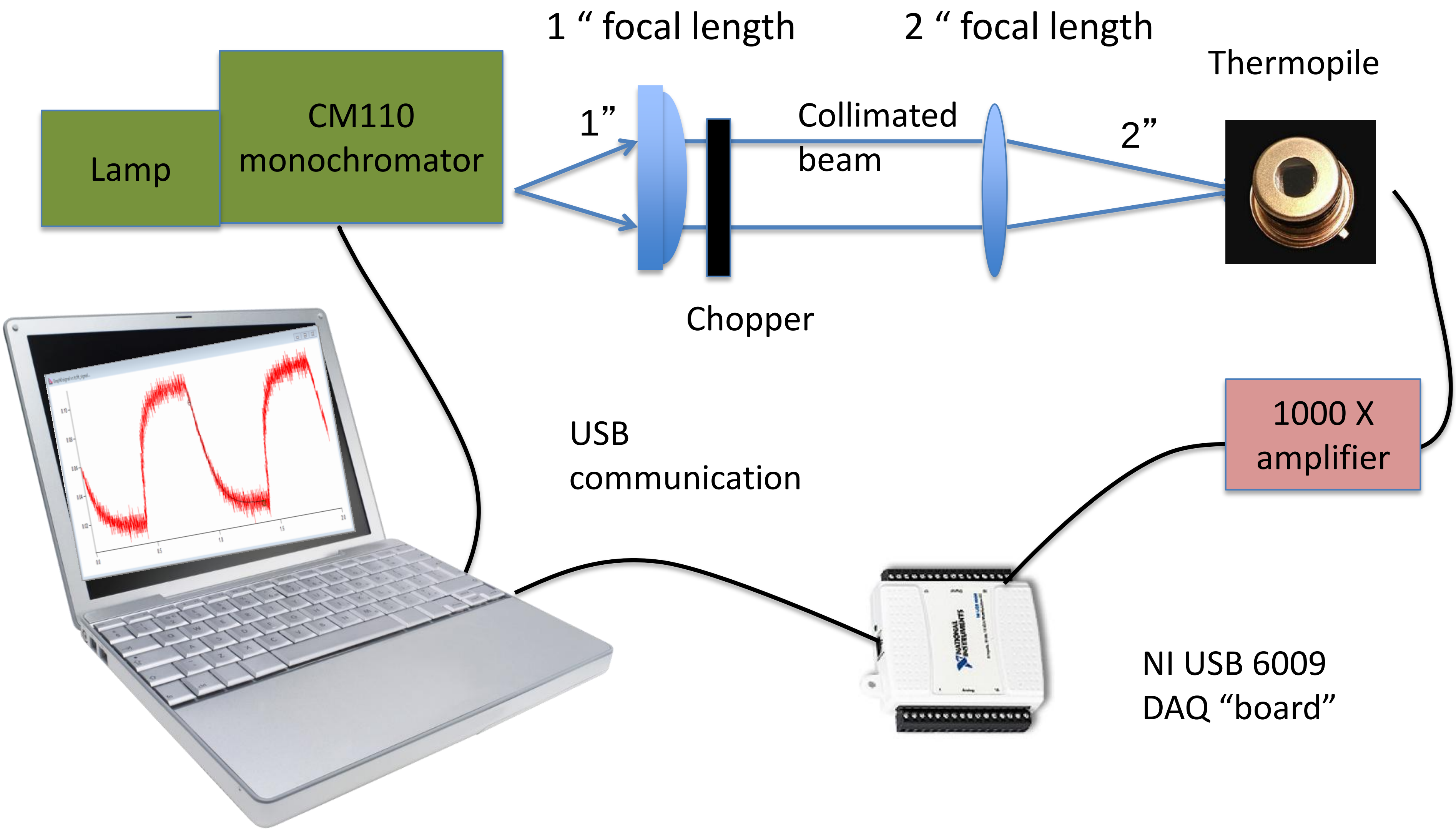
Characterization of Spectral Output of Light Source (Lab #2)

