Recent developments in radiometry

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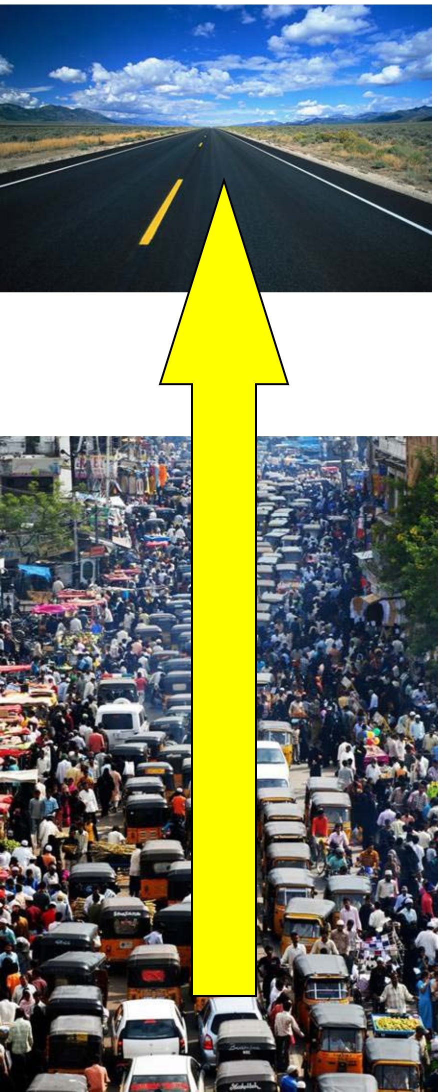
Charles Bamber

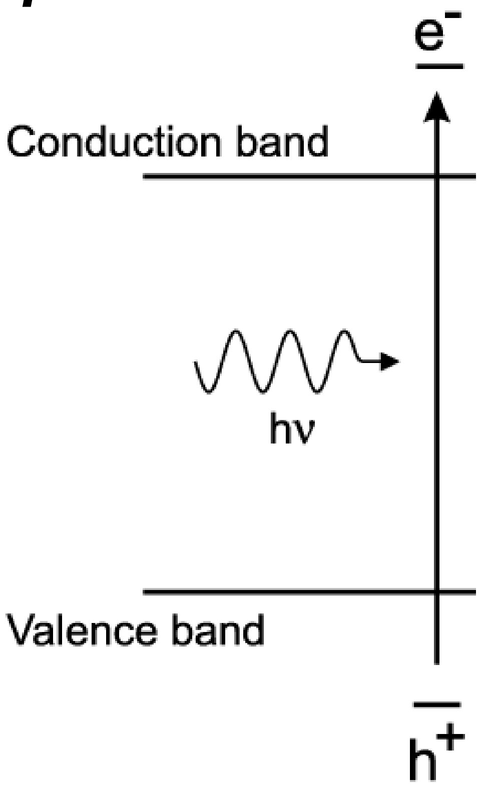
National Research Council Canada
Conseil national de recherches Canada
Canada

Outline

- Radiometry: the measurement of light
- Traceability chain: cryoradiometer to routine calibrations
- Uncertainty budget
- Wavelength uncertainty – test case

In a semiconductor, *absorption of a photon* creates two charge carriers:

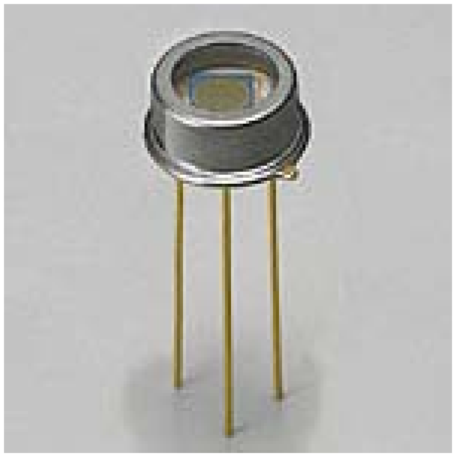


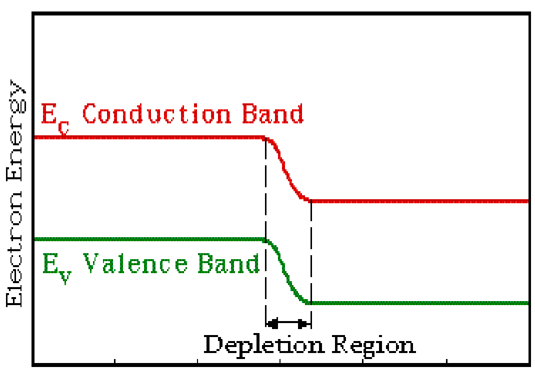


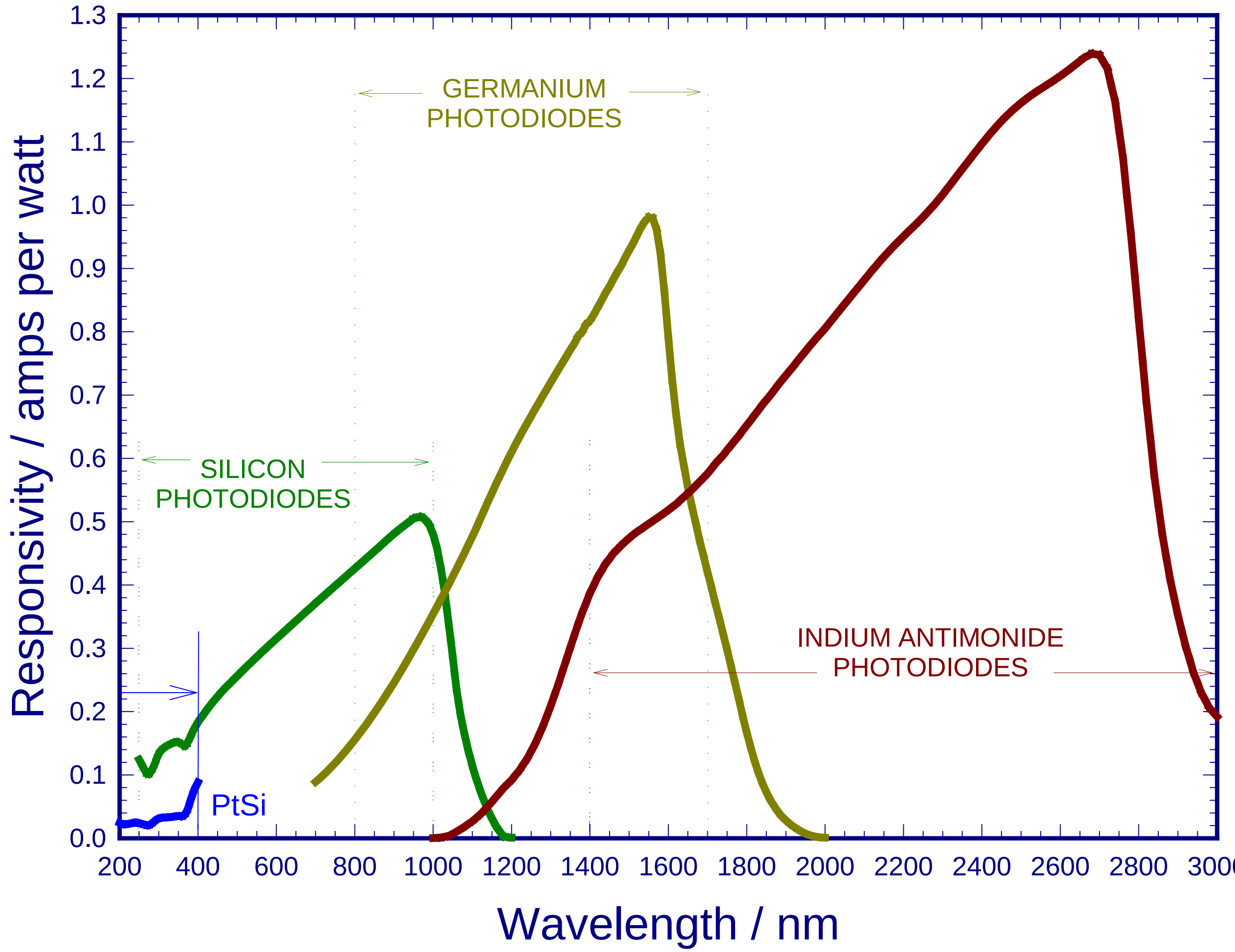
one electron

& one hole

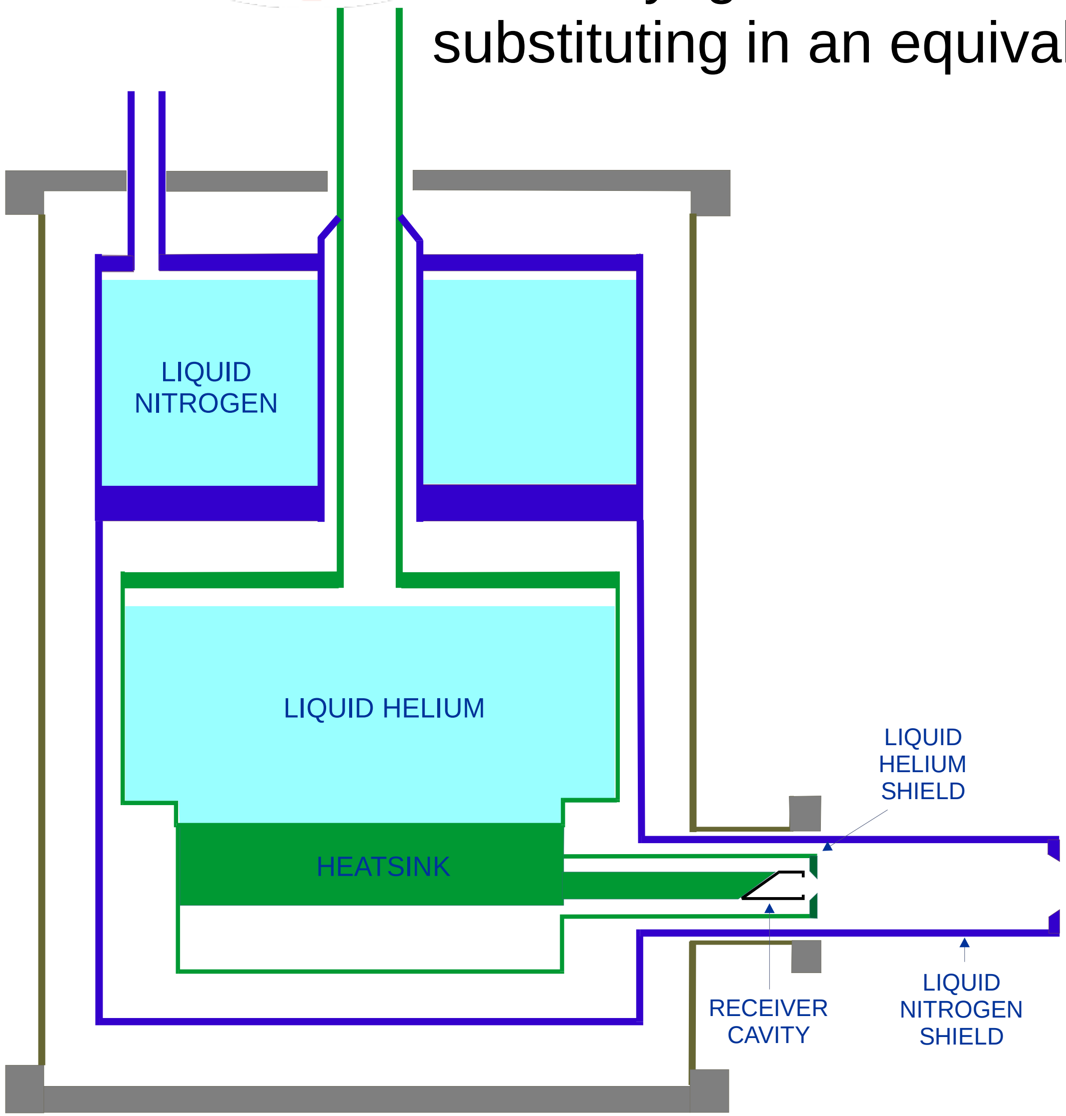
In a p-i-n diode, the ‘energy landscape’ is engineered so that electrons run downhill







