McPHERSON™

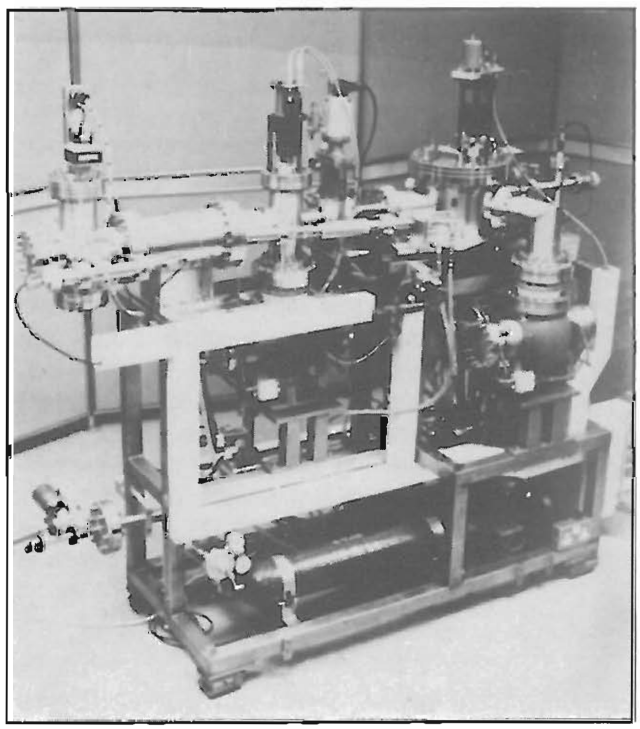
PDA/MCP DETECTORS

MULTICHANNEL SPECTRUM ANALYZERS
PDA/MCP DETECTORS AND COMPATIBLE SPECTROMETERS AND ACCESSORIES

Index

Introduction

Events producing short lived Spectra require fast interpretation. Multichannel Spectral Analyzers as McPherson Spectrometers with PDA's or PDA/MCP's give investigators the tool to research spectra of varied complexity. LONG AND SHORT FOCAL LENGTH SPECTROMETERS FOR THE XUV-VUV-UV-VIS-NIR CAN BE EQUIPPED WITH PHOTODIODE ARRAY AND MICROCHANNEL TYPE DETECTORS. Measurement of Spectra with lifetimes in the nanosecond range are possible. McPherson adapts proven methods and detector systems to its spectrometers. A line of accessories provides the means to convert many standard McPherson Monochromators and Polychromators for use with PDA/MCP DETECTORS. McPherson's PDA/MCP combinations in use on UHV (ULTRA HIGH VACUUM) Spectrometers (as shown above) and the unique utilization of accessories to adapt OMA's of other manufacturers are only two examples of the utility of McPherson's products in Multichannel spectral analysis.



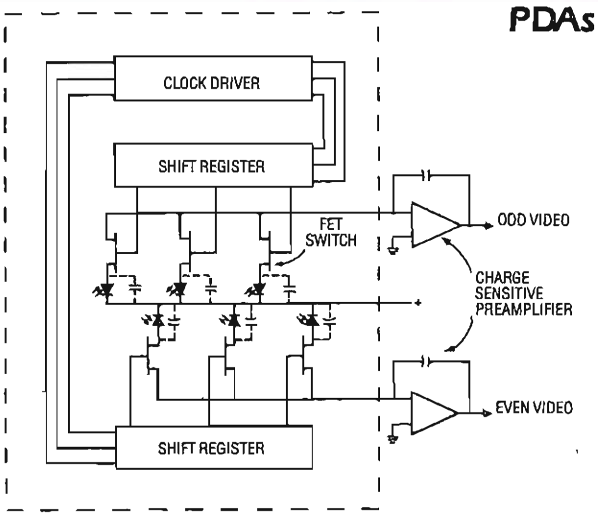
McPherson Model 251 UHV/MCP/PDA Flat Field Spectrometer with peripherals of Culham Laboratories as installed at JET (Joint European Torus).

GLOSSARY of other names for some photodiode array devices compatible with McPherson Spectrometers:
OMA: a trademark of Princeton Applied Research
DARSS: a trademark of Tracor-Northern
OSMA: a trademark of Princeton Instruments
RETICON: a trademark of EG&G

I. The Use of Arrays in Spectroscopy

Many spectroscopists have found the use of Photodiode Arrays (PDAs) and Microchannel Plates (MCPs) in the simultaneous detection of light of different wavelengths to be a valuable tool. PDA's mainly serve the non-vacuum range of the spectrum, while MCPs serve in the vacuum and high vacuum ranges. MCPs, while expensive, can be employed in certain custom designs enabling the use of the high gain these devices provide. The VUV (Vacuum Ultraviolet) and XUV (Extreme Ultraviolet) are well suited to the employment of MCPs in conjunction with PDAs. The spectral range which can be simultaneously viewed is dependent on the size of the PDA or MCP and the spectral dispersion at the focal plane of the spectrometer in which it is mounted. The following discussions will introduce the reader to the use of common and special array detectors in conjunction with McPherson monochromators.

