

**Development of a Gated Optical Multichannel Analyser
for Laser-Plasma Spectroscopy.**

Thesis presented

by

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Abstract.

An Optical Multichannel Analyser (OMA) has been developed for the detection of radiation from laser-produced plasmas (LPPs). The system is based on a gated image - intensified photodiode array (PDA). Software for the control of, and data acquisition from, the OMA system has been developed. A high resolution (10ns) delay generator was also designed and constructed to permit time-resolved optical spectroscopy. The system has been tested and operated with a laser plasma source in the visible and near infra-red (NIR) spectral region (400 → 800nm).

Some initial results from preliminary experiments to extend the usefulness of the OMA system into the vacuum-UV (VUV) are presented.

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CHAPTER I

INTRODUCTION

I.1 Overview.

When the output pulse from a high power laser is focused onto a solid target in vacuo , a short lived, high temperature / high density plasma is formed. As many of the plasma parameters, e.g. electron temperature, dominant ion stage etc., are to some extent controllable, the study of laser-produced plasmas has greatly enhanced man's understanding of the basic physics of hot, ionized matter. To date, these studies have involved the analysis of both radiative (IR to X-ray) and particle (neutral species, ions and electrons) losses from the expanding plasma. Indeed laser-produced plasmas have proven to be versatile sources in atomic spectroscopy for the study of the emission and absorption of light by ions in low, medium and high stages of ionisation.

The development of laser-plasma spectroscopy has been assisted in no small way by developments in instrumentation, in particular by progress in multichannel optical detectors which are capable of recording a complete spectral slice as opposed to traditional point by point recording with scanning photo-multiplier based monochromators. The development of such a detector is described here.

With the advent of very high power lasers, capable of producing focused irradiances in excess of 10^{17} W/cm², it has become possible to generate plasmas which exhibit new and interesting effects. Such effects include the production of anomalously high energy X-rays, electrons and ions, neutron emission, the generation of harmonics of the incident laser wavelength and magnetic field generation at the megagauss level, all of which arise from the plasma-laser light interaction (see Schwartz et al (eds),

1981, for a review of these phenomena) Over the past twenty years or so, much of the research into this particular class of plasma has been primarily motivated by the possibility of attaining the density, temperature and confinement time conditions required to obtain nuclear fusion In recent years, although research on laser-induced plasmas has continued to concentrate on basic physics, there has been a growing interest in the applications of laser-produced plasmas.

The generation, properties, diagnostics and applications of laser-produced plasmas are briefly outlined in sections I 2, I 3 and I 4.

I.2 Formation of a Laser-Plasma.

The initial stages of plasma formation at an irradiated surface differ for the cases of conductors and insulators. As only metal targets were used in this work, the laser-light/surface interactions for these targets will be briefly discussed. Although the laser field penetrates a metallic target to a depth of only a fraction of a wavelength, it couples so strongly to the conduction electrons that heating, evaporation and ionization rapidly occur. The r.m.s. E-field is related to the laser flux (ϕ) by the expression $E=19.4\phi^{1/2}$, so for $\phi=10^{12}\text{W/cm}^2$, $E\approx 2\times 10^9\text{V/m}$, which is of the order of 0.1% of the field experienced by an electron located one Bohr radius from a hydrogen nucleus. The net effect of this laser interaction is to produce a thin layer of cool, low density plasma close to the target surface. This diffuse plasma is formed within the first few optical periods of the laser pulse and is the initial or priming stage in the laser-plasma production process (Fig.1 1).

In the growth phase of the plasma, laser radiation is absorbed by the priming plasma through the mechanism of inverse bremsstrahlung. As the electrons absorb the incoming laser light, their kinetic energy increases and they produce further ionization through collisions with atoms and ions in the plasma. As the plasma electron density (n_e) increases, the proportion of radiation absorbed increases, which in turn increases the electron density and so on. This interplay between the radiation absorption coefficient and the plasma electron density results in an avalanche-like ionization process which rapidly drives n_e towards the critical value (n_c) across a layer close to the target face. At this 'critical density surface' the incident light is reflected back towards the laser source while in the layers just in front of it $n_e \rightarrow n_c$. Once the critical density layer (or deflagration zone) is established, laser radiation can no longer reach the

target surface to generate new plasma by further evaporation and ionization. However, the hot plasma is rapidly driven away from the target surface with a consequent decrease in electron density so that the laser radiation may once again reach the target. For laser pulses of 100 picoseconds duration or greater, the processes of plasma generation, heating and expansion merge into a single, smooth action which takes place throughout the extent of the optical pulse.

Further detail on the generation of laser-plasmas is given in the paper by Carroll and Kennedy (1981)

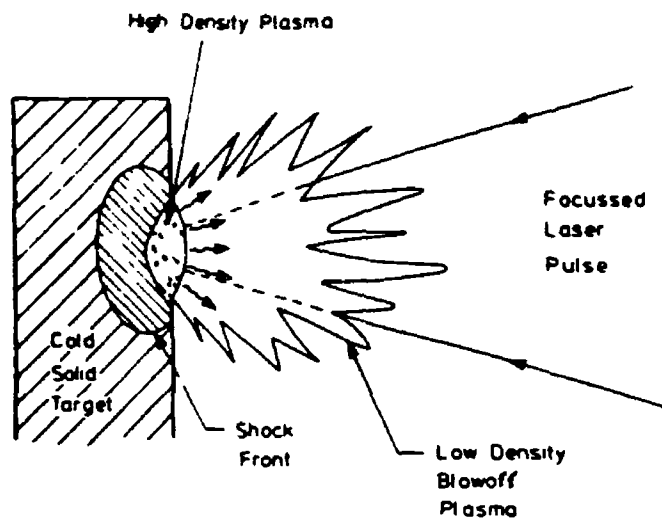


Fig.1.1. Microscopic representation of a laser-plasma source.

I.3 Properties and Diagnostics of Laser-Produced Plasmas.

There are a number of questions concerning laser-produced plasmas which one might conceivably ask. How does the plasma grow and decay in time? What is the electron temperature and the electron density and how do they vary in space and time? What ionic species are present in the plasma? Many of these questions are readily answered by a study of the radiation losses from laser-produced plasmas.

The electron temperature of a plasma may be obtained from a measurement of the slope of the photoionisation continuum which varies as $e^{-hc/\lambda k(T_e)}$ (Galanti and Peacock, 1975). For plasmas in local thermodynamic equilibrium, T_e may be determined by measuring line intensity ratios of highly lying resonance lines (Boiko et al, 1983). The electron density (n_e) of a plasma may also be determined spectroscopically. Malvezzi et al (1975) used Stark broadening of resonance lines in a Be plasma to map the spatial electron density variation up to 2mm away from the deflagration zone.

Line intensity ratios, in particular the α -ratio (resonance / intercombination), are used extensively in determining n_e for a plasma (Ilyukhin et al, 1981).

Since the recombination continuum intensity in a plasma depends on $n_e n_{z_1}$ (n_{z_1} = ion density in charge state z_1), a measurement of the recombination continuum intensity ratio can be used to determine the relative abundances of ions in different charge states (Malvezzi et al, 1979).

A comprehensive review of spectroscopic diagnostics of laser-produced plasmas up to 1983 has been published by DeMichelis and Mattioli (1984).

I.4 Applications of Laser-Produced Plasmas.

In recent years there has been an increasing level of research activity into the applications of laser-produced plasmas. These plasmas are excellent sources of XUV/VUV line and continuous radiation and have hence become popular sources for emission and absorption spectroscopy at short wavelengths. The excellent shot to shot reproducibility of these sources has led to extensive work on the characterization of laser-produced plasmas with a view to using them as XUV/VUV radiometric standards (O'Sullivan et al, 1981, 1982, Fischer et al, 1984). The intense XUV radiation emitted from laser-plasmas makes them suitable sources for high-resolution lithographic work (Nagel et al, 1978, 1984, Nagel, 1985, Yaakobi et al, 1983, O'Neill et al, 1986) Laser-produced plasmas have also been used as X-ray/XUV light sources in microscopy (Rosser et al, 1985, Michette et al, 1986) and Extended X-ray Absorption Fine Structure (EXAFS) studies.

For many years, research into the physics of laser-produced plasmas has been primarily motivated by the fusion program (Mallozzi et al, 1981, Eason et al, 1984). These inertial confinement fusion (ICF) studies continue to record slow but steady progress in the development of a clean power source

Lately, clear evidence of laser action at XUV wavelengths has been obtained by workers at a number of laboratories (M. H. Key (ed), 1990). The use of laser-produced plasmas as short wavelength gain media is a most exciting development and, combined with XUV multilayer mirrors of good reflectivity (Barbee 1986, 1990), should produce a highly versatile source of coherent radiation with many conventional and new applications in science and technology, e g , XUV holography and interferometry (Matthews et al, 1985, Suckewer et al, 1985, Jaegle et al, 1987).

Central to the development of laser-plasma sources has

been the study of radiation losses in a range of spectral regions with a variety of detectors. A brief discussion on some of the different types of detectors will be given in the next section.

I.5 Development of Multichannel Detectors.

As most light sources radiate energy over a large spectral range, studies of such sources require detection systems which are capable of quantifying the amount of light emitted over an extensive wavelength range. These measurements require a spectral dispersing device, such as a grating or prism spectrometer with a light detector.

Typical light detectors are photographic film / plates and single-channel electronic detectors, e.g., photodiodes or photomultiplier tubes (PMT). These detectors measure light incident on them within their spectral response ranges. A variety of photographic plates are available which cover the electromagnetic spectrum from X-rays to IR wavelengths. PM-tubes are sensitive in the 250nm to 1,100nm range while photodiodes are available with sensitivities from X-rays to mid infra-red ($\rightarrow 12\mu\text{m}$).

Both detector types, photographic and photoelectric, have advantages and disadvantages for spectral measurements. Photographic film and plates have relatively low sensitivity and poor linearity but high spatial resolution. A major advantage of photographic detection is its ability to record entire spectra simultaneously, thus permanent records are formed for future reference. But measurement of intensity information stored photographically must be carried out in a cumbersome additional step (densitometry, etc.).

Monochromators equipped with PMTs and other single-pixel photodetectors provide spectral information on only a single wavelength or narrow spectral region at any one instant. Therefore, measurement of broad spectral regions generally requires wavelength scanning in which light from different spectral regions sequentially illuminate the detector. Hence variations in source intensity during the scanning time can lead to erroneous data. However, PMTs possess fast response time, high sensitivity and linearity; desirable features of any spectrometric detector.

Yet another spectral analyser is the Optical Multi-

channel Analyser (OMA) This device is a modular electro-optical signal-processing system for the quantisation of light intensity as a function of space or (with a dispersive device) wavelength. In operation, dispersed light is detected on the face of an imaging detector which measures intensity in a number of channels (usually 512 or 1024). The advantages of the electronic readout, linearity and fast response of a photodiode are combined with the spatial resolution, broad spectral coverage and image storage characteristics of a photographic plate.

Initially, the detectors used in the OMA were silicon vidicons or the more sensitive Silicon Intensified Target (SIT) detectors (Talmi, 1978) Both types of detectors were effectively standard TV tubes. However they have since been replaced by the CCD array (Calcott et al, 1988) and the self-scanned photodiode array (PDA) which was specifically designed as a parallel spectrometric detector

A PDA contains a row of photodiode sensors, typically on $25\mu\text{m}$ centres, along with scanning circuitry for individual pixel readout (Fig.1 2) Light incident on the sensing area generates a charge which is collected and stored during the integration period The accumulated charges are then sequentially switched into the video output line for readout to one of the memories in the controller console. The memories may be used for signal averaging or they may be accessed separately for comparison with different sets of data These data may be displayed on a monitor or X-Y recorder or may be passed directly to a minicomputer for storage and further processing.

Two important features of OMAs are.

- (i) The ability to integrate signals in parallel from continuous wave (CW) sources of extremely low intensity for long time periods (up to many minutes for cooled PDAs and hours for CCDs)
- (ii) The ability to integrate signals in parallel from pulsed sources for extremely short exposure times

An intensified PDA detector system possesses a Microchannel Plate based image-intensifier (MCP) which is

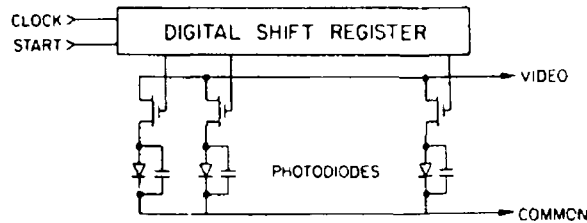


Fig.1.2. Schematic diagram of a typical self-scanned PDA.

fibre-optically or lens coupled to the face of the PDA. A photon incident on the input face of the device is converted to a photoelectron and amplified in a channel of the MCP. The confined electron bunch collides with a phosphor deposited on the output face of the MCP generating a bright output light signal which is either lens or proximity focused onto the PDA. The UV response of the detector can be extended by the deposition of a thin film scintillator onto the input face of the image intensifier for UV \rightarrow visible down conversion (Blouke et al, 1980). Also, image-intensified detector systems may be gated down to nanosecond time scales for time resolved imaging (Luppi et al, 1984).

Such a gated, parallel detector is useful in the observation of the emission and absorption spectra of laser-produced plasmas which are of short duration (often less than a millisecond). At the same time, the intense background scattered laser light may be present for less than the first microsecond or so after plasma creation. Appropriate gate pulses applied to the intensifier can shutter the detector on and off for nanosecond \rightarrow millisecond time periods, thereby blocking this unwanted signal. Gate pulses are derived from commercial high voltage pulse generators with outputs in the 50ns to 100ms range. In fact it is possible to gate a detector for time periods as short as 1ns, where the limiting speed is determined by the gate pulse-rise time and duration.

There are many applications of OMAs with gated

detectors ranging from laser/analytical chemistry to fusion measurements. The advantages of parallel detection with PDAs plus the time-resolving capability inherent in the gated MCP detector have permitted rapid advances in basic and applied spectroscopy in recent years

I.6 Photodiode Arrays (PDA's).

The Photodiode Array consists of a linear array of typically 512 or 1024 silicon pn junction photodiodes. Associated with each diode (see fig.1 3), there is a junction capacitance of typically 0.6pF upon which charge may be stored by the application of a reverse bias of normally 5V. Light in the 200 → 1100nm spectral region incident on the diodes results in the formation of electron-hole pairs and hence the charge on each capacitance is depleted. The amount of charge needed to rebias each diode is a measure of the video signal. Initially a start pulse biases all 1024 diodes. After a predetermined exposure (or integration) time, a pulse is fed to the start input and the recharge sequence is repeated. The resultant recharge pulses are fed to charge sensitive preamplifiers, converted to voltage pulses and usually sampled/digitised and stored in memory. The data so recorded may then be processed and the final spectral image displayed on a VDU or plotted. PDA's will be discussed in more detail in the next chapter. Useful studies of PDAs are given by Talmi and Simpson, 1978, Vogt et al (1978), Simpson (1979) and Hopwood (1980).

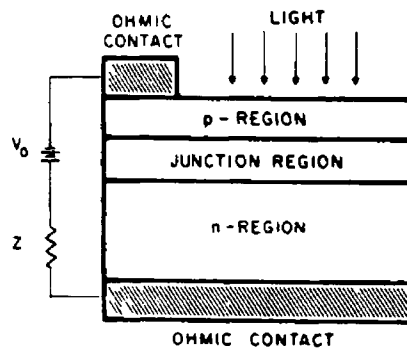


Fig.1.3. Schematic representation of photodiode geometry.

I.7 Microchannel Plate Image Intensifiers (MCP's).

A Microchannel plate (MCP) is an array of $10^4 \rightarrow 10^7$ miniature electron multipliers oriented parallel to each other (Fig.1 4). Channel diameters are in the range $8 \rightarrow 100 \mu\text{m}$ and have length to diameter ratios (α) between 40 and 100. Channel axes are either normal to, or biased at a small angle ($\sim 8^\circ$) to the MCP input surface. The channel matrix is usually fabricated from a lead glass, each channel consisting of a hollow glass fibre which is internally coated in such a way as to optimise the secondary emission characteristics of each channel and to render the channel walls semiconducting so as to allow charge replenishment from an external voltage source. In effect, each channel can be considered to be a continuous dynode structure which acts as its own dynode resistor chain. Each face of the MCP is usually coated with Nichrome or Inconel to form electrodes across which a dc or pulsed voltage may be applied. The total resistance between electrodes is of the order of $10^9 \Omega$. A diagram of a straight channel electron multiplier is shown in fig.1 5. The maximum optical gain of such single stage intensifiers is typically $100 \rightarrow 2000$, while time resolution in the subnanosecond regime can be obtained (Luppi et al, 1984).

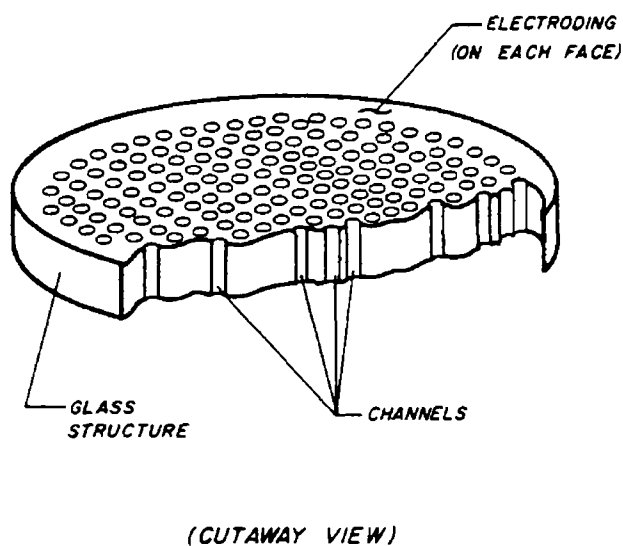


Fig.1.4. A Microchannel Plate

Spatial resolution is limited by the channel dimensions, centre-to-centre spacings and mode of operation (d.c./gated) and is in the 10 → 50 line pairs/mm (lp/mm) range. Devices with 12 μ m diameter channels with 15 μ m centre-to-centre spacings are most often used. A detailed review of MCP's is given in the paper by Wiza (1979).

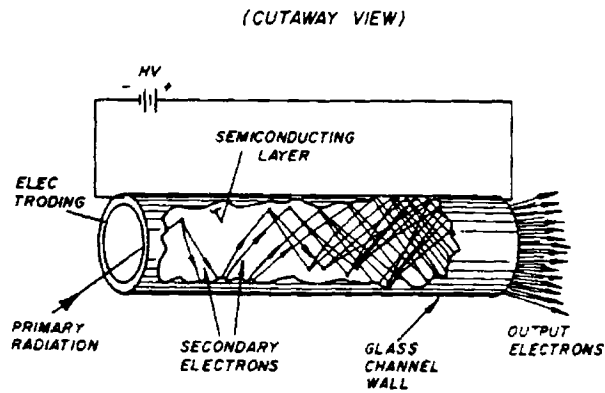


Fig.1.5. A straight channel electron multiplier.

CHAPTER II

DEVELOPMENT AND TESTING OF THE OMA SYSTEM

II.1 The Optical Multichannel Analyser (OMA).

The OMA system comprises a detector head, delay generator, controller/interface unit and BBC microcomputer (Fig.2.1) The detector head consists of a microchannel plate (MCP) image intensifier lens coupled (via f/1.4 optics) to a Reticon 1024S photodiode array (PDA) The controller/interface unit consists of an EG & G Model 1462 detector controller and a Model 1461 detector interface housed in a Model 1461XD virtual memory extended (VME) crate. The delay generator was designed and built by the author as part of the project

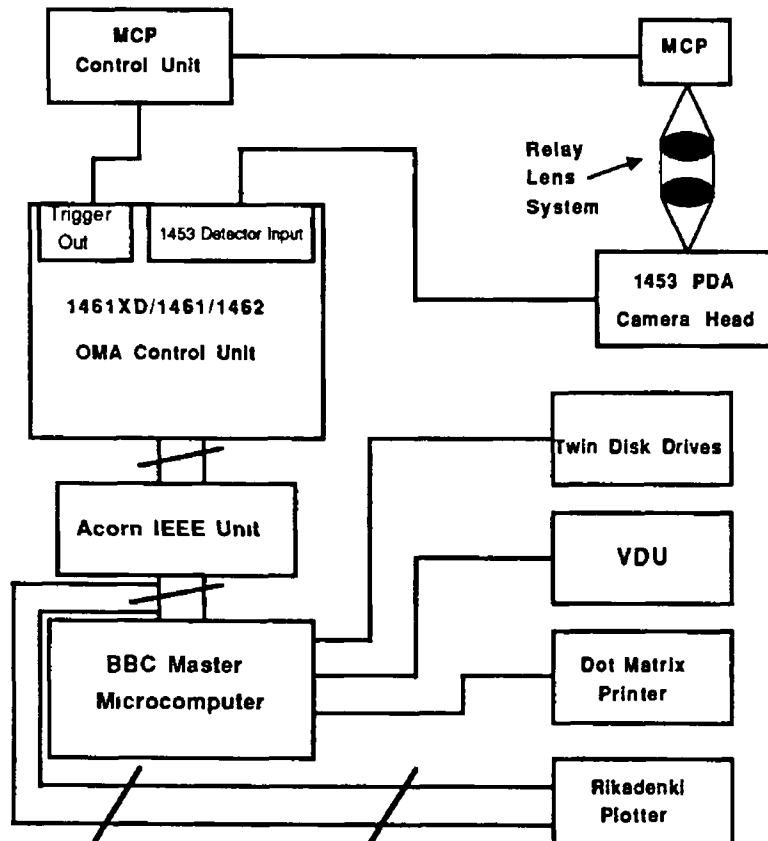


Fig.2.1. Functional block diagram of the Intensified OMA System.

II.2 The Camera Head.

The photodiode array camera head is an EG & G Model 1453 consisting of a Reticon 1024S PDA with a quartz window permitting operation in the 185 → 1100nm spectral range. It is connected to the 1462 detector controller card via a 25-way cable. The PDA itself, can be operated at temperatures as low as -19°C by means of a water assisted Peltier cooler. It is important to use a Nitrogen purge to prevent condensation formation on the PDA, its associated circuitry and Peltier cooler. A flow rate of 80 cc/min was used during operation which was sufficient to counter this effect.

The Reticon S-series (Scientific) self - scanning photodiode arrays have been specifically designed and optimised for applications in spectroscopy. The part number of each device indicates the number of elements in the array (e.g., 128, 512 or 1024)

The 1024S device consists of a row of 1024 silicon photodiodes, each with an associated storage capacitor on which photocurrent can be integrated and a multiplex switch for periodic readout via an integral shift register scanning circuit.

The array of 1024 silicon diode sensor elements are located on 25µm centres corresponding to a density of 40 diodes/mm giving a Nyquist limiting resolution of 20 lp/mm [i.e. 1/ (2 X pixel size)] and an overall length of 25.6mm. The height of the photodiode is 2.5mm giving each element a slit like geometry with a 100:1 aspect ratio making it suitable for coupling to monochromators and spectrographs.

The diodes consist of diffused p-type bars in an n-type silicon substrate (Fig 2 2). Light incident on the sensing area generates charge which is collected and stored on the p-type bars during the integration period. The accumulated charges are then sequentially switched to the video line for readout. Both the n-type and p-type silicon surfaces are photosensitive. Light incident on one of the p-regions will generate charge which is stored on that

diode. Charge generated by light incident on the n-type surface between two p-regions will divide between the adjacent diodes.

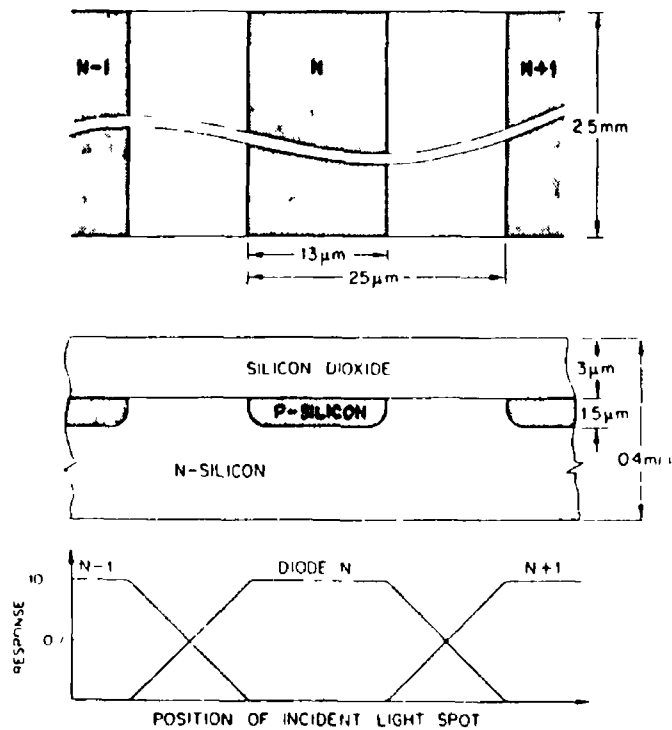


Fig.2.2. Diode geometry and idealised aperture function.

Each cell of the scanning circuit (Fig.2 3) consists of a photodiode and a dummy diode, both with an associated storage capacitance. These diodes are connected through MOS multiplex switches to video and dummy recharge lines. One pair of recharge lines is common to all the odd elements and another pair is common to all the even elements.

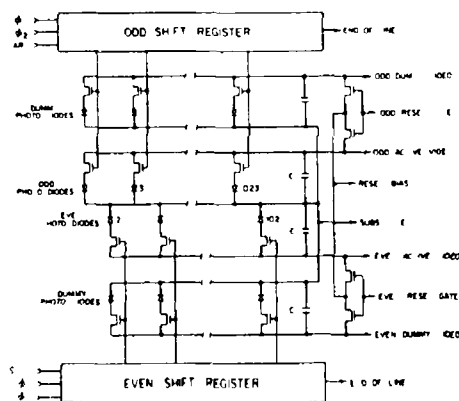


Fig.2.3. Equivalent circuit of 1024S PDA

The multiplex switches are turned on and off in sequence by shift register scanning circuits thereby periodically recharging each cell to 5 volts and storing a charge Q_{sat} on its capacitance. The shift registers are driven by multiphase clocks with periodic start pulses being introduced to initiate each scan. The cell-to-cell sampling rate is determined by the clock frequency. The integration time is the interval between start pulses. The readout time per pixel is $28\mu s$, yielding a minimum integration of approximately 30ms. During this integration time the charge on each capacitor is gradually removed by the reverse current flowing in the associated photodiode. The reverse current is made up of two components: the photocurrent i_p and a small dark leakage current i_d which can often be neglected. The photocurrent is the product of the diode responsivity and incident light intensity. During a line scan time, the charge Q removed from each cell is the product of the photocurrent and the integration time. This charge must be replaced through the video line when the diode is sampled once each scan. Thus, the output signal obtained from each scan of an N element array is a train of N charge pulses, each proportional to the light intensity on the corresponding photodiode. By properly phasing the clock signals to each of the two shift registers, all of the diodes can be sampled in a proper sequence. The two video lines can then simply be connected together to provide a continuous train of output charge pulses. In addition to the signal charge, switching transients are capacitively coupled into the video lines by the multiplex switches. These same transients are introduced into the dummy lines and therefore a clean signal can be recovered by subtraction of the dummy and output signals.

The PDA and associated analog circuitry is mounted in a steel box with input ports for water (to the Peltier cooler), nitrogen gas and connection to the 1462 camera controller board. A quartz window mounted on the PDA extends the useful range of the sensor down to 185nm

(approximately). The head bolts onto the exit slit (port) of any spectrometer via a 4-inch flange (Fig 2.4).

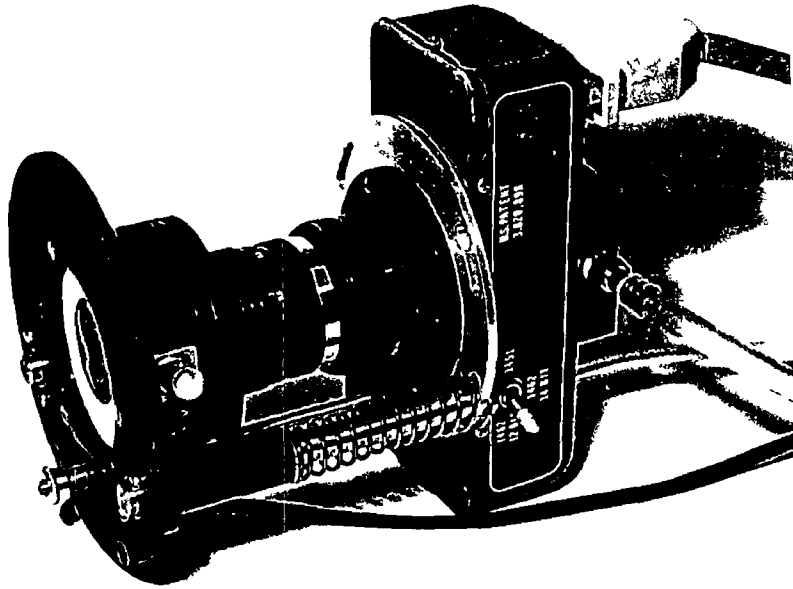


Fig.2.4. The MCP/PDA camera head.

II.3 The ITT Microchannel Plate Image Intensifier.

The microchannel plate was manufactured by ITT and supplied by Delli Delti Ltd., (DDL). It has an S20 photocathode deposited on the input side and a P45 phosphor coating on the exit side (Fig 2.5). It is optimised for light input in the blue-green spectral region and provides a green output image, ideally matched to the spectral response of silicon based imaging detectors, e.g., photodiode arrays and charged-coupled devices. The static (d.c. operation) spatial resolution of the MCP is quoted by DDL to be 25 lp/mm. The 12 μ m centre to centre spacing of each channel implies a Nyquist resolution limit of ~40 lp/mm. The dynamic resolution (pulsed/gated mode) is given by DDL as 10 lp/mm. The device is gateable and can be operated with gate widths as short as 30ns. Below this value, the effective optical gain drops dramatically. The maximum dynamic optical gain is approximately 2000 at 500nm. A somewhat similar value was obtained experimentally by the author at the 633nm He-Ne wavelength (see section II.7).

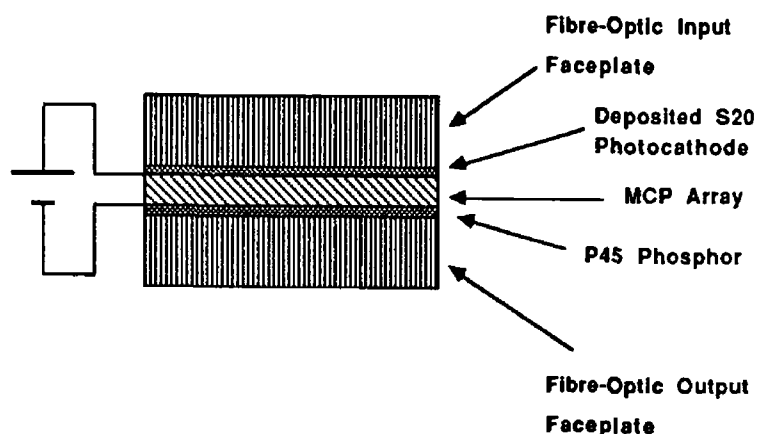


Fig.2.5. Schematic diagram of a proximity focus image intensifier.