The cryogenic radiometer measures optical power by substituting in an equivalent amount of electrical power



Responsivity is the ratio of the amount of current that flows out of the device for a given input optical power

$$S_{pow}(\lambda) = I(\lambda)/P(\lambda)$$

The calibration of every client detector is traceable to the cryorad

cryogenic radiometer

↓

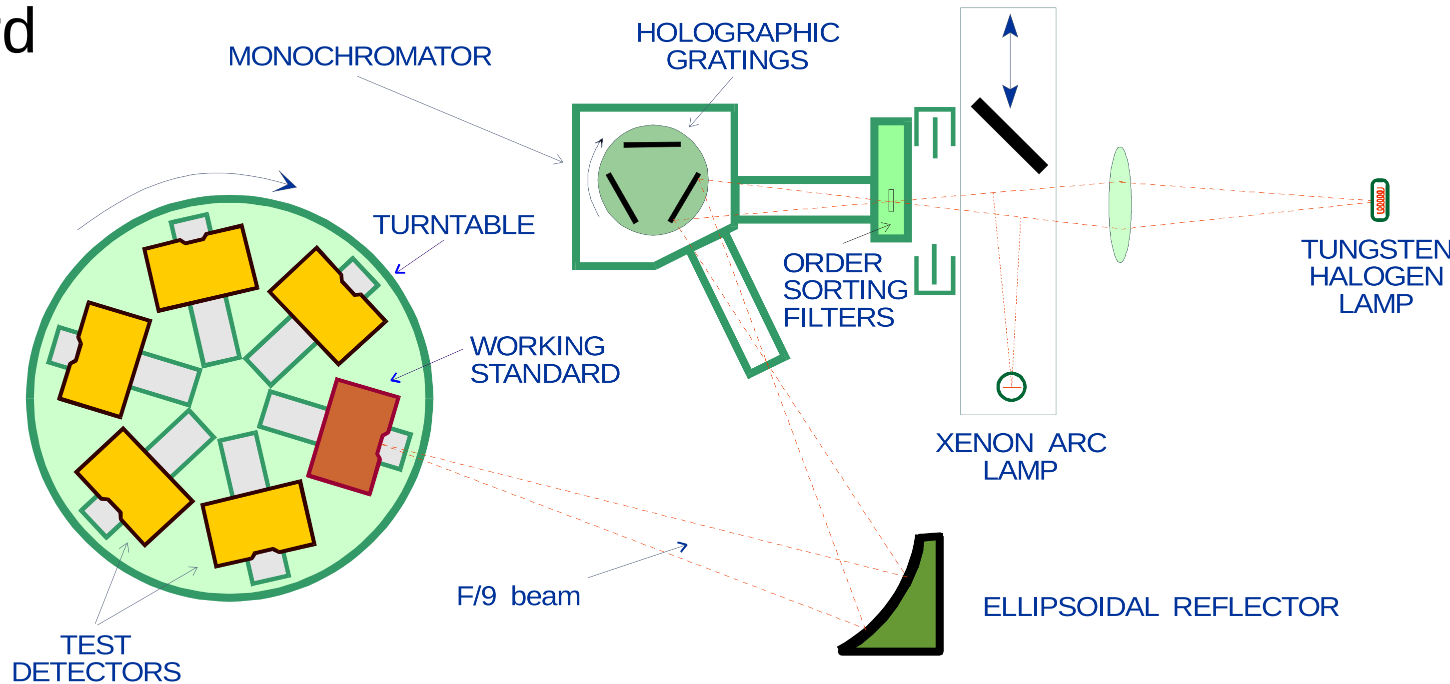
transfer radiometer

↓

working standard

↓

client detector



cryorad→ transfer standard

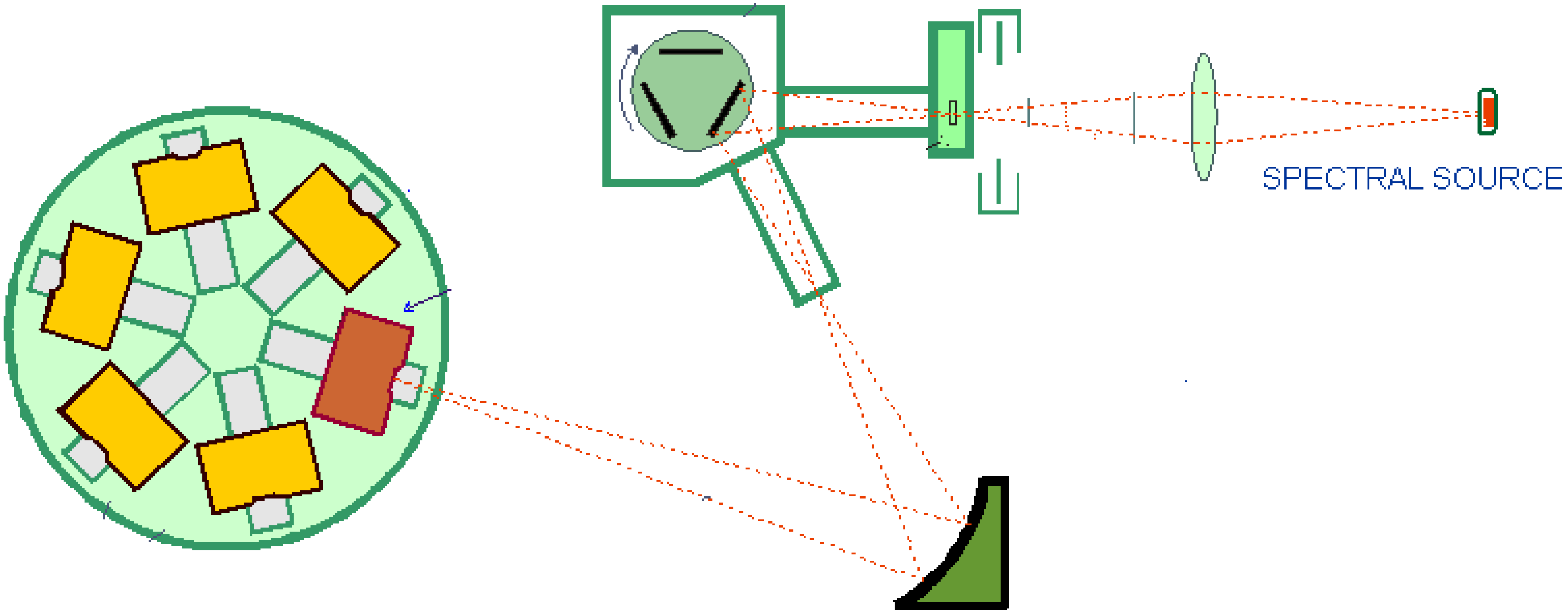
Each link in the traceablility chain has its own uncertainty budget

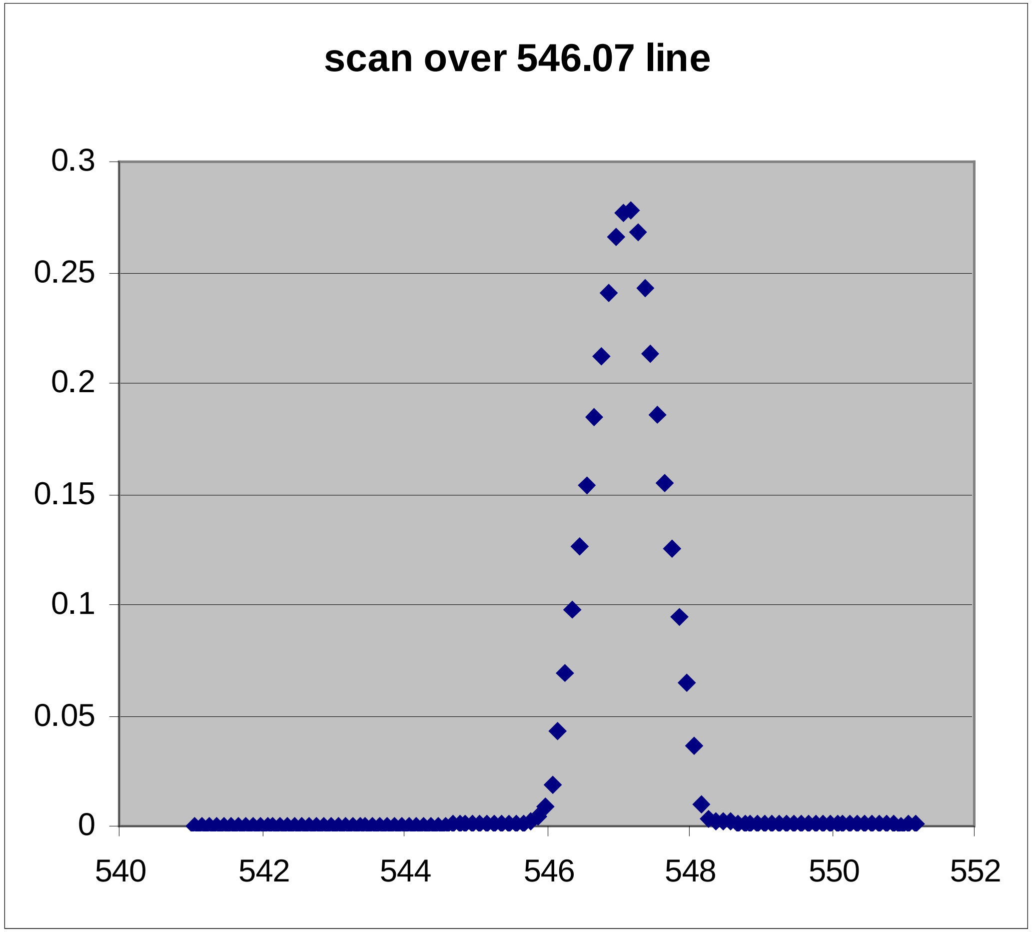
Source Of Uncertainty	Cryogenic radiometer effects	Calibration Of Electronic Equipment	Measurement Repeatability	Monochrom. Wavelength Calibration (± 0.1 nm)	Monochrom. Bandwidth Effects 5 nm FWHM	**Overall Uncertainty %**
Type	B	B	A	B	B	
Wavelength nm	Magnitude of uncertainty component , %					
300	.017	.010	0.03	0.021	0.026	**0.049**
320	.017	.010	0.03	0.020	0.042	**0.059**
340	.017	.010	0.03	0.025	0.025	**0.051**
360	.017	.010	0.03	0.020	0.027	**0.049**
380	.017	.010	0.03	0.034	0.021	**0.054**
400	.017	.010	0.03	0.027	0.001	**0.045**
450	.017	.010	0.02	0.024	0.016	**0.041**
500	.017	.010	0.02	0.021	0.004	**0.035**
550	.017	.010	0.02	0.018	0.000	**0.034**
600	.017	.010	0.02	0.016	0.003	**0.033**
650	.017	.010	0.02	0.015	0.006	**0.033**
700	.017	.010	0.02	0.015	0.006	**0.032**
750	.017	.010	0.02	0.013	0.006	**0.032**
800	.017	.010	0.04	0.012	0.006	**0.047**
850	.017	.010	0.04	0.011	0.008	**0.047**
900	.017	.010	0.03	0.010	0.002	**0.038**
950	.017	.010	0.02	0.002	0.015	**0.032**
1000	.017	.010	0.02	0.066	0.025	**0.076**

