Spectrometers for Imaging Applications

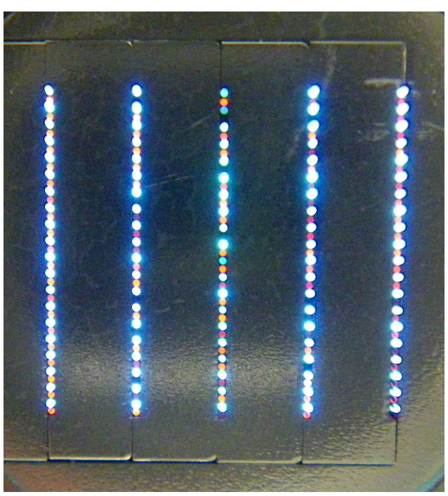
Dispersive spectrometers image spectra; that is their function. Imaging the spectrum is required to resolve discrete wavelengths. The spectrum is a one-dimensional dataset originating from one discrete point in a source. While we presumably always want a spectrum from a spectrometer, we may also want more. We might want to collect spectra for several sources simultaneously, for example. Alternatively, several regions in one source might be of interest. These days, an instrument capable of imaging both spectral and spatial features of source is called an imaging spectrometer.

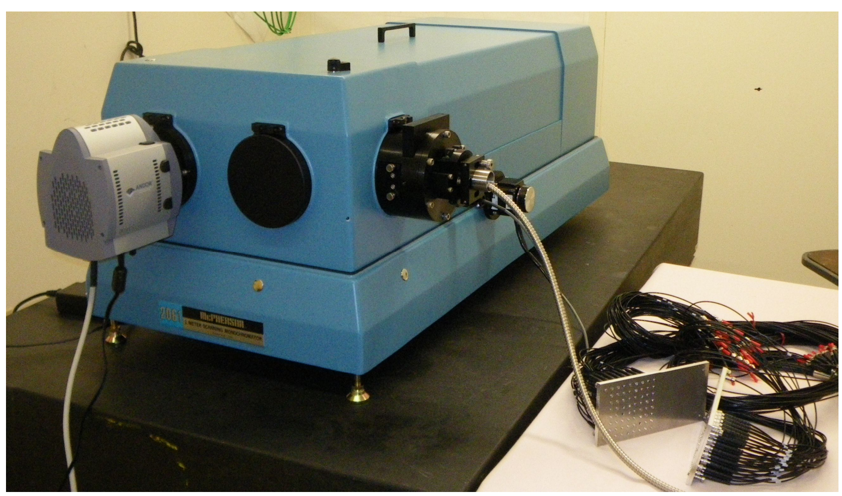
While almost all spectrometers do a good job of imaging spectra, they may not always be spatially discriminating. With some adjustment to the optics, spatial sensitivity can improve. It is likely that light through put and possible that spectral resolution will be compromised. Still, it is often efficient to multiplex spectrometers capabilities. In addition, when the spectrometer provides a 1:1 image, flux per pixel is improved. This is helpful in spectroscopy applications like Raman, luminescence or LIBS. It is also helpful when spectral investigation of spatially distinct sources or events is required. This might the changing spectra across a candles flame or a thermonuclear fusion experiment.

Development and use of novel optics in McPherson instruments improves imaging and suits two-dimensional CCD, CMOS and intensified detectors. No optical system is perfect, and the best choice of optics depends totally on the needs of the experiment. Balancing cost, complexity, surface quality, imaging performance, and spectral resolution, requires serious consideration before making an investment in a research-grade spectrometer.

Imaging Spectrometer Application

The pictured one meter McPherson spectrometer can simultaneously monitor spectra from 100 input fibers on one commercial 1024*1024 pixel, ~13mm square CCD. Sub Angstrom spectral resolution is attained in all channels. The spectrometer accepts various diffraction gratings that may be optimized for spectral resolution or for wavelength range coverage. With sensitive, cooled CMOS or CCD detectors, the accessible 50mm focal plane is ideally suited for simultaneously intercepting and analyzing multiple spectra from spatially distinct regions.





Types of Mirrors used in Spectrometers

Concave spherical mirrors for collimation and focusing are in the majority of spectrometers. McPherson instruments use masterpiece pitch-polished spherical optics. They feature at least 1/8 wave surfaces (measured at 632.8), 40/20 scratch dig specifications and 1 nm RMS roughness. These mirrors provide high throughput, low scatter in the UV and excellent image formation in the dispersion plane. They also produce the best system resolution and line shape. When an application requires imaging, we add a masterpiece cylindrical mirror to the optical path.

Parabolic mirrors are ideal for on axis imaging. Off-axis and in both the dispersion and spatial plane, it is common to see a factor 10 or more reduction in performance. Toroidal mirrors will typically provide the least astigmatism across the exit plane but will not provide optimum resolution or spatial information - spherical aberration and coma remain unchanged. Parabolic and toroidal mirrors can both be obtained commercially and tend to be expensive.