The drive unit for the MCP was designed and constructed by Delli Delti. It has two modes of operation - 'focus' or d.c. mode and 'gated' or pulsed mode. During this work, the device was operated exclusively in pulsed mode and synchronised to a solid-state ruby laser.

The MCP may be gated by application of (1) a push button trigger pulse, (11) an external pulse ($>3.2\text{V}$, $>200\text{ns}$) or (111) by a pulse derived from an internal clock circuit covering the 0.1 to 10KHz frequency band in a number of switchable ranges.

A monostable circuit in the drive unit sets the gate pulse-width range via an RC network. This range was set to the 30 \rightarrow 2000ns interval via a 22pF capacitor and 2 \rightarrow 150K Ω resistance. A circuit based on a monostable which provides a crude delay from trigger in the 0 \rightarrow 10 μs range with an accuracy of approximately 5% of full scale is included in the drive unit. To achieve time resolution of the order of the laser pulse duration ($\sim 30\text{ns}$), it was decided to build a crystal based delay generator with a delay increment of 10ns. In the following section details of this unit are given.

II.4 The Delay Generator.

The main components of the delay generator are an Evan's Electronics Model 4145-2 digital programmable time delay module, a Coutant Model HTC1 power supply and five binary coded decimal (BCD) thumbwheel switches (Fig.2 6). A simple circuit consisting of a pair of HEX-inverters with Schmitt inputs is used to shape the input trigger pulse. A current amplifier (emitter follower) was included at the delay generator output to enable the driving of low impedance loads.

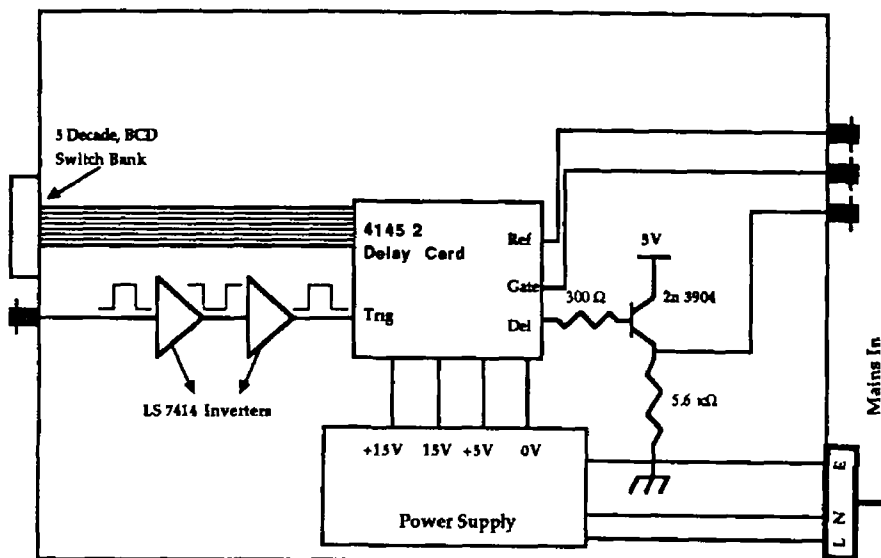


Fig.2.6. Block diagram of delay generator.

The Model 4145-2 programmable time delay has three outputs each of which generates a time-delayed pulse following a trigger pulse or transition applied to a single input (Fig 2.7). One output produces a reference pulse having a fixed delay relative to the input. At another, a pulse is delayed beyond the reference by an amount determined by external programming. The third generates a pulse coincident in time with the programmed delay interval. The widths of the reference pulse and the delayed pulse are independently adjustable with on-board pots. The nominal fixed delay between the 'trigger' and 'reference' pulses (t_0) is 450ns. Using a Tektronix PG501 pulse

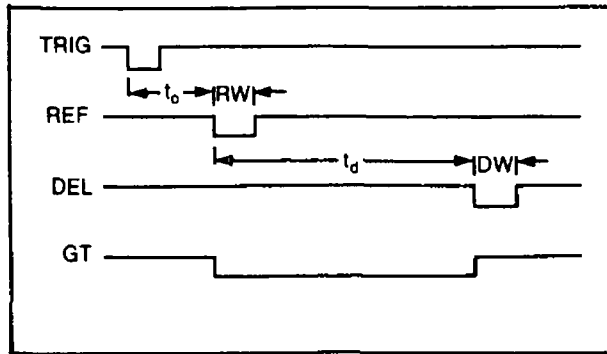


Fig.2.7. Pulse timing diagram.

generator and a Hewlett Packard 54502A 400MHz digital oscilloscope, a comparable value of 462 ± 10 ns was obtained for this delay. The delay range of the delayed pulse, (t_d) can vary from 0 to $999\ 99\mu$ s in steps of 10ns. All pulse inputs and outputs are TTL logic compatible.

The Model 4145-2 has a crystal controlled oscillator which establishes an accurate time base - typically $< \pm 0.005\%$. Digital delay programming is accomplished with external thumbwheel switches via 20 negative true logic input lines arranged as 5 decade BCD units. The Coutant Model HTC1 power supply is a dual output linear power supply capable of supplying up to 3A at 5V and 1A at ± 15 V.

One of the main considerations of the delay generator design was noise immunity. Pulsed solid-state lasers produce both mains borne (via the ground line) and radiated (RFI) noise. To reduce the effects of RFI, the system was enclosed in a well shielded box, while mains borne noise was reduced by the use of a line conditioning filter. All input signals were decoupled via 100pF capacitors and carried on shielded transmission lines. In practice, the above precautions were found to result in excellent noise immunity and reproducible performance of the delay generator.

II.5 The Detector Controller/Interface.

The control and readout of the 1453 photodiode array camera head was provided by an EG & G 1462 detector controller and 1461 detector interface mounted in a 1461XD VME crate. The controller card, installed in the 1461XD, utilises both on and off board timing circuitry, various amplifiers, latches and a 12-bit analog-to-digital converter (ADC) to control the spectral data acquisition by the detector. It can acquire a spectrum of 1024 pixels in 30ms and temporarily store the spectral data. This data can be processed before down-loading to the host computer for storage, graphical display, analysis or hard-copying.

The Model 1461 Detector Interface is the crucial link between the computer and the detector of the OMA. It provides for computer control of the OMA system via parallel, RS232 and IEEE-488 ports. It permits software control of the PDA based detector and also functions as an intelligent buffer for the host computer. It is based on a Motorola 68000 (16-bit) microprocessor programmed to control PDA detectors, manipulate the spectra and send the results to the host computer (in this case a BBC Master). The 1461 consists of a CPU card with 128K of ROM and 32K of RAM storage. IEEE commands are grouped into several categories: Set-up, Data Acquisition, Curve Transfer, Curve Calculation and Status. A simple command structure of question and answer type format allows for ease of communication with the host computer.

Although the 1461XD and its associated VME cards are programmable over IEEE, RS232 or programmable interface buses, it was decided to use the IEEE interface as it provided the most flexible approach to instrument control and data acquisition as it encompassed all command modes. A BBC Master (128K RAM) computer with an ACORN IEEE-488 interface was chosen as the host computer due to budget constraints.

A transmission from the computer to the 1461 consists of a command followed by a space, one or more numbers as

necessary, and a terminator. The command consists of one or more upper case letters. The numbers, where necessary, are decimal, while the terminator is either a carriage return <CR> or a carriage return followed by a line feed <CRLF> (as used by the BBC Master). The terminator is selected by a switch on the rear panel of the IEEE-488. Several commands can be sent on one line by separating them with a semicolon. For example, the sequence of commands:

```
ET 0 1 <CRLF> set exposure time to 0.1s
DT 5 <CRLF> set detector temp to 5°C
DA 4 <CRLF> set data acquisition mode to mode 4
```

could be transmitted as a single compound command with the sequence:

```
ET 0.1;DT 5;DA 4 <CRLF>
```

The following steps summarise the procedure to communicate with the 1461 via the IEEE-488 GPIB interface:

1. Wait for the Command Done bit.
2. Send a command.
3. Receive the 1461's response, (if any)
4. Get an error message, (if any).
5. Go to Step 1.

An example of the question and answer type format in communicating with the 1461 can be seen when one enquires of its status. If one asks it to identify itself using the command ID <CRLF>, the detector interface will return its model number, in this case, 1461.

The command:

```
ID ;VER ;CL ;DM ;DLEN ;FREQ <CRLF>
```

asks the detector interface of its status, enquiring of its identity (1461), its software version number (VER 1.92), the cooler status (0/1, unlocked,locked), the identity of the detector controller (1462), the number of pixels in the detector (1024) and the line frequency setting (50Hz) and the 1461 will respond as shown in brackets. Lines 820 to 1020 in Program "OMA1" shows this command structure in operation using the BBC microcomputer:

```
820 cmd%=OPENIN("COMMAND")
830 data%=OPENIN("DATA")
```

```

850 PRINT#cmd%,"CLEAR"
860 PRINT#cmd%,"REMOTE ENABLE"
870 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
880 PRINT#cmd%,"UNLISTEN"
890 oma%=OPENIN("11")
900 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
910 PRINT#data%,"FREQ 50"
920 PRINT#data%,"ID ;VER ,CL ,DM ;DLEN ;FREQ "
930 PRINT#cmd%,"UNLISTEN"
940 PRINT#cmd%,"TALK",oma%
950 INPUT#data%,ID$,VER$,ACL$,ADM$,ADL$,AFRQ$
960 PRINT "ID = ";ID$
970 PRINT "SOFTWARE VERSION = ",VER$
980 IF ACL$ ="1 " THEN PRINT "COOLER LOCKED"ELSE PRINT
    "COOLER UNLOCKED"
990 PRINT "DETECTOR CONTROLLER IN USE IS MODEL ";ADM$
1000 PRINT "DETECTOR ARRAY LENGTH = ";ADL$
1010 PRINT "LINE FREQUENCY = ",AFRQ$
1020 PRINT#cmd%,"UNTALK"

```

The above segment of code demonstrates the simplicity of OMA control/communication using the IEEE-488 command protocol. IEEE commands (e.g TALK, LISTEN, etc.) are sent from the computer to the OMA controller via the command (cmd%) channel and machine specific commands (e.g., DT, ID, FREQ, etc.) via the data (data%) channel using simple PRINT statements. Responses (if any) are read into the computer via the data channel using INPUT statements. Using this simple structure a comprehensive control and data acquisition/processing/display package was constructed. An outline of the main features of this package is given in the next section

II.6 BBC/OMA Software Package.

Before the OMA could be used as a detection system, comprehensive controlling software was required. The program modules were written in a menu-driven, user-friendly format to permit any user to control the apparatus without detailed knowledge of the actual software coding. Once the software has been loaded the program menu appears on the screen asking the user to choose an option from the following list.

Record a spectrum
Read data from the 1461 memory
Read data from disk
Plot a graph of present data
Manipulate memories in the 1461
Print graph on Rikadenki plotter
View a directory
Stepper test
ASCII file convert
File manipulation
End

Associated with each option is a program which is initiated when a selection has been made. All programs are software linked, i.e. loaded and run automatically at the request of the user through the main menu. This means that it is not necessary to load, run, end and reload programs continually. A brief overview of these programs and their uses now follows. For completeness full listings of the programs are given in Appendix I as a reference for future users.

Program "MENU1": This program, as the name suggests, is the main menu for the system control. From it, access to the other programs within the package may be obtained.

Program "OMA1": When the experimenter selects "Record a spectrum", this program is loaded. The initial (default) experimental parameters (e.g., the exposure time, detector temperature, acquisition mode, number of scans, etc.) are read from the Controller by this program. Then, by a series

of question and answer type steps, the operator can select any or all of the parameters and reset them to the value required for a particular experiment. Once the particular parameters have been selected, the experiment can be initialised. A second experiment may be carried out by re-running the program or else the user can return to the main menu for the acquisition, analysis and transfer of the experimental data.

Program "MONITOR": This program permits process monitoring. On the execution of the run command in the OMA program, the internal clock of the BBC is initialised. MONITOR uses this clock to time the experimental events. Exposure time, number of scans, number of ignored scans and the number of memories allocated to the experiment are read from the detector interface. By adding the number of scans to the number of ignored scans and multiplying the result by the exposure time, this program calculates the time required to run an experiment. As the elapsed time (read from the BBC clock) is longer than that necessary for the experiment, data can be read from the memory location specified at the start of the program, plotted on the BBC VDU and if required, output to a printer. During the next time interval, a second experimental run is made and the next memory location is downloaded, displayed etc. This procedure is repeated for each of the six memory locations in the 1461 detector/controller interface.

Program "GETDAT": This program is selected to "get" or download data from the detector interface and is initiated when the "Read data from the 1461" option is selected. Once the data has been received by the host computer, it is displayed on the screen as a graph of intensity (in counts) versus channel number. From this display, the user can decide if the data is useful or not. A number of options are then available which permit the user to save or delete the data. If the data is of use, it can be written to a disk file to be reloaded and analysed at a later stage. When all required data has been downloaded, the user is returned to the main menu.

Program "PLOT": When "Plot a graph of present data" is selected from the menu, this program is loaded and (on receipt of a filename) opens the file and reads in data. The data are then plotted point by point or as a continuous curve as intensity versus channel number. A sub-menu is then displayed, allowing the user to recalibrate the graph in terms of intensity versus wavelength (if so desired). The graph can also be expanded to highlight a particular peak of the spectrum, or alternatively the entire spectrum can be analysed to find the wavelength or channel number at which a particular peak falls. It can also be used to find the peak intensity or the FWHM of a particular peak. Another option is to sum the detected light intensity over a particular range of the PDA between two channel numbers or wavelengths. At any stage, a screen dump to a dot matrix printer may be obtained, yielding a hard copy of the displayed graph. After each step the user is returned to the sub-menu. Once finished the user may return to the main menu.

Program "PRNTER1": This program is similar to, but not as versatile as, the PLOT program. It outputs a graph to a Rikadenki digital plotter with an IEEE port and is used in conjunction with the "Print graph on Rikadenki plotter" menu option. The Rikadenki is a high resolution plotter which gives both a more aesthetically pleasing and more detailed copy of the data than that obtained by a screen dump. The default graph axes are intensity versus channel number, with the option of recalibration of the latter to wavelength. The experimental parameters relevant to the particular data set used can also be included on the plot if required. There is a further option which enables the plotting of a number of graphs on the same scale to compare data. This is achieved by the use of the program "PRNTER2". PRNTER2 is similar to PRNTER1, but plots new data over a graph with previously drawn and scaled axes.

Program "PARAM": When a graph has been dumped to the printer, the user is asked if the conditions under which the spectrum was recorded are to be defined. If it is so

desired, this program is called, allowing the input of the values of experimental parameters such as detector temperature, exposure time, number of scans and the data filename. These are then output to the printer with the graph.

Program "DATADSUB": When the user selects the menu option "*Manipulate memories in the 1462*", DATADSUB allows the manipulation of data in the detector interface before being downloaded to the host computer. The user can add together two sets of data or subtract one set of data from another as required. This option provides for the removal of (for example) a background reading from an experimental spectrum. It also permits noise reduction by multichannel signal averaging of successive spectra.

Program "DATLOAD": This program permits the reading of a data file from disk (used when menu option "*Read data from disc*" is selected). It is helpful when sifting through a large number of stored data sets. It is also of use in printing the actual data values on the computer's VDU.

Program "DUMP": This program is called from programs such as PLOT, GETDAT and MONITOR, where graphs of spectra are displayed on the screen. The program examines the screen, converts it to a form suitable for the dot matrix printer and downloads the data to it. Thus, the printer gives an exact copy of the graph shown on the screen.

Program "CAT": If the user wishes to "*View a directory*", this program displays the contents of a disk on the VDU.

Program "FILCON" is used to convert a data file stored on disk to its ASCII form ("*ASCII file convert*" option on menu). BBC files in ASCII form can be transferred to an IBM PC using the KERMIT communication package where they can be operated on with more powerful statistical and plotting packages than those available to the BBC.

The "*File Manipulation*" option on the menu gives the user the facility to manipulate files that are stored on disk. The user can:

- (1) add/subtract two data files,

- (11) divide/multiply a data file by a number,
- (11i) smooth a data file

The program FILADSB is used for option (1) while the programs FILDIV and FILSMO are used for options (11) and (11i) respectively

Program "FILADSB" reads two data files from disk, performs the addition or subtraction operation and writes the result to a new file on the disk

Program "FILDIV" reads a data file from disk, performs division or multiplication by any number and then writes the data to a new file on the disk.

Program "FILSMO" is a multipoint smoothing routine. It averages data using a standard Savitsky-Golay adjacent points averaging algorithm.

$$X_j = \sum_{i=j-n}^{j+n} X_i / 2n+1 = 1/2n+1 \sum_{i=j-n}^{j+n} X_i$$

where n is the order of smooth

The "Stepper Test" menu option allows the user to check the operation of the stepper motor(s) on the experimental apparatus. In operation Program "STEPPER" is run on a separate BBC computer

Two further programs were written for communicating with a Philips PM3311 60MHz Digital Oscilloscope which was used for displaying and storing output pulses from the laser and laser-plasmas during this work. Program "DSCOPE" and Program "DSCOPE1" allowed data acquired by the oscilloscope to be transferred to the BBC for processing and storage on disk. DSCOPE reads data displayed on Channels A and B simultaneously while DSCOPE1 reads data displayed on a single channel only.

II.7 OMA System Performance.

In order to test the operation of the OMA system and its associated software, spectra of a number of laser-produced plasmas were recorded with the unintensified 1453 PDA directly. The experimental set up is shown in figure 2.8. The ruby laser is actively Q-switched by a pockels cell and has an energy up to 1.5 joules with a duration of 30ns and a pulse repetition rate up to 1Hz. The system has

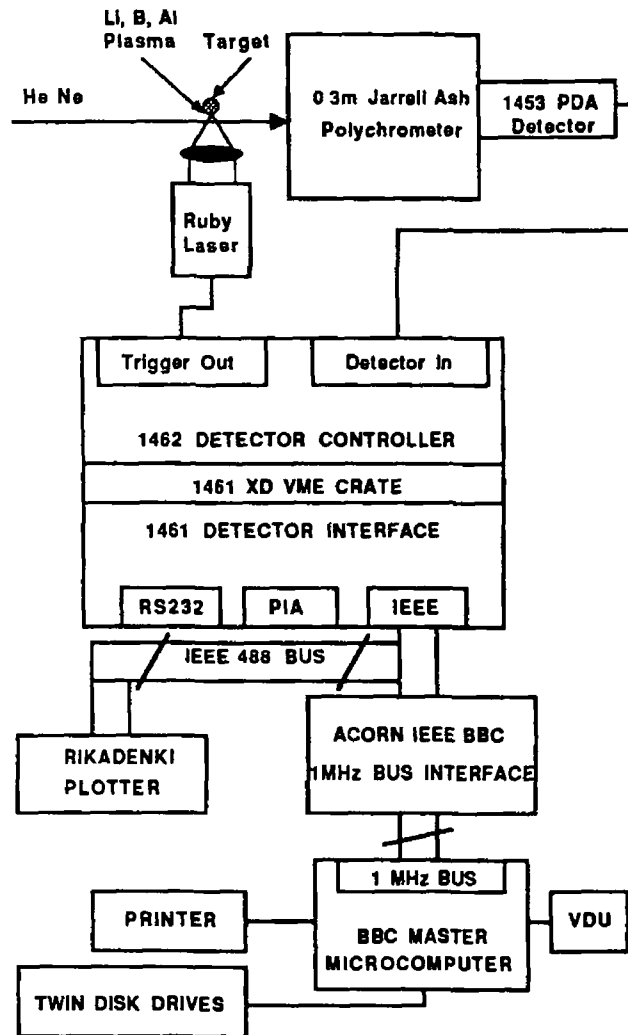


Fig.2.8. Experimental set-up for testing the unintensified PDA.

been described in detail by Brilly (1986) and will not be discussed further here. The 1453 camera head was bolted onto the exit port of a 0.3 metre Jarrell-Ash polychromator (exit slit removed). The ruby laser flashlamps were

triggered under software control with a pulse derived from the PDA 'START' pulse and appearing at the 'TRIG OUT' BNC connector on the 1462 camera controller. Although the Q-switched pulse appeared some 750 μ s after the trigger pulse, the 30ms integration time used on the detector ensured that the laser/plasma light pulse was captured by the PDA. A background signal (due to dark current) was placed in a second memory by covering the slit of the polychromator and repeating the experiment. Subtraction of the two memories yielded the 'background corrected' spectrum.

A series of experiments were carried out with Li, B and Al targets in air covering the 400 \rightarrow 700nm spectral range. Alignment of each target with the optic axis of the polychromator was achieved with the aid of a He-Ne laser. Figure 2.9 shows examples of a lithium plasma, formed in air in the vicinity of the 610.4nm (2p-3d) line, at various points from the plasma core outwards. The narrowing of this resonance line in the cooler/less dense region of the plasma is clear from this figure. The very narrow line at 632.8nm is the He-Ne alignment laser which is only 3 \rightarrow 4 pixels FWHM and illustrates the inherent resolution of the PDA itself.

In order to get a feel for the 'single shot' noise count of the system, two background spectra were recorded at a PDA temperature of 5 $^{\circ}$ C and exposure time of 30ms and placed in two successive memories of the 1461 detector interface modules. The spectra were subtracted and the result is shown in figure 2.10 a. The average fluctuation is approximately ± 5 counts although excursions of up to ± 50 counts from the mean have been observed. The experiment was repeated under identical conditions for 25 and 50 laser shots and as can be seen from figures 2.10.b and 2.10.c the average noise fluctuations drop to ± 2 counts and ± 1 count. The latter result for 50 shots agrees with a value cited by EG&G (Burdett, 1989).

In order to deduce the effective optical gain of the MCP, a spectrum of a He-Ne laser was recorded with the

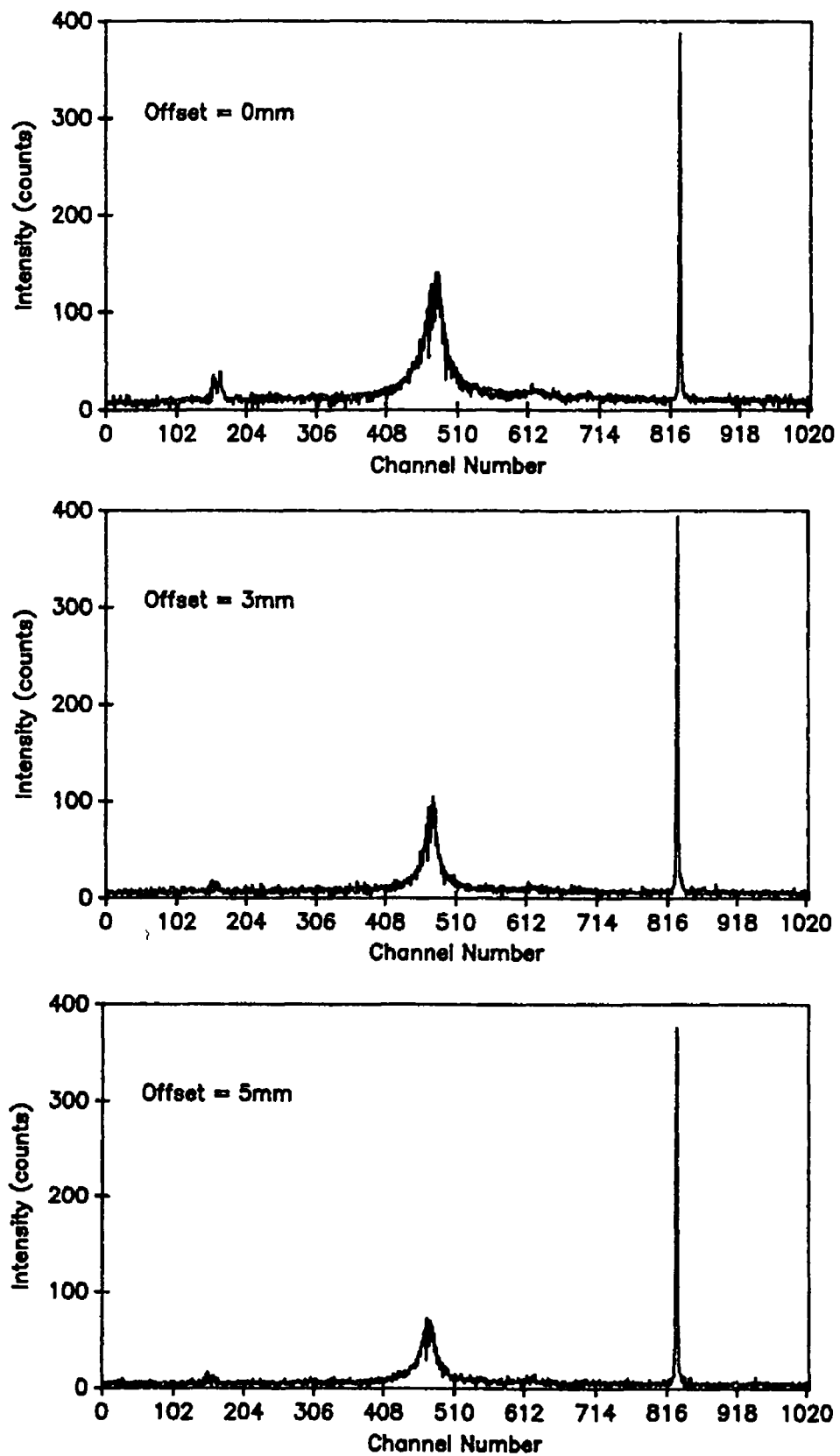


Fig.2.9. Spectra of a lithium plasma formed in air in the vicinity of the 610.4nm, $2p \rightarrow 3d$ line at various points from the core outwards (using unintensified PDA).

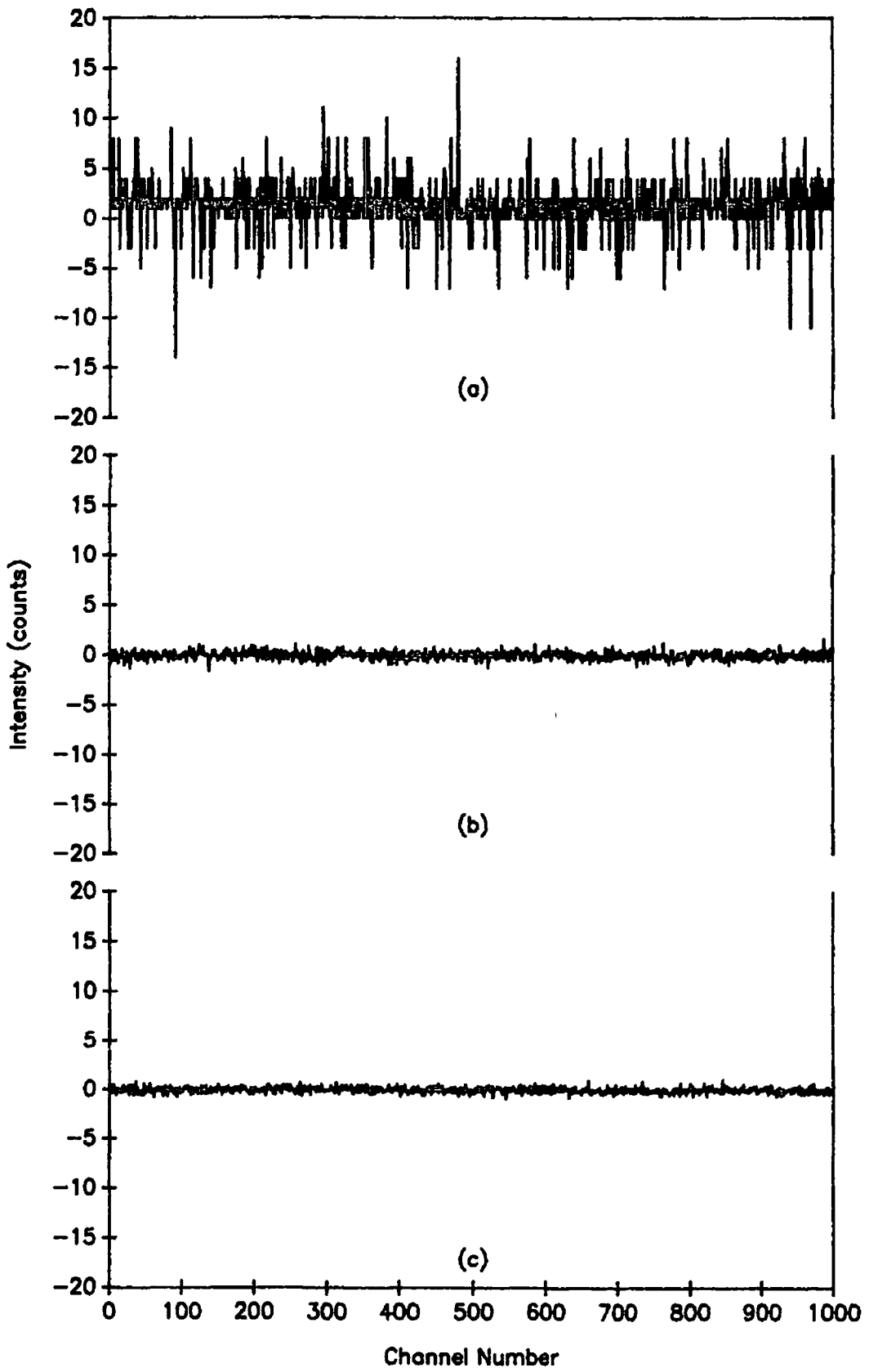


Fig.2.10. Noise count from the 1453 camera head.
(a) single shot, (b) 25 shots and (c) 50 shots.

intensified PDA The experimental set-up is shown in figure 2.11 The MCP was triggered via a line scan start pulse

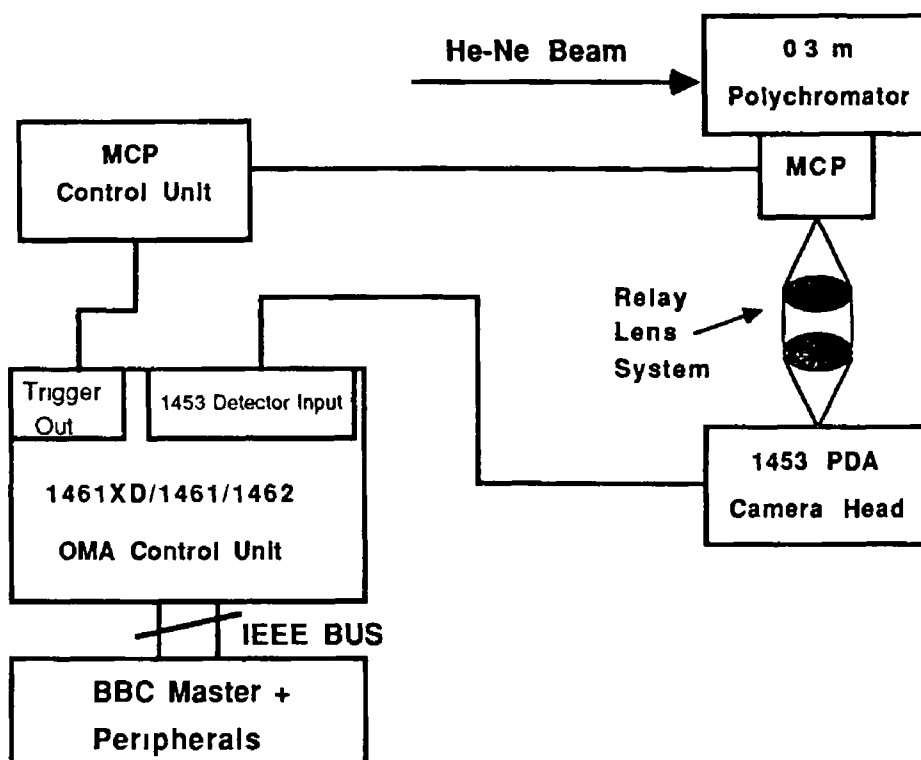


Fig.2.11. Experimental set-up to deduce effective optical gain of the MCP.