PDAs and MCPs



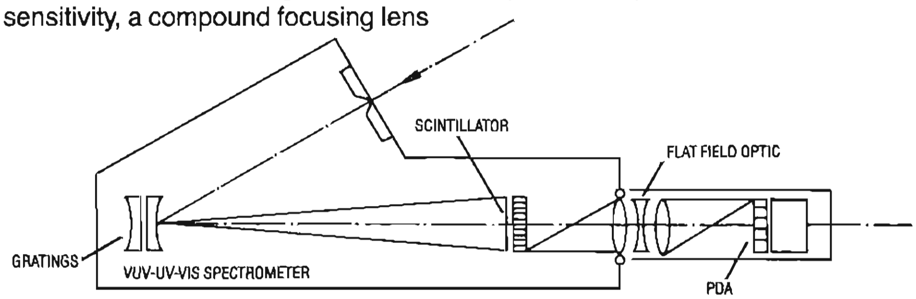
Simplified PDA Block Diagram
of a Reticon Array Circuit
Note: Reticon is a registered trademark of EG&G Reticon Corp.

Photodiode Arrays

Photodiode Arrays act as parallel detectors providing spectral information across the focal plane in which they are placed. These arrays are offered as computer controlled detectors by several manufacturers. A typical array has 1024 diodes, or pixels, 25 μm. wide in the dispersive direction by 2.5 mm. in the vertical direction, although other arrangements are also available. Each pixel has an associated storage capacitor which is sequentially read and the data are stored by the computer for further evaluation. Typically PDAs have a spectral response in the UV-visible portion of the spectrum with special versions being offered at an added expense. Image intensified PDA's are also offered by several manufacturers to provide better signal to noise characteristics at low light levels.

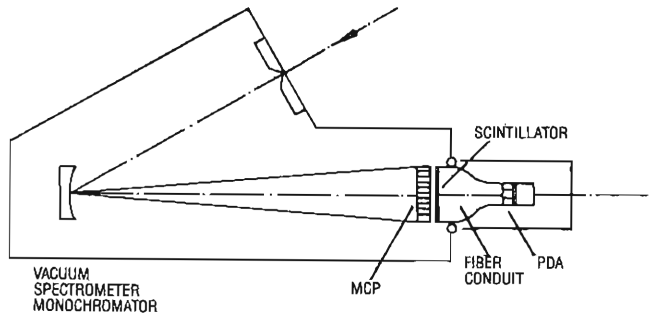
Scintillator PDAs

While several manufacturers offer a UV enhanced PDA at an increased expense, McPherson offers a less expensive scintillator for use with VUV monochromators. If PDA's are operated in a higher vacuum, outgassing of heatsink cements connecting PDA's to Peltier cooling elements may cause problems. To maintain PDA's in a suitable environment and assure that vacuum monochromators function within the intended spectral range, the operating environments of PDA's and monochromators have to be separated. Sufficient energy levels should be at investigators disposal when considering such a detection system. The scintillator consists of a fiber optic plate which is coated by a phosphor to convert the UV light to visible light favoring PDA sensitivity, a compound focusing lens system, and the PDA. A vacuum seal is formed around the lens system. While this system is a less expensive alternative, the resolution is somewhat degraded. In the visible portion of the spectrum, the phosphor acts as a translucent plate rather than a scintillator thus reducing the intensity of the visible light and causing a slight broadening of spectral lines. In the UV, where the phosphor becomes a true scintillator, the isotropic nature of the emission causes a further broadening. The sensitivity of the Scintillator PDA is effected by the efficiency of the phosphor used. This approach is practical where resolution loss is not a problem and in the 10^{-6} torr or better vacuum region where MCP operation is possible but economically impractical.



MCPs

Microchannel plates may be used in the VUV at an increased expense utilizing the higher gain of these devices. The array consists of several channels which have a secondary emitting semiconductor coated along the inside. These secondary electrons produce an avalanche of charge which accounts for the high gain of the MCPs. MCPs can respond to electron, ions, photons, UV Photons, soft X-rays, and metastable particles. McPherson offers a MCP/PDA detector for multichannel detection in our grazing incidence and other VUV spectrometers. The detector system consists of a MCP with 8 μm. channels spaced 15 μm. apart at an 8° channel bias angle across a 40 mm. diameter. A fine grain phosphor is used to convert the electrons produced by the MCP into visible light which can be detected by the PDA. The phosphor coats the front surface of a fiber optic reducer which maps the 40 mm. diameter MCP output onto the 25.4 mm. 1024 pixel PDA.