Since wavelength uncertainty is often the biggest component, address that

- upgrade monochromator
- perform in-house wavelength calibration
- generate corrections to beat manufacturer's spec

A spectral source is scanned with the monochromator

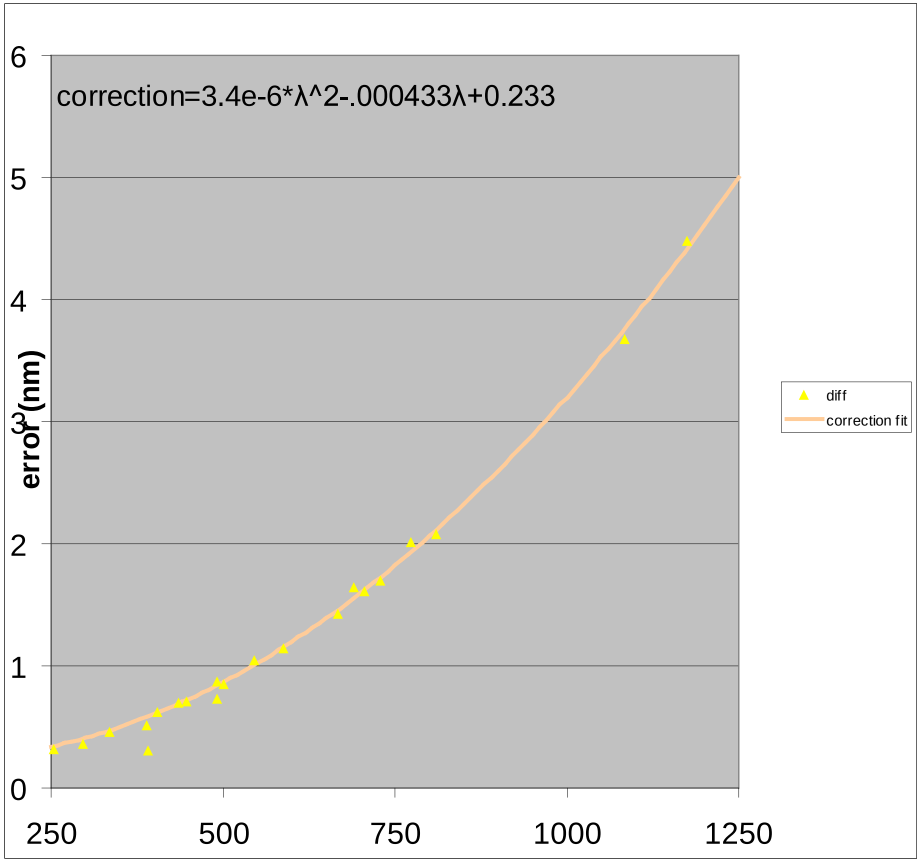


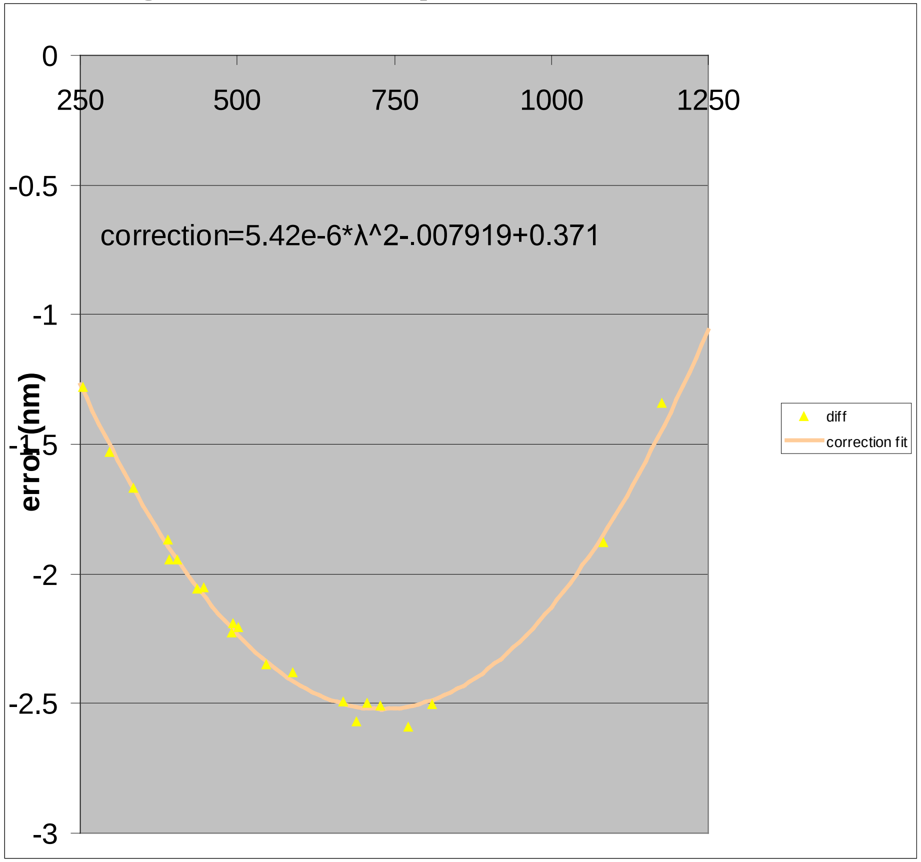


Corrections can be generated for the difference between measured wavelength and accepted value

