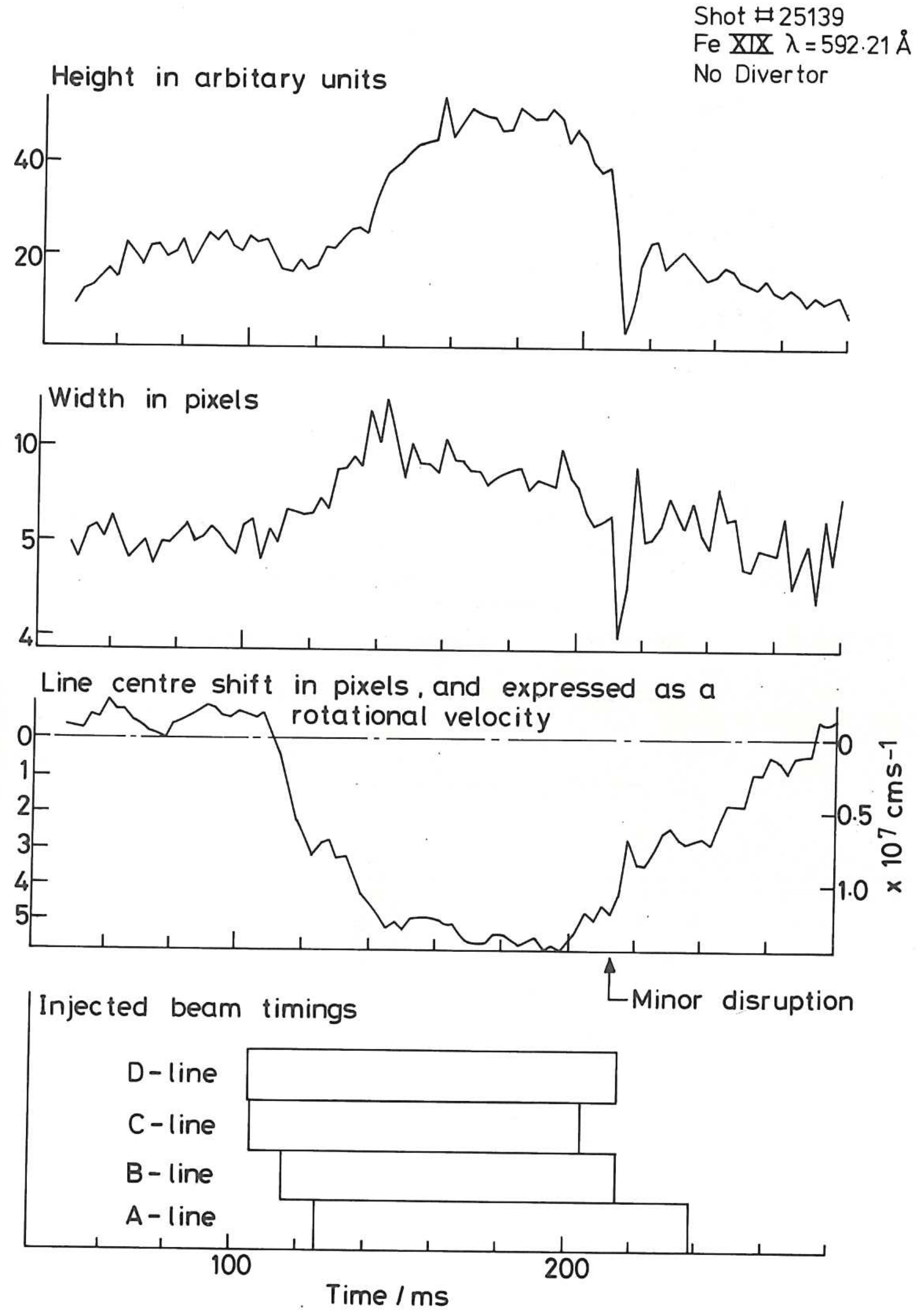

Figure 6. Monochromator mode data, showing effect of rotation.

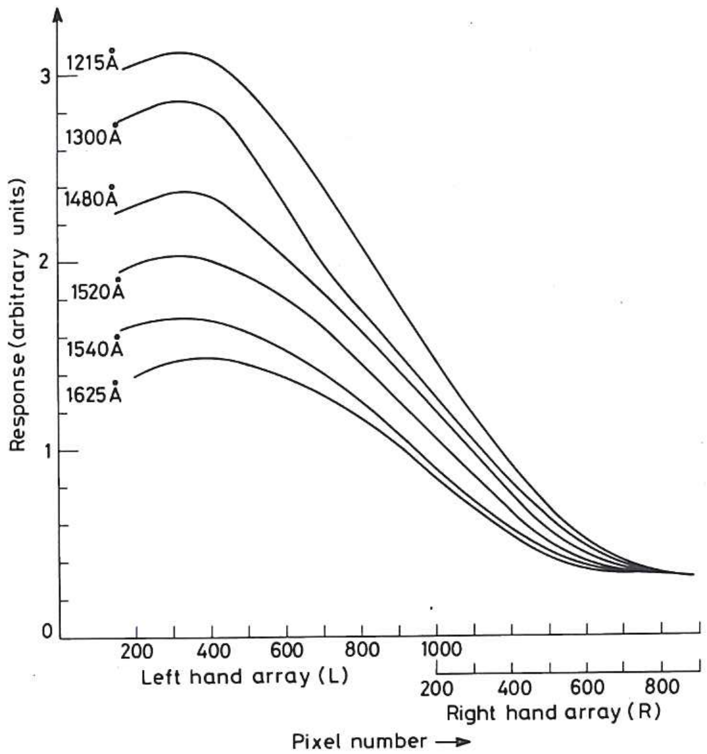

Figure 7. Variation in instrument sensitivity across the detector at a range of wavelengths.

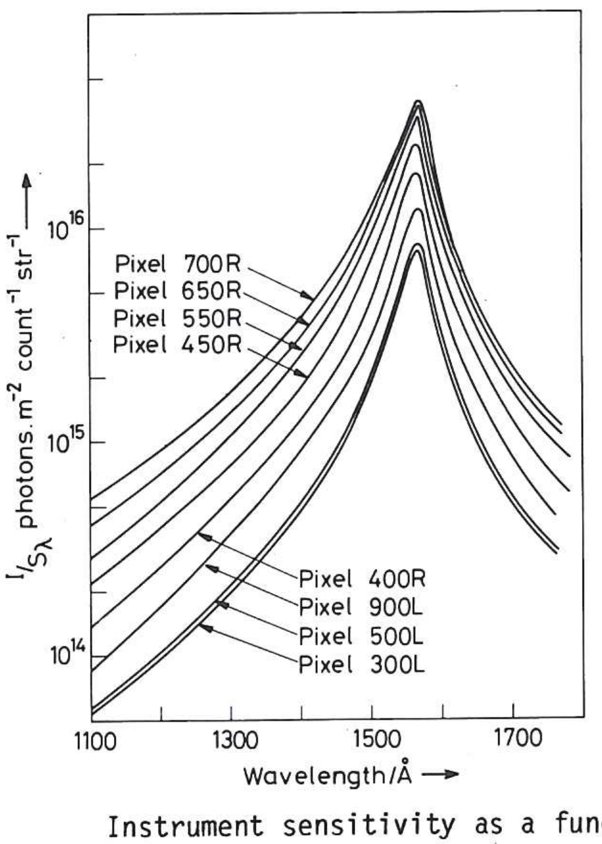

Figure 8 Instrument sensitivity as a function of wavelength.