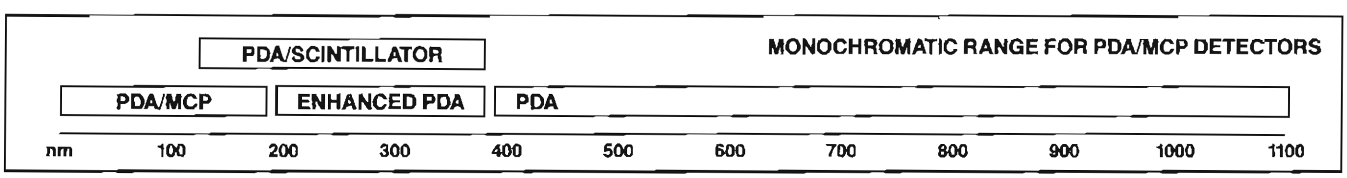


Streak Camera, Etc.

Various other multichannel detection systems may be mounted in a similar manner to McPherson spectrometers. An example of such a device is a Streak Camera, which may be mounted in the focal plane to simultaneously detect spectral and temporal characteristics. Vidicon type detectors and charge transfer devices, such as CCDs & CIDs, are also compatible with numerous McPherson Monochromators.

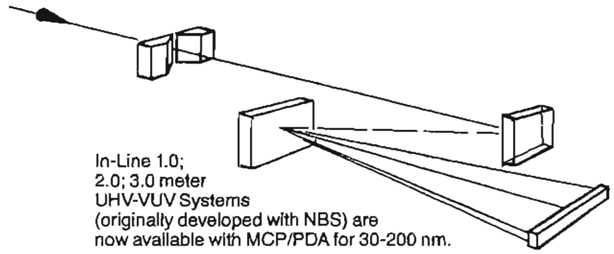
II. The Adaption of a PDA or MCP to the Focal Plane of the Monochromator

PDA's (Photodiode arrays) with cover plates have a sensitivity range determined by the semiconducting material and transmissivity of glass, quartz or other materials used. Since refractive index of cover plates can influence resolution, fused fiber plates are employed in some instances. Sensitivity enhanced PDA's carry scintillators on the front face of the fiber plate or diodes. Investigators intending to use PDA's have to pay attention to the sensitivity characteristics, especially where the lower UV and vacuum UV range is concerned. MCP/PDA combinations are necessary in the VUV (Vacuum Ultraviolet) and in cases where low energy levels require detection.



II. A. Choosing a Monochromator

McPherson Monochromators Suitable for:
'A' Arrays
'B' Scintillator/PDA
'C' MCP/Array



Model	Focal Length (meters)	f/no.	Optical System	Detector Type	Dispersion[h] mm./pixel) 1200 C/mm Grating	Wavelength[g] Range with Grating Changes
2061B[a]	1.0	8.7, 7.0	Czerny-Turner	A, B	0.021	185 nm.-78 µm.
207	0.67	5.8, 4.7	Czerny-Turner	A, B	0.031	185 nm.-78 µm.
209	1.33	11.6, 9.4	Czerny-Turner	A, B	0.015	185 nm.-78 µm.
216[k]	1.0	8.7	Corrected Loci	A, B	0.021	185 nm.-4 µm.
2162[k]	2.0	17.4	Corrected Loci	A, B	0.010	185 nm.-4 µm.
2163[k]	3.0	26.1	Corrected Loci	A, B	0.0069	185 nm.-4 µm.
217	1.0	8.7	Corrected Loci[g]	B, C	0.021	105 nm.-4 µm.
2172	2.0	17.4	Corrected Loci	B, C	0.010	105 nm.-4 µm.
2173	3.0	26.1	Corrected Loci	B, C	0.0069	105 nm.-4 µm.
218	0.35[d]	6.9[d]	Crossed Czerny-Turner	A, B, C	0.075[d]	105 nm.-60 µm.
219	0.5	8.7	Corrected Loci	A, B, C	0.041	105 nm.-60 µm.
225	1.0	10.4	McPherson 15°	B, C	0.021	<30 nm.-1.2 µm.
2252	2.0	31.9	McPherson 15°	B, C	0.010	<30 nm.-600 nm.
2253	3.0	26.9	McPherson 15°	B, C	0.0069	<30 nm.-600 nm.
231	1.0	22.9	Seya Namioka	B, C	0.021	<30 nm.-1.2 µm.
234[b]	0.2	4.5	64° concave grating	B, C	0.083	<30 nm.-2.2 µm.
235	0.5	11.4	Seya Namioka	B, C	0.041	<30 nm.-1.2 µm.
247	2.2	42.6[f]	Grazing Incidence	C	0.00057-0.0037	<1 nm.-250 nm.
248	1.0	49.9[f]	Grazing Incidence	C	0.0012-0.0067	<1 nm.-180 nm.
249	3.0	60[f]	Grazing Incidence	C	0.00042-0.0022	<1 nm.-240 nm.
251	0.9	14[f]	Toroidal Flat Field Grazing Incidence	C	0.086-0.1[i]	10 nm.-170 nm.
252	1.5	50[f]	Grazing Incidence	C	0.00082-0.0045	<1 nm.-180 nm.
262	10.6	71.1[f]	Grazing Incidence	C	0.00012-0.00062	3 nm.-72.5 nm.
265	6.6	44.5	Eagle	A, B, C	0.0031	<30 nm.-2.4 µm.
270[c]	0.35[e]	6.4[e]	Czerny-Turner[g]	A, B	0.050	185 nm.-8 µm.
270D	0.35[e]	6.4[e]	Double Czerny-Turner	A, B	0.025	185 nm.-8 µm.
285	0.5	7.6	Double Czerny-Turner	A, B	0.021	185 nm.-78 µm.