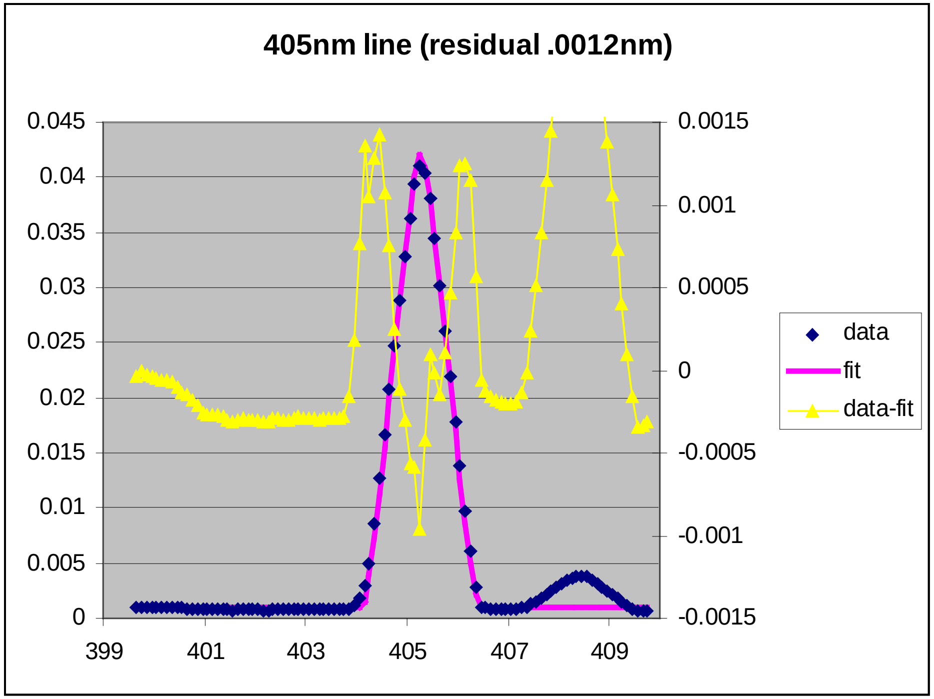
547.12-546.07=1.05

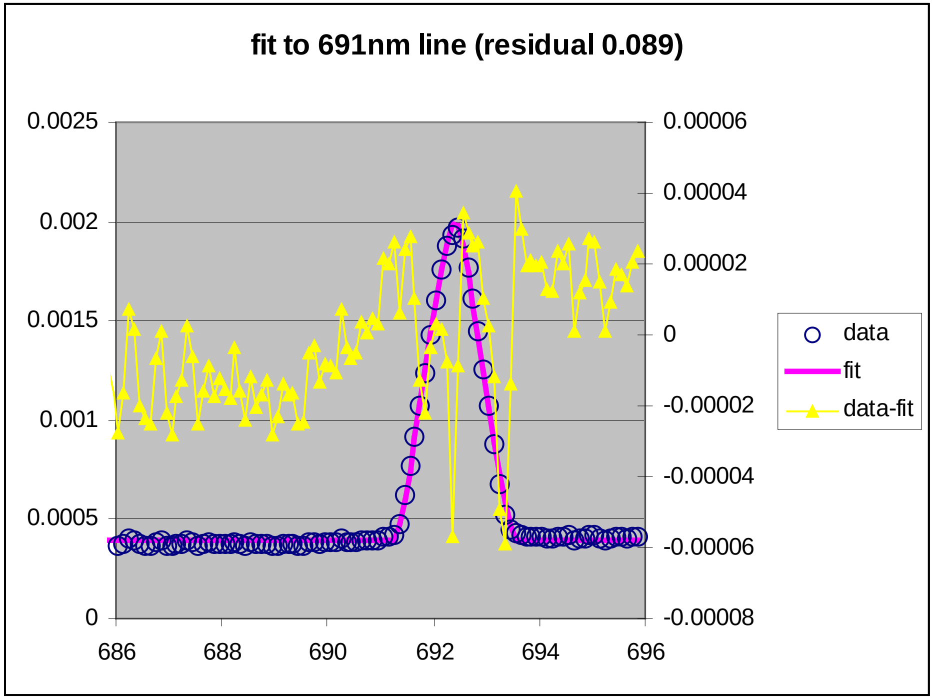
Each monochromator was calibrated with Hg & He spectral sources





