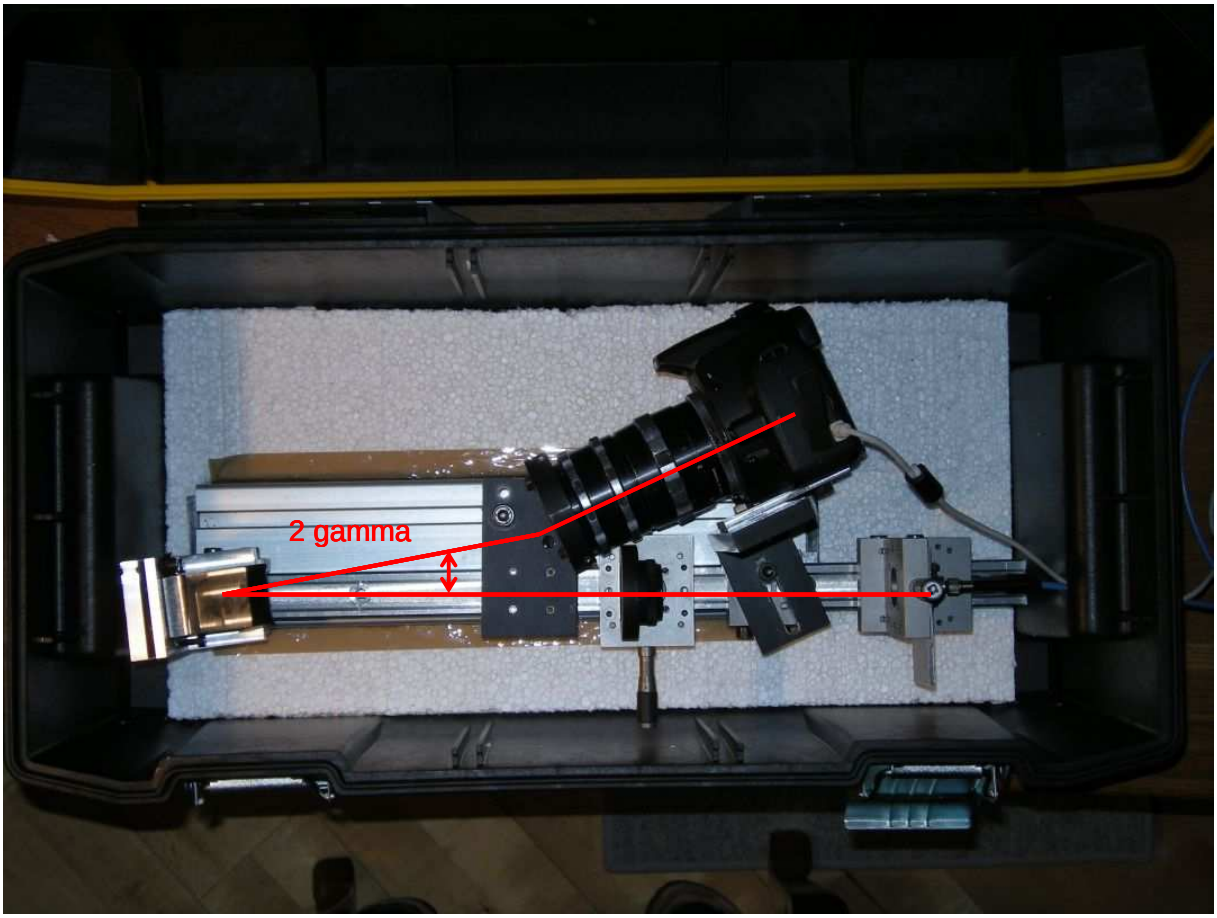
Echelle March 2011

Summary

During the change of the camera lens in the echelle I noticed a strong astigmatism in the echelle spectra. The cause was found in the incorrect focusing of the collimator and camera lens. By adjusting both focal distances the astigmatism was eliminated.