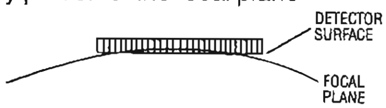
[a]Model 2051 may also be adapted with a photodiode array
[b]Only Model 234 purchased with MCP/PDA provisions are acceptable
[c]McPherson/Heath EU-700 may also be adapted with a photodiode array
[d]An extended focal plane is required to achieve this
[e]Existing instruments require an extended focal plane (focal length .4m., f/no. 7.3)
[f]Horizontal aperture ratio
[g]Corrected Optics on 217M1 & 217M2
[h]Resolution may be degraded by the array response
[i]450 G/mm grating
[j]Wavelength range is also determined by the array
[k]Models purchased prior to 1985 require factory modification

NOTE: McPherson also offers Scintillator equipped PMT's for single channel VUV use.

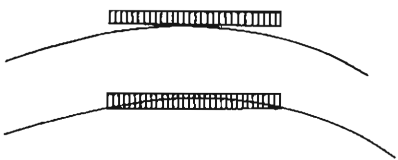
* See descriptive section and listing of available accessories.

II.B. Adaptation of the Array to the Focal Plane

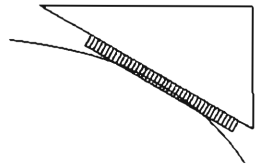
While corrected flat field gratings do exist, as in the McPherson Model 251 0.3 m. Toroidal Flat Field Grazing Incidence Spectrometer, most spectrometers produce a focal plane which is curved. When a flat PDA or MCP is placed in this focal plane, this curvature then becomes a concern. The error produced by placing a flat detector in a curved focal plane, commonly known as the sagitta, will be dependent on both the focal length and the active length of the PDA or MCP. The MCP or PDA may optimally be placed so that two wavelengths are in focus along the array, therefore minimizing the degradation in the resolution along any portion of the focal plane.



As can be seen in the drawings of the worst cases, the resolution may be degraded at the ends or the middle of the focal plane.

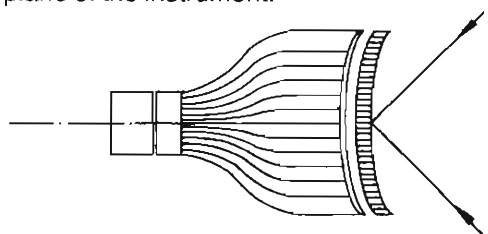


This problem becomes less severe as the focal length of the spectrometer increases. This resolution degradation also will depend on the inherent PDA/MCP resolution. In most cases the resolution of the PDA or MCP is not sufficient to show any degradation in the resolution of a spectral line due to placing a flat array in a curved focal plane.



Wedge adapters are provided for the Czerny-Turner and Corrected Loci spectrometers to optimize alignment of the PDA in the focal plane. Conversion of Monochromators to Polychromators via PDA or MCP requires attention since the normal of the exit slit plane may only be traversed by "in focus" spectra in one point. Spectral range to either side of the original slit position may be in or out of focus and subsequently mounted PDA's or MCP's will require the correct tilt to receive focused energy over their active length and pixels.

In grazing incidence spectrometers, it is possible at an increased expense to place a curved MCP along the focal plane of the instrument.

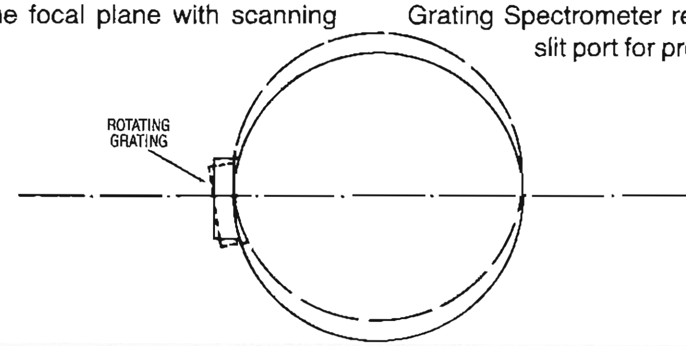


The channels of the MCP must be maintained at a constant length preserving a constant gain across the length of the MCP. This requires the curvature on the front face of the fiber optic reducer with a phosphor to match the back curvature of the MCP. In this manner, the MCP may be placed at the focal plane of the spectrometer, providing focused spectra across the entire pixel region.