R.J. Ellingson and M.J Heben

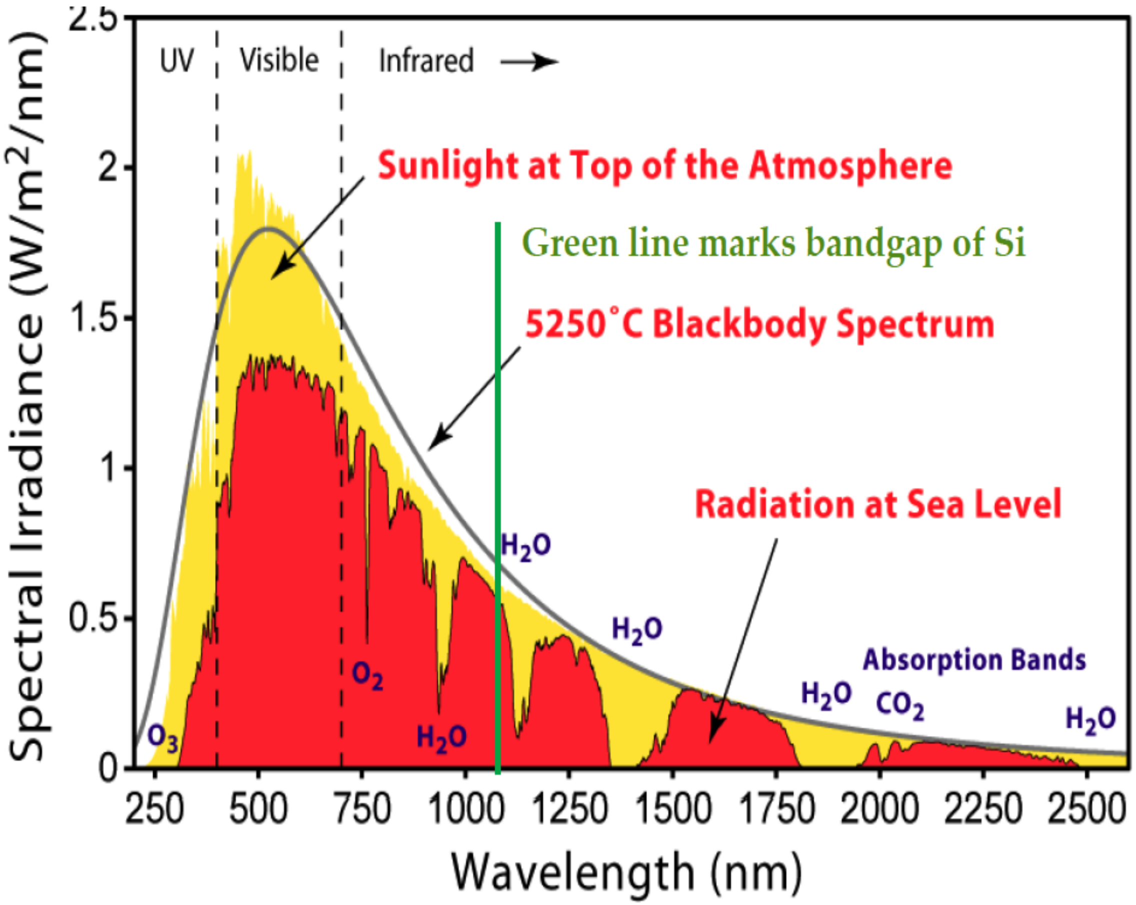
September 9, 2014

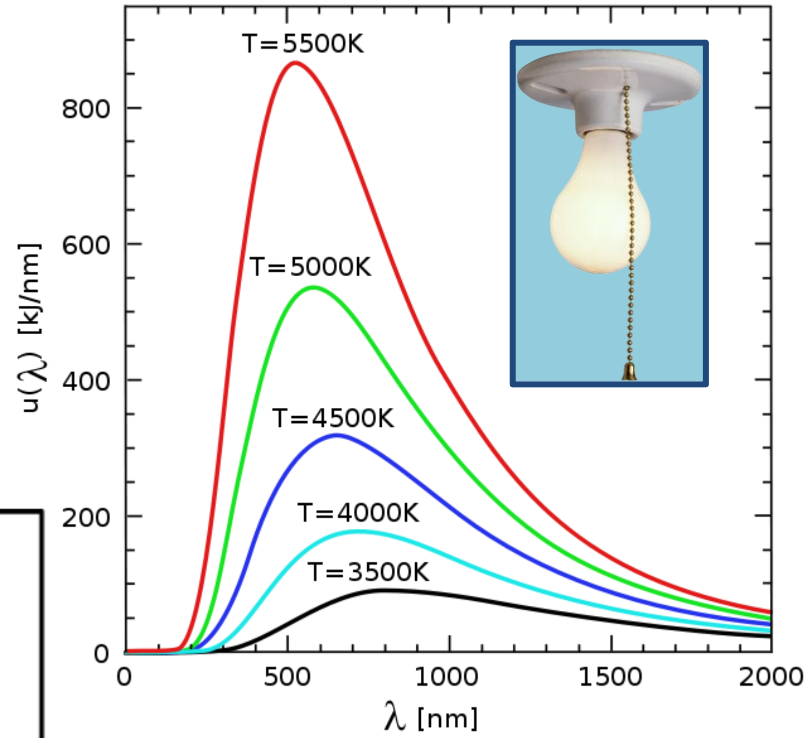
PHYS 4580, 6/7280

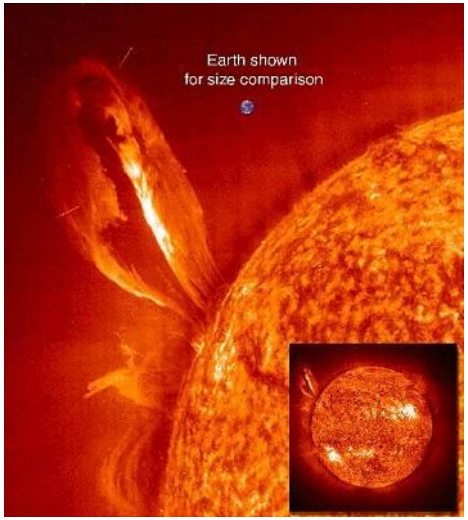
Response time of the thermopile (at one wavelength)



Our Sun, and other Blackbody light sources, emit more than one wavelength of light.





