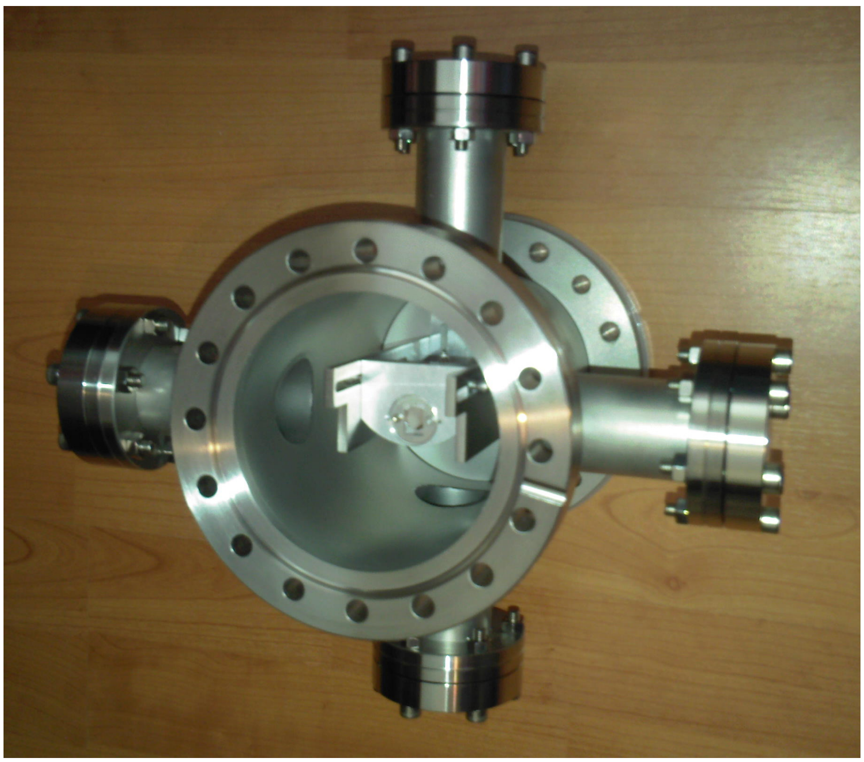
Transmission grating spectrometer

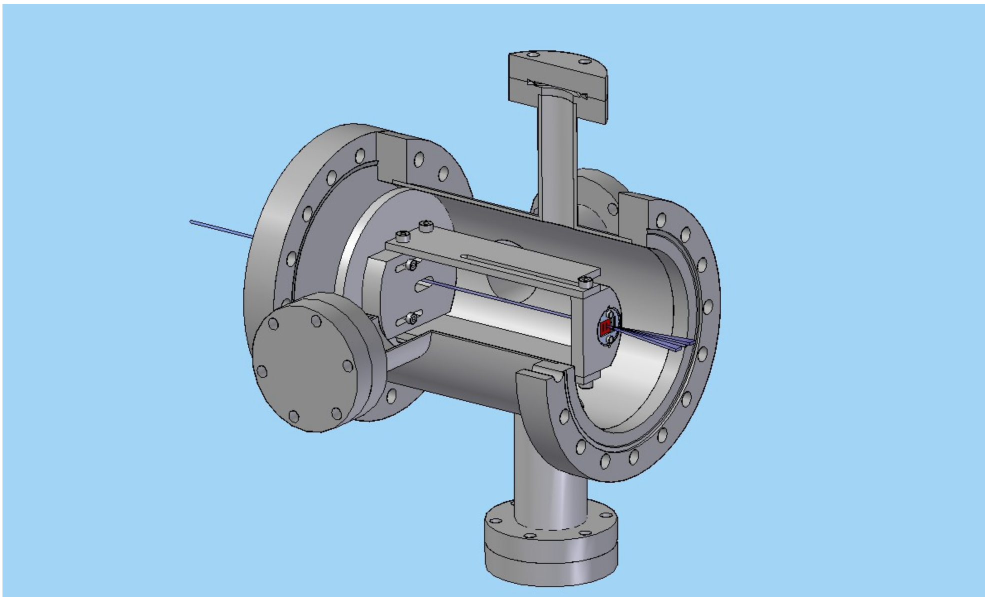


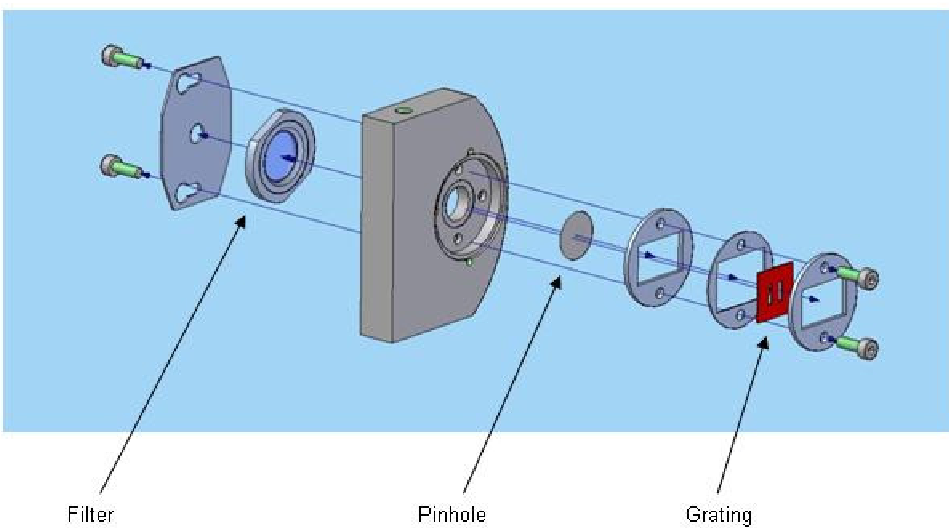
Contents

1. Hardware

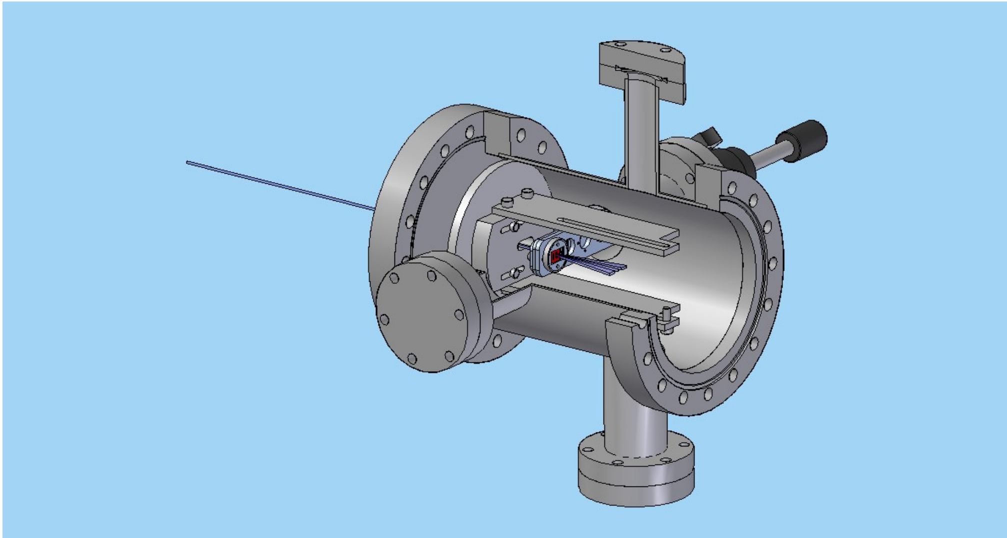