II.C. Rotation of the Focal Plane with Scanning

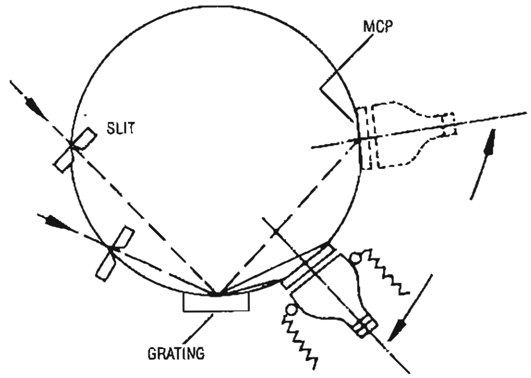
In Czerny-Turner Corrected Loci, and Ebert optical systems, where scanning is accomplished by rotating a plane grating, the focusing optics remain stationary providing a fixed focal plane. However, when concave gratings are employed and scanning is accomplished by rotation of the grating as in Seya Namioka, McPherson 15°, and Type IV Corrected Holographic Grating Optical Systems, a rotation of the focal plane with scanning occurs.

As can be seen in the drawing, as the grating is rotated, the Rowland circle on which the focal plane is located is redefined. Due to this rotation of the Rowland circle, a rotation in the focal plane occurs. McPherson provides a bellows on which the PDA or MCP is mounted, allowing either to be tilted to adjust for this rotation. The Model 234 .2 m. Type IV Corrected Holographic Grating Spectrometer requires modification of the exit slit port for proper attachment of the bellows.

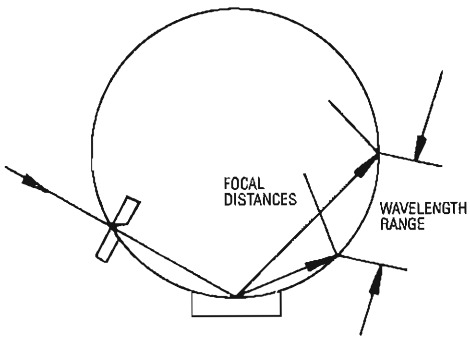


II.C. Rotation of the Focal Plane with Scanning (cont.)

McPherson's line of Grazing Incidence Spectrometers is designed to allow correct placement of the MCP in the focal plane of the instrument. A bellows attachment is provided to allow the MCP to be correctly aligned along the focal plane of the instrument. With the exception of the Model 251 0.3 m. flat field Toroidal grating Spectrometer, McPherson's Grazing Incidence spectrometers scan by moving the exit assembly along the Rowland circle. In this way, once the initial alignment of the MCP along the focal plane of the instrument is made, movement of the MCP assembly along the Rowland circle, to center the desired wavelength range is easily accomplished. The Entrance slit position is also selectable to change the grazing angle.



II.D. Dispersion



1. Grazing Incidence

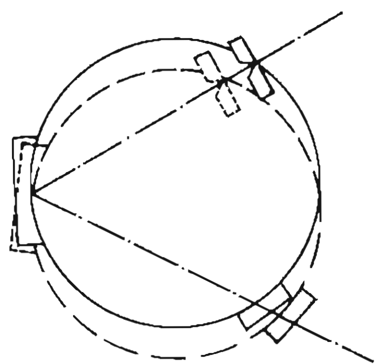
It should be noted that in grazing incidence optical designs and to a lesser extent in other optical designs employing concave gratings, the focal distance varies along the wavelength range. Due to this change, the dispersion varies across the focal plane at which the MCP sits. This effect is more severe in grazing incidence spectrometers due to the greater rate of change of the focal radius within the detector's field of view.

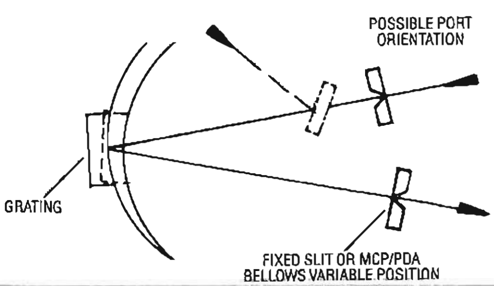
II.E. Focal Properties

1. Seya Namioka

Various optical systems have different means for correcting the focal properties of the monochromators. An example of this problem are the Seya Namioka and the Type IV Corrected Holographic Grating Optical Design, where the Rowland circle is redefined with scanning and the focal point and angle of the focal plane changes.

McPherson offers a bellows attachment which allows for correction in the rotation of the plane and the focal point.