derived from the 1462 detector/controller card. At a gain setting of 9% of maximum, a peak count of 1440 was obtained at a gate width (exposure time) of $2\mu\text{s}$ corresponding to a peak flux of approximately 7.2×10^6 photons for a PDA sensitivity of 5×10^3 photons per count (EG&G 1452, 3, 4 camera head manual). The intensity of the line as measured in the focal plane of the polychromator was $0.5\mu\text{W}$ (approx), yielding an incident flux of 3.2×10^6 photons distributed over 12 pixels FWHM (fig 2.12). Hence for an input flux per pixel of roughly 2.7×10^5 photons to the MCP, the flux incident on the PDA is 7.2×10^6 per pixel, yielding an effective gain of 27 (approx) at the 9% gain setting. Hence the maximum gain of the lens coupled MCP is 300 (approx). However, due to a mismatch between the f/1.4 relay lens

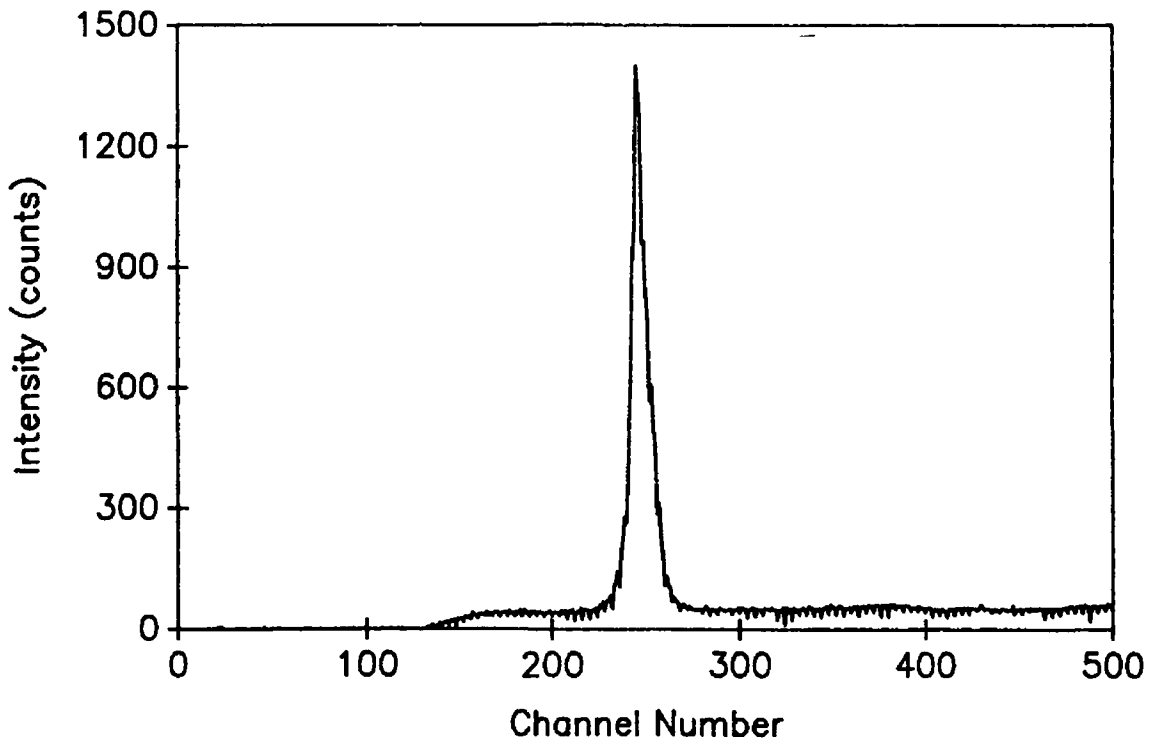
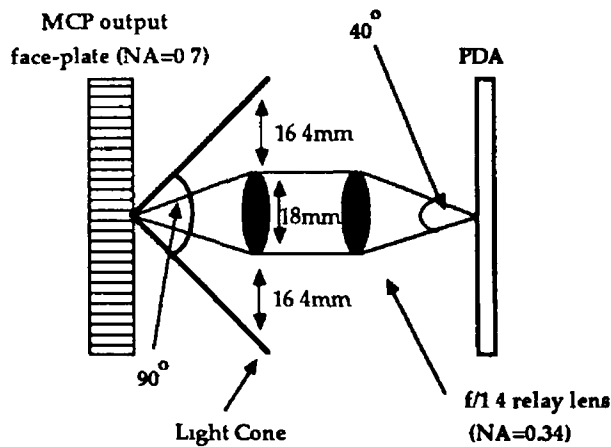


Fig.2.12. Intensified He-Ne Spectrum.

(connecting MCP to PDA) and the fibre-optic faceplate of the MCP (with numerical aperture of 0.7), the optical coupling efficiency of MCP to PDA is <10% - the diagram below illustrates this problem clearly (Fig 2.13) Hence at full MCP gain the optical gain could be as high as 3000 (DDL quote a value in excess of 2000).



$$\begin{aligned}
 \text{Collection Efficiency} &= (\text{Dia Lens} / \text{Dia Light Cone})^2 \\
 &= (18 \text{ mm} / 50.8 \text{ mm})^2 \\
 &= 12.5\% \text{ (excl. reflection/ absorption/ scattering loss)}
 \end{aligned}$$

Fig.2.13. f/No. mismatch of relay lens to MCP faceplate.

The degradation in spatial resolution due to the lens coupled MCP was investigated by measuring the broadening of a narrow He-Ne line on moving from the unintensified to intensified PDA (Fig.2 14) As can be seen, the FWHM of the line increased from 3 → 4 to 8 pixels which is in good agreement with the manufacturer's figures of a factor of 2 or so on going from PDA (~20 lp/mm) to gated MCP (~10 lp/mm).

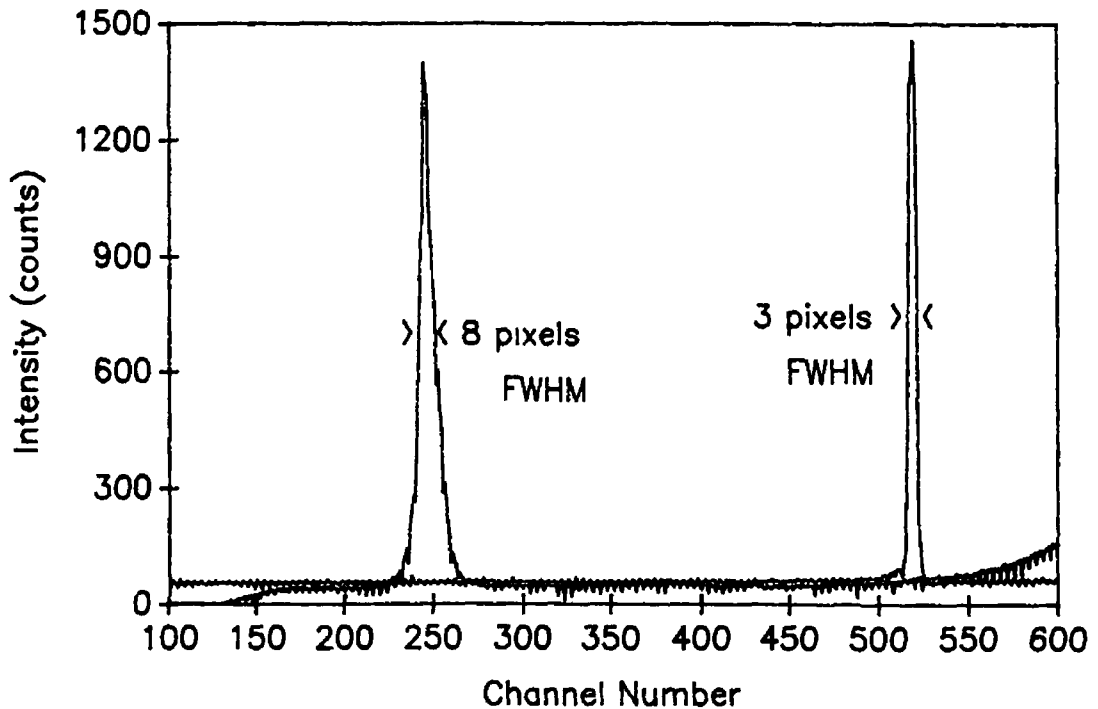


Fig.2.14. Degredation in spatial resolution due to lens coupling MCP to PDA.

In order to test the operation of the gated intensified OMA, a number of spectra in the 300→700nm spectral range were recorded. The layout for these experiments is shown in figure 2 15. A line scan synchronised pulse (obtained from the 'trig out' BNC connector on the 1462) is fed via a voltage-doubling pulse transformer to the remote trigger input of the ruby laser. A pre-pulse from the laser pockels cell drive unit (3μs ahead of the opening of the cell) is fed to the digital delay generator described in section II.4. After a programmed delay (to synchronise the opening of the MCP with the production of the Q-switched pulse from the ruby

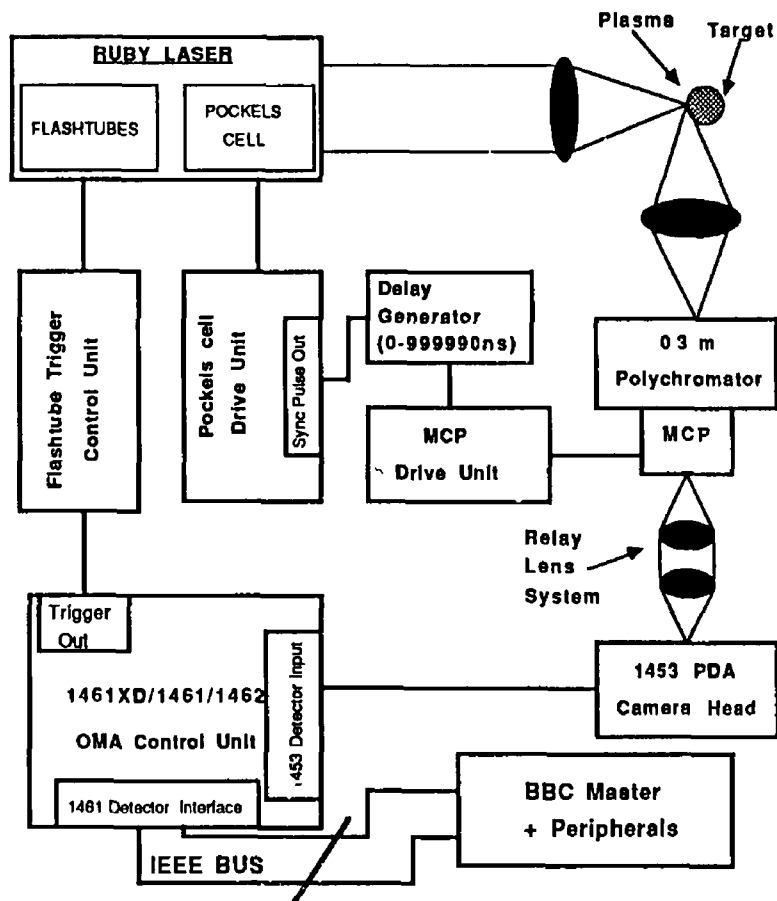


Fig.2.15. Experimental layout for detection of laser-produced plasmas using the gated intensified OMA.

laser), the MCP unit is triggered. Variation of the delay permits the recording of spectra with a time resolution of ~30ns. Figures 2.16, 2.17 and 2.18 show lithium laser-plasma spectra recorded in the vicinity of the 610.4nm line for various MCP gains, gate widths and delays. A lithium plasma combined with the He-Ne laser line is shown in Fig.2 19 to indicate the instrumental resolution.

As can be seen from figure 2.16 the optical gain of the MCP rises very rapidly with gain setting. The gain settings of 2, 4, 6 and 8 represent MCP drive voltages of 200, 400, 600 and 800 volts. For typical MCP image intensifiers the gain scales approximately with voltage according to the formula (Wiza, 1979)

$$G \propto \exp(0.007V)$$

which predicts an increase of X4 for each of the settings. Observation of the first three peak heights of 90, 360 and

1120 counts show good general agreement with this relationship.

From figure 2 17 it is clear that the peak intensity of the 610.4nm line does not increase very linearly with gate width. Obviously for a continuous wave light source or rectangular light pulse of duration greater than the maximum gate width one would expect to see a linear count (intensity) versus gate width relationship. The actual increase in detected intensity with gate width was complicated in this experiment by the shape of the plasma emission pulse at 610.4nm. As one might expect, at short gate widths the detected intensity increased more rapidly with gate width while at longer gate widths (as the plasma pulse decayed) the opposite was observed. Note In the above experiments the delay generator was set at 2.87 μ s in order to synchronise the opening of the MCP with the plasma emission pulse

Figure 2 18 shows the fall off in 610.4nm intensity as the gate width of 500ns is swept over the 0 \rightarrow 4500ns delay range. Significant light emission is observed right out to the microsecond range indicating the production of excited states of neutral atoms via recombination from ionic species long after the disappearance of the 30ns ruby laser pulse

The effect of signal averaging is shown in figure 2 20 where a spectrum of a single shot L1 plasma is compared with that obtained from the average of 16 laser shots. The unintensified PDA was used to record these spectra. Extra, unidentified structure is clearly present in the multi-shot spectrum which is buried in noise on the single shot recording.

Finally, the 'grassy' structure on these spectra result from variations in the pixel to pixel gain of the PDA and MCP. Such fluctuations can be as high as 20% of saturation (Antcliff et al, 1984, Cromer et al 1985). These set of data include the typical value of 5% of full scale deflection. However, some pixels exhibit excursions of up to 20%.

Having completed the design, building and testing of the intensified OMA system, a decision was made to investigate the possibility of extending the detection range of the OMA system to the vacuum UV region below 200nm

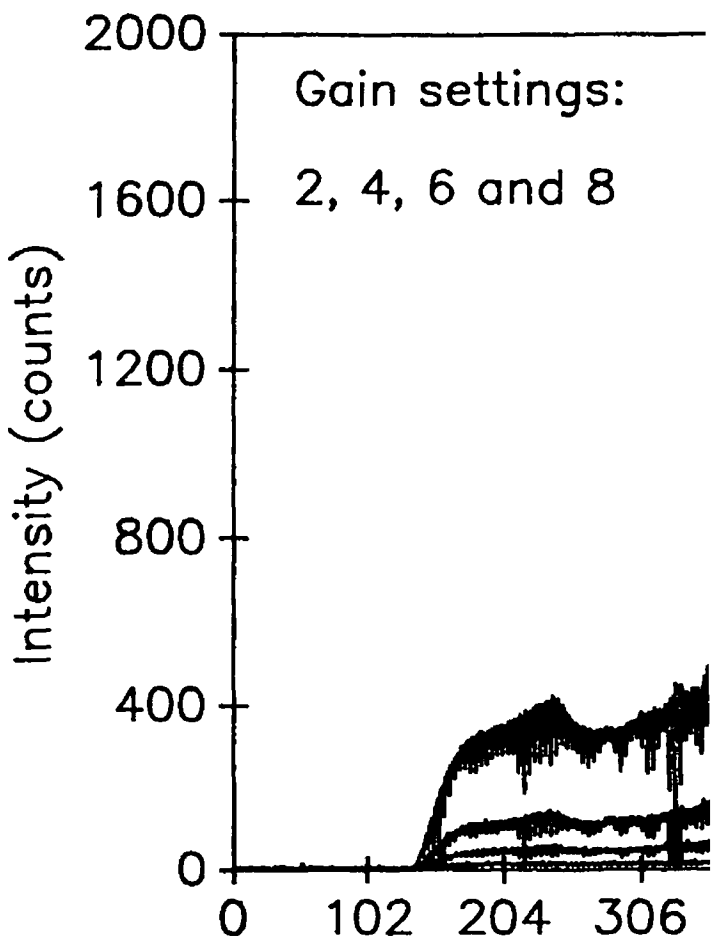
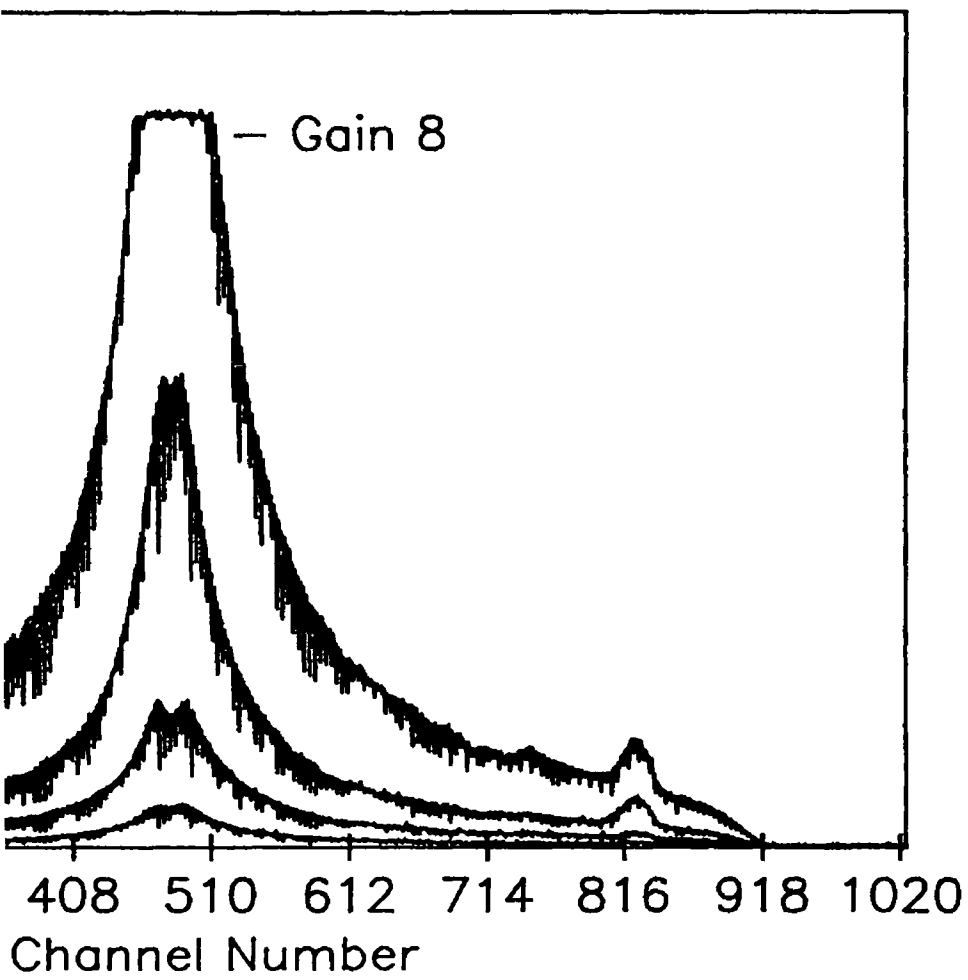


Fig. 2 16 Lithium plasma spectra recorded at various
MCP gains.



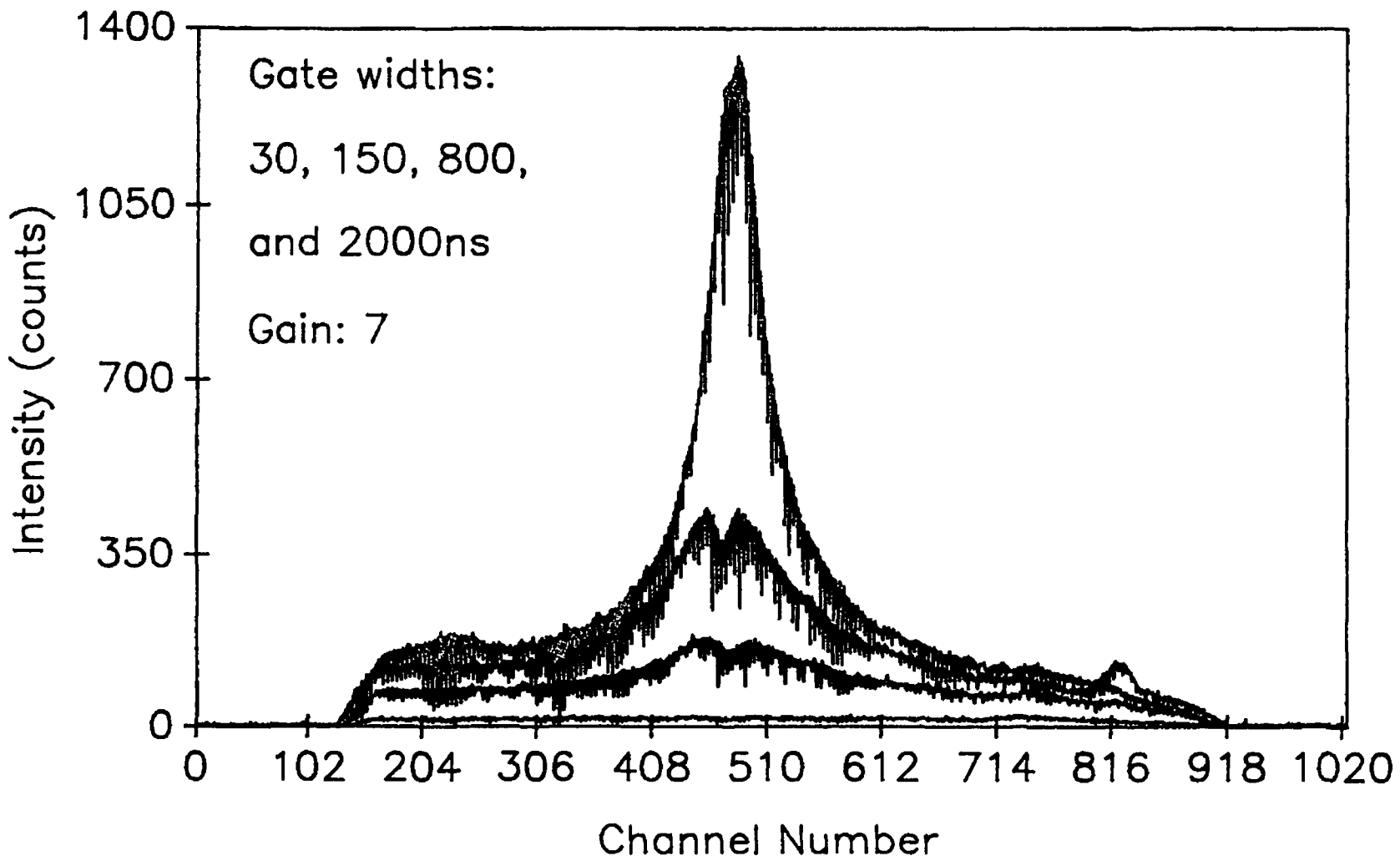
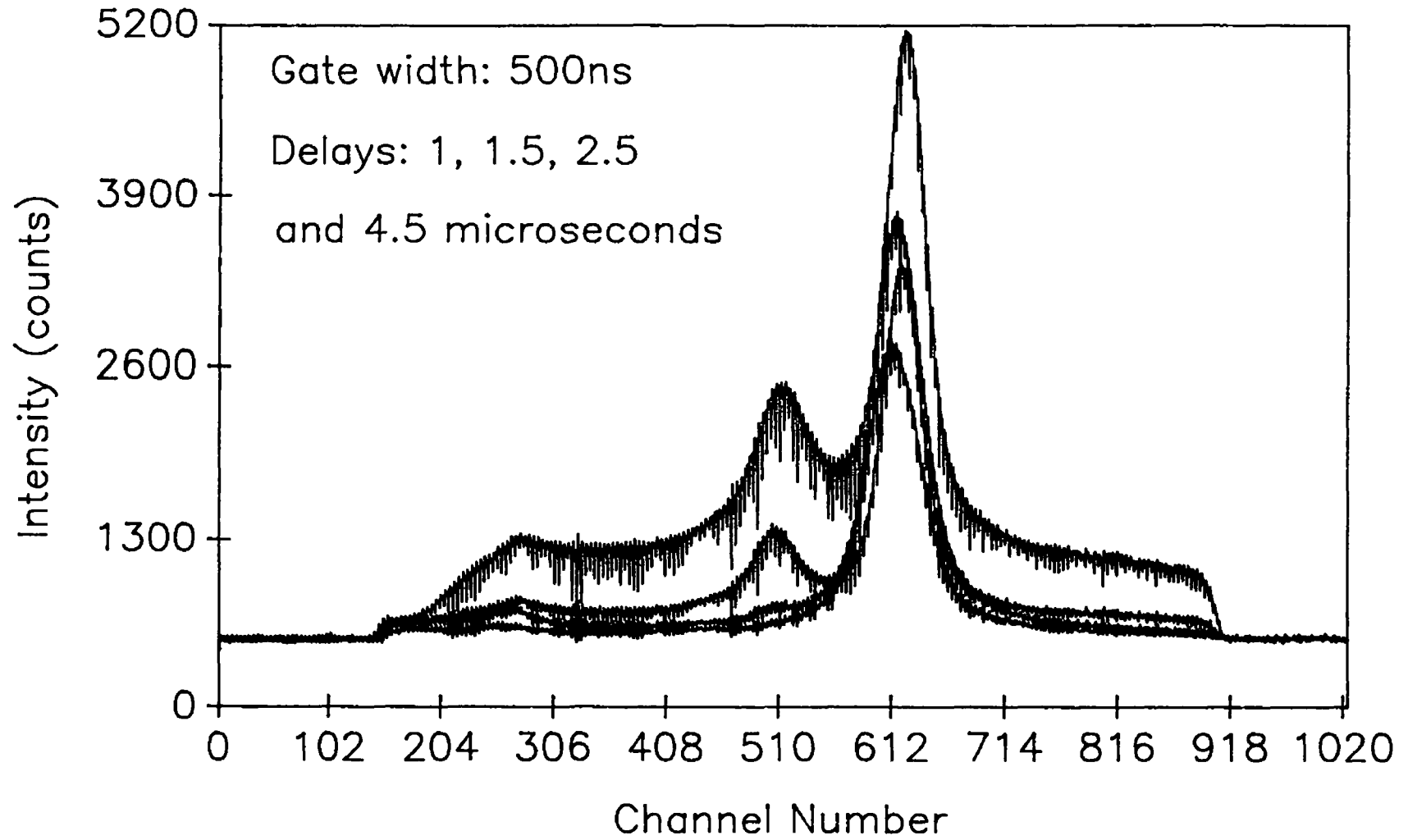


Fig.2.17. Lithium plasma spectra recorded at various MCP gate widths.

Fig.2.18. Lithium plasma spectra recorded at various delay times.



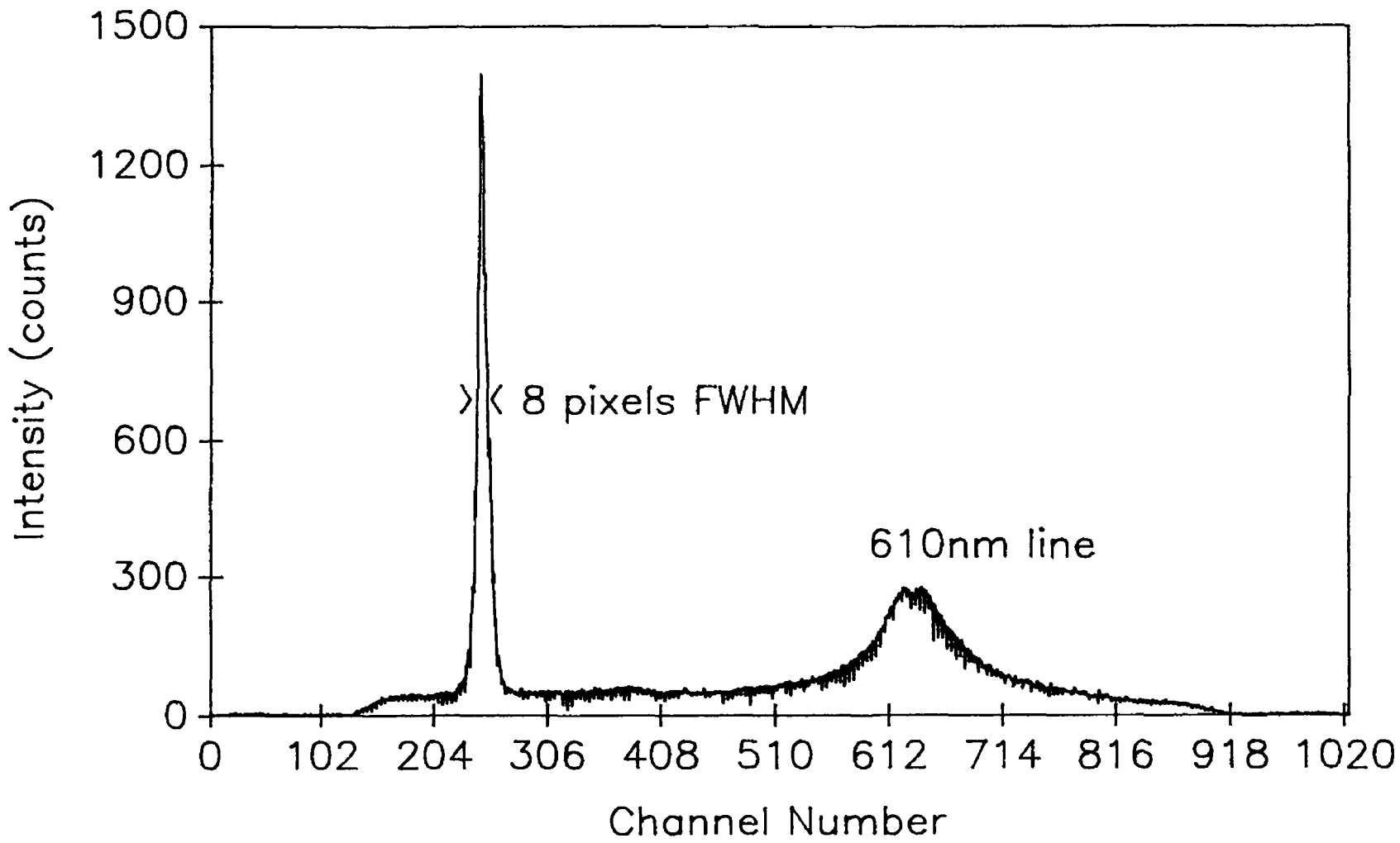


Fig.2.19. Spectrum of a Lithium plasma combined with a He-Ne line to indicate instrument resolution.