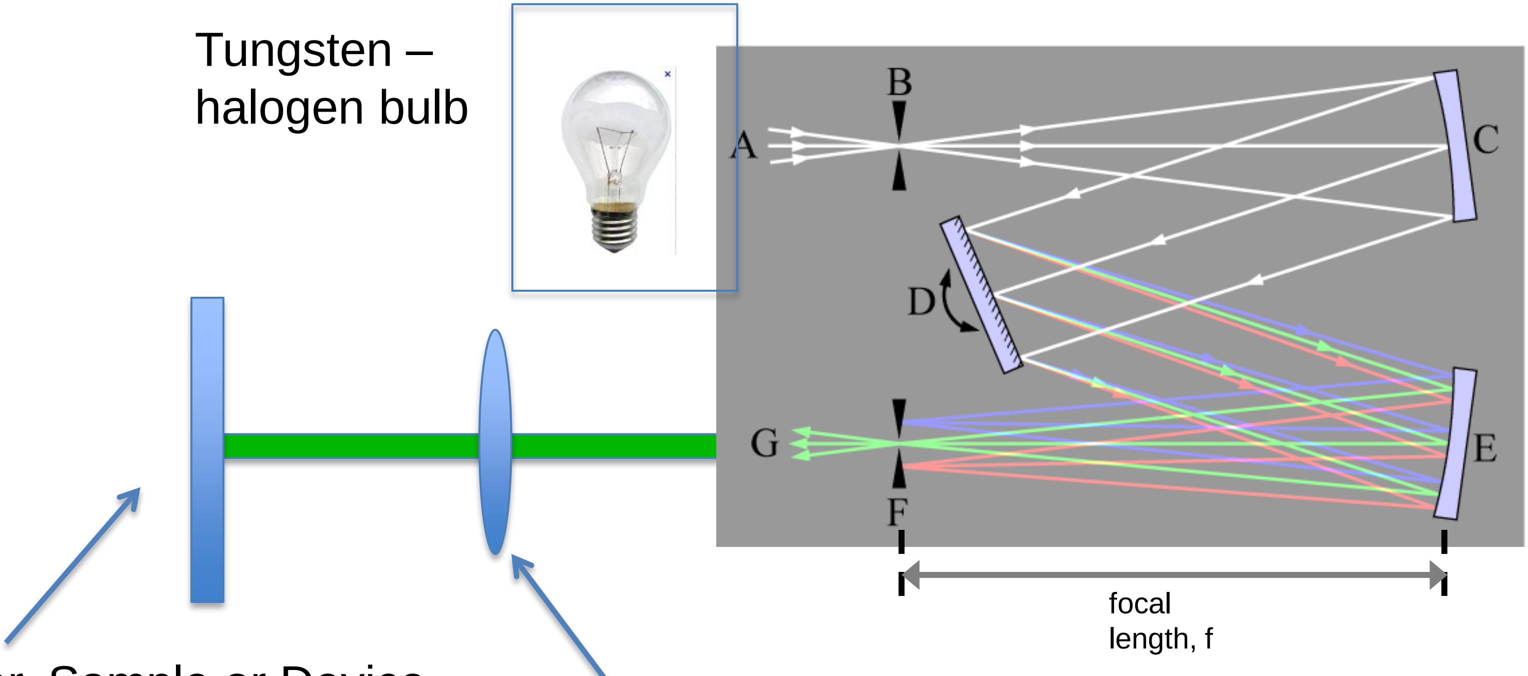


The "Set-Up"