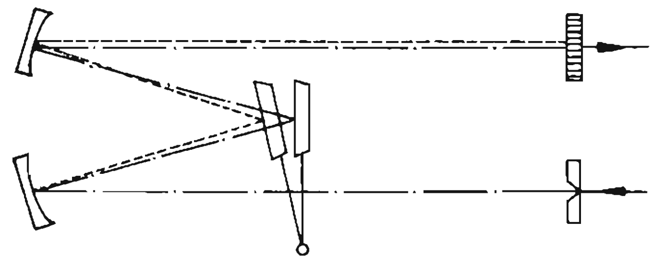
2. McPherson's 15°

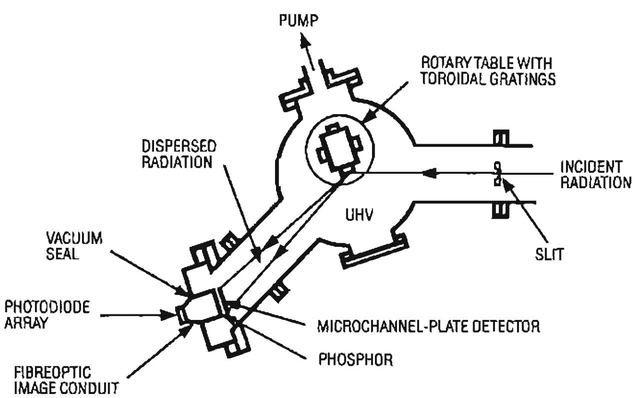
Optical Design corrects for the focal point problem. In this system, as the grating is rotated, it is translated forward toward the slits to provide mechanical aberration correction in the focusing properties. Rotation of the focal plane still occurs with scanning, so that a bellows attachment is also needed for alignment of the detector at the focal plane.

II.E. Focal Properties (cont.)

3. Corrected Optics and Corrected Loci

While the Czerny-Turner Optical Design has a fixed, non-rotating focal plane, two means exist for correcting its focal properties. One means is the use of Corrected Optics to provide aberration correction across the entire wavelength range. The second means is the Corrected Loci Optical Design which is a patented mechanical correction for coma across the entire wavelength range.





Elements of a Grazing-Incidence Flat-Field Diagnostic

4. Flat Field

The Model 251 spectrometer has been designed to map a broad spectrum along a flat focal plane without the need for mechanically repositioning the MCP. This UHV Diagnostic Spectrometer features double or quadruple grating turrets remotely operable to cover a wide VUV/XUV range. A Model 251D (double) allows two wavelengths to be viewed simultaneously.

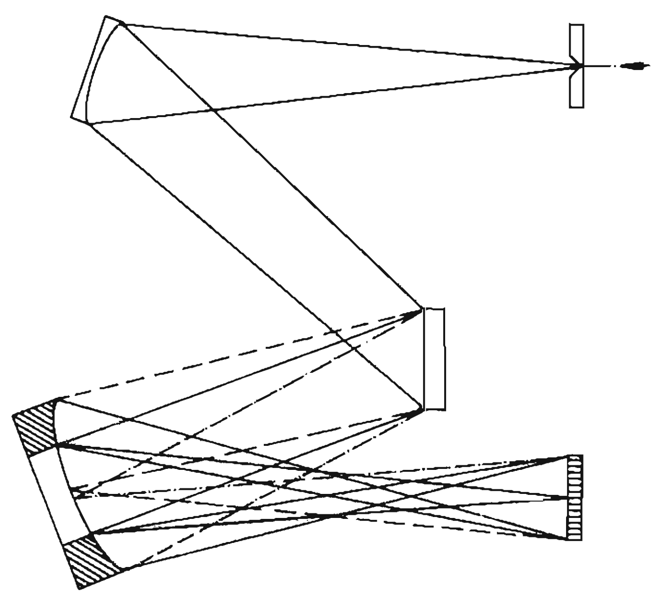
II.F. Notes Worth Consideration

Adapting a PDA or MCP to a Monochromator in Czerny-Turner Optical Designs.

Many Monochromators feature optics which illuminate their exit slits only. When a PDA is placed at the focal plane, edge energy losses may occur as shown in the diagram, to alleviate this edge effect a larger mirror is recommended, when converting a monochromator into a spectrograph.

McPherson Monochromators are ideally suited for PDA conversion. Their original designs consider adaptation of photographic plate and film use. Larger exit mirrors are common in all models that are suitable to hold spectrographic or polychromator type accessories.

The Monochromator shown features optics to intercept all dispersed energy available for pixel illumination across the PDA or MCP. The shaded areas represent the energy lost when the exit focusing mirror is of insufficient size.