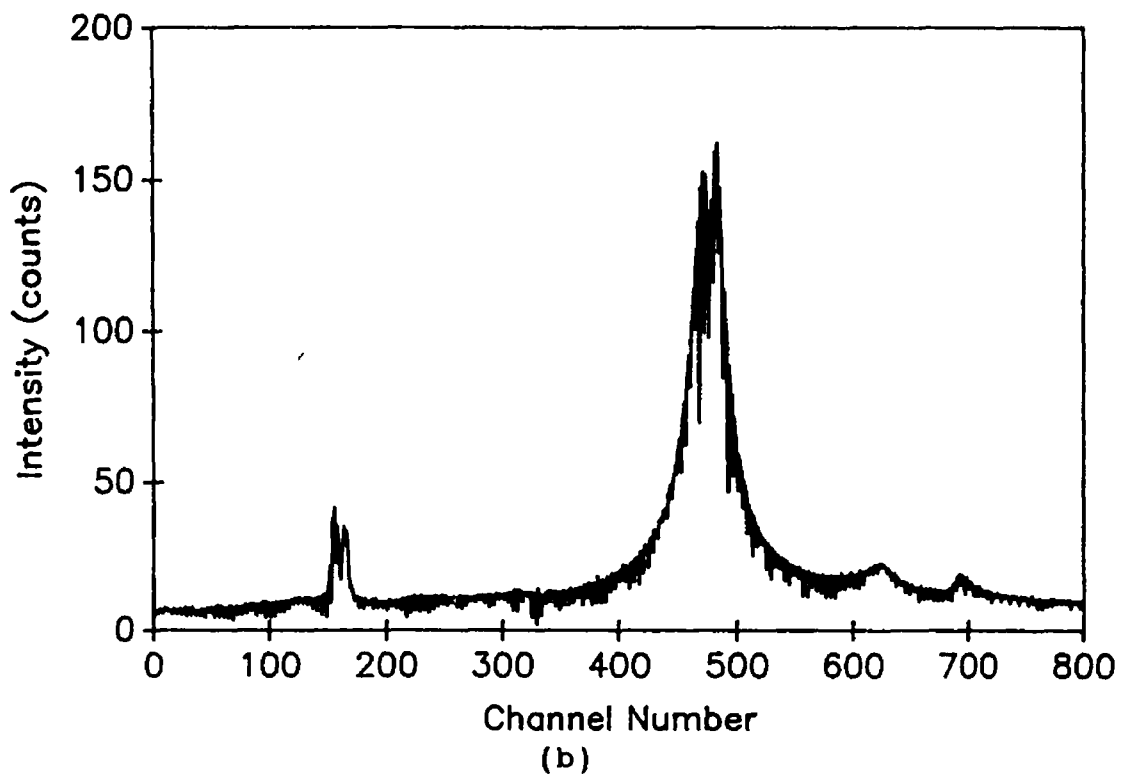
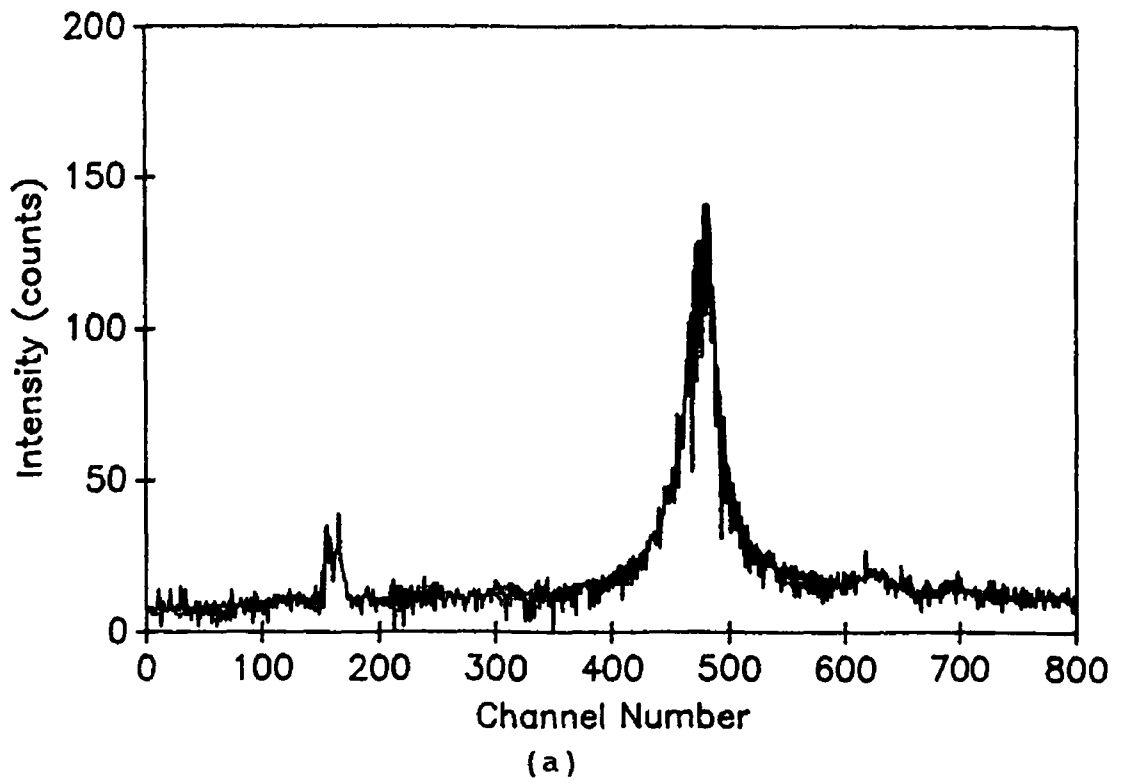


Fig.2.20. Effect of signal averaging:
(a) single shot, (b) average of 16 shots.

CHAPTER III

EXTENSION OF THE OMA SYSTEM INTO THE VUV

III.1 Introduction.

In the last few years, a number of laboratories around the world, e g Cromer et al (1985) in the USA, Kiehn et al (1987) in the UK, Jannitti et al (1987) in Italy and Schwob et al (1987) in Israel have developed multichannel extreme-UV (XUV) and vacuum-UV (VUV) sensitive OMA systems as a replacement for inconvenient photographic plates. Although the specific details of each system vary, they all use the combination of an image intensifier coupled to a photodiode array (PDA) or charge-coupled device (CCD)

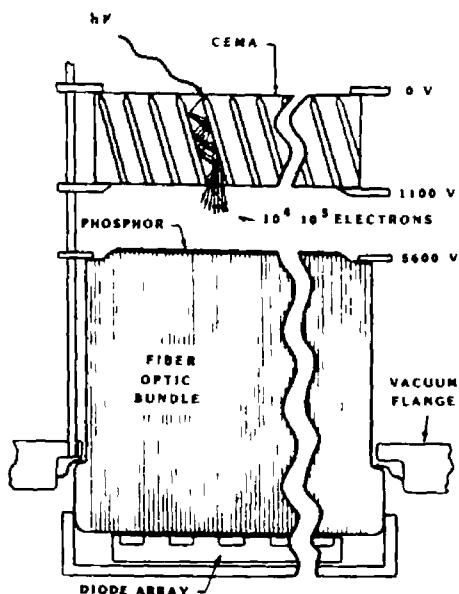


Fig.3.1. OMA design developed by Galileo Electro-Optics and Cromer et al (1985).

To date, two XUV/VUV OMA designs have been tested and operated. The most popular has been developed by Galileo Electro-Optics in collaboration with Cromer et al (1985) at the National Bureau of Standards (now known as the National Institute for Standards and Technology), USA. A diagram of this design is shown in figure 3.1. A VUV photon incident

on a MgF_2 photocathode initiates an electron avalanche in an MCP fibre channel. The amplified electron bunch is accelerated across a small ($\leq 500\mu\text{m}$) gap at a potential difference of 4 → 5 kV. The high electric field reduces bunch spreading and hence maintains a good degree of spatial resolution. The electron bunch is incident on a thin phosphor (P45) coating deposited on a fibre-optic image conduit. The visible light so generated is guided by the fibre stub onto a PDA. This device has been adopted by many groups worldwide and is the leading design.

A simpler approach utilises the scintillator coated face-plate fibre-optically coupled to a standard image intensified PDA (Fig 3.2). Such a device has been used in the extreme-UV by Jannitti et al (1987).

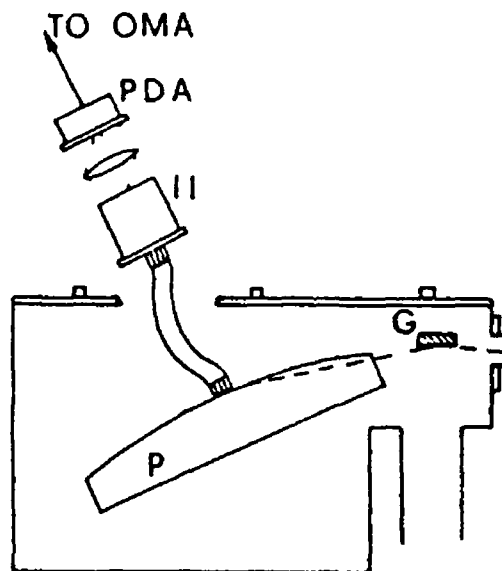


Fig.3.2. The XUV OMA design used by Jannitti et al (1987).

The possibility of operating a similar design in the VUV is investigated here and some preliminary results are given.

III 2 VUV OMA Configuration.

The VUV camera consists of a flexible coherent fibre bundle (optional) with a thin (thickness $10\mu\text{m}$) plastic scintillator film (NE102A) laid down on one end while the other end of the guide is butt coupled to a fibre-optic

magnifier (1.18) mounted in a vacuum tight flange (Fig 3.3) The magnifier matches the 10 X 8mm imaging area of the fiber bundle to the 18mm diameter imaging area of the MCP. A vacuum-UV (VUV) image incident on the scintillator is converted to a visible light pattern with a peak intensity in the blue-green region of the spectrum and transmitted through the fibre image guide out of the vacuum chamber onto the intensified PDA

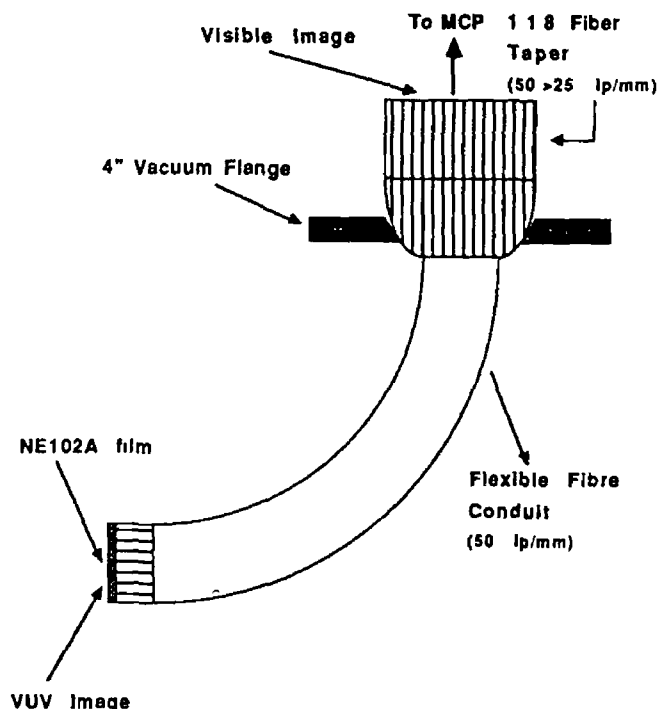


Fig.3.3. VUV OMA configuration.

III.3 Scintillators and Phosphors.

Although the terms scintillator and phosphor are synonymous (Thewlis, 1962), one may distinguish between bulk crystalline materials (scintillators) and thin granular layers of (for example) the rare earth oxysulphides (phosphors) Phosphors are often identified by a commercial 'P-number' and the exact details of their manufacture are usually company confidential

There are four popular VUV scintillator materials: sodium salicylate ($\text{NaC}_7\text{H}_6\text{O}_3$), tetra-phenyl-butadiene (TPB, $\text{C}_{28}\text{H}_{22}$) coronene ($\text{C}_{24}\text{H}_{12}$) and the plastic scintillator NE102A.

For work in the soft X-ray region (below 10nm) phosphor materials are preferred as their conversion efficiency ϕ (number of visible photons out/number of incident X-ray photons) increases with X-ray photon energy (Sams III et al, 1988). On the other hand, scintillators are known to be a factor of 4 or so more efficient than phosphors in the VUV (Samson, 1967) and are therefore preferred for use at longer wavelengths

Comprehensive information on the preparation and deposition of films, the relative/absolute fluorescent efficiency, fluorescent spectrum and decay time of sodium salicylate is given in the text by Samson (1967). Sodium salicylate is the benchmark to which all other XUV and VUV scintillators are compared. Its main advantage is a constant quantum efficiency for radiation between 20 and 360nm. However it does suffer from ageing effects on a time scale of hours and is therefore not useful for long term work.

The fluorescence efficiency of TPB relative to sodium salicylate over the wavelength range 73.5→316nm is presented in the paper by Burton and Powell (1973). Their work indicates a significant improvement in ϕ for TPB over sodium salicylate as one moves into the XUV.

Coronene (Inokuchi et al, 1964) is a hydro-carbon based compound which fluoresces in the green region of the visible spectrum with a fluorescent peak near 500nm. It is reported to be 2 → 3 times more efficient than sodium salicylate in the 150 → 300nm spectral range. Its green output is well matched to silicon based detectors (Blouke et al, 1980) but has found little application to date.

The plastic scintillator NE102A contains scintillation crystals of *p*-terphenyl (primary solute) and bis-1, 4-(2-phenyl-5-oxazolyl)-benzene (secondary solute contracted to read POPOP). The crystals are dissolved in the plastic polyvinyltoluene. The peak of the fluorescent emission is located at 420nm and the fluorescent decay time is 2.2ns (Samson, 1967). Although the fluorescent efficiency of plastic scintillators is much less than that of sodium

salicylate and is not even approximately constant with wavelength (Samson, 1967), such materials have the advantages of an extremely smooth surface and are available commercially as thin sheets of thickness down to $5\mu\text{m}$. Hence they require no special preparation/handling and are easily laid down on optical substrates.

Some preliminary measurements were made of the relative efficiency of a sodium salicylate film, a tetraphenyl-butadiene film (thicknesses $<10\mu\text{m}$) and $10\mu\text{m}$ NE102A film using the experimental set-up shown in figure 3.4. The

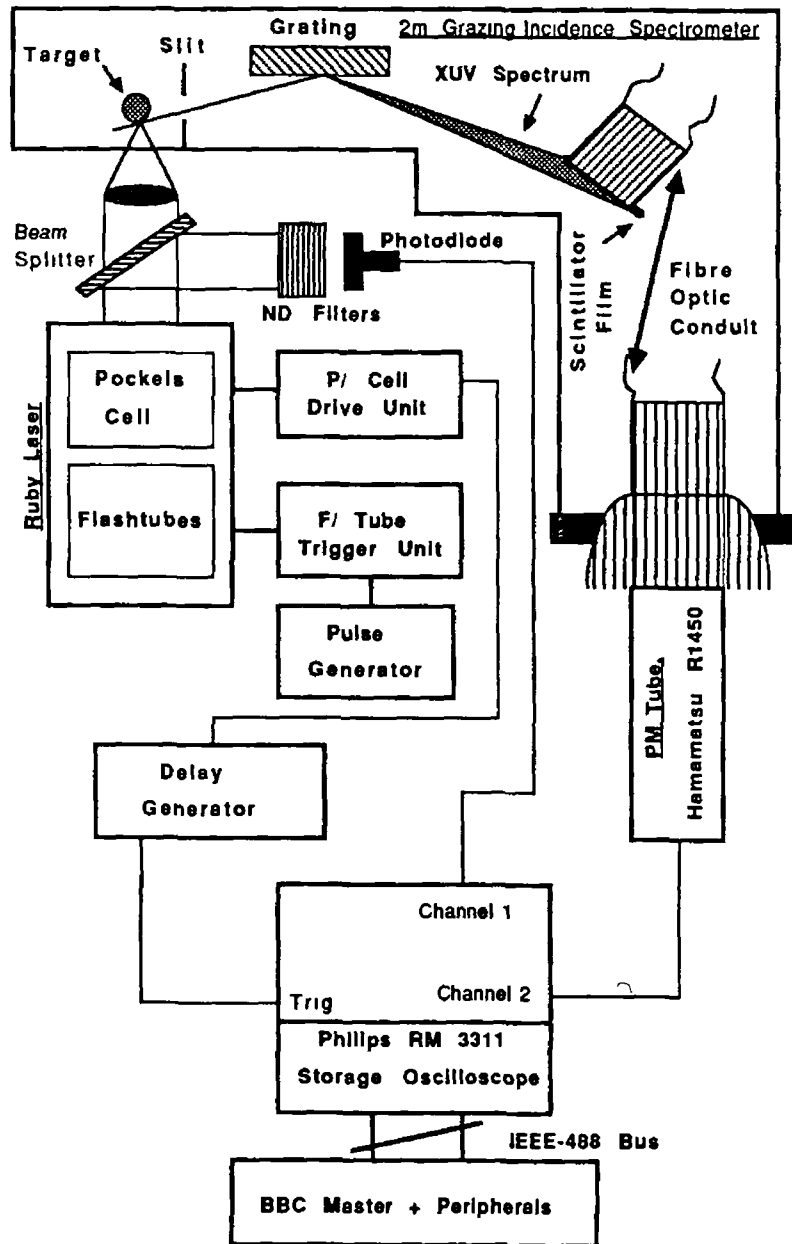


Fig.3.4. Experimental set-up for scintillator relative efficiency measurements.

laser flashlamps are triggered by a pulse generator with a pulse repetition frequency (PRF) of 0.1 Hz. The oscilloscope was triggered by a pre-pulse ($3\mu\text{s}$ ahead of the laser pulse) from the pockels cell drive unit. The delay generator was used to set the delay from trigger to a value close to $3\mu\text{s}$ in order to synchronise the oscilloscope with the optical laser pulse. A fraction of the laser pulse was passed through a series of neutral density filters and onto a fast photodiode (BPX 65) connected to channel 1 of the oscilloscope. The diode was operated at a 9V reverse bias with a 50Ω load.

The target of interest (Al, Ti or W) was located on the optic axis of a 2 metre grazing incidence spectrometer which has been described in detail by Brilly (1986). A flexible fibre-optic conduit with a scintillator coating (NE102A, TPB or sodium salicylate) on its end face was located on the Rowland cylinder of the spectrometer at the 20nm position. The bandwidth of XUV radiation accepted by the fibre-optic conduit was $\sim 1\text{nm}$. The other end of the flexible conduit was butt-coupled to a vacuum tight fibre-optic taper and viewed by a photomultiplier tube connected to channel 2 of the oscilloscope. Stored waveforms with a resolution of 8ns per point were transferred to a BBC master via an IEEE interface for storage on disk or plotting. A typical curve for NE102A is shown in figure 3.5. Software listings for waveform transfer over the IEEE bus are given in programs "DSCOPE" and "DSCOPE1" in Appendix I. The measurements (made at 20nm) indicate that NE102A is a factor of 2 \rightarrow 3 lower in efficiency than both TPB and sodium salicylate. In spite of its lower relative efficiency it was decided to use NE102A as it was available in thin sheet (5, 10 and $50\mu\text{m}$) form and required no special preparation or handling. Further, it is three times more efficient in the 140 \rightarrow 160nm region than in the XUV (Samson, 1967) and was hence expected to perform not too differently from sodium salicylate in this region.

The choice of a $10\mu\text{m}$ film was set by the requirement that the spatial resolution of the system should not drop

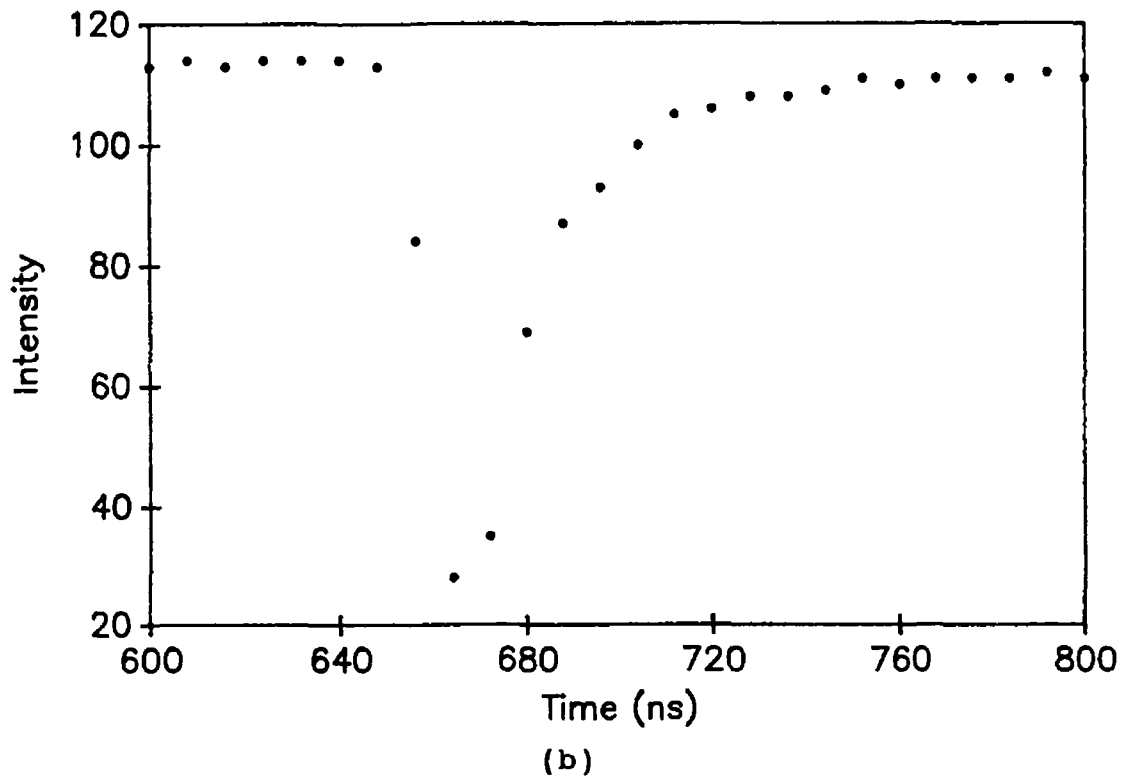
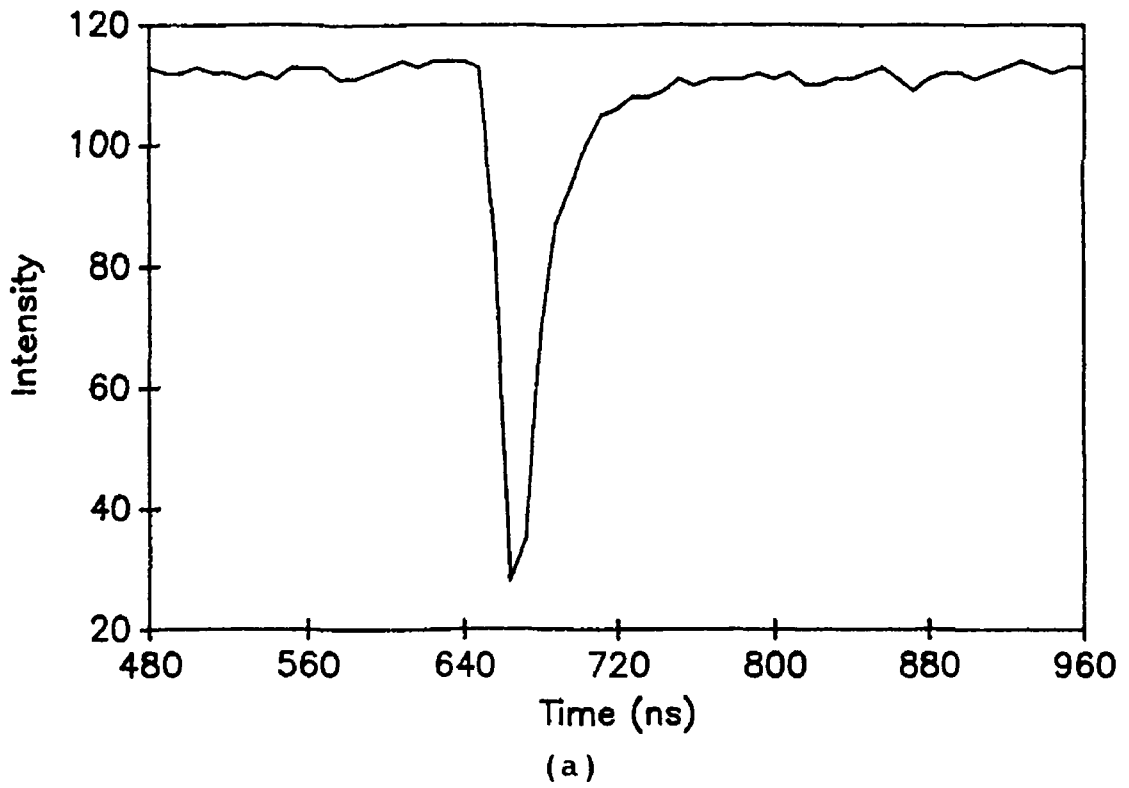


Fig.3 5. Typical response curve for the relative efficiency of NE102A (a), while (b) shows the waveform point-to-point separation.

below 10 lp/mm if at all possible. As can be seen from figure 3.6, for a 50 lp/mm fibre-bundle/stub with 10 μ m channel diameters, a scintillator coating of 10 μ m yields a Nyquist resolution limit of 25 lp/mm, well within the required value.

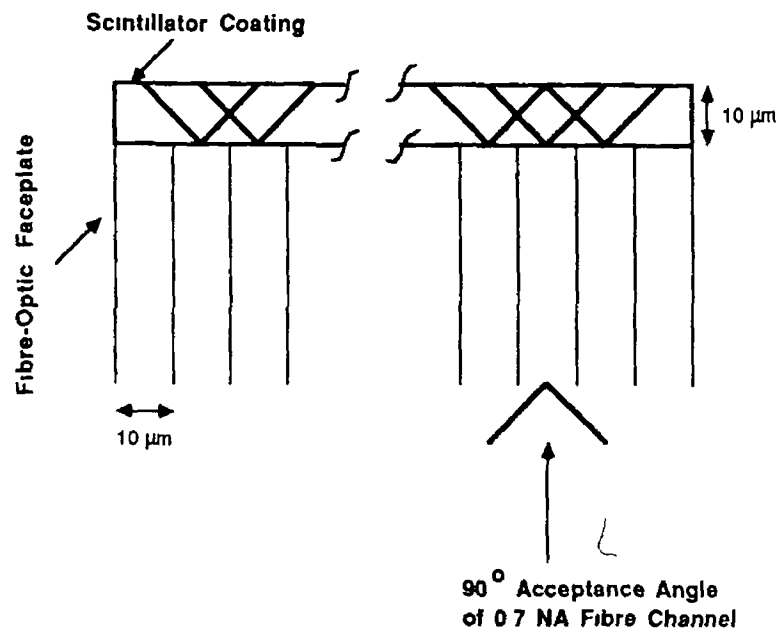


Fig.3.6. Optical cross-talk in coated fibre-optic faceplates.

$$\sin \alpha = \text{N.A.} = 0.7$$

$$\Rightarrow \alpha \approx 45^\circ$$

$$\Rightarrow 2\alpha \approx 90^\circ$$

$$2d \approx 2 \times 10\mu\text{m} = 20\mu\text{m}$$

$$\Rightarrow \text{a resolution limit} \approx 25 \text{ lp/mm}$$

Hence for a resolution limit of 10 lp/mm a scintillator of up to 25 μ m thickness is permitted

As regards the time response of these materials, values of 2.2ns for NE102A and 7 \rightarrow 12ns for sodium salicylate are given in Samson (1967). To this author's knowledge a figure for the fluorescence decay time of TPB is apparently not available in the open literature. In the present experiment a decay time in the range of some tens of nanoseconds was obtained which limits the usefulness of TPB in time resolved imaging/spectroscopy

III.4 System Resolution - Edge Test.