Light Source

Monochromator

Tungsten – halogen bulb

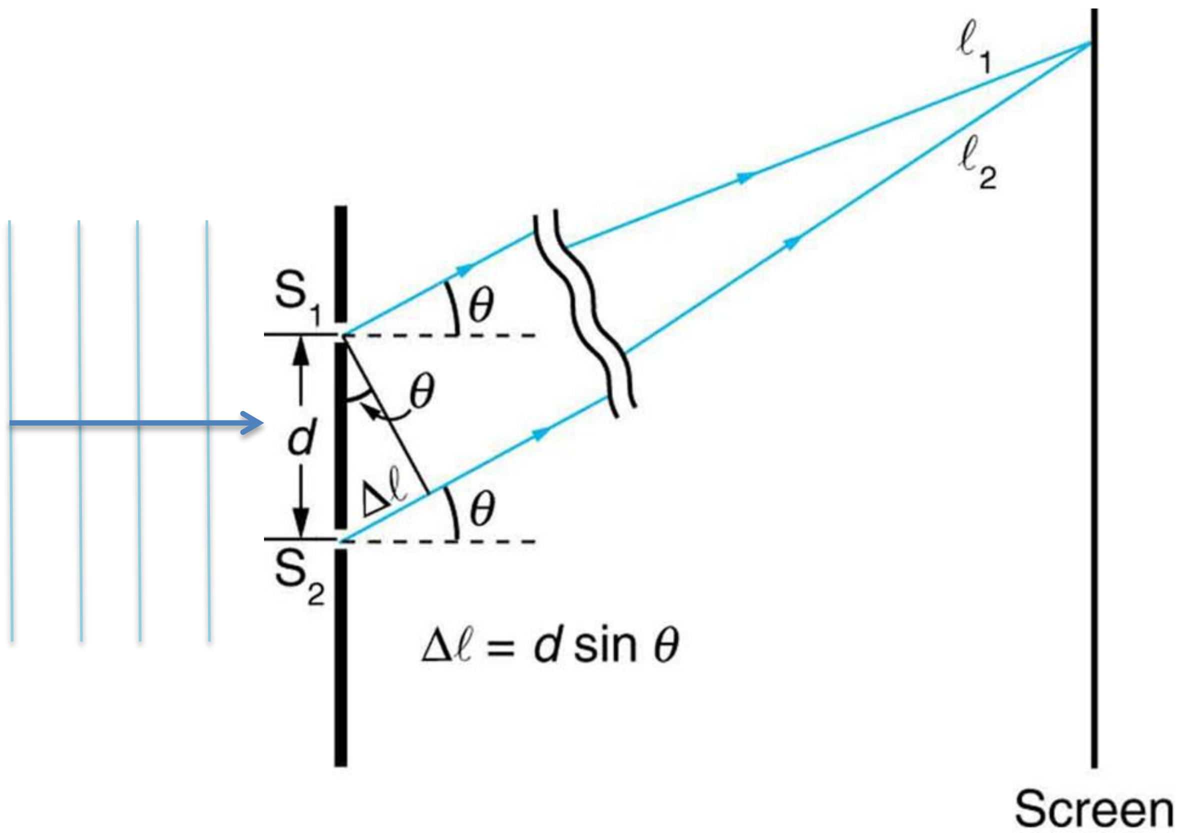


Detector, Sample or Device (perhaps with I/V measurement)

A lens or two

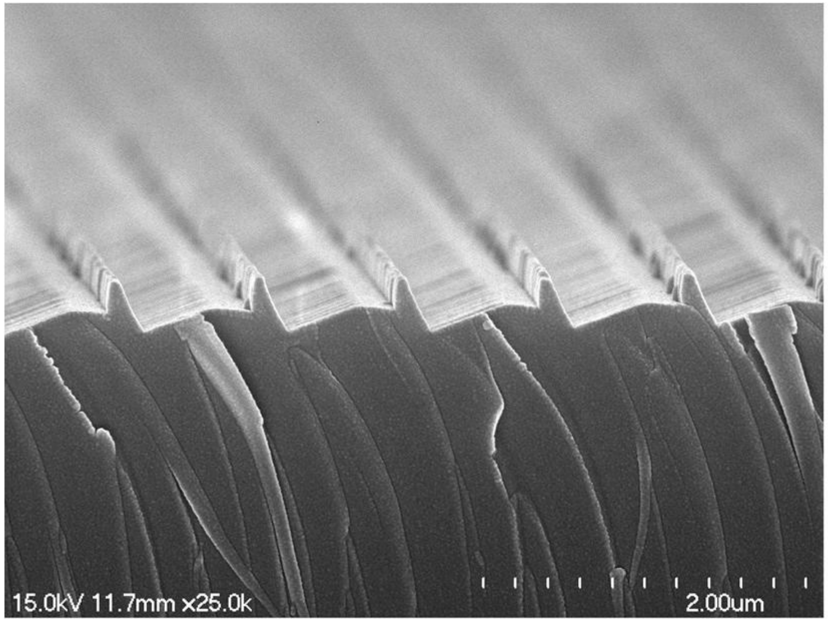
Samples – semiconductor layers, transparent conductive layers, PV devices
Detectors – calibrated thermopile, photodiode