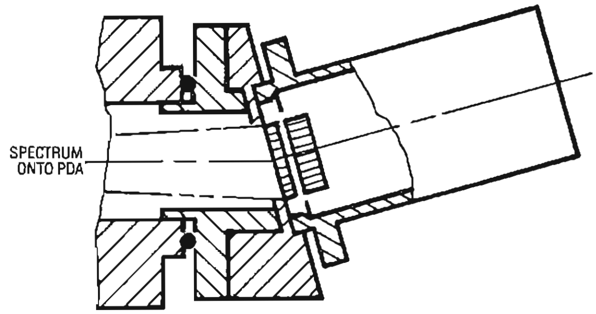


II.G. Hardware to Convert Monochromators

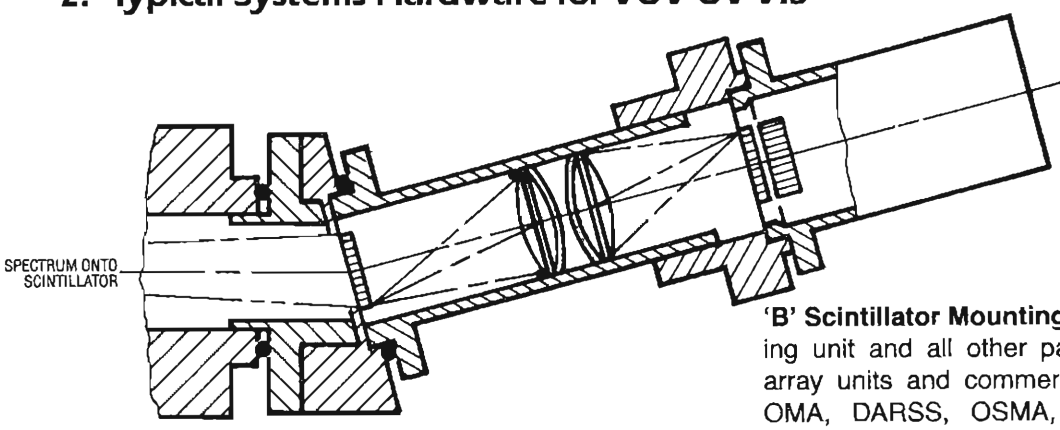
McPherson Monochromators suitable for conversion permit removal of exit slit and attachment of 'A' Array; 'B' Scintillator and 'C' MCP/Array combinations of the following configurations:

1. Typical Systems Hardware for UV-VIS-NIR

'A': Array Mounting Kit consists of all parts to attach preassembled array units via a focal plane wedge and flange assembly. It is typically configured as follows and can be supplied to fit the listed comercially available detector array assemblies to the listed McPherson Monochromators.



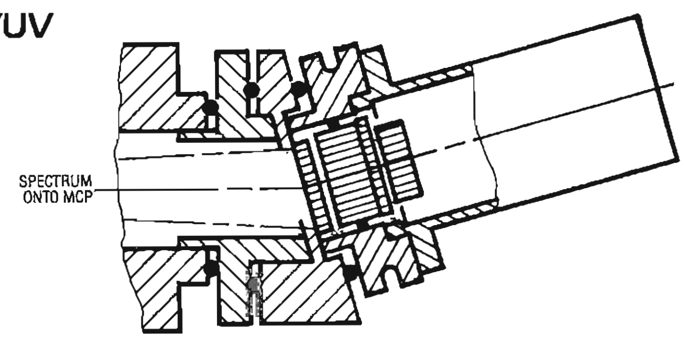
2. Typical Systems Hardware for VUV-UV-VIS



'B' Scintillator Mounting Kit contains optical refocusing unit and all other parts to attach preassembled array units and commercially available detectors as OMA, DARSS, OSMA, etc. to listed McPherson Monochromators.

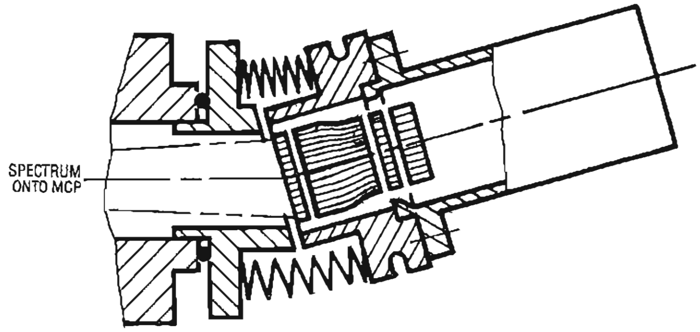
3. Typical Systems Hardware for UHV-VUV

'C_1' MCP/PDA Mounting Kit The commercial OMA, etc. is in this case contacted to the exit face of the fiber transfer element. Check listing as to adaptation to McPherson Monochromators.



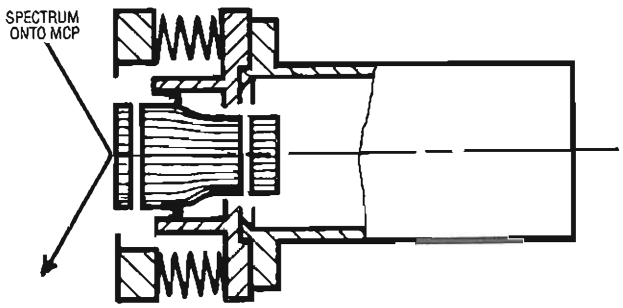
3. Typical Systems Hardware for UHV-VUV

'C_2' Same MCP/PDA as version 'C_1' but features reducer fiber taper to intercept greater spectral range for same array (typically 1024 pixels).