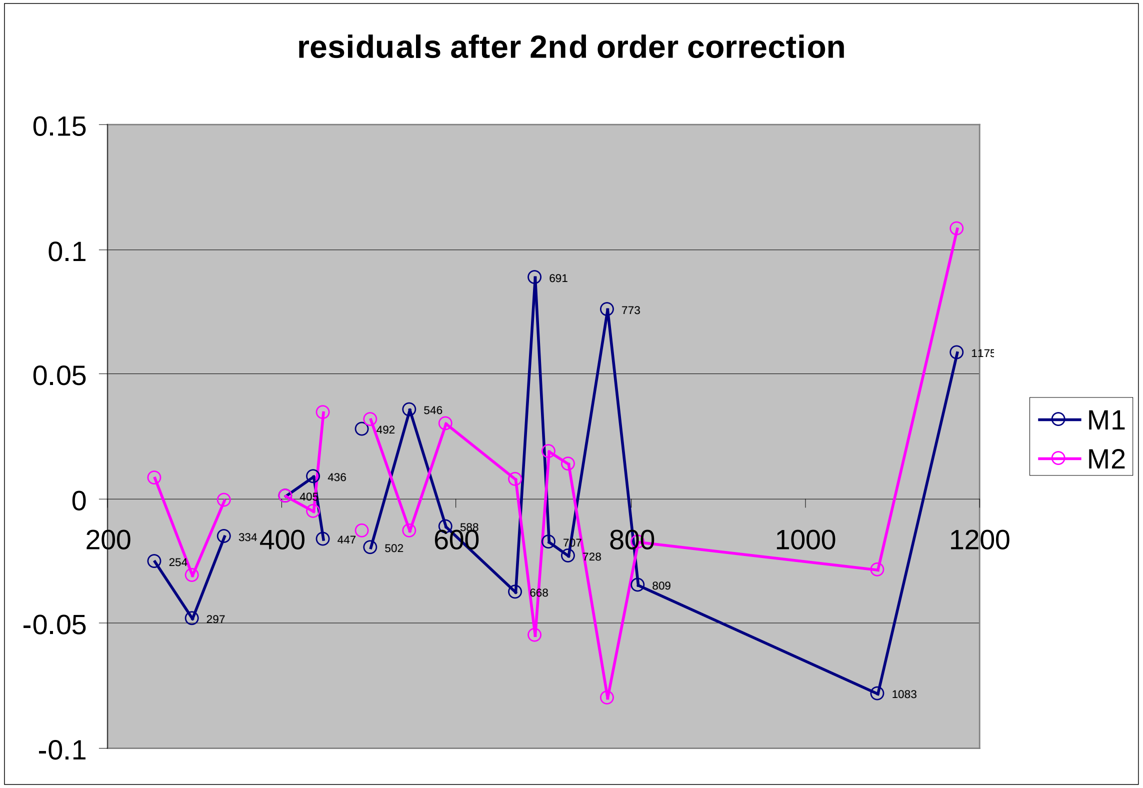
Underlying contaminant peaks could skew the centroid





Note the asymmetry

Are the residuals real?



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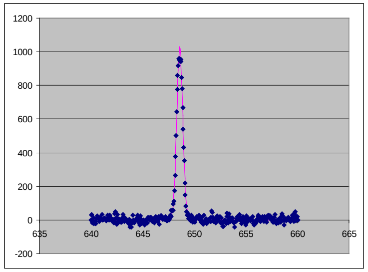
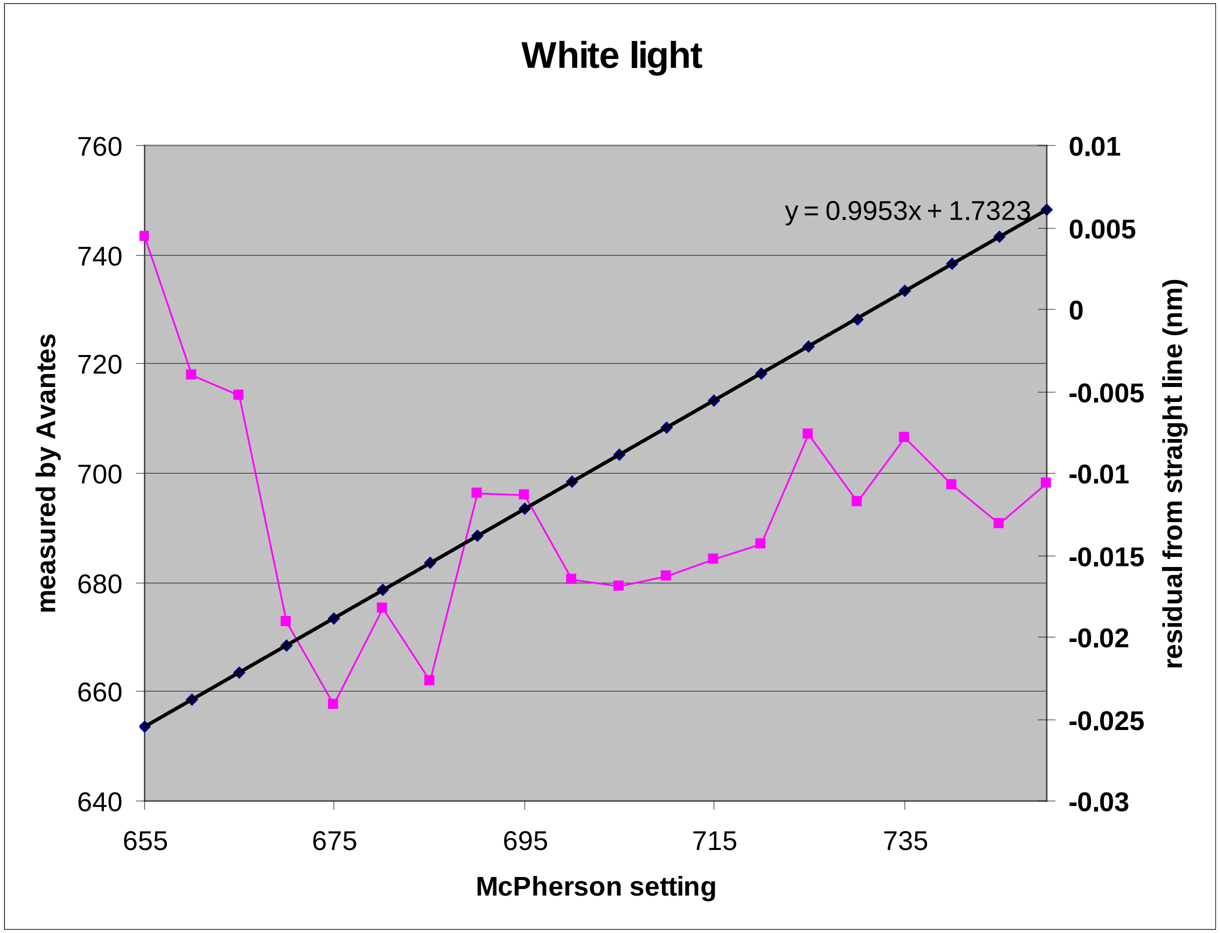
Checking with an independent spectrometer