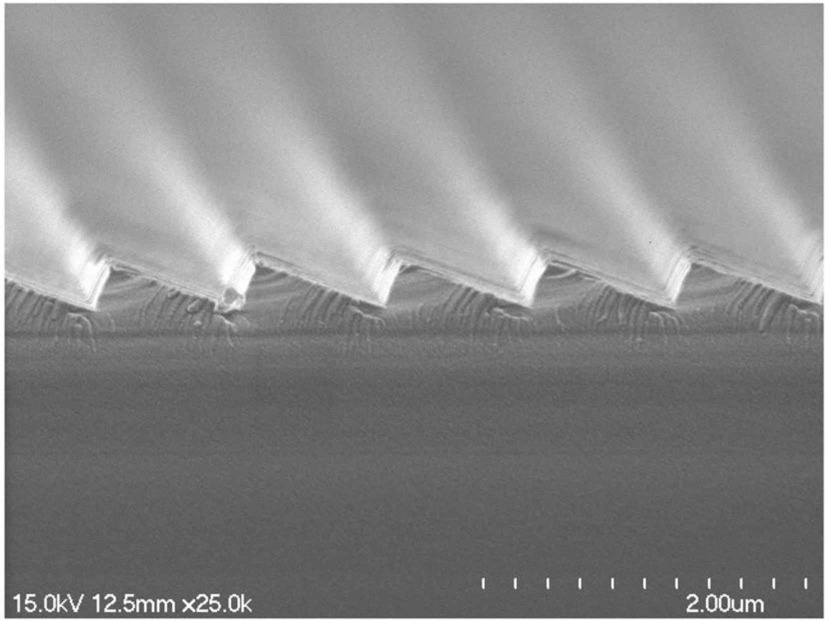
Diffraction – Meeting the Conditions for (Constructive) Interference

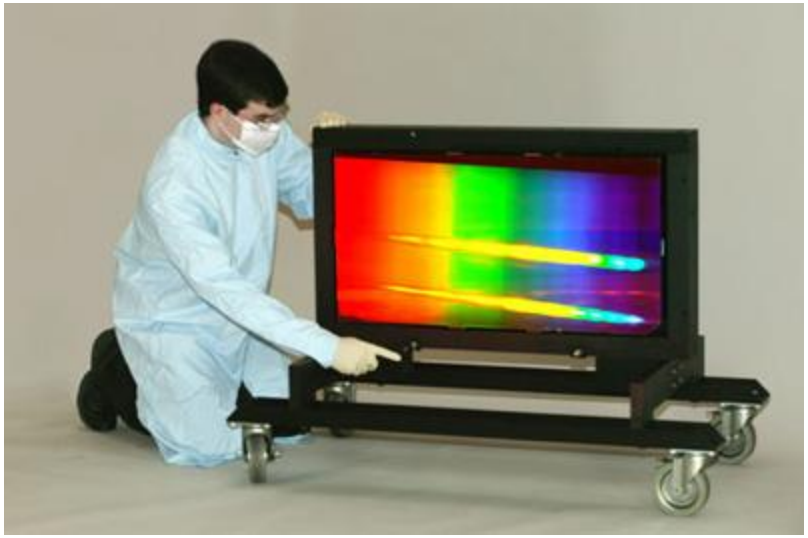


Adapted from cnx.org

Diffraction Grating





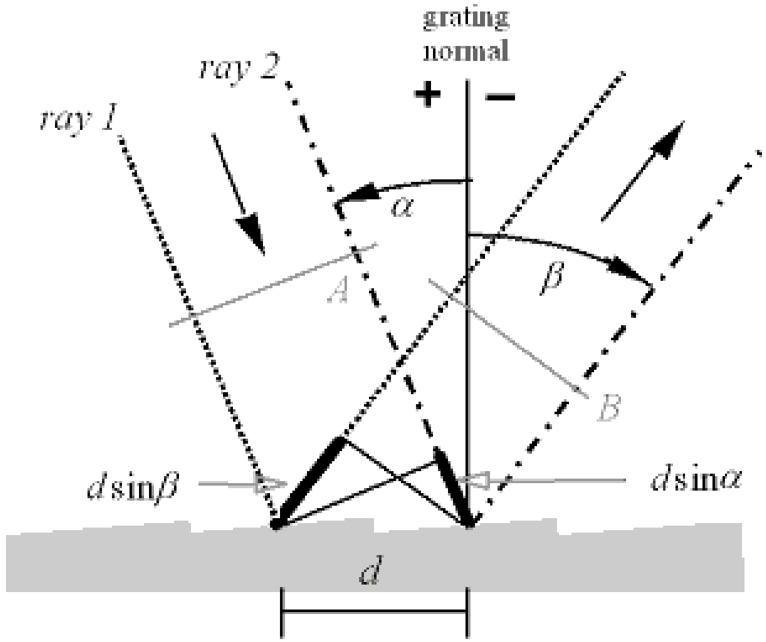


The Grating Equation (general case)

$m\lambda = d\,(\sin\alpha + \sin\beta)$

Where m is the diffraction order and d is the groove spacing.