The spectrometer can be assembled in a couple of ways.

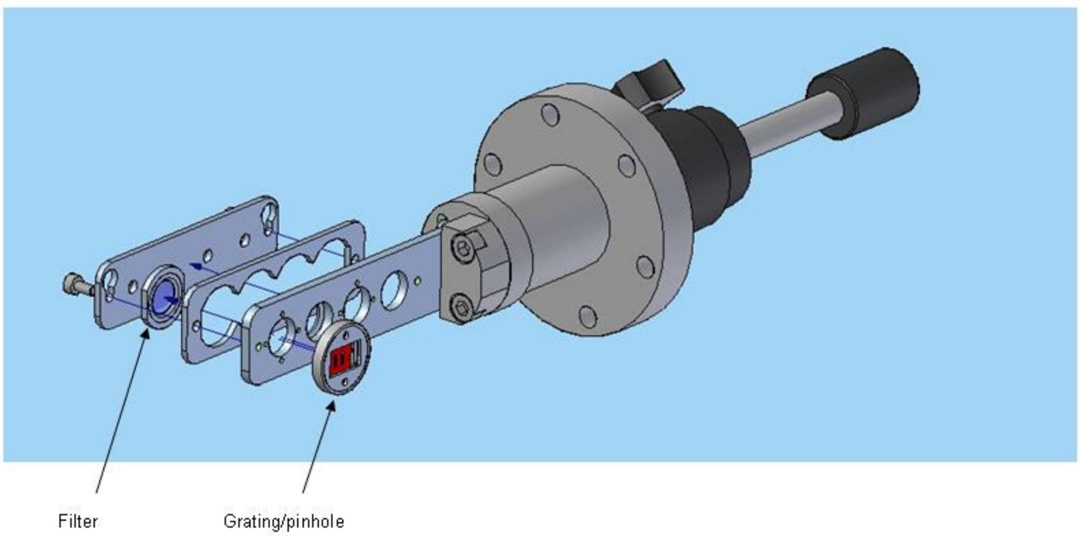
Semi fixed setup. The grating is placed at a position during assembly and cannot be adjusted under vacuum conditions. A filter slide can be added at one of the free CF40 ports.