To make an estimate of the resolution of the system under VUV illumination, the composite detector was placed on a recently designed target chamber (Connolly, 1990) The experimental set-up is shown in figure 3.7. A blade was

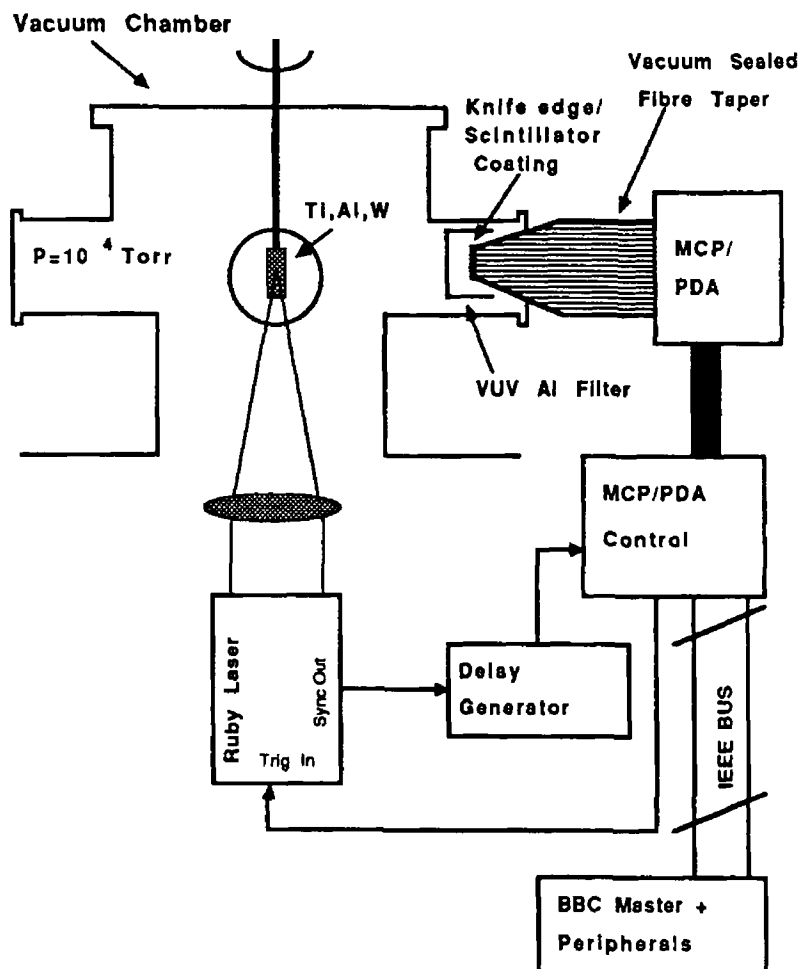


Fig.3.7. Experimental set-up for system resolution test.

placed in contact with the NE102A film on the fibre-taper to act as an abrupt cut-off (fig 3.8) Care was taken to ensure that the edge lay reasonably parallel to the photodiode pixels The parallelism could only be set approximately to within $\sim 3^\circ$ and as is clear from figure 3 8 this results in edge spreading of as much as $5 \rightarrow 6$ pixels for 2.5mm long pixels with $25\mu\text{m}$ centre to centre spacing

The light source was a titanium plasma which yields bright emission in the $13 \rightarrow 80\text{nm}$ bandpass of an aluminium filter used to reject UV and visible emission from the

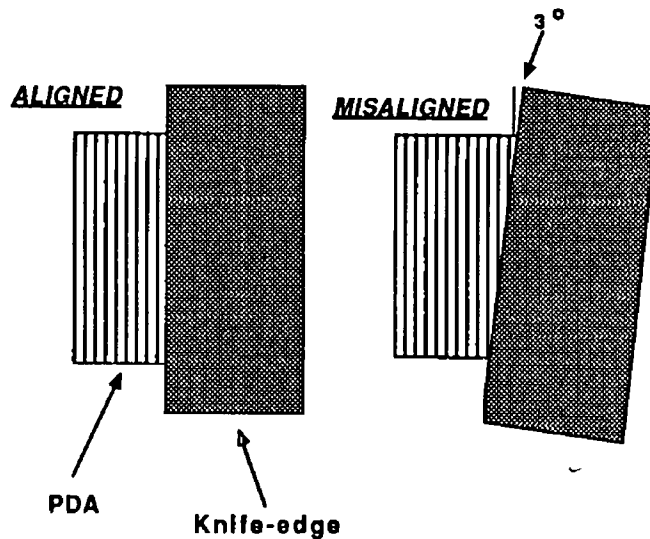
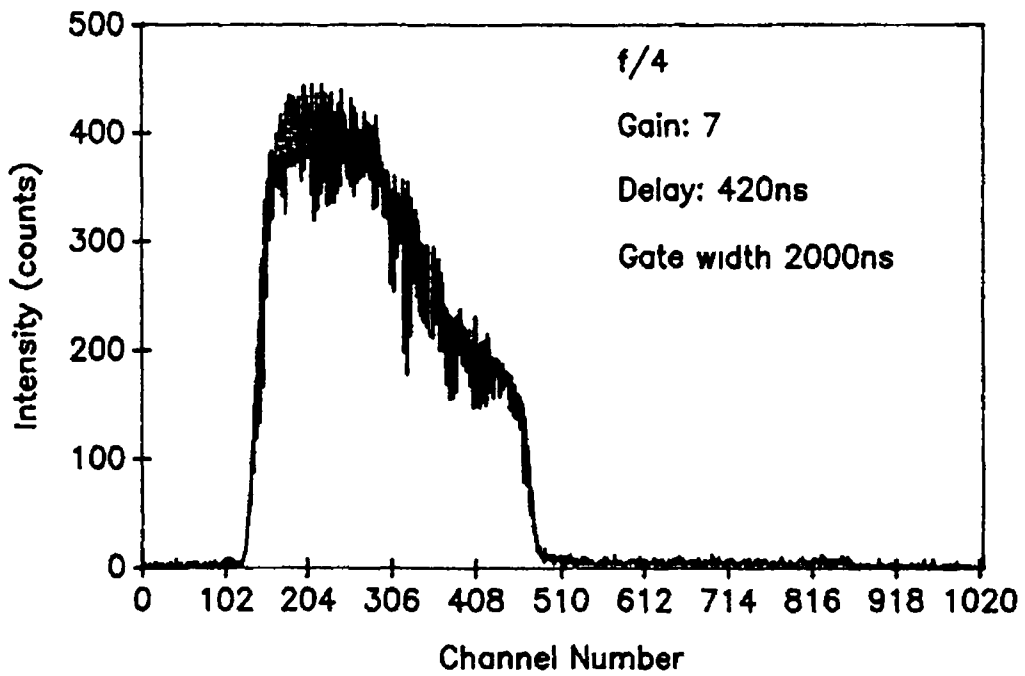


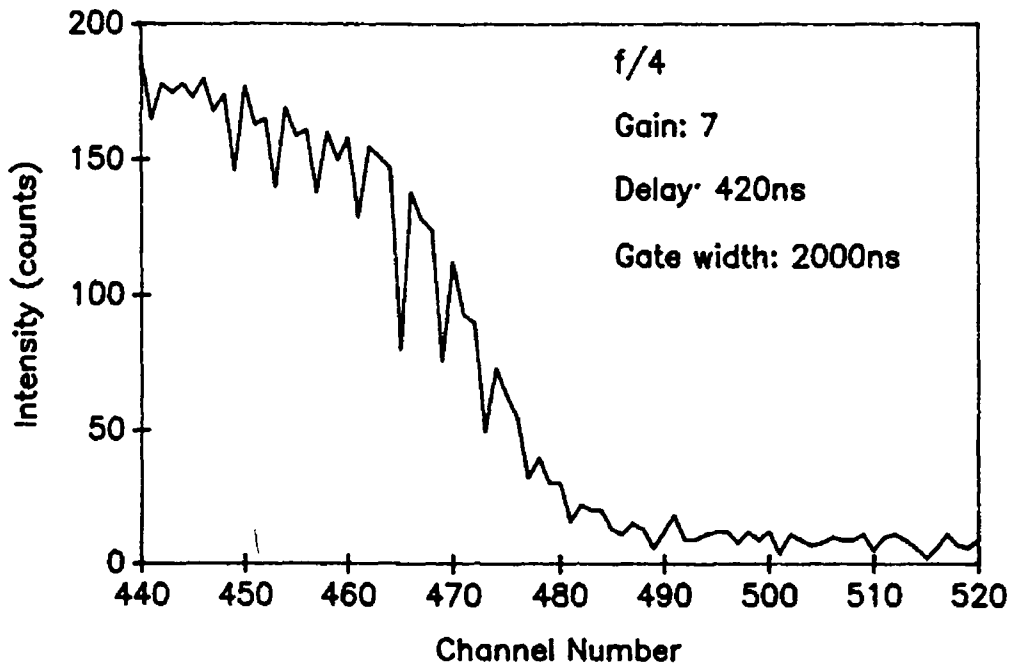
Fig.3.8. Effect of knife-edge alignment on resolution.

plasma However, residual scattered laser light from the plasma reached the detector and yielded a background signal on which the VUV signal lay. By sweeping the gate of detector past the main laser pulse with the delay generator, the scattered laser light signal was significantly reduced. To account for the remaining laser scatter signal (~40% of the total signal) the VUV plus laser scatter signal was first recorded. By placing a thin glass slide in front of the plasma, the visible laser scatter signal only was recorded. Accounting for glass slide transmission, subtraction of these two single shot signals yielded the VUV signal only. This procedure was repeated for different MCP gains and camera apertures (f-numbers). The results from a selection of these tests can be seen in figures 3.9 and 3.10.

A comparison between edge response using f/1.4 and f/4 relay optics between MCP and PDA is shown in figure 3.10. Clearly, as one might expect, f/4 produces a sharper response with an estimated 10 → 90% rise of ~10 pixels (accounting for the magnification of X 1.8 of the fibre taper). The value exceeds that due to spreading by non-parallelism of knife edge and pixel orientation and is hence due to the inherent response of the composite detector system. A measurement of the edge response at f/8



(a)



(b)

Fig.3.9 Image obtained from edge test. The entire image is shown in (a), while a magnified view of the edge is shown in (b).

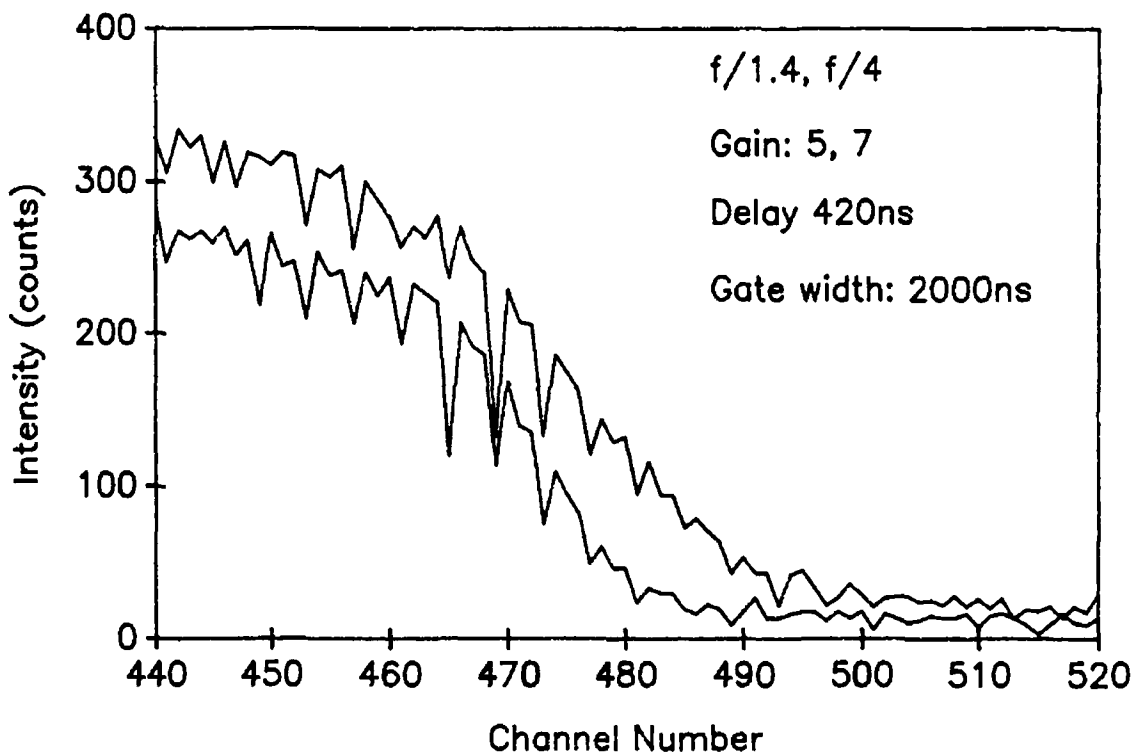


Fig.3.10. Edge response using f/1.4 and f/4 relay optics.

did not yield any improvement. The procedure outlined is clearly approximate but yields a worst case value for the VUV detector resolution.

One could further speculate on the Rayleigh resolution criterion by looking at two overlapping edge tests as shown in figure 3.11. Setting the crossing point at 50% one can clearly resolve the two lines (Rayleigh). Hence, a

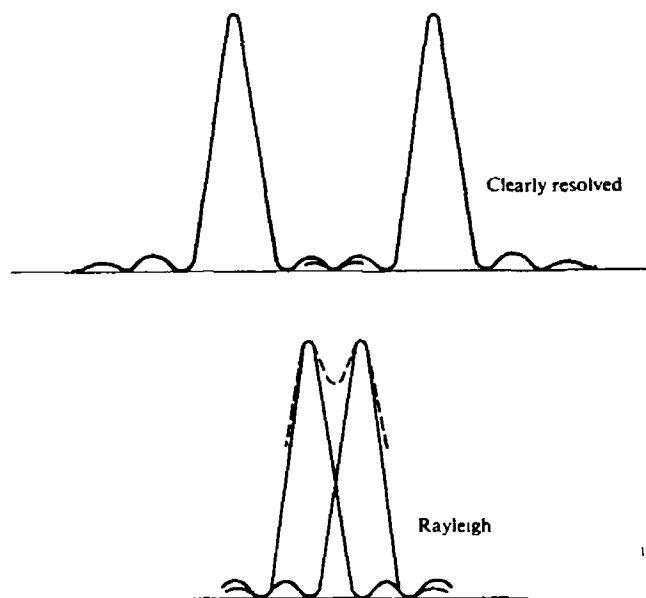


Fig.3.11. Rayleigh resolution criterion.

'Rayleigh' resolution estimate from the present edge test is roughly 5 → 6 pixels or ~4 lp/mm (accounting for the fibre taper magnification) which is close to the limit set for angular spreading and about half that of the MCP itself (10 lp/mm). The discrepancy is most likely due to ripples in the scintillator film which prevents perfect contact with the fibre-optic surface. Such ripples increase the effective thickness of the scintillator by increasing the number of pixels which can collect fluorescent light from an interaction at the scintillator surface.

III 5 Tungsten Continuum Spectrum at ca. 150nm.

Having detected broadband VUV radiation with the scintillator based OMA system, it was decided to attempt the recording of the spectrum of tungsten in the VUV. The experimental setup is shown below (Fig 3.12)

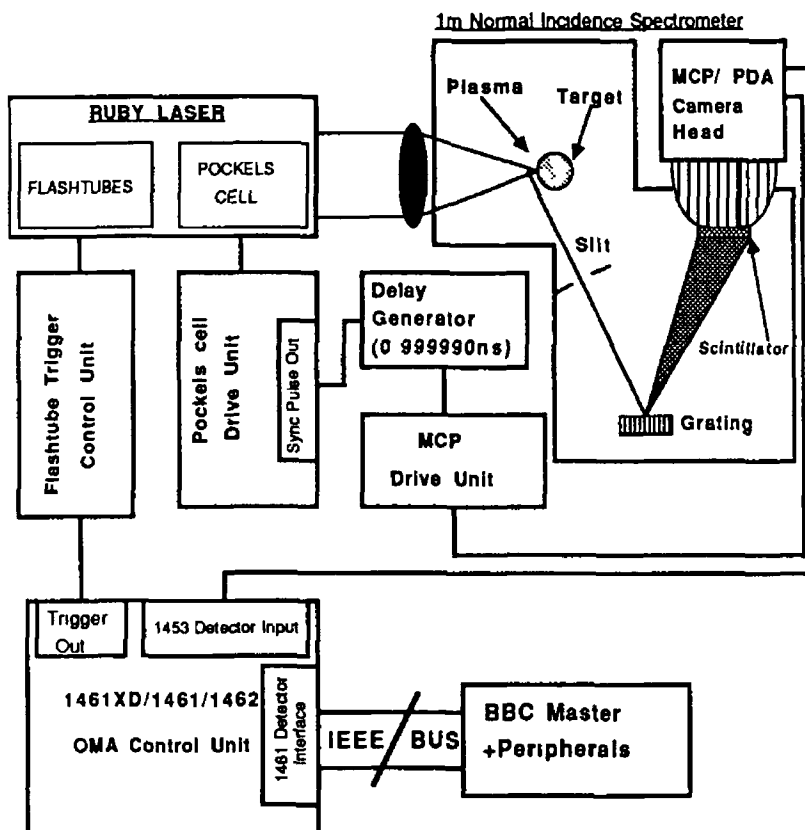


Fig.3.12. Experimental set-up for tungsten continuum detection

The monochromator was a McPherson 1 metre normal incidence instrument. A fibre-optic taper with a $10\mu\text{m}$ film of NE102A scintillator mounted in a vacuum flange was attached to the exit port of the monochromator with the exit slit removed to permit viewing of a $\sim 10\text{mm}$ slice of spectrum. The image intensified OMA system was butt coupled onto the exit face of the fibre-optic taper. The electronic synchronisation of the laser pulse was as described in section II 7.

As in the edge test experiments a glass plate which can be placed in the path of the plasma radiation was used

to discriminate between scattered laser light and VUV signals

Spectra of the tungsten VUV continuum were recorded by averaging 50 laser shots at three different pressures, 1×10^{-4} Torr, 0.2 Torr and 2 Torr and the result is shown in figure 3.14. The expected drop off in VUV light intensity with increasing pressure is clear from these spectra. However the counts are very low with single shot value of ~5 counts, which implies an incident flux of < 100 photons per pixel on the face of the MCP

The VUV flux incident on the scintillator is typically 10^7 photons/pixel (O'Sullivan et al, 1981, Fischer et al, 1984) for such plasmas and hence the conversion efficiency of the scintillator based OMA is only 0.01% - the limiting factor in this design. Consequently it is concluded that although one could use such a VUV OMA design with multishot averaging, it is clearly wasteful of light flux and hence laser component lifetime. In the following chapter (section IV 2) some suggestions for significant improvement of this system are made.

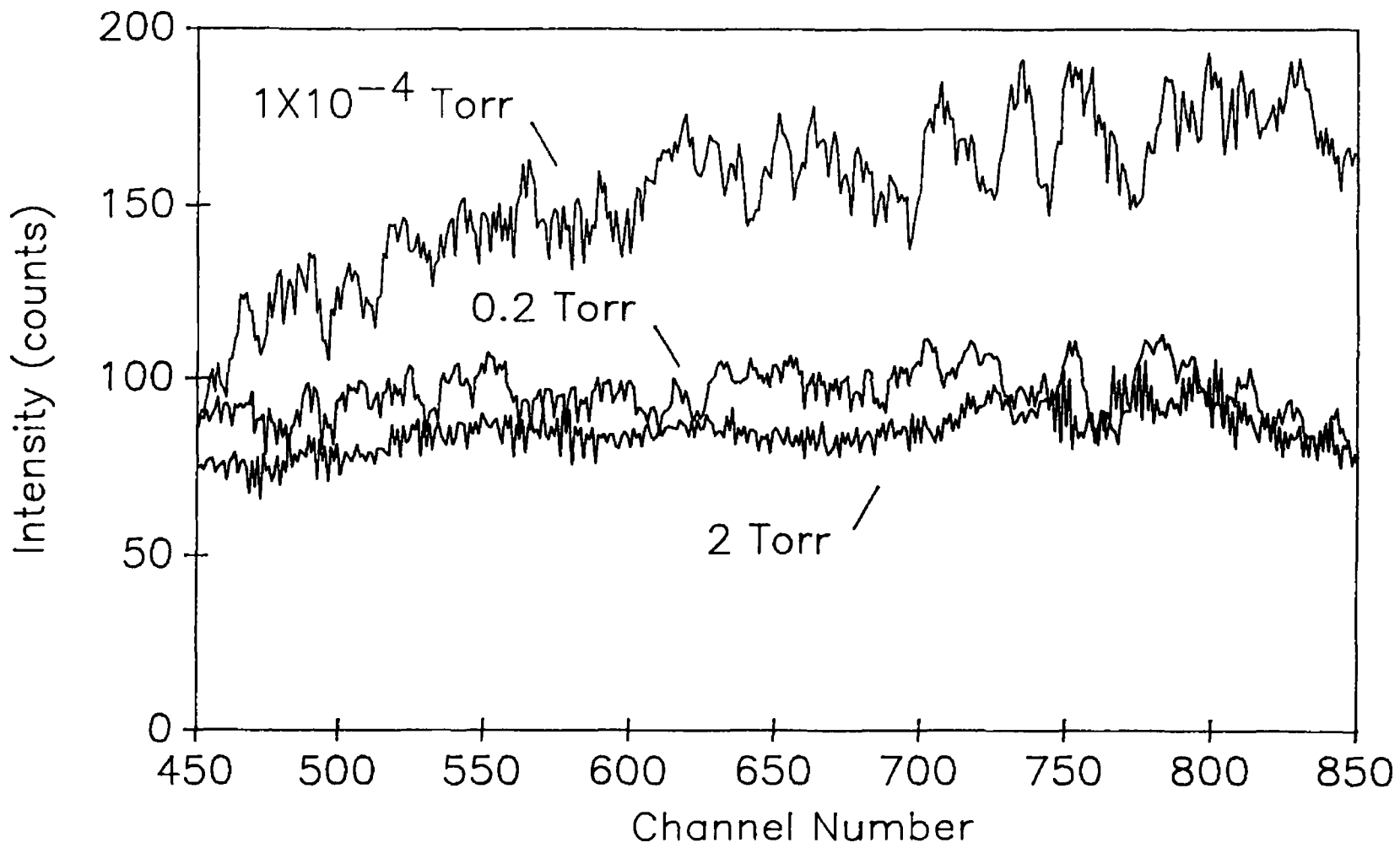


Fig.3.14. Tungsten continuum spectrum at ca. 150nm.

CHAPTER IV

SUMMARY, CONCLUSIONS AND FUTURE WORK

IV.1 Summary/Conclusions.

A gated optical multichannel analyser has been developed for laser-plasma spectroscopy. It consists of an image-intensified PDA, a detector/controller interface with computer and a delay generator which was designed and built specifically for this project. A 'user-friendly' software package was designed and coded/constructed to control the system. The system's detection range was extended into the VUV by means of a VUV to visible light converter.

The visible/UV performance of the system has been tested comprehensively and shows that it is ideally suited to time-resolved spectroscopy of laser-plasmas. However, the 'effective' VUV to visible light conversion efficiency of the scintillator (which is of the order of 0.01%) limits the usefulness of the system for spectroscopy below 200nm. The spatial resolution of the system in the visible is ≈ 10 lp/mm with f/4 MCP to PDA coupling optics and is limited by the dynamic resolution of the MCP. In the VUV, the resolution drops to $\sim 7 \rightarrow 8$ lp/mm and is most likely the result of a non-uniform contact of NE102A film to the fibre-optic surface (section III.4). The temporal resolution of ~ 30 ns is well within the limit needed for spectroscopy with Q-switched (10 \rightarrow 100ns) lasers.

IV.2 Future Work.

In order to increase the VUV flux in the focal plane of the spectrometer, the Laser Plasma group at D.C.U. is developing toroidal mirror optics to improve the coupling of the plasma light into the vacuum spectrometer by a factor of 50 or so. Also, fibre-optically coupling the MCP to the PDA will add a further order of magnitude, resulting

in single shot sensitivity [some 500 times greater than that observed here. Initial studies at D C U with vacuum evaporated layers of tetra-phenyl-butadiene on fibre-optic windows indicate that micron thick layers with resolution >25 lp/mm and sensitivity five times greater than that obtained with NE102A can be obtained (G.Hughes, 1990)

As mentioned in section II.7, the 'grassy' appearance of the spectra obtained with the image-intensified OMA is due to variations in the gain of each individual pixel at any particular drive voltage. The effect is well known (Antcliff et al, 1984, Cromer et al, 1985) and can be accounted for by determining a 'pixel gain conversion function' from a measurement of the flat field response of the system. By illuminating the detector with a uniform light field I , the response $I(p)$ where p is a pixel number, may be obtained. Multiplication of the raw recorded data by the reciprocal of the flat field response function $I^{-1}(p)$ will result in a gain corrected spectrum or image. Unfortunately, a flat field source was not available for this project and this work remains to be done.

It is also intended to use the scintillator coated MCP in conjunction with XUV and VUV thin filters and a pinhole camera for space and wavelength resolved imaging of laser-plasmas in the future. Together with the time resolution of the gated MCP, a good deal of quality data on the time history of expanding plasmas should be obtained. A large area fibre-optically coupled CCD will be used for readout.

Apart from its use for scintillation detection, the OMA system, software and electronics that have been developed during this project will also be used as the readout device for a new type of VUV image intensifier to be purchased from Galileo Electro-Optics (USA) under an EC contract involving partners from The Netherlands, Germany, Sweden and Ireland (UCD, UCC and DCU). The instrument will be used for many years to come as the kernel detector in spectroscopic studies of laser-produced plasmas by the group at Dublin City University.

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(1979)

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Appl Phys Lett 43, 686 (1983).

APPENDIX I

```

10 REM Program name · "MENU1"
20 MODE7
30 CLEAR
40 *FX4,1
50 *FX15,0
60 CLS
70 PROCsetup
80 PROCinput
90 PROCreset
100 PROCprocess
110 END
120 DEF PROCsetup
130 PRINTTAB(39,2);CHR$(129)," *****OPTION MENU*****"
140 PRINTTAB(39,4);CHR$(129);"The following options are
    available·"
150 PRINTTAB(2,7),CHR$(129);CHR$(157);CHR$(135);"Record a
    spectrum ";CHR$(156)
160 PRINTTAB(2,8),CHR$(129),CHR$(157);CHR$(135);"Read data
    from the 1461 memory ";CHR$(156)
170 PRINTTAB(2,9);CHR$(129),CHR$(157);CHR$(135);"Read data
    from disc.";CHR$(156)
180 PRINTTAB(2,10);CHR$(129);CHR$(157),CHR$(135);"Plot a
    graph of present data. ",CHR$(156)
190 PRINTTAB(2,11),CHR$(129);CHR$(157),CHR$(135);
    "Manipulate memories in the 1461 ",CHR$(156)
200 PRINTTAB(2,12);CHR$(129),CHR$(157),CHR$(135);"Print
    graph on Rikadenk1 plotter ";CHR$(156)
210 PRINTTAB(2,13);CHR$(129),CHR$(135),"Monitor an
    experiment ";CHR$(156)
220 PRINTTAB(2,14),CHR$(129);CHR$(157);CHR$(135);"View a
    directory. ";CHR$(156)
230 PRINTTAB(2,15);CHR$(129);CHR$(157);CHR$(135);"Stepper
    Test.",CHR$(156)
240 PRINTTAB(2,16);CHR$(129),CHR$(157),CHR$(135);"ASCII
    File Convert.",CHR$(156)
245 PRINTTAB(2,17);CHR$(129),CHR$(157);CHR$(135);"File
    Manipulation.";CHR$(156)
250 PRINTTAB(2,18);CHR$(129),CHR$(157),CHR$(135);"End.
    ";CHR$(156)
260 PRINTTAB(39,19);CHR$(129),"Use arrows to move bar up
    and down!"
270 PRINTTAB(39,22);CHR$(129);" Press RETURN to select an
    option"

280 BAR=7 T=7.B=18
290 VDU31,1,BAR,136,130,157,135
300 ENDPROC
310 DEF PROCinput
320 REPEAT.DIR=GET
330 PROCupdown
340 UNTIL DIR=13
350 ENDPROC
360 *DISC
370 DEF PROCprocess
380 IF BAR=7 THEN CLEAR.CHAIN"·0.OMA1"
390 IF BAR=8 THEN CLEAR.CHAIN"·0 GETDAT"
400 IF BAR=9 THEN CLEAR.CHAIN" 0 DATLOAD"

```

```
410 IF BAR=10 THEN CLEAR CHAIN":0 PLOT"
420 IF BAR=11 THEN CLEAR.CHAIN"·0 DATADSB"
430 IF BAR=12 THEN CLEAR:CHAIN".0 PRNTER1"
440 IF BAR=13 THEN CLEAR:CHAIN" 0.MONITOR"
450 IF BAR=14 THEN CLEAR R%=0.CHAIN":0.CAT"
460 IF BAR=15 THEN CLEAR.CHAIN"·0 STEPPER"
465 IF BAR=16 THEN CLEAR:CHAIN".0.FILCON"
467 IF BAR=17 THEN CLEAR:CHAIN".0.FILDIV"
470 IF BAR=18 THEN CLS.END
480 ENDPROC
490 DEF PROCupdown
500 VDU31,1,BAR,137,129,157,131
510 IF DIR=138 BAR=BAR+1:IFBAR>B THEN BAR=T
520 IF DIR=139 BAR=BAR-1:IFBAR<T THEN BAR=B
530 VDU31,1,BAR,136,130,157,135
540 ENDPROC
550 DEF PROCreset
560 *FX4,0
570 ENDPROC
```

```

600 REM Program Name  "OMA1"
610 MODE3
620 CLEAR
630 ON ERROR GOTO 2880
640 REM This is the initialisation section of the
650 REM program.The user can select the detector
660 REM parameters (all or some) in turn and set them to
670 REM the values appropriate for the experiment.
680 REM First some basic procedures are carried out to
690 REM show that the host computer is controlling and
700 REM reading the detector interface correctly i.e.
710 REM that the system is functioning properly.To do
720 REM this the host asks the detector interface for its
730 REM  IDENTITY NUMBER (i.e. 1461),
740 REM  DETECTOR MODULE (the detector in use),SOFTWARE
    VERSION in use
750 REM  the COOLER status (whether locked or unlocked),
760 REM  the DETECTOR ARRAY LENGTH and the LINE FREQUENCY
770*IEEE
780 CLS
790 CLEAR
800 PRINT PRINT TAB(20),"****INITIALISATION ROUTINE****"
    :PRINT
810 PRINT:PRINT"At any stage of this program you may
    return to the main menu by typing 'ESCAPE':PRINT
820 cmd%=OPENIN("COMMAND")
830 data%=OPENIN("DATA")
840 PRINT#cmd%,"BBC DEVICE NO",0
850 PRINT#cmd%,"CLEAR"
860 PRINT#cmd%,"REMOTE ENABLE"
870 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
880 PRINT#cmd%,"UNLISTEN"
890 oma%=OPENIN("11")
900 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
910 PRINT#data%,"FREQ 50"
920 PRINT#data%,"ID ;VER ;CL ;DM ;DLEN ;FREQ "
930 PRINT#cmd%,"UNLISTEN"
940 PRINT#cmd%,"TALK",oma%
950 INPUT#data%,ID$,VER$,ACL$,ADM$,ADL$,AFRQ$
960 PRINT "ID = ";ID$
970 PRINT "SOFTWARE VERSION = ";VER$
980 IF ACL$ ="1 " THEN PRINT "COOLER LOCKED"ELSE PRINT
    "COOLER UNLOCKED"
990 PRINT "DETECTOR CONTROLLER IN USE IS MODEL ";ADM$
1000 PRINT "DETECTOR ARRAY LENGTH = ";ADL$
1010 PRINT "LINE FREQUENCY = ",AFRQ$
1020 PRINT#cmd%,"UNTALK"
1030 PRINT:PRINT.PRINT
1040 PRINT "If any of these values are wrong there may be
    some "
1050 PRINT " problem with the device Do not continue, "
1060 PRINT " try running the program again. If the values"
1070 PRINT " are still wrong check the apparatus. "
1080 INPUT "CONTINUE (Y OR N)",ANS$
1090 IF ANS$="N" GOTO 2940
1100 IF ANS$<>"Y" AND ANS$<>"N" GOTO 1080
1110 CLS·X=0
1120 PRINT.PRINT TAB(20);"***PARAMETER SELECTION ROUTINE**"

