Lecture and Lab #2
Characterization of Spectral output of Light Source

R.J. Ellingson and M.J Heben

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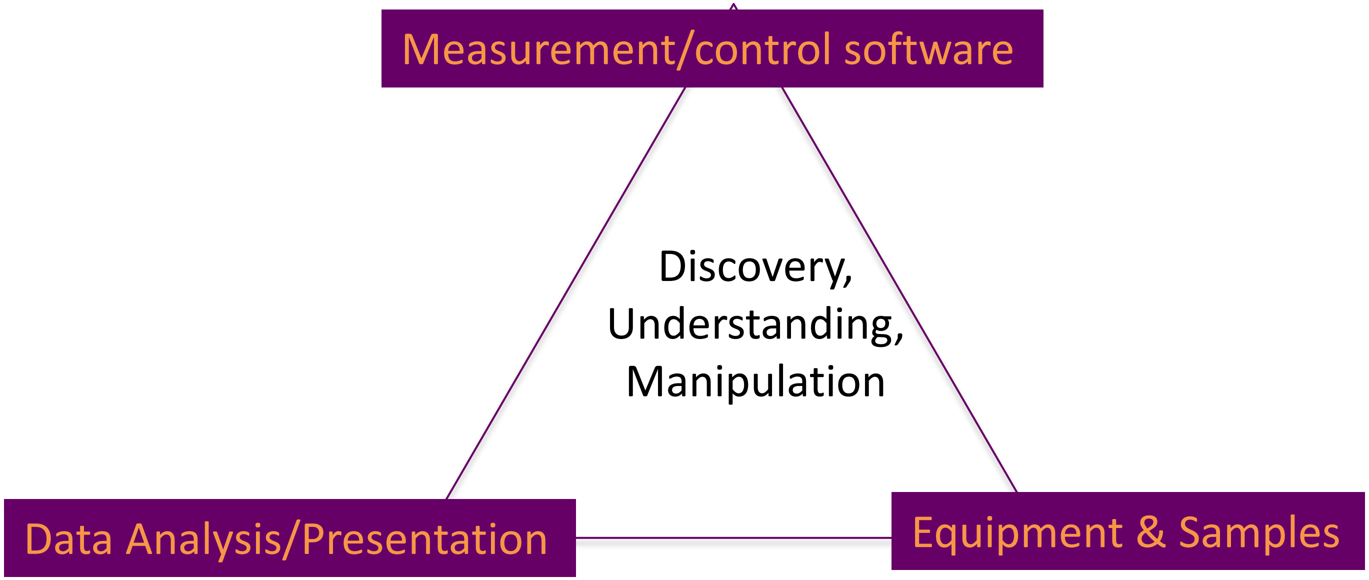
PHYS 4580, 6280, and 7280

Last week

- Exercise to introduce students to:
  - LabVIEW (Measurement/control)
  - Igor Pro (Analysis/Presentation)
  - Optical measurement experimental Set-up.
- Time constant of Thermopile Detector