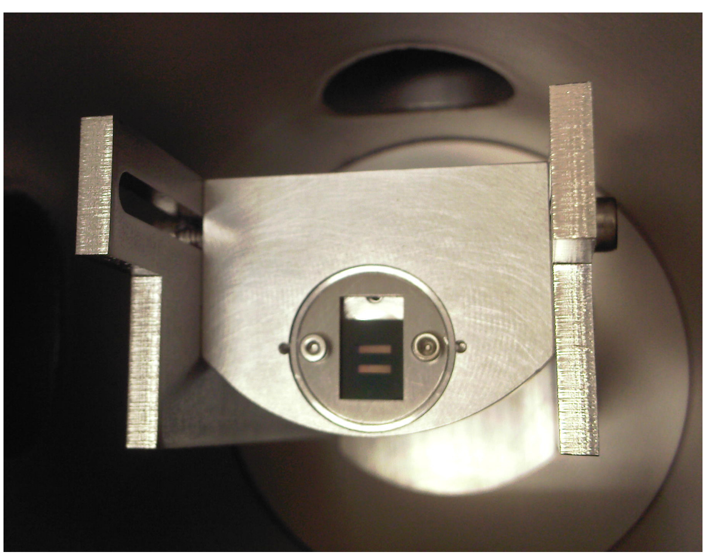




Adjustable setup. The grating is mounted on a slide and can be shifted sideways with the linear motion feedthrough. Filters can be mounted at the same slide or at an additional slide on the opposite port. The grating slide can be mounted at two distances from the camera.

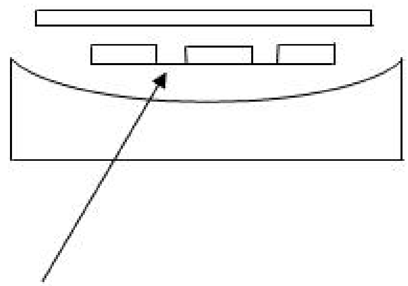






Picture of the mounted grating.

When placing the grating in the plastic container always put the freestanding grating area facing the concave bottom of the container as in picture below.



2. Analysis

2.1 Grating

The grating consists of 10,000 lines/mm free standing silicon nitride bars. The grating period is 100 nm, bars are 40 nm wide. The thickness of the silicon nitride is 175 – 200 nm. The grating bars are supported by support bars at 1.5 µm spacing. No gold or other coating is applied. Because of the ratio between bar width and grating period the second order is suppressed by a factor 0.095 as compared to the first order.

Radiation of wavelength λ is diffracted by the grating according eq 1.

$$d \cdot \sin\theta = m \cdot \lambda \quad \text{(Eq 1)}$$

d = grating period
m = diffraction order.

Obtainable resolution can be calculated with eq 2 and eq 3.

Dispersive resolution:

$$\frac{\lambda}{\Delta\lambda} = N \cdot m \quad \text{(Eq 2)}$$

N = number of grating bars
M = diffraction order.

Example: with λ=13.5 nm, N=700 (70 µm slit), m=1 the dispersive resolution is:

$\Delta\lambda_{disp}$=0.02 nm.

Geometrical resolution:

$$\Delta\lambda = \frac{d}{m}\left[\frac{(S+A)}{L_1} + \frac{A}{L_2}\right] \qquad \text{(Eq 3)}$$

S = entrance slit size or source size if no entrance slit is used

A = grating width (or second slit/pinhole size)
L1 = distance source/entrance slit - grating
L2 = distance grating - CCD

Example: with d=100 nm, m=1, S=0.2 mm, A=70 μm, L1=1099 mm, L2=102 mm the dispersive resolution is:

$\Delta\lambda_{geom}$=0.093 nm

So the theoretical resolution is determined by the geometrical resolution.

The following figure shows a CCD recording of a spectrum. The zero order peak does not fall on the chip in this particular picture. Spectra are extracted by making a plot along the red line. These plots can be made very easily with for example “ImageJ” (see next section). The “secondary” spectrum is caused by combination of the fine grating diffraction with the diffraction by the support bars (m=1). The “offset” is used in the calculation of the wavelength range scaling.