```

```

.PRINT PRINT
1130 CMDV$="DT ;ET ;SYNC ,DA ;I ;J ;K ,MEM ;MAX.MEM "
1140 PROClisten
1150 PRINT#cmd%,"TALK",oma%
1160 INPUT#data%,ADT$,AET$,ASYNCS$,ADA$,AI$,AJ$,AK$,AMEM$,
    AMAX$
1170 PRINT "DETECTOR TEMP. = ";ADT$;"DEG. C."
1180 PRINT "EXPOSURE TIME = ";AET$;" SEC."
1190 IF ASYNCS$="0 " PRINT "NORMAL SYNCHRONISATION IN
                                OPERATION "
1200 IF ASYNCS$="1 " PRINT "LINE SYNCHRONISATION IN
                                OPERATION "
1210 IF ASYNCS$="2 " PRINT "EXTERNAL SYNCHRONISATION IN
                                OPERATION "
1220 PRINT"DATA ACQUISITION MODE = ";ADA$
1230 PRINT"MEMORY COUNT = ";AJ$
1240 PRINT"SCAN COUNT = ",AI$
1250 PRINT"IGNORED SCAN COUNT = ",AK$
1260 PRINT"STARTING MEMORY = ",AMEM$
1270 PRINT#cmd%,"UNTALK"
1280 PRINT:PRINT "Do you wish to alter any of these
                                parameters?"
1290 PRINT INPUT "Y OR N (E to end ,ST to start again)",
    REP$
1300 IF REP$="Y" THEN GOTO1580
1310 E%=VAL(AET$) D%=VAL(ADT$)·S%=VAL(AJ$)
1320 REMIF X=1GOTO720
1330 IF REP$="E" THEN GOTO 2940
1340 IF REP$="ST" THEN GOTO 770
1350 IF REP$<>"ST" AND REP$<>"E" AND REP$<>"Y" AND REP$<>
"N" THEN PRINT "ERROR,choose again please' " ·GOTO 1290
1360 CLS.PRINT:PRINT
1370 PRINT TAB(9);"*****"
1380 PRINT TAB(9);"*
1390 PRINT TAB(9);"* Now the experimental parameters are
    selected *"
1400 PRINT TAB(9);"* If you are satisfied with these
    parameter values *"
1410 PRINT TAB(9);"* and wish to start the experiment
    type 'RUN' *"
1420 PRINT TAB(9);"* If you wish to alter a parameter
    type 'CH'.(E or ST) *"
1430 PRINT TAB(9);"*
1440 PRINT TAB(9);"*****"
1450 INPUT "Your choice is";Q$
1460 IF Q$="CH" THEN GOTO 1580
1470 IF Q$="ST" THEN GOTO 770
1480 IF Q$="E" THEN GOTO 2940
1490 IF Q$<>"ST" AND Q$<>"RUN" AND Q$<>"E" AND Q$<>"CH"
THEN PRINT "ERROR,Please choose again." ·GOTO 1450
1500 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
1510 PRINT#data%,"RUN"
1520 PRINT#cmd%,"UNLISTEN"
1530 CLS
1540 TIME=0:PRINT:PRINT INPUT "Do you wish to continue
    (input C) or return to main menu (M)";H$
1550 IF H$<>"C" AND H$<>"M" THEN PRINT"ERROR,choose again"
    :GOTO 1540

```



```

1560 IFH$="M" THEN GOTO 2920 ELSE GOTO 600
1570
1580 REM Subroutine to change experimental parameters
1590 CLS
1600 PRINT "To change a particular parameter please  "
1610 PRINT "  select the corresponding code value.  "
1620 PRINT:PRINT:PRINT
1630 PRINT TAB(10);"PARAMETER ";TAB(40);"CODE ";TAB(55);
    "RANGE "
1640 PRINT
1650 PRINT TAB(10);"Detector temp.",
    TAB(42);"1";TAB(52);"5 -> -19 Deg. "
1660 PRINT TAB(10);"Exposure time ";
    TAB(42);"2";TAB(52);" 03 -> 14400 Sec."
1670 PRINT TAB(10);"Synchronisation ";
    TAB(42);"3",TAB(52),"Normal or Line"
1680 PRINT TAB(10);"Data acquisition mode ";
    TAB(42);"4";TAB(52);"1 -> 17 or RYO"
1690 PRINT TAB(10);"Memory count ",
    TAB(42);"5",TAB(52);"1 -> ",AMAX$
1700 PRINT TAB(10);"Scan count ";
    TAB(42);"6",TAB(52);"1 -> 16960"
1710 PRINT TAB(10);"Ignored scan count ";
    TAB(42);"7";TAB(52);"1 -> 24464"
1720 PRINT TAB(10);"Starting memory ";
    TAB(42);"8",TAB(52);"1 -> 6(DP)·12(SP) "
1730 INPUT "Parameter code = ",C$
1740 FOR I=1 TO LEN(C$)
1750 IF MID$(C$,I,1)<"1" OR MID$(C$,I,1)>"8" THEN PRINT
    "ERROR, select parameter again"·GOTO 1730
1760 NEXT I
1770 C=VAL(C$)
1780 IF C=1 THEN PROCtemp ELSE GOTO 1800
1790 GOTO 1110
1800 IF C=2 THEN PROCexp ELSE GOTO 1820
1810 GOTO 1110
1820 IF C=3 THEN PROCsync ELSE GOTO 1840
1830 GOTO 1110
1840 IF C=4 THEN PROCdatmode ELSE GOTO 1860
1850 GOTO 1110
1860 IF C=5 THEN PROCaltercount ELSE GOTO 1880
1870 GOTO 1110
1880 IF C=6 THEN PROCaltercount ELSE GOTO 1900
1890 GOTO 1110
1900 IF C=7 THEN PROCaltercount ELSE GOTO 1920
1910 GOTO 1110
1920 IF C=8 THEN PROCmem ELSE GOTO 1110
1930 GOTO 1110
1940
1950
1960 DEF PROCtemp
1970 CMD$ ="DT "
1980 INPUT "New detector temp = ";T
1990 CMDV$ = "DT "+STR$(T)
2000 PROClisten
2010 ENDPROC
2020
2030

```

```

2040 DEF PROCexp
2050 CMD$ ="ET "
2060 INPUT "New exposure time = ";E
2070 CMDV$ ="ET "+STR$(E)
2080 PROClisten
2090 ENDPROC
2100
2110
2120 DEF PROCsync
2130 PRINT:PRINT
2140 PRINT TAB(10),"SYNC MODE";TAB(40);"CODE"
2150 PRINT
2160 PRINT TAB(12);"Normal";TAB(42);"1"
2170 PRINT TAB(12);"Line";TAB(42);"2"
2180 PRINT TAB(12);"External";TAB(42),"3"
2190 PRINT:PRINT
2200 PRINT "REMEMBER! External synchronisation only
          applies to the 1463 detector. "
2210 PRINT " DO NOT SELECT THIS FOR THE 1462 "
2220 PRINT.PRINT
2230 INPUT "Sync mode required is ",N
2240 IF N=1 THEN CMDV$ = "NS "
2250 IF N=2 THEN CMDV$ = "LS "
2260 IF N=3 THEN CMDV$ = "XS "
2270 IF N<>1 AND N<>2 AND N<>3 THEN PRINT "ERROR,Please
          select sync mode again " :GOTO 2230
2280 PROClisten
2290 ENDPROC
2300
2310
2320 DEF PROCaltercount
2330 IF C=5 THEN CMD$="J "
2340 IF C=6 THEN CMD$="I "
2350 IF C=7 THEN CMD$="K "
2360 PRINT.INPUT "New count value is";V
2370 CMDV$ = CMD$ + STR$(V)
2380 PROClisten
2390 ENDPROC
2400
2410
2420 DEF PROClisten
2430 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
2440 PRINT#data%,CMDV$
2450 PRINT#cmd%,"UNLISTEN"
2460 ENDPROC
2470
2480
2490 DEF PROctalk
2500 PRINT#cmd%,"TALK",oma%
2510 INPUT#data%,PAR$
2520 PRINT#cmd%,"UNTALK"
2530 ENDPROC
2540
2550 DEF PROCdatmode
2560 CLS:PRINT:PRINT TAB(20);"*****DATA ACQUISITION MODE
          SELECTION*****" PRINT
2570 PRINT "WARNING!---- If there is any data in the "
2580 PRINT "detector interface memory that you wish to "

```

```

2590 PRINT "use please output it now because changing "
2600 PRINT "the data acquisition mode may clear the
           memory      "

2610 PRINT:PRINT.INPUT "Do you wish to down load any data
           from memory [Y OR N (E OR ST)] ",Z$
2620 IF Z$="Y" THEN GOTO2920
2630 IF Z$="E" THEN GOTO 2940
2640 IF Z$="ST" THEN GOTO 770
2650 IF Z$<>"ST" AND Z$<>"E" AND Z$<>"Y" AND Z$<>"N" THEN
           PRINT "ERROR,Please choose again "·GOTO 2610
2660 PRINT:INPUT "Do you wish to select a preset mode
           (Input P) or ROLL YOUR OWN (Input R)";Q$
2670 IF Q$<>"P" AND Q$<>"R" THEN PRINT "ERROR,choose
           again":GOTO 2660
2680 IF Q$="P" GOTO 2720
2690 INPUT"Roll you own mode is";COMMAND$
2700 CMDV$="RYO "+COMMAND$
2710 GOTO 2770
2720 PRINT.INPUT "New data acquisition mode is ";M$
2730 FOR I=1TOLEN(M$)
2740 IF MID$(M$,I,1)<"0" AND M$<>"RYO" OR MID$(M$,I,1)>"9"
           ANDM$<>"RYO" THEN PRINT"ERROR,choose again.":GOTO2720
2750 NEXTI
2760 CMDV$="DA "+M$
2770 PROClisten
2780 ENDPROC
2790
2800 DEF PROCmem
2810 PRINT:PRINT:INPUT "Memory at which you wish to start
           recording is";N$
2820 FOR I=1TOLEN(N$)
2830 IF MID$(N$,I,1)<"0" OR MID$(N$,I,1)>"9" THEN PRINT
           "ERROR,choose again." GOTO2810
2840 NEXTI
2850 CMDV$="MEM "+N$
2860 PROClisten
2870 ENDPROC
2880 IF ERR=17 THEN PRINT ·PRINT "(E)nd or Return to
           (M)enu ·"; ·INPUT D$ ELSE PRINT ERR,ERL .END
2890 IFD$<>"E" AND D$<>"M" THEN PRINT"ERROR,Choose again"
           :GOTO 2880
2900 IF D$="E" THEN 2940
2910 IF D$="M" THEN CLEAR
2920*DISC
2930 CHAIN":0.MENU1"
2940 END

```

```

5400 REM Program Name "MONITOR"
5410 MODE128
5420 CLEAR
5430 ON ERROR GOTO 6510
5440 PRINT:PRINT"At any time during this program you can
           return to main menu by 'ESCAPE'"
5450 DIM V(4200)
5460 IFH%=1 THEN6190
5470 *IEEE
5480 cmd%=OPENIN("COMMAND")
5490 data%=OPENIN("DATA")
5500 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
5510 PRINT#cmd%,"BBC DEVICE NO",0
5520 PRINT#cmd%,"CLEAR"
5530 PRINT#cmd%,"REMOTE ENABLE"
5540 PRINT#cmd%,"UNLISTEN"
5550 oma%=OPENIN("11")
5560 PRINT·PRINT:INPUT "MEMORY =",M$
5570 INPUT"Input starting channel",S$
5580 INPUT"Input number of channels to be down-loaded",F$
5590 S=VAL(S$):F=VAL(F$)
5600 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
5610 PRINT#data%,"J ;K ;ET "
5620 PRINT#cmd%,"UNLISTEN"
5630 PRINT#cmd%,"TALK",oma%
5640 INPUT#data%,J$,K$,ET$
5650 PRINT#cmd%,"UNTALK"
5660 PRINT"HIT ANY KEY TO BEGIN".C$=GET$
5670 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
5680 PRINT#data%,"DC "+M$+",""+S$+",""+F$
5690 PRINT#cmd%,"UNLISTEN"
5700 PRINT#cmd%,"TIMEOUT ON"
5710 PRINT#cmd%,"TALK",oma%
5720 PRINT#cmd%,"READ BINARY",10000
5730 CNT=0:TIM=0
5740 T$=""
5750 REPEAT.I%=BGET#data%
5760 PRINT#cmd%,"STATUS"
5770 INPUT#cmd%,state%
5780 IF(state%AND2)=2THENI%=44.TIM=-1
5790 T%=T%+CHR$(I%)
5800 UNTILI%=44
5810 V(CNT)=VAL(T%)
5820 CNT=CNT+1
5830 IF NOTTIM THEN GOTO5740
5840 Vmax=0:Vmin=100000
5850 FOR I%=1 TO F
5860 IF V(I%)>Vmax THEN Vmax=V(I%)
5870 NEXT I%
5880 FOR I%=1 TO F
5890 IF V(I%)<Vmin THEN Vmin=V(I%)
5900 NEXT I%
5910 IF Vmax=Vmin THEN Vmax=Vmax+5.Vmin=Vmin-4
5920 PRINT:INPUT "Do you wish to preset Vmax (Y or N)",B$
5930 IF B$<>"Y" AND B$<>"N" THEN PRINT "ERROR,Please
           choose again!":GOTO 5920
5940 IF B$="N" THEN GOTO 6000
5950 INPUT "Vmax =",Z$

```

```

5960 FOR I=1 TO LEN(Z$)
5970 IF MID$(Z$,I,1)<"0" OR MID$(Z$,I,1)>"9" THEN PRINT
      "ERROR,Please choose again!"·GOTO 5950
5980 NEXT I
5990 Vmax=VAL(Z$)
6000 PRINT INPUT "Do you wish to preset Vmin (Y or N)",W$
6010 IF W$<>"Y" AND W$<>"N" THEN PRINT "ERROR,Please
      choose again!"·GOTO 6000
6020 IF W$="N" THEN GOTO 6080
6030 INPUT "Vmin =";U$
6040 FOR I=1 TO LEN(U$)
6050 IF MID$(U$,I,1)<"0" OR MID$(U$,I,1)>"9" THEN PRINT
      "ERROR,Please choose again!" GOTO 6030
6060 NEXT I
6070 Vmin=VAL(U$)
6080 PRINT:PRINT:PRINT "Do you wish to plot point by point
      (input P) or continuously (input C)"
6090 PRINT:INPUT "Your choice is";CH$
6100 IF CH$<>"P" AND CH$<>"C" THEN PRINT "ERROR,Please
      choose again!" GOTO 6090
6110 IF CH$="P" THEN K=1 ELSE K=0
6120 PROCaxes
6130 PROCplot
6140 M=VAL(M$):ET=VAL(ET$) J=VAL(J$)·K=VAL(K$)
6150 Q=M*ET*(J+K)
6160 PRINT TAB(60,0);"TIME=" Q "Sec ";TAB(0,0), INPUT
      "Dump(D) or Continue(ANY KEY)",H$
6170 *DISC
6180 IF H$="D" THEN H%=1 O%=1 X%=3.CLEAR:CHAIN ".0.DUMP"
6190 IF TIME>=Q% THEN H%=0 GOTO5400 ELSE 6190
6200
6210
6220 DEF PROCaxes
6230 CLS
6240 MOVE 96,80:DRAW 1216,80 MOVE 96,80:DRAW 96,960
6250 FOR I=0 TO 10
6260 PRINT TAB(I*7+5,30);INT( (F/10)*I+S ),
6270 NEXT
6280 FOR I=0 TO 10
6290 MOVE 96+I*112,80.PLOT 1,0,-8
6300 NEXT
6310 FOR I%=0 TO 9
6320 PRINT TAB(1,29-I%*3);INT( ((Vmax-Vmin)/9)*I%+Vmin );
6330 NEXT
6340 FOR I%=0 TO 9
6350 MOVE 96,80+I%*96·PLOT 1,-8,0
6360 NEXT
6370 ENDPROC
6380
6390
6400 DEF PROCplot
6410 VDU 24,96;80;1216,960,
6420 xscale=1120/F:yscale=880/(Vmax-Vmin)
6430 Smin = S
6440 FOR I%=0 TO F-1
6450 x=(S+I%-Smin)*xscale+96 y=(V(I%)-Vmin)*yscale+80
6460 IF I%=0 THEN MOVE x,y ELSE PLOT 5+64*K,x,y
6470 NEXT I%

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```
6480 VDU 26
6490 ENDPROC
6500
6510 IFERR=222THEN PRINT PRINT TAB(20);"*****File does not
      exist*****":GOTO5730
6520 IFERR=17THEN 6530 ELSE PRINT ERR.REPORT.END
6530 PRINT:PRINT.INPUT"Do you wish to END(E) or return to
      main menu(R)";G$
6540 IF G$<>"E" ANDG$<>"R" THEN PRINT"ERROR".GOTO 6530
6550 IF G$="E"THEN 6580
6560 *DISC
6570 CLEAR.CHAIN" 0.MENU1"
6580 END
```

```

3200 REM Program name = "GETDAT"
3210 MODE128
3220 CLEAR:H=0
3230 ON ERROR GOTO 3250
3240 GOTO 3310
3250 IFERR=17THEN 4630 ELSE 3270
3260 IF ERR<>198 THEN REPORT PRINTERR.PRINTERL END
3270 IF Z$="1" THEN 3290
3280 IF Z$="3" THEN 3300
3290 PRINT:PRINT"NO ROOM - Trying other side of
disc":Z$="3":GOTO 4210
3300 PRINT:PRINT"DISC FULL - Place new disc in drive and
hit SPACE to continue":X$=GET$.GOTO 4170
3310 PRINT:PRINT"At any time during this program you can
return to main menu by 'ESCAPE'"
3320 DIM V(4200)
3330*IEEE
3340 cmd%=OPENIN("COMMAND")
3350 data%=OPENIN("DATA")
3360 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
3370 PRINT#cmd%,"BBC DEVICE NO",0
3380 PRINT#cmd%,"CLEAR"
3390 PRINT#cmd%,"REMOTE ENABLE"
3400 PRINT#cmd%,"UNLISTEN"
3410 oma%=OPENIN("11")
3420 PRINT:PRINT:INPUT TAB(20);"MEMORY Location to be down
loaded = ",M$
3430 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
3440 PRINT#data%,"MAX MEM "
3450 PRINT#cmd%,"UNLISTEN"
3460 PRINT#cmd%,"TALK",oma%
3470 INPUT#data%,MAX$
3480 PRINT#cmd%,"UNTALK"
3490 MAX=VAL(MAX$)·M=VAL(M$)
3500 IF M<0 OR M>MAX THEN PRINT:PRINT"ERROR, choose
again":GOTO 3420
3510 PRINT:PRINT:INPUT TAB(20);"Input starting channel",S$
3520 FOR I=1 TO LEN(S$)
3530 IF MID$(S$,I,1) <"0" OR MID$(S$,I,1) >"9" THEN
PRINT"ERROR,choose again":GOTO 3510
3540 NEXT I
3550 PRINT:PRINT·INPUT TAB(20);"Input number of channels to
be down-loaded";F$
3560 FOR I=1 TO LEN(F$)
3570 IF MID$(F$,I,1) <"0" OR MID$(F$,I,1) >"9" THEN
PRINT"ERROR,choose again":GOTO 3510
3580 NEXT I
3590 S=VAL(S$).F=VAL(F$)
3600 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
3610 PRINT#data%,"DC "+M$+", "+S$+", "+F$
3620 PRINT#cmd%,"UNLISTEN"
3630 PRINT#cmd%,"TIMEOUT ON"
3640 PRINT#cmd%,"TALK",oma%
3650 PRINT#cmd%,"READ BINARY",10000
3660 CNT=0 TIM=0
3670 T$=""
3680 REPEAT:I%=BGET#data%
3690 PRINT#cmd%,"STATUS"

```

```

3700 INPUT#cmd%,state%
3710 IF(state%AND2)=2THENI%=44.TIM=-1
3720 T%=T%+CHR$(I%)
3730 UNTILI%=44
3740 V(CNT)=VAL(T%)
3750 CNT=CNT+1
3760 IF NOTTIM THEN GOTO3670
3770 Vmax=0:Vmin=100000
3780 FOR I%=0 TO CNT-1
3790 IF V(I%)>Vmax THEN Vmax=V(I%):Imax=I%
3800 NEXT I%
3810\FOR I%=0 TO CNT-1
3820 IF V(I%)<Vmin THEN Vmin=V(I%):Imin=I%
3830 NEXT I%
3840 FOR I%=0 TO CNT-1
3850 PRINT TAB(10),V(I%),TAB(20);I%
3860 NEXT I%
3870 PRINT TAB(10);"Vmax = ",Vmax,"      Imax = ";Imax,"
      Vmin = ";Vmin;"      Imin = ",Imin
3880 PRINT:INPUT "Do you wish to preset Vmax (Y or N)",B$
3890 IF B$<>"Y" AND B$<>"N" THEN PRINT "ERROR, Please
      choose again!"·GOTO 3880
3900 IF B$="N" THEN GOTO 3960
3910 INPUT "Vmax =";Z$
3920 FOR I=1 TO LEN(Z$)
3930 IF MID$(Z$,I,1)<"0" OR MID$(Z$,I,1)>"9" THEN PRINT
      "ERROR, Please choose again!" GOTO 3910
3940 NEXT I
3950 Vmax=VAL(Z$)
3960 PRINT:INPUT "Do you wish to preset Vmin (Y or N)";W$
3970 IF W$<>"Y" AND W$<>"N" THEN PRINT "ERROR, Please
      choose again!":GOTO 3960
3980 IF W$="N" THEN GOTO 4040
3990 INPUT "Vmin =";U$
4000 FOR I=1 TO LEN(U$)
4010 IF MID$(U$,I,1)<"0" OR MID$(U$,I,1)>"9" THEN PRINT
      "ERROR,Please choose again!":GOTO 3990
4020 NEXT I
4030 Vmin=VAL(U$)
4040 PRINT.PRINT:PRINT "Do you wish to plot point by point
      (input P) or continuously (input C)"
4050 PRINT.INPUT "Your choice is";CH$
4060 IF CH$<>"P" AND CH$<>"C" THEN PRINT "ERROR,Please
      choose again!":GOTO 4050
4070 IF CH$="P" THEN K=1 ELSE K=0
4080 PROCaxes
4090 PROCplot
4100 PRINT TAB(58,0);"I(counts) v's Ch No" ;TAB(0,0),
      :INPUT" Dump(D) Main(M) Get(G) Save(S)",H$
4110 IF H$<>"D" AND H$<>"S" AND H$<>"M" AND H$<>"G" THEN
      GOTO 4100
4120*DISC
4130 IF H$="D" THEN O%=4:X%=3:CLEAR:CHAIN ":0.DUMP"
4140 IF H$="M" THEN CLEAR.CHAIN ".0.MENU1"
4150 IF H$="G" THEN GOTO 3200
4160 CLS.PRINT:INPUT"Enter name of file under which you
      wish to save the data",NAME$
4170 PRINT:PRINT:INPUT "Do you wish to save on drive 1 or

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```

        drive 3";Z$
4180  IF Z$<>"1" AND Z$<>"3" THEN PRINT"ERROR choose
        again":GOTO 4170
4190  *DISC
4200  IF Z$="1" THEN GOTO 4230
4210  *DRIVE3
4220  GOTO 4240
4230  *DRIVE1
4240  PROCcheck
4250  IFX=0 GOTO 4270
4260  IF H=0 GOTO 4160
4270  X=OPENOUT(NAME$)
4280  FOR I%=0 TO CNT
4290  PRINT#X,V(I%)
4300  NEXTI%
4310  CLOSE#0
4320  GOTO 4080
4330  END
4340  DEF PROCaxes
4350  CLS
4360  MOVE 96,80:DRAW 1216,80·MOVE 96,80:DRAW 96,960
4370  FOR I=0 TO 10
4380  PRINT TAB(I*7+5,30);INT( (F/10)*I+S ),
4390  NEXT
4400  FOR I=0 TO 10
4410  MOVE 96+I*112,80.PLOT 1,0,-8
4420  NEXT
4430  FOR I%=0 TO 9
4440  PRINT TAB(1,29-I%*3),INT( ((Vmax-Vmin)/9)*I%+Vmin );
4450  NEXT
4460  FOR I%=0 TO 9
4470  MOVE 96,80+I%*96:PLOT 1,-8,0
4480  NEXT
4490  ENDPROC
4500
4510
4520  DEF PROCplot
4530  VDU 24,96,80;1216,960;
4540  xscale=1120/F.yscale=880/(Vmax-Vmin)
4550  Smin = S
4560  FOR I%=0 TO F-1
4570  x=(S+I%-Smin)*xscale+96.y=(V(I%)-Vmin)*yscale+80
4580  IF I%=0 THEN MOVE x,y ELSE PLOT 5+64*K,x,y
4590  NEXT I%
4600  VDU 26
4610  ENDPROC
4620
4630  PRINT.PRINT:INPUT"Do you wish to END(E) or return to
        main menu(R)";G$
4640  IF G$<>"E" ANDG$<>"R" THEN PRINT"ERROR".GOTO 4630
4650  IF G$="E"THEN 4780
4660  *DISC
4670  CLEAR·CHAIN":0 MENU1"
4680  DEF PROCcheck
4690  X=OPENIN(NAME$)
4700  IF X=0 THEN GOTO 4770
4710  PRINT TAB(20);"***** FILE ALREADY EXISTS *****"
4720  PRINT·INPUT "Do you wish to enter a new name (input N)

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      or delete existing file (input D)",M$
4730  IF M$<>"N" AND M$<>"D" THEN PRINT"ERROR choose
      again":GOTO 4720
4740  IF M$="N" THEN H=0 GOTO 4770
4750  IF M$="D" THEN H=1
4760  CLOSE#0
4770  ENDPROC
4780  END
```

```

8700 REM Program name . "PLOT"
8710 ON ERROR GOTO 9810
8720 MODE128
8730 C=800 hold=0.recalibrated=0.choice=1
8740 PRINT·PRINT:PRINT TAB(20);"****PLOTTING ROUTINE****"
8750 PRINT:PRINT:INPUT"Do you wish to continue (input C)
      or return to main menu (R)";L$
8760 IF L$<>"C" AND L$<>"R" THEN PRINT"ERROR,choose again"
      .GOTO 8750
8770 IF L$="R" THEN Y=1:PROCreset:GOTO 9440
8780 C=800:hold=0·recalibrated=0.choice=1
8790 PRINT:PRINT:INPUT "Name of data file to be plotted";
      NAME$
8800 PRINT.PRINT "Input the channel numbers at which you
      wish to start and finish plotting."
8810 PRINT.INPUT "Starting channel number";S$
8820 FOR I=1 TO LEN(S$)
8830 IF MID$(S$,I,1)>"9" OR MID$(S$,I,1)<"0" THEN PRINT
      "ERROR,Please input value again!":GOTO 8810
8840 NEXT I
8850 S=VAL(S$)
8860 PRINT:INPUT "Final channel number";F$
8870 FOR I=1 TO LEN(F$)
8880 IF MID$(F$,I,1)>"9" OR MID$(F$,I,1)<"0" THEN PRINT
      "ERROR,Please input value again!":GOTO 8860
8890 NEXT I
8900 F=VAL(F$)
8910 PRINT:PRINT:PRINT"Is the file on drive 1 or drive 3
      [RETURN if you don't know ]";.Z$=GET$
8920 IF Z$<>"1" AND Z$<>"3" AND Z$<>CHR$(13) THEN PRINT
      "ERROR,Please choose again!":GOTO 8910
8930 IF Z$=CHR$(13) THEN R%=1·CHAIN":0 CAT"
8940 IF Z$="1" THEN GOTO 8970
8950 *DRIVE3
8960 GOTO 8980
8970 *DRIVE 1
8980 X=OPENIN(NAME$)
8990 IF S=1 THEN GOTO 9030
9000 FOR I=1 TO S-1
9010 INPUT# X,V
9020 NEXT I
9030 Vmax=0:Vmin=100000
9040 FOR I=S TO F
9050 INPUT# X,V
9060 IF V>Vmax THEN Vmax=V
9070 IF V<Vmin THEN Vmin=V
9080 NEXT I
9090 CLOSE#0
9100 CLS·PRINT:PRINT:PRINT"Vmax= ";Vmax
9110 PRINT:INPUT "Do you wish to preset Vmax (Y or N)";B$
9120 IF B$<>"Y" AND B$<>"N" THEN PRINT "ERROR,Please
      choose again!":GOTO 9110
9130 IF B$="N" THEN GOTO 9190
9140 INPUT "Vmax =";Z$
9150 FOR I=1 TO LEN(Z$)
9160 IF MID$(Z$,I,1)<"0" OR MID$(Z$,I,1)>"9" THEN PRINT
      "ERROR,Please choose again!":GOTO 9140
9170 NEXT I

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9180 Vmax=VAL(Z$)
9190 PRINT:PRINT"Vmin= ",Vmin
9200 PRINT:INPUT "Do you wish to preset Vmin (Y or N)";W$
9210 IF W$<>"Y" AND W$<>"N" THEN PRINT "ERROR,Please
                                choose again!"·GOTO 9200
9220 IF W$="N" THEN GOTO 9280
9230 INPUT "Vmin =";U$
9240 FOR I=1 TO LEN(U$)
9250 IF MID$(U$,I,1)<"0" OR MID$(U$,I,1)>"9" THEN PRINT
    "ERROR,Please choose again!"·GOTO 9230
9260 NEXT I
9270 Vmin=VAL(U$)
9280 PRINT:PRINT:PRINT "Do you wish to plot point by point
    (input P) or continuously (input C)"
9290 PRINT·INPUT "Your choice is";CH$
9300 IF CH$<>"P" AND CH$<>"C" THEN PRINT "ERROR,Please
    choose again!":GOTO 9290
9310 IF CH$="P" THEN T=1 ELSE T=0
9320 PROCaxes
9330 PROCplot
9340 PRINT TAB(55,0)"I(counts) v's Ch no.".GOTO 9370
9350 VDU23,200,&30,&18,&18,&1C,&36,&63,&C3,0
9360 PRINT TAB(55,0)"I(counts) v's "CHR$(200)"(nm)"
9370 INPUT TAB(0,0),"Dump(D) Main(M) Plot(P) Recal(R)
    Analyse(A)";T$
9380 IF T$<>"D" AND T$<>"M"AND T$<>"P"AND T$<>"R" AND
    T$<>"A" THENGOTO 9370
9390 IF T$="A" THEN GOSUB 10130
9400 IF T$="P" THEN CLS.GOTO 8780
9410 IF T$="D" THEN O%=2 .X%=2:choice=0.GOTO 9440
9420 IF T$="R" THEN PROCcal.PROCplot:GOTO 9350
9430 IF T$="M" THEN PROCreset.choice=1
9440*DISC
9450 IF choice=1 THEN CHAIN ".0.MENU1" ELSE CHAIN"·0 DUMP"
9460 END
9470 DEF PROCaxes
9480 CLS
9490 MOVE 96,80:DRAW 1216,80 MOVE 96,80:DRAW 96,960
9500 FOR I=0 TO 10
9510 PRINT TAB(I*7+5,30),INT( ((F-S)/10)*I+S );
9520 NEXT
9530 FOR I=0 TO 10
9540 MOVE 96+I*112,80:PLOT 1,0,-8
9550 NEXT
9560 FOR I%=0 TO 9
9570 PRINT TAB(1,29-I%*3);INT( ((Vmax-Vmin)/9)*I%+Vmin );
9580 NEXT
9590 FOR I%=0 TO 9
9600 MOVE 96,80+I%*96·PLOT 1,-8,0
9610 NEXT
9620 ENDPROC
9630 DEF PROCplot
9640 X=OPENIN(NAME$)
9650 IF S=1 GOTO 9690
9660 FOR I=1 TO S-1
9670 INPUT# X,V
9680 NEXT I
9690 VDU 24,96,80,1216,960,

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9700 xscale=1120/(F-S)·yscale=880/(Vmax-Vmin)
9710 Smin = S
9720 FOR I=S TO F
9730 INPUT# X,V
9740 x=(I-Smin)*xscale+96:y=(V-Vmin)*yscale+80
9750 PLOT 5+64*T,x,y
9760 NEXT I
9770 CLOSE#0
9780 VDU 26
9790 ENDPROC
9800
9810 IF ERR=222THEN PRINT:PRINT TAB(20);"**File does not
exist**":GOTO8780 ELSE PRINT ERR:PRINT ERL.REPORT·END
9820 DEF PROCcal
9830 IF recalibrated=1 THEN GOTO 9890
9840 CLS:PRINT:PRINT:PRINTTAB(20);"***** RECALIBRATION
ROUTINE *****"
9850 PRINT.INPUT TAB(28);"Known channel number",G
9860 PRINT:INPUT TAB(28);"Corresponding wavelength";H
9870 PRINT:INPUT TAB(28);"Second known channel number";J
9880 PRINT:INPUT TAB(28),"Corresponding wavelength";K
9890 CLS
9900 Wmin=H-((G-S+1)*((K-H)/(J-G))).
Wmax=K+(((K-H)/(J-G))*(F-J))
9910 MOVE96,80·DRAW 1216,80:MOVE96,80 DRAW96,960
9920 IF Wmax-Wmin>10 THEN GOTO 9990
9930 @%=&20109
9940 FOR I=0TO10
9950 PRINT TAB(I*7+5,30),(((Wmax-Wmin)/10)*I+Wmin);
9960 NEXT
9970 @%=10
9980 GOTO 10020
9990 FOR I=0TO10
10000 PRINTTAB(I*7+5,30);INT((((Wmax-Wmin)/10)*I+Wmin)+.5);
10010 NEXT
10020 FORI=1TO10
10030 MOVE96+I*112,80.PLOT1,0,-8
10040 NEXT
10050 FORI%=0TO9
10060 PRINTTAB(1,29-I%*3),INT((((Vmax-Vmin)/9)*I%+Vmin)+.5);
10070 NEXT
10080 FOR I=0TO9
10090 MOVE96,80+I*96:PLOT1,-8,0
10100 NEXT
10110 recalibrated = 1
10120 ENDPROC
10130 REM SUB ROUTINE TO ANALYSE GRAPH
10140*FX4,1
10150 VDU23,202,&92,&54,&38,&FE,&38,&54,&92,&00
10160 VDU23,203,&10,&30,&70,&FF,&FF,&70,&30,&10
10170 VDU23,201,&08,&0C,&0E,&FF,&FF,&0E,&0C,&08
10180 MOVE C,84:PLOT 6,C,956
10190 PRINT TAB(50,0);" "
10200 IF recalibrated=0 THEN GOTO 10230
10210 PRINT TAB(63,0);"I(cnts) v's ";CHR$(200),"(nm)"
10220 GOTO 10240
10230 PRINT TAB(60,0);"I(cnts) v's Ch No."
10240 PRINT TAB(0,0);"Slw [";CHR$(203)," ",CHR$(201);"]

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Fst[< >] Hold(H) Integ(I) Data(D) Clr(R) Exp(E)";
:X$=GET$
10250 IFX$=CHR$(136) THEN PROCbar(-1)
10260 IFX$=CHR$(137) THEN PROCbar(1)
10270 IFX$="H" THEN PROChold
10280 IFX$="<" OR X$="," THEN PROCbar(-20)
10290 IFX$=">" OR X$="." THEN PROCbar(20)
10300 IFX$="I" THEN PROCintegrate PROCremove
10310 IFX$="D" THEN PROCdata
10320 IFX$="R" THEN PROCremove
10330 IF X$="E" THEN PROCexpand GOTO 10360
10340 IFX$=CHR$(13) THEN PROCreset.CLOSE#0:GOTO 10390
10350 GOTO 10240
10360 IF recalibrated=1 GOTO10380
10370 PROCaxes:PROCplot:hold=0.recalibrated=0:GOTO 9340
10380 PROCcal:PROCplot:hold=0.recalibrated=0:GOTO 9360
10390 IF recalibrated=1 GOTO10410
10400 PROCaxes.PROCplot:hold=0.recalibrated=0:GOTO 9340
10410 PROCcal.PROCplot:hold=0:recalibrated=0:GOTO 9360
10420 END
10430 DEF PROCbar(I)
10440 MOVE C,84:PLOT 6,C,956
10450 C=C+I
10460 IF C>1216 THEN C=96
10470 IF C<96 THEN C=1216
10480 MOVE C,84:PLOT 6,C,956
10490 ENDPROC
10500 DEF PROChold
10510 IF hold = 1 THEN PRINT TAB(0,0),"Already held input
R to remove";.X$=GET$;.GOTO10600
10520 POINT=(C-96)/xscale+S
10530 VDU5
10540 PLOT 4,C,960
10550 PLOT0,2,-4
10560 PRINT CHR$(202),
10570 VDU4
10580 hold=1
10590 C=C-2.MOVE C,84:PLOT 6,C,956
10600 ENDPROC
10610 DEF PROCremove
10620 IF hold=0 THEN GOTO 10710
10630 B=C
10640 C=INT((POINT-S)*xscale+96.5)
10650 hold=0
10660 GCOL4,1.PROChold
10670 MOVE C,84.PLOT 6,C,956.C=C+2.MOVE C,84:PLOT 6,C,956
10680 hold=0
10690 C=B
10700 GCOL0,1
10710 ENDPROC
10720 DEF PROCintegrate
10730 IF hold=0 THEN GOTO 10890
10740 PRINT TAB(0,0);"
10750 PRINT TAB(0,0),FNinv("WORKING");
10760 LOW=POINT:HIGH=(C-96)/xscale+S
10770 intgr=0
10780 X=OPENIN(NAME$)
10790 IF S=1 GOTO 10820

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10800 FOR I=1 TO S-1:INPUT#X,V
10810 NEXT I
10820 IF LOW>HIGH THEN TEMP =LOW:LOW=HIGH.HIGH=TEMP
10830 FOR I=S TO F
10840 IF I>=LOW AND I<=HIGH THEN intgr=intgr+V
10850 NEXTI
10860 PRINT TAB(0,0)"INT=",intgr;" Dump(D)";.X$=GET$
10870 IFX$="D" THEN X%=2:CHAIN".0.DUMP"
10880 CLOSE#0
10890 ENDPROC
10900 DEF PROCdata
10910 PRINT TAB(0,0),"
10920 PRINT TAB(0,0);FNinv("WORKING");
10930 D=INT((C-96)/xscale+S)
10940 X=OPENIN(NAME$)
10950 FOR I=1 TO D-1:INPUT#X,V.NEXTI
10960 INPUT#X,V:CNT=V
10970 PRINT TAB(0,0);"
10980 IF recalibrated=0 GOTO 11050
10990 D= Wmin + (K-H)/(J-G)*(D-S)
11000 @%=&20409
11010 PRINT TAB(0,0);CHR$(200) "= ";D
11020 @%=10
11030 PRINT TAB(15,0);"CNT = ";CNT," Dump(D)";.X$=GET$
11040 GOTO 11060
11050 PRINT TAB(0,0);"CH="D;" CNT=",CNT;" Dump(D)",:X$=GET$
11060 IFX$="D" THEN X%=2 CHAIN":0 DUMP"
11070 CLOSE#0
11080 ENDPROC
11090 DEF PROCreset
11100*FX4,0
11110 CLS
11120 ENDPROC
11130 DEF FNinv(W$)
11140 COLOUR 0:COLOUR 129·PRINT W$,:COLOUR 1:COLOUR 128
11150 =""
11160 DEF PROCexpand
11170 IF hold =0 THEN GOTO 11210
11180 LOW=POINT.HIGH = (C-96)/xscale+S
11190 IF LOW>HIGH THEN TEMP=LOW LOW = HIGH.HIGH = TEMP
11200 S=LOW:F=HIGH
11210 ENDPROC