Setup

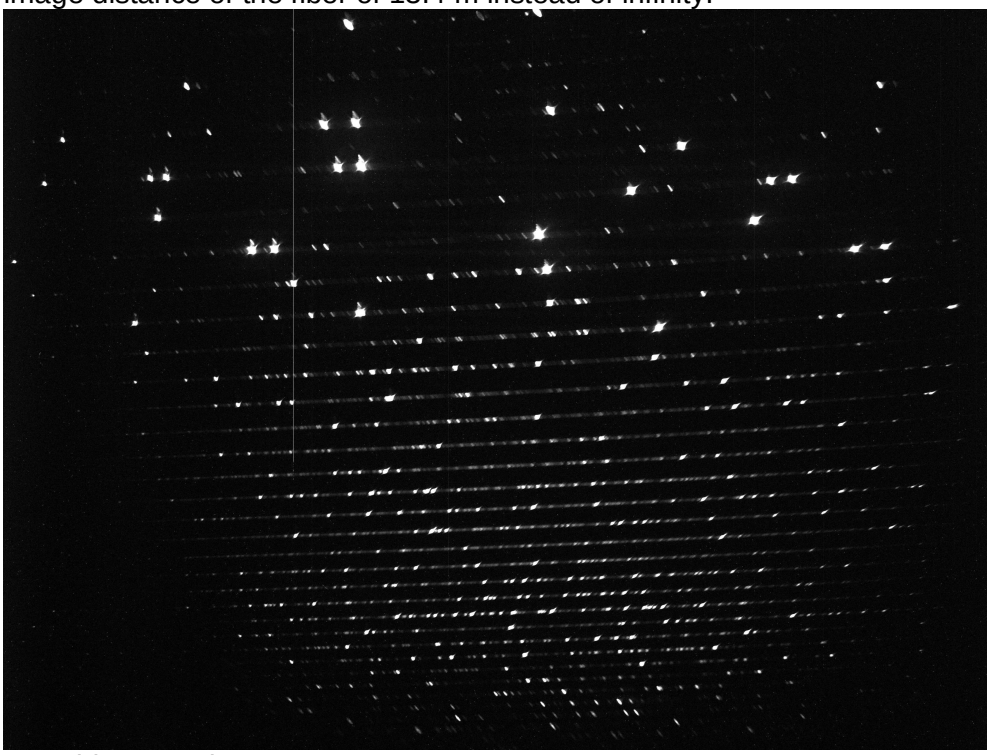


Echelle 69 L/mm R2
Cross disperser: 300 l/mm
Collimator : diameter: 25 mm, focal length: 150 mm (Thorlabs achromat)
Canon 350D replaced by CCD: SBIG8300 some time ago
Camera lens: Schacht Travenar f1:3.5 135 mm replaced by f1:1.8 85 mm
Length camera adapter 135 mm lens: 29.0 mm
Length camera adapter Canon EOS 85 mm lens: 27.5 mm
Calculated:

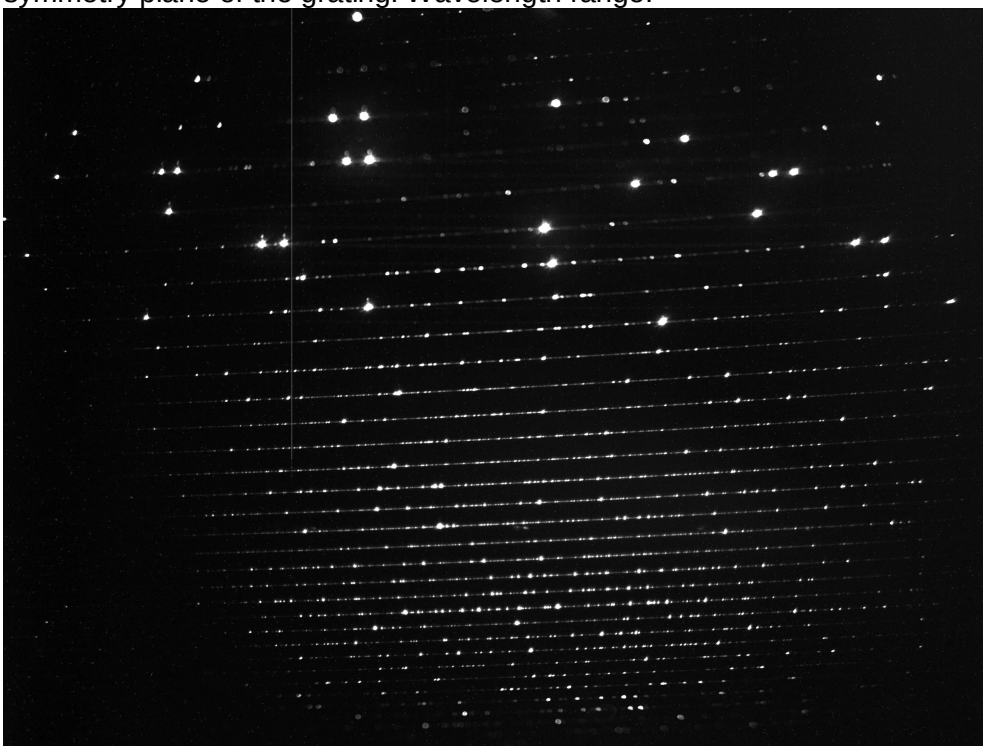
Backfocus Pentax:	45.5	Canon EOS:	44.0	
Backfocus SBIG:	17.5			
Difference:	28.0		26.5	
Actual length of tubing	29.0		27.5	too long?!

The correct focusing of the collimator lens corresponds to a distance of 123.0 mm between the flanges of fiber holder and lens holder.
Micrometer reading:
1.8 mm → 123.0 mm focused → 150 mm lens – fiber distance
After the camera lens change, the collimator had to be moved by 1.7 mm to get the best focus at green wavelengths.

camera lens set at infinity, collimator 150 + 1.7 (micrometer 3.5 mm). This corresponds to an image distance of the fiber of 13.4 m instead of infinity.



Two things can be seen:
notice the astigmatism at top and bottom, where out of focus due to chromatic aberration.
In the center of the image we are on the other side of the focus, the lines slant the other way, a typical sign of astigmatism! This is different from the slant produced by the angle gamma, the offset of the incident collimated light to the symmetry plane of thegrating.
Even at best focus resolution is reduced. (Enlarge image to see!)
Next: properly focused collimator and camera, no astigmatism, only chromatic aberration.
The tilt of the astigmatism is caused by the offset angle gamma of the collimator axis to the symmetry plane of the grating. Wavelength range:



correct focus is important for good resolution:

FWHM at best focus with offset collimator focus 1.5 mm: 9 pixel
FWHM at best focus both lenses: 4.9 x 4.7 pixel (theory from fiber size: 5.2 pixel diameter), almost a factor two of improvement of resolution!

Conclusion

At large angle of incidence (echelle grating or large number of lines/mm) it is important to collimate the incident light very precisely, otherwise astigmatism (and coma) will occur. This is particularly well visible with a fiber spectrometer, where the image should be a round spot (some ellipticity caused by the angle gamma). Well collimated the image size is indeed as large as calculated by simple geometric optics (diffraction effects can be neglected at the fiber size and focal ratio of the collimator). Bad focusing of the collimator introduces loss of resolution and slant in the spectra, at different angles in and out of focus.