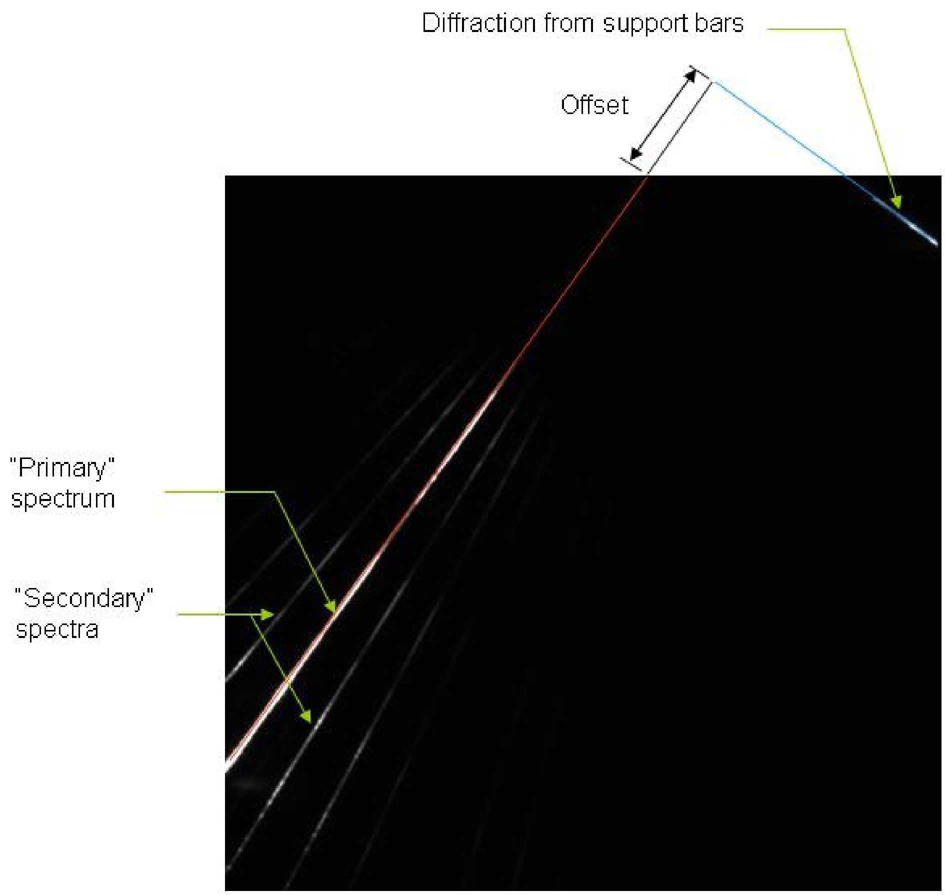


Figure 1, example of CCD image. Weak lines have been enhanced.

2.2 Corrections and wavelength calibration

To get absolute calibrated spectra the results should be corrected for:

- If working with a gas discharge source: gas absorption (ie Xe);
- Air absorption of residual gas in the chamber;
- CCD sensitivity;
- filter transmission of used filters;
- grating efficiency;

The wavelength scale can be determined by using a reference spectrum recorded with a filter with a sharp absorption edge, like Si3N4. Measure spectra with a Zr filter and also with a Zr/Si3N4 filter. By dividing the Zr/Si3N4 filtered spectrum by a Zr filtered spectrum the transmission curve of the Si3N4 filter is found.

Shifting the spectra such that the found Si3N4 line coincides with a known Si3N4 curve yields the wavelength scale.

Figure 2 shows an example (ZrSi3N4 filtered spectrum not shown). The wavelength scaling achieved with this method is accurate to +/- 0.1 nm.

Always use a cooled camera to reduce noise. To get stray light out of the recordings take a background image at the same measuring conditions (pressure, recording time) as used for recording the actual spectra. A good way would be to make an image with only the pinhole mounted. Store the background separately because you might need the 0-order peak to find the start point of your wavelength scale.

Si3N4 windows can be bought at for instance Silson in the UK (www.silson.com). A Si3N4 and Al filter calibration file is included with this manual.