Reflective diffraction grating



Sin (β) = - Sin(-β)

Figure 2-2. Geometry of diffraction, for planar wavefronts. Two parallel rays, labeled *1* and *2*, are incident on the grating one groove spacing *d* apart and are in phase with each other at wavefront *A*. Upon diffraction, the principle of constructive interference implies that these rays are in phase at diffracted wavefront *B* if the difference in their path lengths, $d\sin a + d\sin b$, is an integral number of wavelengths; this in turn leads to the grating equation.

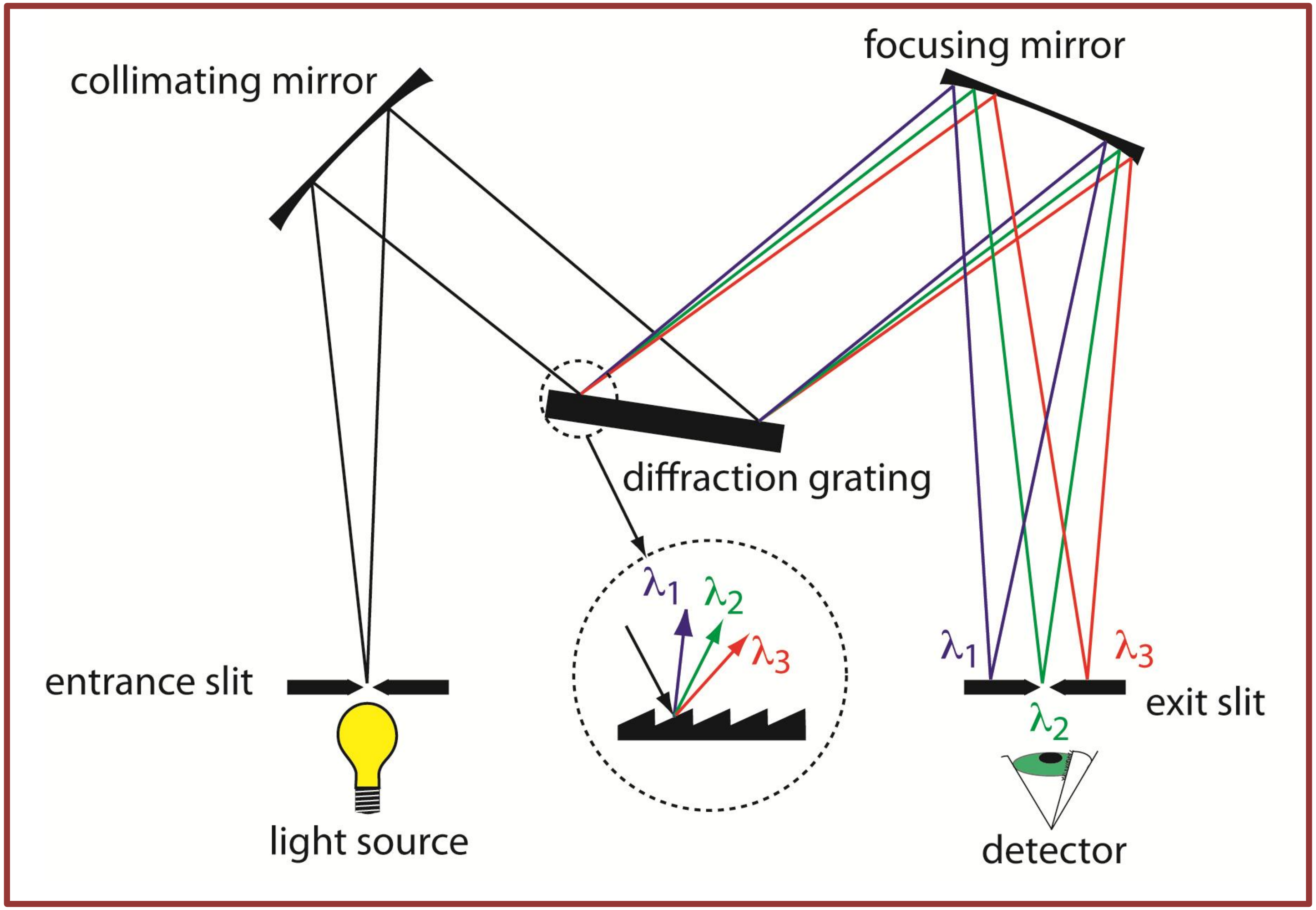
http://www.newport.com/Grating-Physics/383720/1033/content.aspx

http://en.wikipedia.org/wiki/Diffraction_grating

Monochromator

$$m\lambda = d\,(\sin\alpha + \sin\beta)$$

Where m is the diffraction order and d is the groove spacing.



Diffraction Order, m

$$m\lambda = d\,(\sin\alpha + \sin\beta)$$

Where m is the diffraction order and d is the groove spacing.

What is a typical value for *d*, the groove spacing?