```

```

10 REM Program name "PRNTER1"
20 ON ERROR GOTO 1260
30 A%=0.B%=0:C%=0:D%=0:H=0 XAX$="0":YAX$="0"
40*DISC
45*DRIVE 1
50 MODE128
60 DIM V(4200)
70 PRINT:PRINT TAB(21),"**SELECTION OF DATA FOR PLOT**"
150 PRINT:INPUT"Name of file for output",NAME$
155 IF NAME$="" THEN 150
160 PRINT:INPUT"Starting channel required on graph ";S$
162 FOR I=1 TO LEN(S$)
164 IF MID$(S$,I,1)<"0" OR MID$(S$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO 160
166 NEXT I
170 PRINT:INPUT"Final channel required on graph ";F$
172 FOR I=1 TO LEN(F$)
174 IF MID$(F$,I,1)<"0" OR MID$(F$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO170
176 NEXT I
180 S=VAL(S$).F=VAL(F$)
230 Vmin=6000000.Vmax=0
240 Xmin=S:Xmax=F*R=0
250 PRINT:INPUT"Do you wish to calibrate graph
(Y or N)";O$
260 IF O$="N" THEN GOTO 360
270 IFO$<>"Y" OR O$<>"N" THEN PRINT"ERROR":GOTO 250
280 CLS:PRINT:INPUT TAB(26),"Known channel number";A$
282 FOR I=1 TO LEN(A$)
284 IF MID$(A$,I,1)<"0" OR MID$(A$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO280
286 NEXT I
290 PRINT:INPUT TAB(26);"Corresponding wavelength";C$
292 FOR I=1 TO LEN(C$)
294 IF MID$(C$,I,1)<"0" AND MID$(C$,I,1)<> "." OR
MID$(C$,I,1)>"9" AND MID$(C$,I,1)<> "." THEN
PRINT"ERROR,choose again":GOTO290
296 NEXT I
300 PRINT:INPUT TAB(26),"Second known channel number";B$
302 FOR I=1 TO LEN(B$)
304 IF MID$(B$,I,1)<"0" OR MID$(B$,I,1)>"9" THEN PRINT
"ERROR,choose again".GOTO300
306 NEXT I
310 PRINT:INPUT TAB(26);"Corresponding wavelength",D$
312 FOR I=1 TO LEN(D$)
314 IF MID$(D$,I,1)<"0" AND MID$(D$,I,1)<> " " OR
MID$(D$,I,1)>"9" AND MID$(C$,I,1)<> " " THEN
PRINT"ERROR,choose again".GOTO310
316 NEXT I
318 A=VAL(A$):B=VAL(B$):C=VAL(C$):D=VAL(D$)
320 Xmin1=C-((A-S)*((D-C)/(B-A)))
: Xmax1=D+((F-B)*((D-C)/(B-A))):R=1
360 X=OPENIN(NAME$)
370 IFS=1GOTO410
380 FORI=1TOS-1
390 INPUT# X,V(I)
400 NEXTI
410 FOR I%= S TO F

```



```

420 IF NOT EOF#X THEN INPUT#X,V(I%) ELSE I%=F
430 IF V(I%)>Vmax THEN Vmax=V(I%)
440 IF V(I%)<Vmin THEN Vmin=V(I%)
450 NEXT I%
460 CLS:PRINT·PRINT TAB(21);"*****SCALING ROUTINE*****"
461 PRINT·PRINT:PRINT TAB(15);"Vmax = ";Vmax
462 PRINT·INPUT TAB(26);"Do you wish to preset Vmax";REP$
470 IF REP$<>"Y"AND REP$<>"N" THEN PRINT "ERROR,choose
again.":GOTO460
480 IF REP$="N"GOTO510
490 PRINT·INPUT "Vmax=",V$
492 FOR I = 1 TO LEN(V$)
494 IF MID$(V$,I,1)<"0" OR MID$(V$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO490
496 NEXT I
500 Vmax=VAL(V$)
510 PRINT:PRINT:PRINT TAB(15);"Vmin = ",Vmin
512 PRINT:INPUT TAB(26);"Do you wish to preset Vmin";ANS$
520 IF ANS$<>"Y"AND ANS$<>"N" THEN PRINT "ERROR,choose
again.".GOTO510
530 IF ANS$="N"GOTO570
540 PRINT:INPUT "Vmin=";K$
542 REM·FOR I = 1 TO LEN(K$)
544 REM:IF MID$(K$,I,1)<"0" OR MID$(K$,I,1)>"9" THEN
PRINT"ERROR,choose again".GOTO540
546 REM·NEXT I
550 Vmin=VAL(K$)
560 CLOSE# X
570 PRINT:PRINT:INPUT TAB(26);"Select continuous graph(C)
or points(P)";B$
580 IFB$<>"C" AND B$<>"P" THEN PRINT "ERROR,choose
again.".GOTO570
590 IF B$="P" THEN H=1 ELSE H=0
600 CLS
640 CLS:PROCaxes
650 PROCgraph
660 PRINTVmax.PRINTVmin
670 PRINT·PRINT:INPUT "Do you wish to plot another
graph(YorN)";D$
680 IFD$<>"Y" AND D$<>"N" THEN PRINT "ERROR,choose
again.".GOTO 670
685 IF D$="N" THEN 700
690 IF D$="Y" CLS·PRINT:PRINT
691 INPUT "Do you wish to plot a new graph (input 1 )
or plot new graph on last scale (input 2 )";Q$
693 IF Q$="1" CLEAR·CLOSE#0.GOTO10
694 IF Q$="2" CLEAR:GOTO751
700 *DISC
740 CHAIN ".0.MENU1"
750 END
751 *DISK
752 *DR.0
753 CHAIN ":0.PRINTER2"
754 END
760 DEF PROCaxes
770*IEEE
780 cmd%=OPENIN("COMMAND")
790 data%=OPENIN("DATA")

```

```

800 ESTR$=CHR$(13)+CHR$(10)
810 PRINT#cmd%, "END OF STRING", ESTR$
820 PRINT#cmd%, "BBC DEVICE NO", 0
830 PRINT#cmd%, "CLEAR"
840 PRINT#cmd%, "REMOTE ENABLE"
850 PRINT#cmd%, "UNLISTEN"
860 printer%=OPENIN("10")
870 PRINT#cmd%, "LISTEN", printer%, "EXECUTE"
875 PRINT#data%, "M200,200X1,220,10H"
876 IF R=0 THEN GOTO 890
880 PRINT#data%, "M200,1700X1,220,10H"
890 PRINT#data%, "M200,200X0,150,10H"
900 PRINT#data%, "M50,700Q1PINTENSITY (counts)"
910 PRINT#data%, "M2000,100QPCHANNEL NUMBER"
915 IF R=1 THEN PRINT#data%, "M2000,1770QPWAVELENGTH (nm)"
920 PRINT#data%, "M500,1770QPFILE = "+NAME$
950 FORI%=0TO10
960 A%=INT(((Xmax-Xmin)/10*I%+Xmin)+.5)
970 Y%=150
980 PRINT#data%, "M"+STR$(I%*220+200)+", "+STR$(Y%)
990 PRINT#data%, "P"+STR$(A%)
1000 NEXT
1005 IF R=0 GOTO 1063
1010 FORI%=0TO10
1020 A%=INT(((Xmax1-Xmin1)/10*I%+Xmin1)+.5)
1030 Y%=1720
1040 PRINT#data%, "M"+STR$(I%*220+200)+", "+STR$(Y%)
1050 PRINT#data%, "P"+STR$(A%)
1060 NEXT
1061 GOTO 1064
1063 PRINT#data%, "M200,1700":PRINT#data%, "D2400,1700"
1064 PRINT#data%, "M2400,200" PRINT#data%, "D2400,1700"
1070 FORI%=0TO10
1080 B%=INT((((Vmax-Vmin)/10)*I%+Vmin)+.5)
1090 X%=150
1100 PRINT#data%, "M"+STR$(X%)+", "+STR$(I%*150+200)
1110 PRINT#data%, "Q1P"+STR$(B%)
1120 NEXT
1130 ENDPROC
1140 DEF PROCgraph
1150 IFS=1GOTO1160
1160 Smin=S
1170 PRINT#data%, "M200,200"
1180 SCALEX=2200/(F-S).SCALEY=1500/(Vmax-Vmin)
1190 FOR I%=S TO F
1200 C%=(S-Smin)*SCALEX+200 D%=(V(I%)-Vmin)*SCALEY+200
1210 PRINT V(I%), I%
1220 IFH=0THEN PRINT#data%, "D"+STR$(C%)+", "+STR$(D%) ELSE
PRINT#data%, "M"+STR$(C%)+", "+STR$(D%)+ "N1"
1230 S=S+1 NEXT I%
1240 PRINT#data%, "H"
1250 ENDPROC
1260 IF ERR=222 THEN PRINT:PRINT TAB(21);"*****File does
not exist*****":CLS·GOTO70 ELSE PRINT ERR:REPORT·END

```

```

10 REM Program name "PRNTER2"
20 ON ERROR GOTO 1260
30 A%=0:B%=0:C%=0:D%=0:H=0.XAX$="0".YAX$="0"
40*DISC
45*DRIVE 1
50 MODE128
60 DIM V(4200)
70 PRINT.PRINT TAB(21);"***SELECTION OF DATA FOR PLOT***"
150 PRINT.INPUT"Name of file for output";NAME$
155 IF NAME$="" THEN 150
160 PRINT INPUT"Starting channel required on graph ";S$
162 FOR I=1 TO LEN(S$)
164 IF MID$(S$,I,1)<"0" OR MID$(S$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO 160
166 NEXT I
170 PRINT.INPUT"Final channel required on graph ";F$
172 FOR I=1 TO LEN(F$)
174 IF MID$(F$,I,1)<"0" OR MID$(F$,I,1)>"9" THEN PRINT
"ERROR,choose again".GOTO170
176 NEXT I
180 S=VAL(S$):F=VAL(F$)
230 Vmin=6000000.Vmax=0
240 Xmin=S:Xmax=F.R=0
250 PRINT.INPUT"Do you wish to calibrate graph (Y/ N)",O$
260 IF O$="N" THEN GOTO 360
270 IFO$<>"Y" OR O$<>"N" THEN PRINT"ERROR".GOTO 250
280 CLS PRINT.INPUT TAB(26),"Known channel number";A$
282 FOR I=1 TO LEN(A$)
284 IF MID$(A$,I,1)<"0" OR MID$(A$,I,1)>"9" THEN PRINT
"ERROR,choose again" GOTO280
286 NEXT I
290 PRINT INPUT TAB(26);"Corresponding wavelength";C$
292 FOR I=1 TO LEN(C$)
294 IF MID$(C$,I,1)<"0" AND MID$(C$,I,1)<>"." OR
MID$(C$,I,1)>"9" AND MID$(C$,I,1)<>"."THEN PRINT
"ERROR,choose again":GOTO290
296 NEXT I
300 PRINT.INPUT TAB(26),"Second known channel number";B$
302 FOR I=1 TO LEN(B$)
304 IF MID$(B$,I,1)<"0" OR MID$(B$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO300
306 NEXT I
310 PRINT:INPUT TAB(26);"Corresponding wavelength",D$
312 FOR I=1 TO LEN(D$)
314 IF MID$(D$,I,1)<"0" AND MID$(D$,I,1)<>"." OR
MID$(D$,I,1)>"9" AND MID$(C$,I,1)<>"."THEN PRINT
"ERROR,choose again".GOTO 310
316 NEXT I
318 A=VAL(A$):B=VAL(B$).C=VAL(C$):D=VAL(D$)
320 Xmin1=C-((A-S)*((D-C)/(B-A)))
: Xmax1=D+((F-B)*((D-C)/(B-A)))R=1
360 X=OPENIN(NAME$)
370 IFS=1GOTO410
380 FORI=1TOS-1
390 INPUT# X,V(I)
400 NEXTI
410 FOR I%= S TO F
420 IF NOT EOF#X THEN INPUT#X,V(I%) ELSE I%=F

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```

430 IF V(I%)>Vmax THEN Vmax=V(I%)
440 IF V(I%)<Vmin THEN Vmin=V(I%)
450 NEXT I%
460 CLS.PRINT.PRINT TAB(21),"*****SCALING ROUTINE*****"
461 PRINT.PRINT PRINT TAB(15),"Vmax = ",Vmax
462 PRINT INPUT TAB(26),"Do you wish to preset Vmax",REP$
470 IF REP$<>"Y"AND REP$<>"N" THEN PRINT "ERROR,choose
again " GOTO460
480 IF REP$="N"GOTO510
490 PRINT:INPUT "Vmax=",V$
492 FOR I = 1 TO LEN(V$)
494 IF MID$(V$,I,1)<"0" OR MID$(V$,I,1)>"9" THEN PRINT
"ERROR,choose again"·GOTO490
496 NEXT I
500 Vmax=VAL(V$)
510 PRINT PRINT PRINT TAB(15),"Vmin = ",Vmin
512 PRINT INPUT TAB(26),"Do you wish to preset Vmin",ANS$
520 IF ANS$<>"Y"AND ANS$<>"N" THEN PRINT "ERROR,choose
again " GOTO510
530 IF ANS$="N"GOTO570
540 PRINT INPUT "Vmin=",K$
542 REM FOR I = 1 TO LEN(K$)
544 REM IF MID$(K$,I,1)<"0" OR MID$(K$,I,1)>"9" THEN
PRINT"ERROR,choose again" GOTO540
546 REM NEXT I
550 Vmin=VAL(K$)
560 CLOSE# X
570 PRINT INPUT TAB(26),"Select continuous graph(C) or
points(P)",B$
580 IFB$<>"C" AND B$<>"P" THEN PRINT "ERROR,choose
again "·GOTO570
590 IF B$="P" THEN H=1 ELSE H=0
600 CLS
640 CLS.PROCaxes
650 PROCgraph
660 PRINTVmax·PRINTVmin
670 PRINT INPUT "Do you wish to plot another graph
(YorN)",D$
680 IFD$<>"Y" AND D$<>"N" THEN PRINT "ERROR,choose
again.".GOTO 670
690 IF D$="Y" CLEAR CLOSE#0 GOTO10
700 *DISC
740 CHAIN " 0.MENU1"
750 END
760 DEF PROCaxes
770 *IEEE
780 cmd%=OPENIN("COMMAND")
790 data%=OPENIN("DATA")
800 ESTR$=CHR$(13)+CHR$(10)
810 PRINT#cmd%,"END OF STRING",ESTR$
820 PRINT#cmd%,"BBC DEVICE NO",0
830 PRINT#cmd%,"CLEAR"
840 PRINT#cmd%,"REMOTE ENABLE"
850 PRINT#cmd%,"UNLISTEN"
860 printer%=OPENIN("10")
870 PRINT#cmd%,"LISTEN",printer%,"EXECUTE"
1130 ENDPROC
1140 DEF PROCgraph

```

```

1150 IFS=1GOTO1160
1160 Smin=S
1170 PRINT#data%, "M200,200"
1180 SCALEX=2200/(F-S) SCALEY=1500/(Vmax-Vmin)
1190 FOR I%=S TO F
1200 C%=(S-Smin)*SCALEX+200 D%=(V(I%)-Vmin)*SCALEY+200
1210 PRINT V(I%),I%
1220 IFH=0THEN PRINT#data%,"D"+STR$(C%)+", "+STR$(D%) ELSE
PRINT#data%,"M"+STR$(C%)+", "+STR$(D%)+ "N1"
1230 S=S+1 NEXT I%
1240 PRINT#data%,"H"
1250 ENDPROC
1260 IF ERR=222 THEN PRINT TAB(21);"***File does not
exist*****" CLS GOTO70 ELSE PRINT ERR REPORT.END

```

```

7210 REM Program Name "PARAM"
7220 MODE3
7230 PRINT PRINT TAB(20),"****PARAMETER INPUT ROUTINE****"
7240 PRINT PRINT INPUT "Exposure time = ",E$
7250 PRINT PRINT INPUT "Detector temperature = ",D$
7260 PRINT PRINT INPUT "No of scans ";S$
7270 PRINT PRINT INPUT "Slit width = ",W$
7280 PRINT PRINT INPUT "Sample = ",F$
7290 VDU2 VDU1,15
7300 PRINT CHR$(2) PRINT"Exposure time = "E$,"      Detector
      temperature = ",D$
7310 PRINT CHR$(2):PRINT"No of scans ";S$,"      Slit
      width = ",W$
7320 PRINT CHR$(2) PRINT"Sample = ",F$
7330 VDU2.VDU1,14
7340 PRINT PRINT"          -----*-----"
7350 PRINT"                ----*----"
7360 PRINT"                -*-"
7370 PRINT CHR$(3)
7380 *DISC
7390 IF X%=4 THEN CHAIN " 0.GETDAT".IF X%=2 THEN CHAIN
      " 0.PLOT".IF X%=3 THEN CHAIN " 0.MONITOR"
7400 IF X%=2 THEN CHAIN " 0 PLOT" ELSE GOTO 7410
7410 IF X%=3 THEN CHAIN ".0 MONITOR"

```

```

7900 REM Program Name "DATADSB"
7910 MODE3
7920 *IEEE
7930 PRINT PRINT TAB(20), "*****MEMORY MANIPULATION*****"
7940 cmd%=OPENIN("COMMAND")
7950 data%=OPENIN("DATA")
7960 PRINT#cmd%,"BBC DEVICE NO",0
7970 PRINT#cmd%,"CLEAR"
7980 PRINT#cmd%,"REMOTE ENABLE"
7990 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
8000 PRINT#cmd%,"UNLISTEN"
8010 oma%=OPENIN("11")
8020 CLS.PRINT.INPUT "Do you wish to add [input '1'] or
subtract [input '2'] two memories",H$
8030 IF H$<>"1" AND H$<>"2" THEN PRINT "ERROR, Please
choose again!" GOTO 8020
8040 IF H$="1" THEN PROCadd
8050 IF H$="2" THEN PROCsub
8060 PRINT PRINT "Do you wish to manipulate memories
further?"
8070 PRINT.INPUT "Yes(Y) or No(N)";Q$
8080 IF Q$<>"Y" AND Q$<>"N" THEN PRINT "ERROR, Please
choose again!" GOTO 8070
8090 IF Q$="Y" THEN GOTO 8020
8100 *DISC
8110 CHAIN " 0 MENU1"
8120
8130
8140 DEF PROClisten
8150 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
8160 PRINT#data%,CMDV$
8170 PRINT#cmd%,"UNLISTEN"
8180 ENDPROC
8190
8200
8210 DEF PROCtalk
8220 PRINT#cmd%,"TALK",oma%
8230 INPUT#data%,PAR$
8240 PRINT#cmd%,"UNTALK"
8250 ENDPROC
8260
8270
8280 DEF PROCsub
8290 PRINT.PRINT "Input to MEMORY A the memory you want to
subtract "
8300 PRINT.INPUT "MEMORY A=",A$
8310 FOR I=1 TO LEN(A$)
8320 IF MID$(A$,I,1)>"9" OR MID$(A$,I,1)<"0" THEN PRINT
"ERROR, Please choose again!" GOTO 8300
8330 NEXT I
8340 PRINT.PRINT "Input to MEMORY B the memory from which
you want to subtract "
8350 PRINT.INPUT "MEMORY B=",B$
8360 FOR I=1 TO LEN(B$)
8370 IF MID$(B$,I,1)>"9" OR MID$(B$,I,1)<"0" THEN PRINT
"ERROR, Please choose again!".GOTO 8350
8380 PRINT "NOTE. The result will be stored in memory ";B$
8390 NEXT I

```

```

8400 CMDV$="SUB "+A$+", "+B$
8410 PROClisten
8420 ENDPROC
8430
8440
8450 DEF PROCadd
8460 PRINT "Input to MEMORY A the memory you want to add."
8470 PRINT.INPUT "MEMORY A=",A$
8480 FOR I=1 TO LEN(A$)
8490 IF MID$(A$,I,1)>"9" OR MID$(A$,I,1)<"0" THEN PRINT
      "ERROR, Please choose again'.GOTO 8470
8500 NEXT I
8510 PRINT:PRINT "Input to MEMORY B the memory to which
      you want to add."
8520 PRINT.INPUT "MEMORY B=";B$
8530 FOR I=1 TO LEN(B$)
8540 IF MID$(B$,I,1)>"9" OR MID$(B$,I,1)<"0" THEN PRINT
      "ERROR, Please choose again'.GOTO 8520
8550 NEXT I
8560 PRINT "NOTE: The result will be stored in memory ";B$
8570 CMDV$="ADD "+A$+", "+B$
8580 PROClisten
8590 ENDPROC
8600 END

```



```

4800 REM Program Name "DATLOAD"
4810 IF L%=1 THEN GOTO 5060
4820 L%=0
4830 ON ERROR GOTO 5120
4840 CLS
4850 MODE128
4860 CLEAR PRINT·PRINT TAB(20), "***READING DATA FILES***"
4870 DIM V(1025)
4880 PRINT.INPUT "Name of data file to be loaded is",NAME$
4890 *DISC
4900 *DRIVE 1
4910 Y=OPENIN(NAME$)
4920 CNT=1
4930 REPEAT
4940 INPUT#Y,V(I%)
4950 CNT=CNT+1
4960 UNTIL EOF#(Y)
4970 CLOSE#Y
4980 PRINT TAB(5),"INT",TAB(15);"CH"
4990 FOR I% = 1 TO CNT STEP 5
5000 PRINT V(I%), I%;V(I%+1); I%+1,V(I%+2), I%+2; V(I%+3),
    I%+3,V(I%+4),I%+4;V(I%+5);I%+5
5010 NEXT I%
5020 INPUT"Do you wish a print out of the data",REP$
5030 IF REP$<>"Y" AND REP$<>"N" THEN PRINT "ERROR":GOTO
    5020
5040 IF REP$="N" THEN GOTO 5060
5050 L%=1:O%=3:CHAIN" 0 DUMP"
5060 PRINT.PRINT.PRINT"Do you wish to load more data?"
5070 PRINT.INPUT"Yes(Y) or No(N)",A$
5080 IF A$<>"Y" AND A$<>"N" THEN PRINT "ERROR,Please
    choose again!":GOTO 5070
5090 IF A$="Y" THEN GOTO 4840
5100 *DRIVE 0
5110 CHAIN ":0.MENU"
5120 IF ERR=222 PRINT·PRINT TAB(20);"****File does not
    exist****" ·GOTO4860 ELSE PRINT ERR REPORT.END
5130 END

```

```

6599 REM Program Name = "DUMP"
6600 P%=&A00
6610 MDE=0           :REM Graphics mode
6620 NCOL=80        :REM no. of columns of text
6630 NLIN=32        REM no  of lines of text
6640 OSWRCH=&FFEE   :REM Operating system routine for
                    writing character
6650 OSRDSC=&FFB9   :REM Operating system routine for
                    reading byte from screen
6660 OSBYTE=&FFF4   :REM Operating system routine
6670 GAP%=P%        :REM P% is the program counter
6680 FORI=0TO2STEP2
6690 P%=GAP%
6700 OB=P%          :REM The 8 bytes from the screen
                    memory will be stored at
6710                :REM OB and the rotated resultant 8
                    bytes will be
6720 IM=P%+8        :REM at IM
6730 MEM=&70         :REM Address of sreen memory to be
                    printed next.
6740 COL=P%+16      .REM Column number currently being
                    printed.
6750 LIN=P%+17      REM Line number currently being
                    printed
6760 REG=P%+18
6770 P%=P%+19
6780 [OPTI
6790 DUMP LDX #MDE   \ OSBYTE with &85 in the
                    accumulator returns the
6800     LDA #&85    \ bottom of the display memory and
                    this is stored at
6810     JSR OSBYTE  \ MEM
6820     STX MEM
6830     STY MEM+1
6840     LDA #NLIN   \ Store the number of lines in LIN
                    and the number of
6850     STA LIN     \ columns in COL
6860     LDA #2      \ The commands LDA n ,JSR OSWRCH
                    are equivalent to
6870     JSR OSWRCH  \ VDU n in BASIC so this command
                    turns on printer
6880     LDA #27
6890     JSR PRNT    \ The PRNT subroutine sends the
                    character to the
6900     LDA #65     \ printer only and these commands
                    set the printer
6910     JSR PRNT    \ line spacing.
6920     LDA #8
6930     JSR PRNT
6940     LDA #10
6950     JSR PRNT
6960     LDA #10
6970     JSR PRNT
6980 .NXTL LDA #NCOL \ Start printing 1 line. Reset COL
                    to the no of
6990     STA COL     \ columns
7000     LDA #27    \ The next control codes sent to
                    the printer tell the