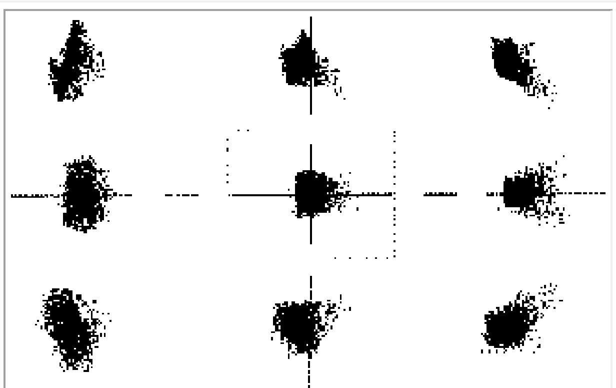
Instrument exit images, on the left optimized for Resolution, on the right corrected for Imaging

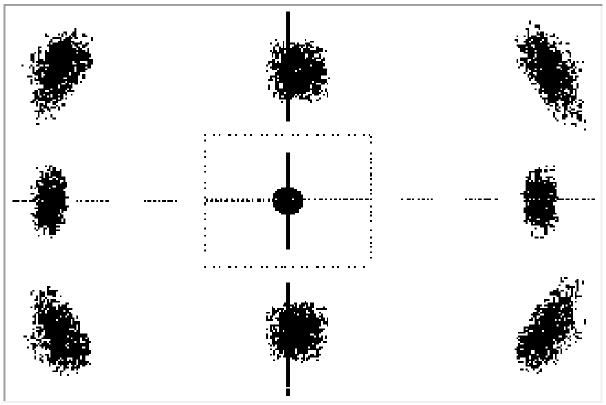
These spot diagrams graphically depict the difference between spectral-resolution and imaging optimization. Ray traced at 600 nm with 2400 G/mm grating in 0.67-meter focal length, f/4.7 system with 100um input image.

Selecting the Optics

The following ray trace diagrams provide examples of 20mm x 26mm field performance. Nine spot diagrams are shown for each mirror type, on-axis and an array at ± 10 mm spatially, ± 13 mm on the dispersion axis. All the individual spots are not to scale, shown at 20X, and based on an input spot size of 100 um.

Spherical mirrors with corrective cylinder
The images are somewhat irregular because the optics are designed to balance best resolution with minimum astigmatism. This method keeps the instrument flexible and useful for imaging or scanning applications and provides best value optical performance.
Average image size 130 x 130 um (FWHM), based on an input image of 100 x 100 um (Model 2061)



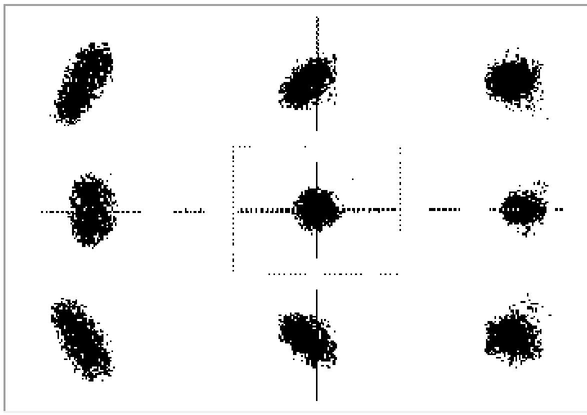


Parabolic mirrors
Superior on-axis images but these one meter focal length parabolic mirrors show significant image degradation off axis (in spectral and spatial directions). Possibly the ideal monochromator mirrors for small slit height, not a good choice for imaging a larger field.

Average image size 153 x 153 um (FWHM), based on an input image of 100 x 100 um (Model 2061)

Toroidal mirrors
Toroidal spectrometer mirrors can provide fairly good image formation and have excellent correction for astigmatism. The do tend to exaggerate spectral resolution losses. They are prohibitively expensive to obtain at qualities equivalent to spheres. Lower cost mirrors, e.g. diamond turned or replicated may not be available in quality suitable for UV-VIS spectroscopy.

Average image size 139 x 139 um (FWHM) , based on an input image of 100 x 100 um (Model 2061)



Some UV-VIS-IR Imaging Systems

Several McPherson Models are suitable for use in imaging applications. All feature 2 input, and 2 output ports for experimental versatility. All use master spherical optics combined with master cylindrical mirror(s), with excellent surface finishes, for imaging. Some feature multiple grating turrets and all operate with any and all existing McPherson accessories.

Model	Focal Length	f/number	Resolution*
2035	350 mm	4.8	0.05-nm
207	670-mm	4.7	0.03-nm
2061	1 meter	7	0.017-nm

*with 1200 G/mm grating and 10 um x 4 mm entrance slit