White light

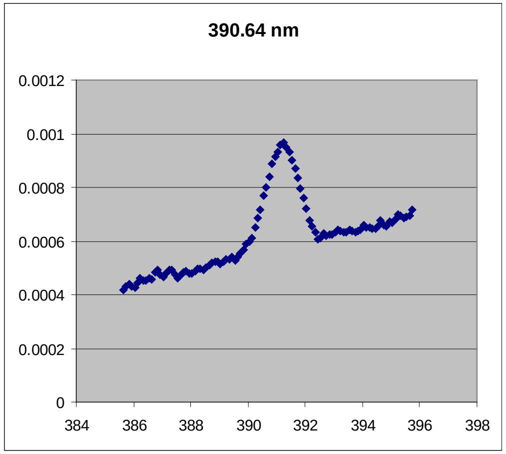
McPherson monochromator

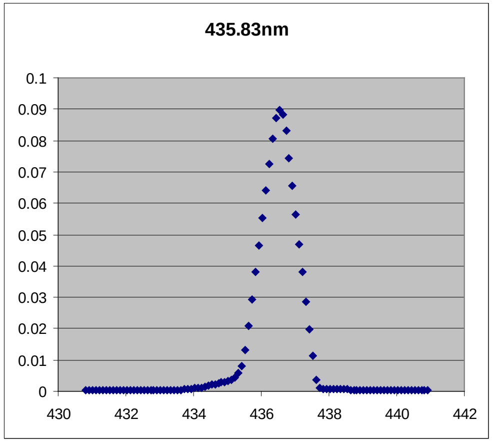
Avantes spectrometer

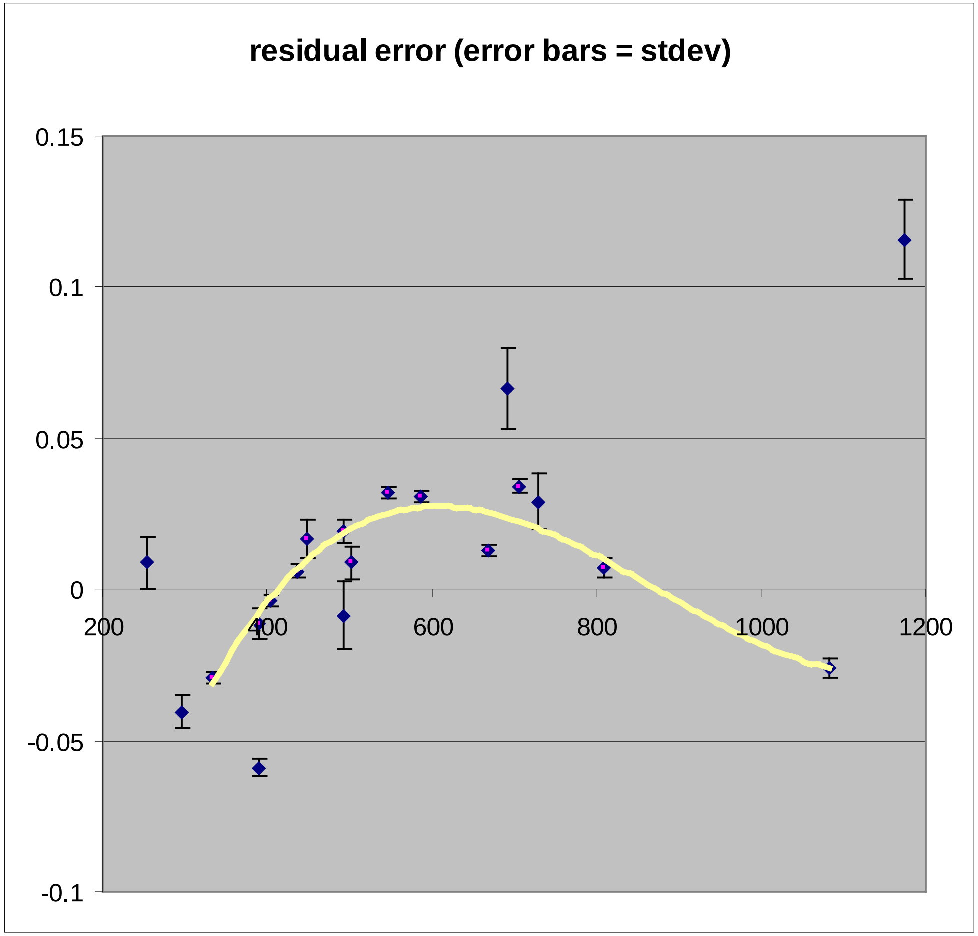




Some spectral lines will be eliminated from the calibration







Lessons learned

- Work on the largest sources of uncertainty
- Know your equipment
- Know the physics
- Be cautious
- Be conservative