Our grating is ruled with a groove density of 1200 g/mm, so what's the value of d?

http://en.wikipedia.org/wiki/Diffraction_grating

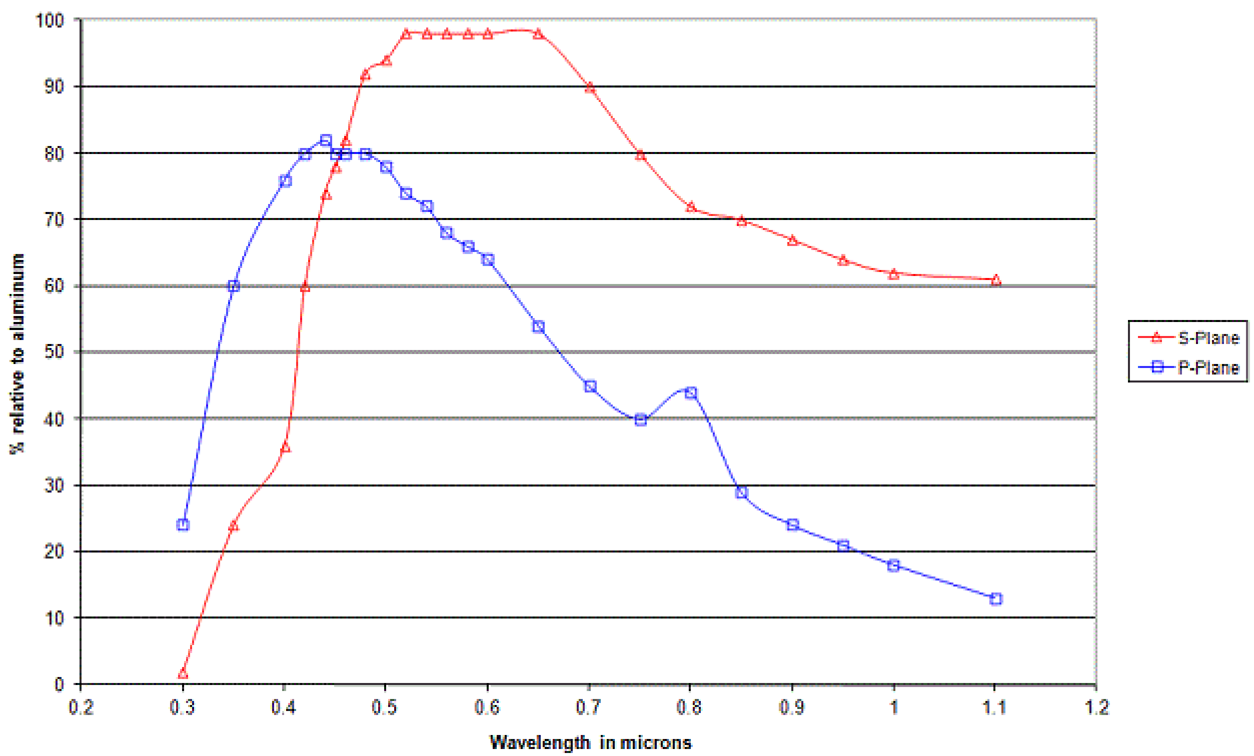
Diffraction Grating Efficiency

DIFFRACTION GRATING SPECIFICATION SHEET

Catalog no.	**53-*-280R**	8/27/2013
Grating Description	1200 g/mm plane ruled reflection grating with 17.5° nominal blaze angle	
Master no.	1597	
Maximum Ruled Area:	groove length:	154 mm
	ruled width:	206 mm

Efficiency Curve	spectral order:	m = 1	polarization(s):	S and P
	Coating:	aluminum		
Remarks				

1597-1, 1200 g/mm, 500 nm, 17.5 deg., M=1, Cat# 53-*-280, Plane ruled, Max RA 154 x 206 mm



Reciprocal Linear Dispersion (RLD)

Light dispersed at the output slit of the monochromator will show a linear dispersion of wavelengths with position across the slit.

Notice that when you are using the largest 2.4 mm slits, that when you set the monochromator wavelength to 500 nm, the output looks more blue on one end (shorter wavelengths), and more yellow on the other side (longer wavelengths).

For the CM 110 monochromator, the RLD is ***<u>6.52 nm/mm</u>***.