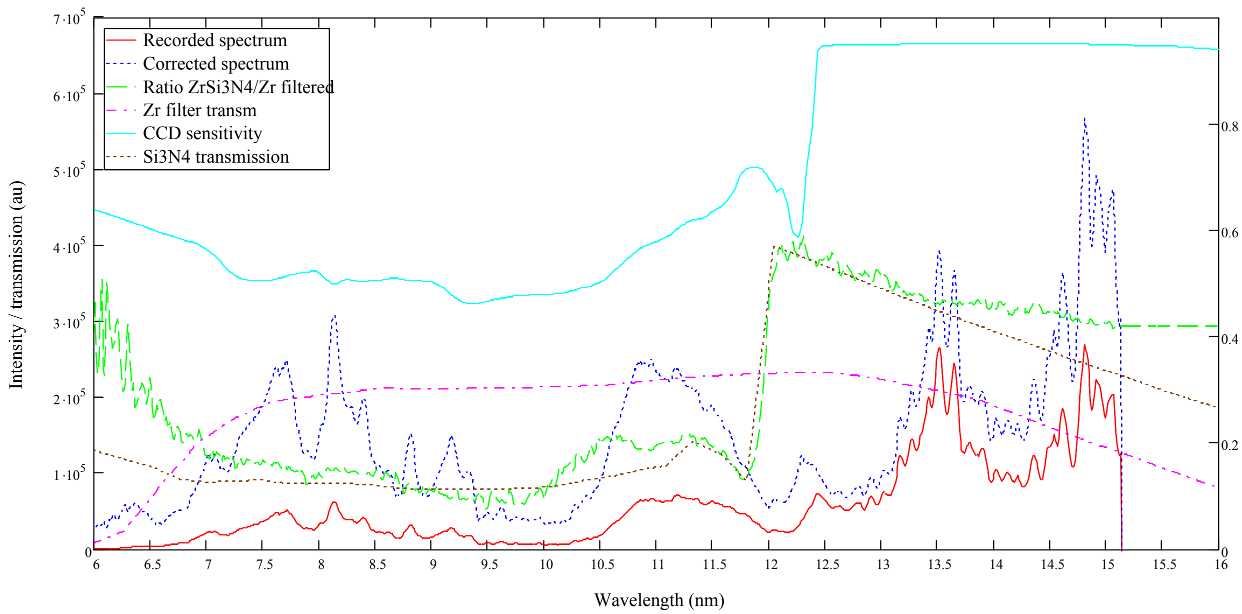


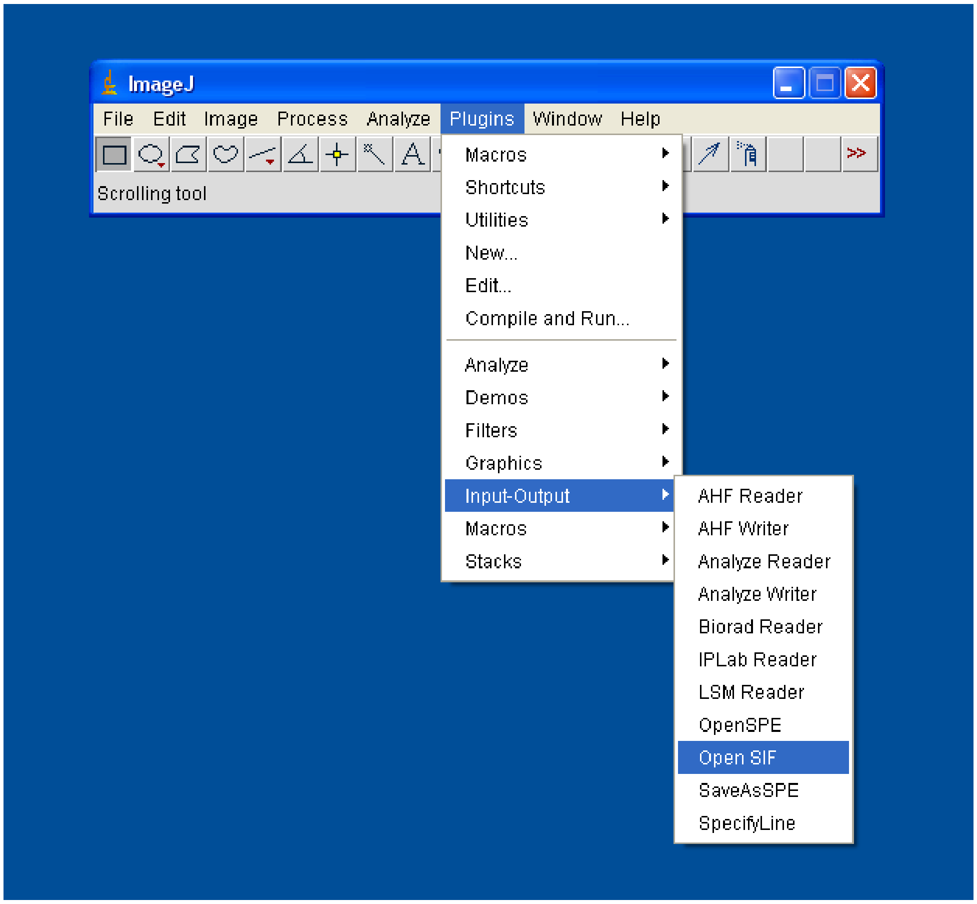
Figure 2, Analysis of recorded spectra.

2.3 ImageJ

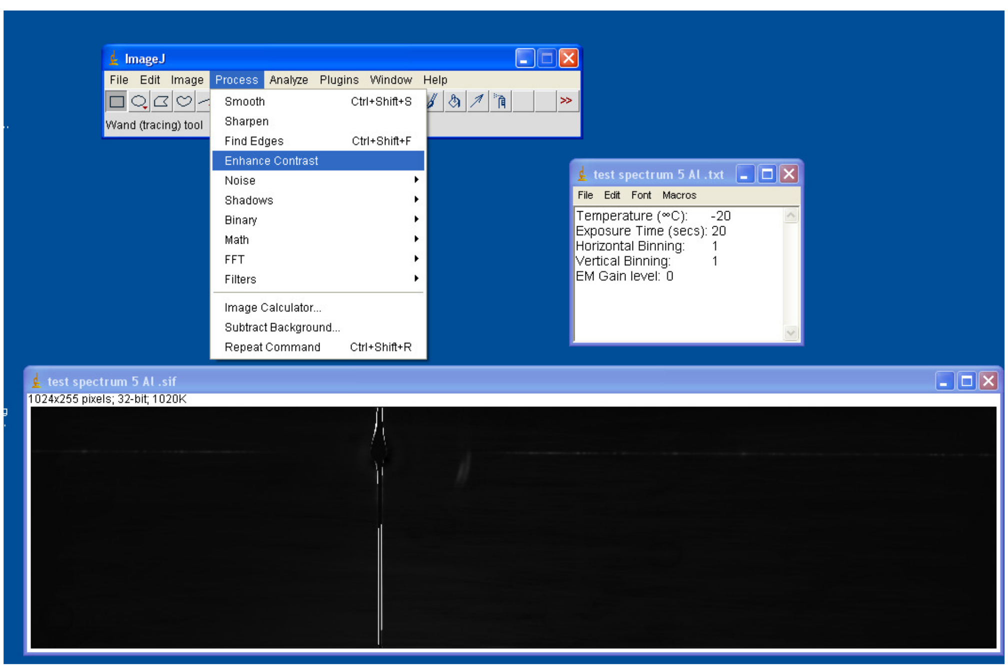
ImageJ can be downloaded from: http://rsb.info.nih.gov/ij/