```

```

7010      JSR PRNT      \ printer to accept 1 line  of bit
                          image data
7020      LDA #76
7030      JSR PRNT
7040      LDA #(NCOL*8 MOD &100)
7050      JSR PRNT
7060      LDA #(NCOL*8 DIV &100)
7070      JSR PRNT
7080.NXTC LDY #0
7090      LDX #0
7100.LP1  TXA          \ The next section transfers 8
                          bytes from the screen
7110      PHA          \ to OB. The OSRDSC call reads a
                          byte from screen memory
7120      LDY #0      \ with the value returned in A
7130      LDA MEM
7140      STA &F6
7150      LDA MEM+1
7160      STA &F7
7170      JSR OSRDSC
7180      STA REG
7190      PLA          \ Restore the X register which
                          was saved on the stack
7200      TAX          \ before the OSRDSC call.
7210      LDA REG
7220      STA OB,X
7230      INC MEM      \ Increment MEM and X by 1 and
                          branch to the start of
7240      BNE M1       \ the loop if X has not reached 8.
7250      INC MEM+1
7260.M1   INX
7270      CPX#8
7280      BMI LP1
7290      JSR PLT
7300      LDX #8      \ Send the 8 bytes stored in IM to
                          the print routine.
7310.LP2  LDA IM-1,X
7320      JSR PRNT
7330      DEX
7340      BNE LP2
7350      DEC COL      \ Decrement COL and return to the
                          start of the loop
7360      BNE NXTC     \ if not zero. If it is zero send a
                          CR LF  sequence
7370      LDA #13      \ to the printer.
7380      JSR PRNT
7390      DEC LIN      \ Decrement LIN and if not zero
                          return to print another line.
7400      BNE NXTL     \ If the end has been reached reset
                          the printer line spacing,turn off
7410      LDA #27      \ the printer and exit from the
7420      JSR PRNT     \ routine
7430      LDA #50
7440      JSR PRNT
7450      LDA #3
7460      JSR OSWRCH
7470      RTS
7480.PRNT PHA          \ This subroutine sends the

```

```

character in the A
7490      LDA #1      \ to the printer only
7500      JSR OSWRCH
7510      PLA
7520      JSR OSWRCH
7530      RTS
7540.PLT  LDA #0      \ This routine translates the 8
                          bytes from memory to a format
7550      TAY          \ suitable for sending to the
                          printer as bit
7560.L1   LDA #0      \ image graphics.
7570      TAX          \ the first byte in IM is made up
                          from all the bit zeroes of the
7580 L2   ROR OB,X     \ bytes in OB and similarly for the
7590      ROL A        \ other 7 bytes.
7600      INX
7610      CPX #8
7620      BMI L2
7630      STA IM,Y
7640      INY
7650      CPY #8
7660      BMI L1
7670      RTS
7680]
7690NEXTI
7700D%=DUMP
7710 CALL DUMP
7720 PRINT TAB(0,0);"
7730 INPUT TAB(0,0);"Do you wish to define parameters
                          (Y/ N)";T$
7740 IF T$<>"Y"AND T$<>"N" THEN GOTO 7730
7750 IF T$="Y" THEN CHAIN":0 PARAM"
7760CLS
7770*FX21,0
7780IFO%=1 THEN CHAIN ":0.MONITOR"
7790IFO%=2 THEN CHAIN ":0.PLOT"
7800IFO%=3 THEN CHAIN ":0.DATLOAD"
7810IFO%=4 THEN CHAIN ":0.GETDAT"
7820 END

```

```

5200 REM Program Name. "CAT"
5210 MODE3
5220 CLS·PRINT·PRINT·INPUT "Do you wish to see the PROGRAM
      directory (input P) or DATA directory (input D)",W$
5230 IF W$<>"P" AND W$<>"D" THEN PRINT "ERROR,choose again"
      :GOTO 5220
5240 IF W$="P" THEN GOTO 5330
5250 PRINT:PRINT:INPUT"Do you wish to see drive 1 or drive
      0";Z
5260 IF Z<>1 AND Z<>3 THEN PRINT"ERROR, choose again"·GOTO
      5250
5270 IF Z=1 THEN GOTO 5300
5280 *CAT3
5290 GOTO 5350
5300 *DISC
5310 *CAT1
5320 GOTO 5350
5330 *DISC
5340 *CAT 0
5350 PRINT·PRINT:INPUT " Do you wish to see another
      directory (input Y or N)";R$
5360 IF R$<>"Y" AND R$<>"N" THEN PRINT "ERROR,choose again"
      :GOTO 5350
5370 IF R$="Y" THEN GOTO 5200
5380 IF R%=0 THEN CHAIN" 0 MENU1" ELSE CHAIN":0 PLOT"
5390 END

```

```

5 REM Program Name. "FILCON"
10 CLS
20 MODE0
30 DIM PIX(1024)
40 ON ERROR GOTO 170
50 INPUT TAB(4,2) "INPUT FILENAME";IN$
60 INPUT TAB(4,4) "OUTPUT FILENAME";OUT$
70*DRIVE1
80 X=OPENIN IN$
90 Y=OPENOUT OUT$
100 FOR I=1 TO 1024
110 INPUT #X,PIX(I)
120 PIXEL$=STR$(PIX(I))+CHR$(13)+CHR$(10)
130 PRINT #Y,PIXEL$
140 NEXT I
150 CLOSE #X
160 CLOSE #Y
170 IF ERR=17 THEN PRINT:PRINT·INPUT"Do you wish to end
(input E) or return to main menu (input M)";D$ ELSE
PRINTERL:PRINT ERR.REPORT END
180 IFD$<>"E" AND D$<>"M" THEN PRINT"ERROR, Choose again"
GOTO 170
190 IF D$="E" THEN 240
200 IF D$="M" THEN CLEAR
210 *DISC
220 *DRIVE0
230 CHAIN":0.MENU1"
240 END

```

```

5 REM Program Name "FILADSB"
10 CLEAR
20 *DISK
30 *DRIVE0
40 MODE 6
50 REM FILE MANIPULATION ROUTINE 'FILADSB'
60 REM DIMENSION ARRAYS
70 DIM Y1(1024),Y2(1024),YRES(1024)
90 INPUT"ENTER INPUT FILENAMES:";FIL1$,FIL2$
100 PRINT.PRINT:PRINT
110 INPUT"ENTER OUTPUT FILENAME:";OFIL$
120 PRINT:PRINT:PRINT
140 N=2*N
150 PRINT:PRINT.PRINT
160 INPUT"ENTER 'A' (ADD) OR 'S' (SUBTRACT) FILES:";ACT$
170 PRINT:PRINT.PRINT
180 REM OPEN FILES ON DRIVE1
190 *DRIVE1
200 R=OPENIN FIL1$
210 S=OPENIN FIL2$
220 T=OPENOUT OFIL$
230 FOR I=1 TO 1024
240 INPUT#R,Y1(I)
250 INPUT#S,Y2(I)
260 NEXT I
270 IF ACT$="S" THEN 320
280 FOR J=1 TO 1024
290 YRES(J)=(Y1(J)+Y2(J))
300 NEXT J
310 GOTO 350
320 FOR J=1 TO 1024
330 YRES(J)=(Y1(J)-Y2(J))
340 NEXT J
350 FOR K=1 TO 1024
360 PRINT#T,YRES(K)
370 NEXT K
380 CLOSE#R
390 CLOSE#S
400 CLOSE#T
410 INPUT"REPEAT. ";Q$
420 IF Q$="Y" THEN 90
430 *DRIVE0
440 CHAIN "MENU1"
450 END

```

```

5 REM Program Name: "FILDIV"
10 CLEAR
20 *DISK
30 *DRIVE0
40 MODE 6
50 REM FILE MANIPULATION ROUTINE 'FILDIV'
60 REM DIMENSION ARRAYS
70 DIM Y1(1024),YRES(1024)
80 REM OBTAIN I/O FILENAMES AND DIVISOR
  (USUALLY NO OF SAMPLES)
82 INPUT "Do you wish to 1  add/subtract files
                    2  smooth a file
                    3. divide a file ";ANS$
84 IF ANS$="1" THEN CLEAR CHAIN":0 FILADSB"
86 IF ANS$="2" THEN CLEAR:CHAIN":0 FILSMO"
90 INPUT"ENTER INPUT FILENAME.";FIL1$
100 PRINT PRINT:PRINT
110 INPUT"ENTER OUTPUT FILENAME ",OFIL$
120 PRINT·PRINT:PRINT
130 INPUT"ENTER DIVISOR (NO OF SPECTRA/FILE).";N
140 PRINT PRINT:PRINT
150 PRINT.PRINT:PRINT
160 REM OPEN FILES ON DRIVE1
170 *DRIVE1
180 R=OPENIN FIL1$
190 FOR I=1 TO 1024
200 INPUT#R,Y1(I)
210 NEXT I
220 INPUT "CHANGE DISK AND ENTER 'GO'";G$
230 IF G$<> "GO" THEN 220
240 T=OPENOUT OFIL$
250 FOR I=1 TO 1024
260 FOR J=1 TO 1024
270 YRES(J)=(Y1(J))/N
280 NEXT J
290 FOR K=1 TO 1024
300 PRINT#T,YRES(K)
310 NEXT K
320 CLOSE#R
330 CLOSE#T
340 INPUT"REPEAT:";Q$
350 IF Q$="Y" THEN 90
360 *DRIVE0
370 CHAIN "MENU1"
380 END

```



```

430 IF V(I%)>Vmax THEN Vmax=V(I%)
440 IF V(I%)<Vmin THEN Vmin=V(I%)
450 NEXT I%
460 CLS PRINT:PRINT TAB(21),"*****SCALING ROUTINE*****"
461 PRINT:PRINT:PRINT TAB(15),"Vmax = ",Vmax
462 PRINT:INPUT TAB(26);"Do you wish to preset Vmax";REP$
470 IF REP$<>"Y"AND REP$<>"N" THEN PRINT "ERROR,choose
again.":GOTO460
480 IF REP$="N"GOTO510
490 PRINT:INPUT "Vmax=";V$
492 FOR I = 1 TO LEN(V$)
494 IF MID$(V$,I,1)<"0" OR MID$(V$,I,1)>"9" THEN PRINT
"ERROR,choose again":GOTO490
496 NEXT I
500 Vmax=VAL(V$)
510 PRINT:PRINT:PRINT TAB(15);"Vmin = ",Vmin
512 PRINT:INPUT TAB(26),"Do you wish to preset Vmin",ANS$
520 IF ANS$<>"Y"AND ANS$<>"N" THEN PRINT "ERROR,choose
again.":GOTO510
530 IF ANS$="N"GOTO570
540 PRINT:INPUT "Vmin=";K$
542 REM:FOR I = 1 TO LEN(K$)
544 REM:IF MID$(K$,I,1)<"0" OR MID$(K$,I,1)>"9" THEN
PRINT"ERROR,choose again":GOTO540
546 REM:NEXT I
550 Vmin=VAL(K$)
560 CLOSE# X
570 PRINT:INPUT TAB(26),"Select continuous graph(C) or
points(P)";B$
580 IFB$<>"C" AND B$<>"P" THEN PRINT "ERROR,choose
again ":GOTO570
590 IF B$="P" THEN H=1 ELSE H=0
600 CLS
640 CLS:PROCaxes
650 PROCgraph
660 PRINTVmax·PRINTVmin
670 PRINT:INPUT "Do you wish to plot another graph
(YorN)";D$
680 IFD$<>"Y" AND D$<>"N" THEN PRINT "ERROR,choose
again.":GOTO 670
690 IF D$="Y" CLEAR.CLOSE#0·GOTO10
700 *DISC
740 CHAIN ".MENU1"
750 END
760 DEF PROCaxes
770 *IEEE
780 cmd%=OPENIN("COMMAND")
790 data%=OPENIN("DATA")
800 ESTR$=CHR$(13)+CHR$(10)
810 PRINT#cmd%,"END OF STRING",ESTR$
820 PRINT#cmd%,"BBC DEVICE NO",0
830 PRINT#cmd%,"CLEAR"
840 PRINT#cmd%,"REMOTE ENABLE"
850 PRINT#cmd%,"UNLISTEN"
860 printer%=OPENIN("10")
870 PRINT#cmd%,"LISTEN",printer%,"EXECUTE"
1130 ENDPROC
1140 DEF PROCgraph

```

```
1150 IFS=1GOTO1160
1160 Smin=S
1170 PRINT#data%, "M200,200"
1180 SCALEX=2200/(F-S) SCALEY=1500/(Vmax-Vmin)
1190 FOR I%=S TO F
1200 C%=(S-Smin)*SCALEX+200:D%=(V(I%)-Vmin)*SCALEY+200
1210 PRINT V(I%),I%
1220 IFH=0THEN PRINT#data%, "D"+STR$(C%)+", "+STR$(D%) ELSE
      PRINT#data%, "M"+STR$(C%)+", "+STR$(D%)+ "N1"
1230 S=S+1.NEXT I%
1240 PRINT#data%, "H"
1250 ENDPROC
1260 IF ERR=222 THEN PRINT TAB(21), "***File does not
      exist*****":CLS:GOTO70 ELSE PRINT ERR:REPORT:END
```

```

7210 REM Program Name "PARAM"
7220 MODE3
7230 PRINT.PRINT TAB(20),"****PARAMETER INPUT ROUTINE****"
7240 PRINT.PRINT:INPUT "Exposure time = ";E$
7250 PRINT.PRINT:INPUT "Detector temperature = ",D$
7260 PRINT:PRINT:INPUT "No. of scans ";S$
7270 PRINT.PRINT:INPUT "Slit width = ";W$
7280 PRINT.PRINT:INPUT "Sample = ";F$
7290 VDU2:VDU1,15
7300 PRINT CHR$(2):PRINT"Exposure time = "E$;"      Detector
      temperature = ";D$
7310 PRINT CHR$(2):PRINT"No. of scans ";S$;"      Slit
      width = ";W$
7320 PRINT CHR$(2):PRINT"Sample = ";F$
7330 VDU2.VDU1,14
7340 PRINT.PRINT"          -----*-----"
7350 PRINT"          ----*----"
7360 PRINT"          -*-"
7370 PRINT CHR$(3)
7380 *DISC
7390 IF X%=4 THEN CHAIN ":0 GETDAT"·IF X%=2 THEN CHAIN
      ":0.PLOT":IF X%=3 THEN CHAIN ":0 MONITOR"
7400 IF X%=2 THEN CHAIN " 0.PLOT" ELSE GOTO 7410
7410 IF X%=3 THEN CHAIN ":0 MONITOR"

```

```

7900 REM Program Name. "DATADSB"
7910 MODE3
7920 *IEEE
7930 PRINT.PRINT TAB(20),"*****MEMORY MANIPULATION*****"
7940 cmd%=OPENIN("COMMAND")
7950 data%=OPENIN("DATA")
7960 PRINT#cmd%,"BBC DEVICE NO",0
7970 PRINT#cmd%,"CLEAR"
7980 PRINT#cmd%,"REMOTE ENABLE"
7990 PRINT#cmd%,"END OF STRING",CHR$(13)+CHR$(10)
8000 PRINT#cmd%,"UNLISTEN"
8010 oma%=OPENIN("11")
8020 CLS:PRINT.INPUT "Do you wish to add [input '1'] or
subtract [input '2'] two memories";H$
8030 IF H$<>"1" AND H$<>"2" THEN PRINT "ERROR, Please
choose again!":GOTO 8020
8040 IF H$="1" THEN PROCadd
8050 IF H$="2" THEN PROCsub
8060 PRINT.PRINT "Do you wish to manipulate memories
further?"
8070 PRINT:INPUT "Yes(Y) or No(N)",Q$
8080 IF Q$<>"Y" AND Q$<>"N" THEN PRINT "ERROR, Please
choose again!":GOTO 8070
8090 IF Q$="Y" THEN GOTO 8020
8100 *DISC
8110 CHAIN ":0.MENU1"
8120
8130
8140 DEF PROClisten
8150 PRINT#cmd%,"LISTEN",oma%,"EXECUTE"
8160 PRINT#data%,CMDV$
8170 PRINT#cmd%,"UNLISTEN"
8180 ENDPROC
8190
8200
8210 DEF PROCtalk
8220 PRINT#cmd%,"TALK",oma%
8230 INPUT#data%,PAR$
8240 PRINT#cmd%,"UNTALK"
8250 ENDPROC
8260
8270
8280 DEF PROCsub
8290 PRINT:PRINT "Input to MEMORY A the memory you want to
subtract "
8300 PRINT:INPUT "MEMORY A=",A$
8310 FOR I=1 TO LEN(A$)
8320 IF MID$(A$,I,1)>"9" OR MID$(A$,I,1)<"0" THEN PRINT
"ERROR, Please choose again!".GOTO 8300
8330 NEXT I
8340 PRINT:PRINT "Input to MEMORY B the memory from which
you want to subtract."
8350 PRINT:INPUT "MEMORY B=",B$
8360 FOR I=1 TO LEN(B$)
8370 IF MID$(B$,I,1)>"9" OR MID$(B$,I,1)<"0" THEN PRINT
"ERROR, Please choose again!".GOTO 8350
8380 PRINT "NOTE: The result will be stored in memory ";B$
8390 NEXT I

```

```

5 REM Program Name "FILSMO"
10 MODE 6
20 REM MULTIPOINT SMOOTHNG ROUTINE
30 DIM YIN(1024),YOUT(1024)
40 INPUT"ENTER I/O FILES·";FILIN$,FILOUT$
50 INPUT "ORDER OF SMOOTH·",N
60 *DRIVE1
70 X=OPENIN FILIN$
80 FOR I=1 TO 1024
90 INPUT#X,YIN(I)
100 NEXT I
110 L=1
120 J=N+L
130 YOUT(J)=0.0
140 FOR K=(J-N) TO (J+N)
150 YOUT(J)=YOUT(J)+YIN(K)
160 NEXT K
170 YOUT(J)=YOUT(J)/(2*N+1)
180 L=L+1
190 IF L<(1024-2*N) THEN 120
200 Y=OPENOUT FILOUT$
210 FOR M=(N+1) TO (1024-N)
220 PRINT#Y,YOUT(M)
230 NEXT M
240 CLOSE#X
250 CLOSE#Y
260 *DRIVE0
270 CHAIN"MENU1"

```

```

12000 REM Program Name· "STEPPER"
12001 REM TAR AND STIP ARE THE FRACTION OF A REVOLUTION
12010 REM OF ABSORBING AND EMITTING TARGETS RESPECTIVELY
12020 REM eg for 200 shots on each target use tar=stip=0 05
12030 MODE128
12040 ON ERROR GOTO 12430
12050 CLEAR
12060 CLS
12070 PRINT "      At any stage you can return to the main
                menu by pressing ESCAPE"
12080 PRINT : PRINT : PRINT
12090 INPUT TAB(4,2) "ENTER NO OF LASER SHOTS/ TARGET
                POSITION.",NL
12100 IF NL=0 THEN NL=10
12110 INPUT TAB(4,4) "NO OF TARGET FACE CHANGES",M
12120 IF M=0 THEN M=10
12130 INPUT TAB(4,6) "EMITTER TARGET STEP SIZE  ",TAR
12140 IF TAR=0 0 THEN TAR=0.01
12150 INPUT TAB(4,8) "SPECTROMETER STEP SIZE  ",STIP
12160 IF STIP=0 0 THEN STIP=0 01
12170 PRINT · PRINT : PRINT PRINT
12180 PRINT : PRINT
12190 HOP = STIP *2000
12200 TAR = TAR *240
12210 FOR G = 1 TO M
12220 FOR K = 1 TO NL
12230 PROCSTEP(1,50,144,145)
12240 PROCSTEP(TAR,100,144,176)
12250 NEXT K
12260 PROCSTEP(HOP,10,144,148)
12270 PRINT "NUMBER OF LASER SHOTS = ",10*G
12280 NEXT G
12290 PRINT : PRINT . PRINT : PRINT
12300 PRINT "DATA AQUISATION OVER"
12310 END
12320 DEF PROCSTEP(N,L,R,M)
12330 A=&FE60
12340 A?2=&FF
12350 FOR KK=1 TO 2000 NEXT KK
12360 FOR C = 1 TO N
12370 ?A=R
12380 FOR I=1 TO L. NEXT I
12390 ?A=M
12400 FOR J=1 TO L: NEXT J
12410 NEXT C
12420 ENDPROC
12430 CLS
12440 *DISK
12450 INPUT TAB(4,2)"Do you wish to return to Main
                Menu(M),run another experiment(R) or end (E)",Q$
12460 IF Q$="R" THEN 12040
12470 IF Q$="E" THEN 12490
12480 CLEAR:CHAIN":0.MENU1"
12490 END

```

```

5 REM Program Name· "DSCOPE"
10 DIM S(128)
20 DIM R(128)
30 FOR K%=0 TO 128
40 R(K%)=0.0
50 S(K%)=0 0
60 NEXT K%
65 INPUT "ENTER FILES· (CHA &CHB)", CHA$,CHB$
70 M%=1
80 *IEEE
90 STA=1
100 FIN=127
110 cmd%=OPENIN("COMMAND")
120 data%=OPENIN("DATA")
130 scope%=OPENIN("8")
140 PRINT#cmd%,"BBC DEVICE NO",0
150 PRINT#cmd%,"CLEAR"
160 PRINT#cmd%,"REMOTE ENABLE"
170 DEL$=CHR$(10)
180 PRINT#cmd%,"END OF STRING",DEL$
190 c$="REG 1,VER B,FCN ON,VER A,FCN ON,BGN 0,END 255,CNT
    1,DAT ALL,DAT ?"
200 PRINT#cmd%,"LISTEN",scope%,"EXECUTE"
210 PRINT#data%,c$+DEL$
220 PRINT#cmd%,"UNLISTEN"
230 PRINT#cmd%,"TALK",scope%
240 INPUT#data%,A$
250 PRINT A$
260 FOR I%=STA TO FIN
270 INPUT#data%,CA$,CB$
280 R(I%)=R(I%)+VAL(CA$)
290 S(I%)=S(I%)+VAL(CB$)
300 PRINT R(I%),S(I%),I%
310 NEXT I%
320 PRINT#cmd%,"UNTALK"
330 PRINT#cmd%,"REMOTE DISABLE"
340 CLOSE#scope%
350 CLOSE#data%
360 CLOSE#cmd%
370 *DISC
380 X=OPENOUT CHA$
390 Y=OPENOUT CHB$
400 FOR L%=1 TO 127
410 PRINT#X,R(L%)
420 PRINT#Y,S(L%)
430 NEXT L%
440 CLOSE#X
450 CLOSE#Y
460 M%=M%+1
470 IF M%<11 THEN 80
480 W=OPENIN CHA$
490 Z=OPENIN CHB$
500 FOR N%=1 TO 127
510 INPUT#W,R(N%)
520 INPUT#Z,S(N%)
530 R(N%)=R(N%)/10 0
540 S(N%)=S(N%)/10.0
545 PRINT N%,R(N%),S(N%)

```

```
550 NEXT N%
560 CLOSE#W
570 CLOSE#Z
580 X=OPENOUT CHA$
590 Y=OPENOUT CHB$
600 FOR L%=1 TO 127
610 PRINT#X,R(L%)
620 PRINT#Y,S(L%)
630 NEXT L%
640 CLOSE#X
650 CLOSE#Y
660 END
```



```

5 REM Program Name: "DSCOPE1"
10 MODE0
20 REM Dimension arrays
40 DIM R(256)
60 DIM R$(256)
70 REM Initialize arrays
80 FOR K%=0 TO 255
90 R(K%)=0.0
110 R$(K%)=""
130 NEXT K%
140 INPUT "ENTER FILE: (CHA)"; CHA$
150 REM Fire laser!
160 ?&FE60=&00
170 FOR IJ%=1 TO 200: NEXT IJ%
180 ?&FE60=&FF
190 FOR IJ%=1 TO 200: NEXT IJ%
200 REM Enter IEEE mode
210 *IEEE
220 STA=1
230 FIN=255
240 cmd%=OPENIN("COMMAND")
250 data%=OPENIN("DATA")
260 scope%=OPENIN("8")
270 PRINT#cmd%,"BBC DEVICE NO",0
280 PRINT#cmd%,"CLEAR"
290 PRINT#cmd%,"REMOTE ENABLE"
300 DEL$=CHR$(10)
310 PRINT#cmd%,"END OF STRING",DEL$
320 REM Get display data stored in register 0
330 c$="REG 0,VER A,FCN ON,BGN 0,END 255,CNT 1,DAT A,DAT ?"
340 PRINT#cmd%,"LISTEN",scope%,"EXECUTE"
350 PRINT#data%,c$+DEL$
360 PRINT#cmd%,"UNLISTEN"
370 PRINT#cmd%,"TALK",scope%
380 INPUT#data%,A$
390 PRINT A$
400 FOR I%=STA TO FIN
410 INPUT#data%,CA$
420 R(I%)=R(I%)+VAL(CA$)
440 PRINT I%,R(I%)
450 NEXT I%
460 PRINT#cmd%,"UNTALK"
470 PRINT#cmd%,"REMOTE DISABLE"
480 CLOSE#scope%
490 CLOSE#data%
500 CLOSE#cmd%
510 *DISC
520 REM Store data on disc
530 X=OPENOUT CHA$
550 FOR L%=1 TO 255
560 R(L%)=INT(R(L%))
580 PRINT#X,R(L%)
600 PRINT L%,R(L%)
610 NEXT L%
620 CLOSE#X
640 END

```

APPENDIX II

Specifications of the Model 4145-2 Digital Programmable Time Delay Module.

Type of Control:	Digital
Nom. Fixed Delay, t_o :	450ns.
Variable Delay, t_d :	0 - 999.99 μ s.
Min. Delay Increment.	10ns.
Max. Jitter + Drift, t_o :	< \pm 1ns.
Max. Jitter + Drift, t_d :	< \pm 2ns.
Trigger Input:	TTL type. Positive or negative true (1)
Program Input:	TTL type. Negative true. Binary Coded Decimal (8-4-2-1). 5 decades
Outputs:	TTL type. Positive or negative true. (1)
Adj. Pulse Width:	20 - 100ns.
Max. Supply @+15V .	100mA.
Current, @-15V.	50mA.
@+5V..	660mA.
Operating Temp. Range:	10°C - 40°C.

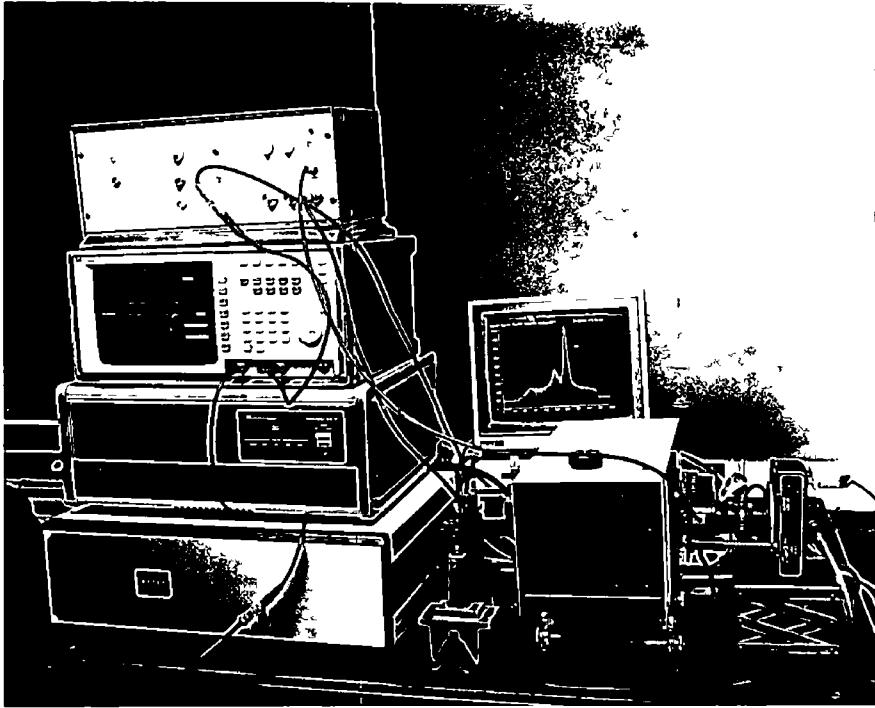
(1): Polarity set by on board jumpers.

Specifications of the ITT Microchannel Plate
Image Intensifier.

Size of useful Photocathode:	18mm
Coupling:	Fibre optic input and output.
Focusing:	Proximity
Resolution (Static):	25 lp/mm.
Dynamic Resolution:	10 lp/mm.
Dynamic Gain:	2000 at 500nm.
Gating:	5ns to 100ns
Trigger Input:	+5 volts.
Trigger Delay:	12ns.
Modes of Operation:	Gated and D C
Extinction Ratio in gating.	100,000.
Other:	

The device can be used as a stand alone camera and is designed to operate with CCD or Reticon diode arrays with fibre-optic coupling

Photograph of the Experimental Set-up for
Testing the Intensified PDA.



The photograph shows the delay generator (bottom left) on which are the 1462XD crate, the Hewlett Packard 54502A oscilloscope and MCP control unit while the intensified PDA and Jarrell Ash polychromator are shown in the bottom right hand side

APPENDIX III

Unrelated Work

In this section work carried out by the author with the laser-plasma groups at DCU and UCD not directly related to the present project is detailed

1) Strontium Spectrum.

The extreme-UV spectrum of a Sr plasma was recorded using a ruby laser and a 2 metre grazing incidence spectrograph at DCU. The spectrum was subsequently analysed by O'Sullivan and Maher (UCD) and resulted in a publication (O'Sullivan and Maher, 1989)

11) Ru, Rh and Pd Spectra.

Spectra of Ru, Rh and Pd plasmas in the 20 → 50nm spectral range were recorded for G. O'Sullivan and M Kane (UCD). The spectra were used by M Kane in his M Sc thesis (Kane, 1988).

111) Ru and Rh Calculations.

Calculations were carried out on 4s → 4p transition arrays in highly ionised Ru and Rh which were used in the analysis of spectra recorded by Padraig Dunne (UCD). The work has resulted in a conference abstract and refereed publication (Dunne et al, 1990 a, b)

References.

- Dunne P, Carroll P K, Corcoran R E, Costello J T and O'Sullivan G, 1st ATMOP conference, QUB, Belfast 2-5 April 1990, pW32 (1990a)
- Dunne P, Carroll P K, Corcoran R E, Costello J T and O'Sullivan G, J.Phys B. At Mol Opt Phys. 23, L239-L245 (1990b)
- Kane M, M Sc thesis (1988)
- O'Sullivan G and Maher M, J Phys B At.Mol.Opt Phys 22, 377-387 (1989).