Therefore, when using the 0.15 mm slits, the spectral band pass of the CM 110 is:

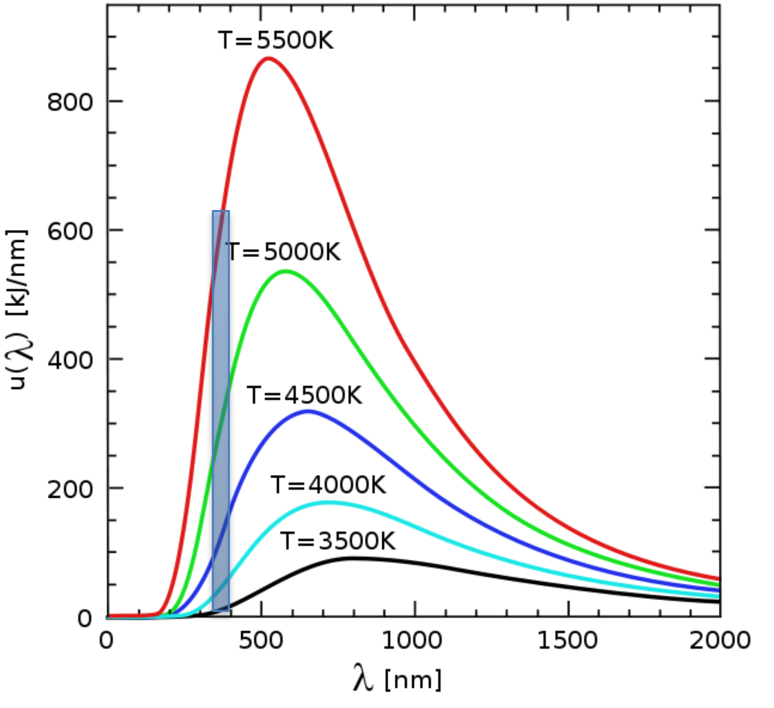
$$\Delta\lambda = (6.52\ nm/mm) * 0.15\ mm = 0.978\ nm$$

More generally, the spectral bandwidth of the monochromator is given by the product of the RLD and the largest (entrance and exit) slit width:

$$\Delta\lambda = RLD * W_{slit}$$

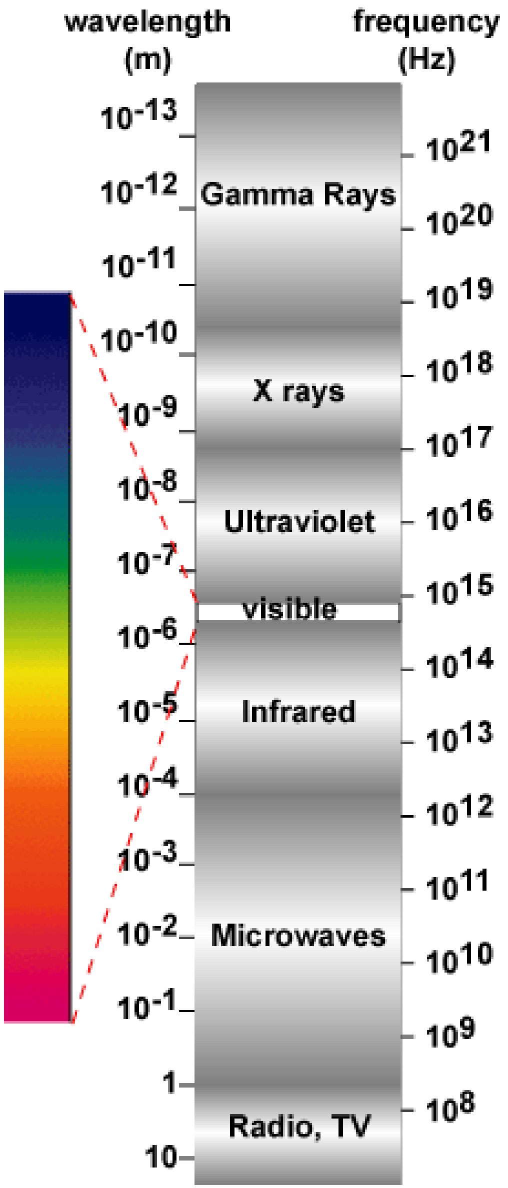
This Lab - Characterize Combined lamp/monochromator output at the sample (detector) location

- Single measurements as f(λ)
- Step through wavelengths
- Also a function of the slit-width:
  - Smaller slits, less photons
  - Larger slits, more photons



Question: How many Watts (or Joules, or Photons/s)/nm are incident at the sample plane (i.e. the detector)?

Photon Energy and Photon Flux



http://www.pveducation.org

Thermopile measure Watts:

$$1 \text{ W} = 1 \text{ J/s} = 6.24 \times 10^{18} \text{ eV/s}$$

Energy of a photon: $E = \frac{hc}{\lambda}$

Convenient relation: $E = \frac{1.24}{\lambda(\mu m)}$ (E in eV)

Definition of photon flux: $\Phi = \frac{\#\ of\ photons}{\sec m^2}$

Spectral irradiance can be expressed in units of:

$W/(m^2\text{-}nm)$

or $eV/(s\text{-}m^2\text{-}nm)$

or # of photons/$(s\text{-}m^2\text{-}nm)$

Where:

- The m^2 term refers to the area on which the photons are incident (we will neglect this term for now).
- The nm term refers to the band-pass width (which depends on the slit width).