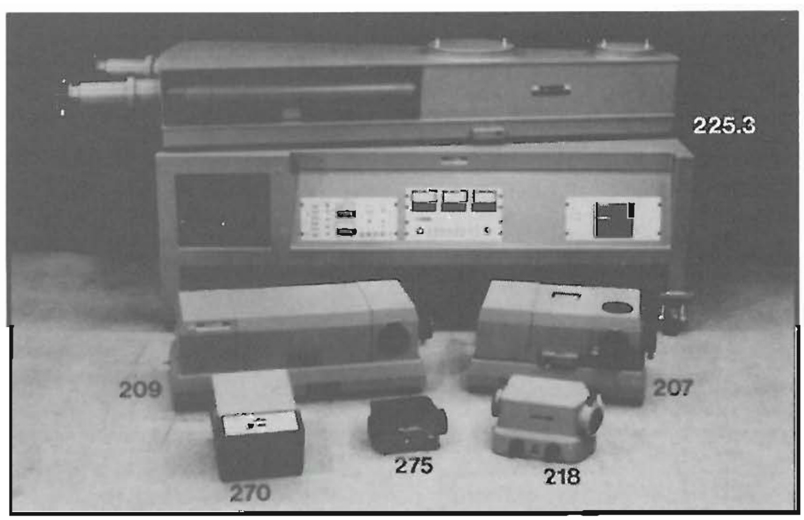
3. Typical Systems Hardware for UHV-VUV

'C_3' Same MCP/PDA version as 'C_2' but with MCP protruding to reach into space of focused grazing incidence rays.

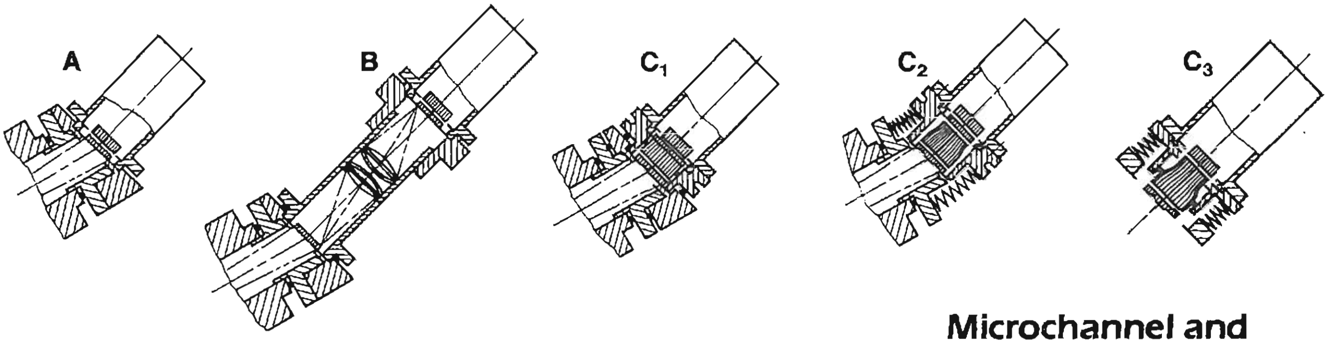


PDA/MCP Adaptable Monochromators

Shown
Model 225.3 - 3.00 meter
209 - 1.33 meter
207 - .66 meter
270 - .35 meter
275 - .2 meter
218 - .3 meter



MCP/PDA Conversion Kits for Monochromators



Monochromator Spectrometer Model	Focal Length (meters)	A	B	C_1	C_2	C_3
2061B[a]	1.0	X	X			
207	0.67	X	X			
209	1.33	X	X			
216[k]	1.0	X	X			
2162[k]	2.0	X	X			
2163[k]	3.0	X	X			
217	1.0		X	X		
2172	2.0		X	X		
2173	3.0		X	X		
218	0.35[d]	X	X	X		
219	0.5	X	X	X		
225	1.0			X	X	
2252	2.0			X	X	
2253	3.0			X	X	
231	1.0			X	X	
234[b]	0.2			X	X	
235	0.5			X	X	
247	2.2					X
248	1.0					X
249	3.0					X
251	0.9					X
252	1.5					X
262	10.6					X
265	6.6	X	X	X		
270[c]	0.35[e]	X	X			
270D	0.35[e]	X	X			
285	0.5	X	X			

Conversion kits are used to convert new or previously supplied Monochromators. Factory installation is recommended.

Microchannel and Diode Array Adaptation Code

A	**For UV-VIS-NIR**
B	**For Near VUV-UV**
C_1	**For Direct Image Near and Far VUV <30 nm and Up**
C_2	**For Reduced Image Near and Far VUV <30 nm and Up**
C_3	**For Grazing XUV, VUV <1 nm and Up**

Diode Array and MCP Assemblies of the following firms are employed in conjunction with listed conversion kits.

MCP's
Microchannel Plates made by Galilelo.

PAR/OMA
Diode Array systems made by Princeton Applied Research, an EG&G Company.

DARSS or SNAP-SHOT
Diode Array systems fitting some McPherson Camera Mounts for Monochromators made by Tracor-Northern.

OSMA
Diode Array custom fitted by Princeton Instruments.

RETICON
Arrays (an EG&G CO.) and ITT arrays as well as Hamamatsu arrays are used by manufacturers of custom systems adapted to McPherson Spectrometers.