Here a few practical tips are explained on how to use ImageJ for making plots of the spectra images.

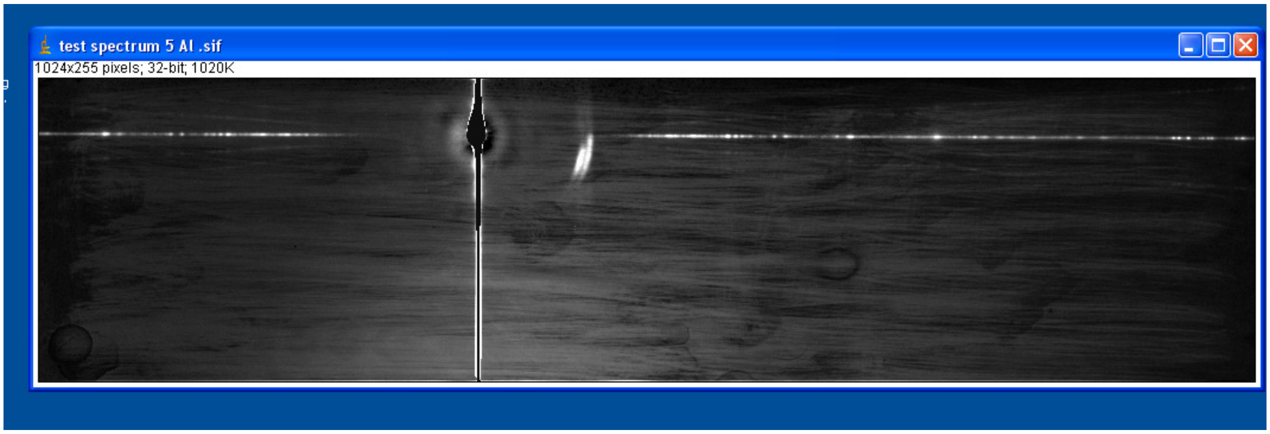
Use the “Open SIF” plugin to open Andor files. This plugin is included with the files supplied with this manual.



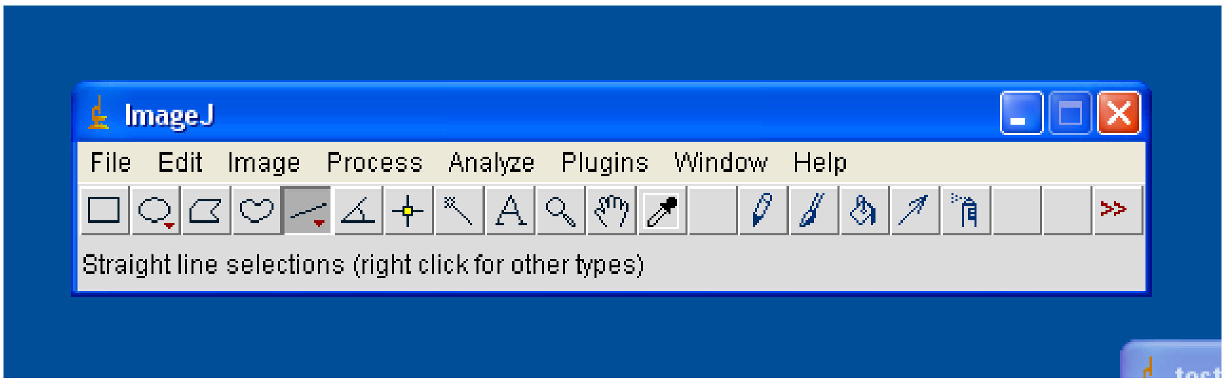
After having opened the file you will want to enhance the contrast to be able to locate the spectrum better:



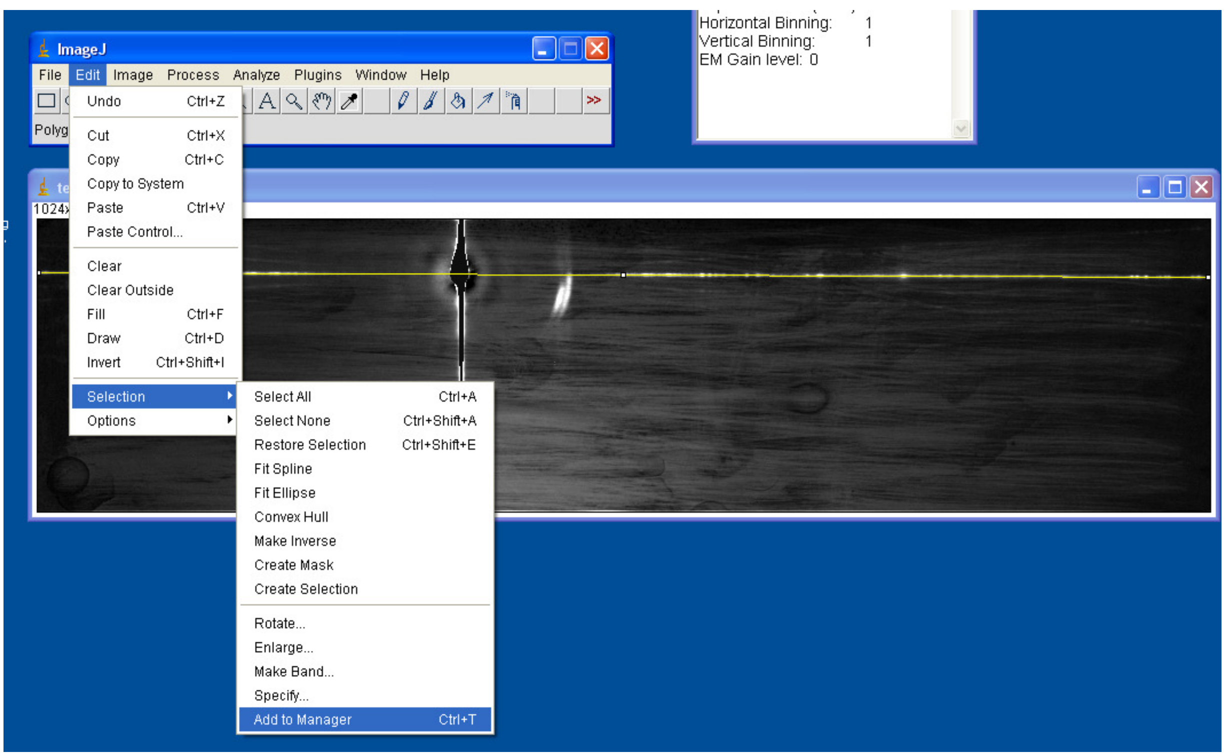
This yields following result:



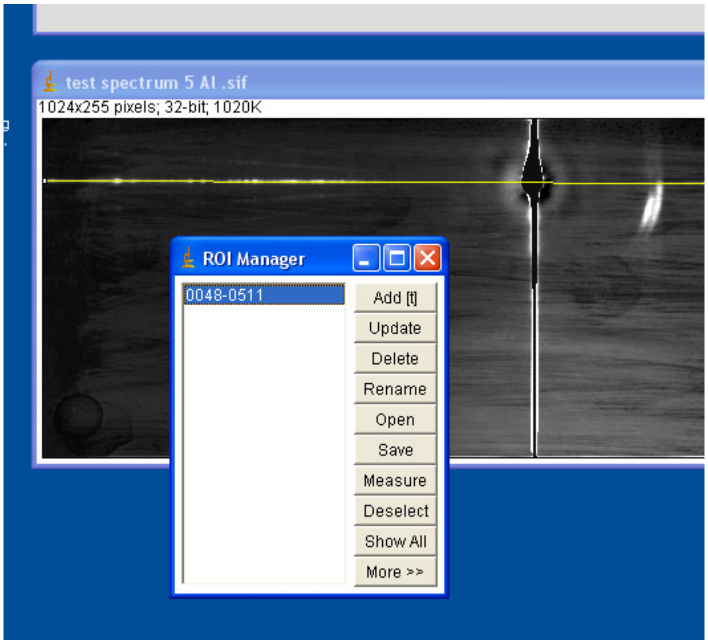
Now you draw a line across the spectrum to make a plot:



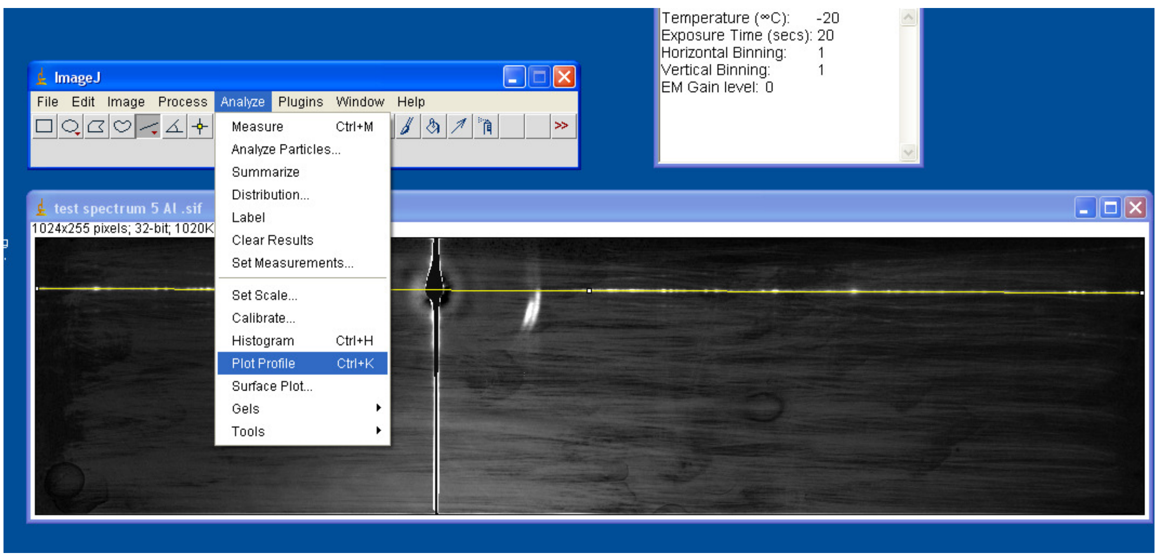
Add this line to the ROI manager to be able to use the same line for other spectra as well.

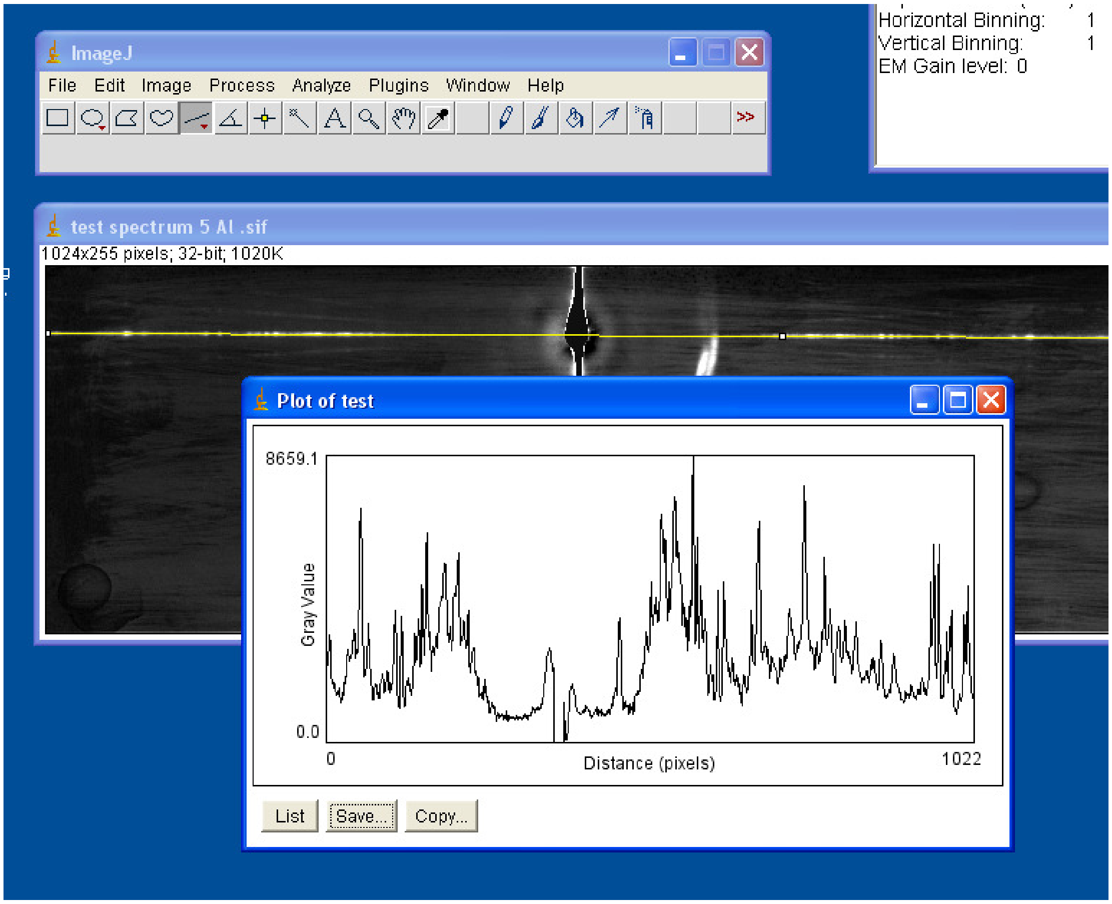


Save the line (and rename it first if you like):



Now make a plot of the section:





Save the plot to be able to import the data later in excel or mathcad.