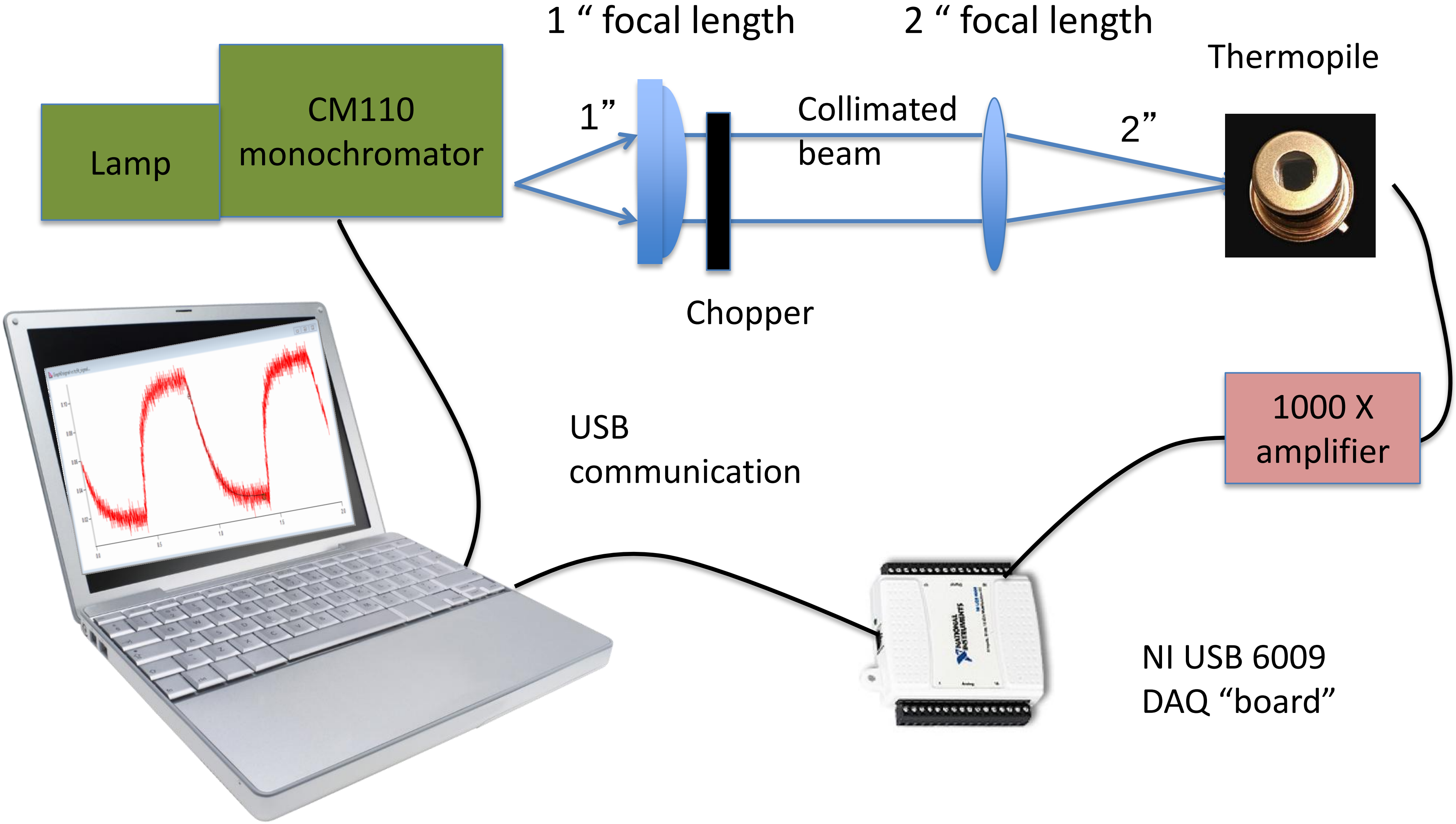
Measurement/control software

Discovery,
Understanding,
Manipulation

Data Analysis/Presentation

Equipment & Samples

Response time of the thermopile (at one wavelength)



1 “ focal length

2 “ focal length

Thermopile

Lamp

CM110 monochromator

1”

Collimated beam

2”

Chopper

USB communication

1000 X amplifier

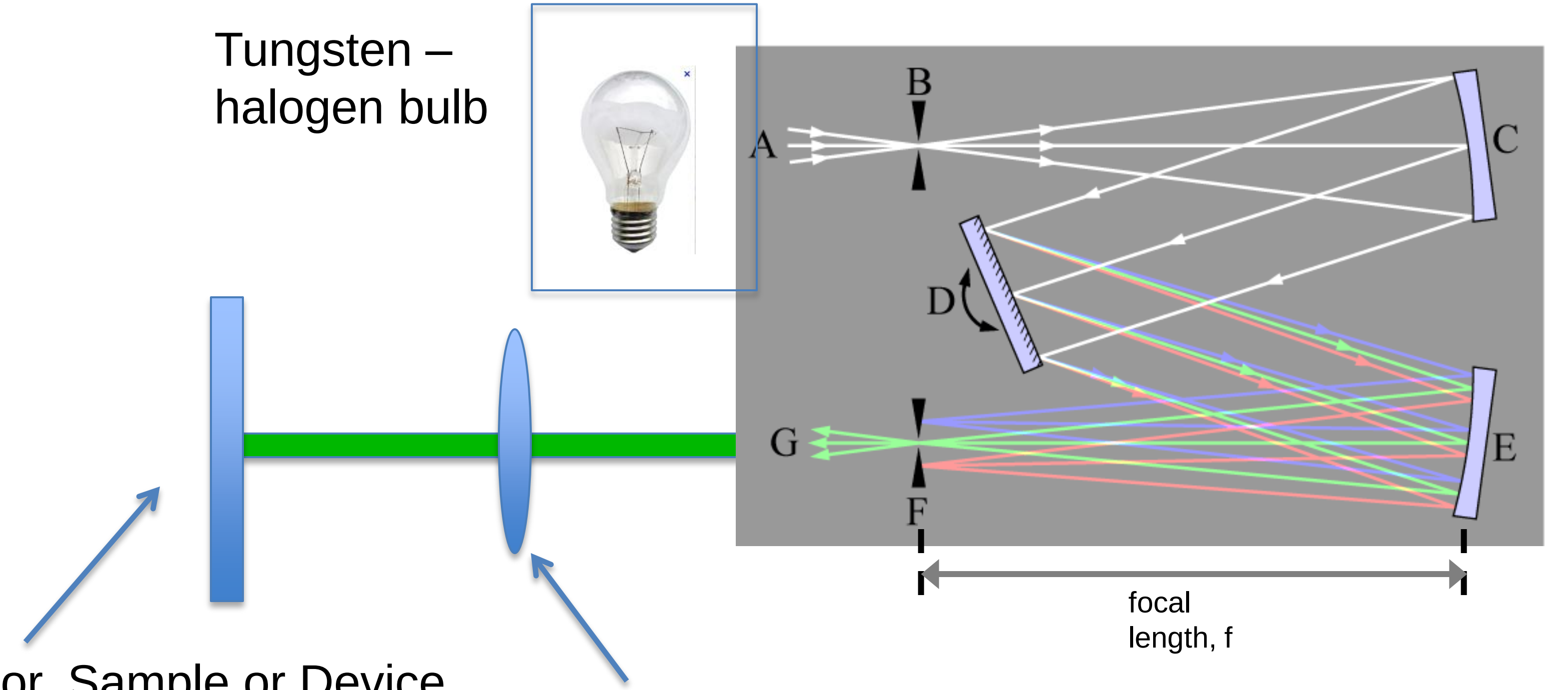
NI USB 6009 DAQ “board”

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

Thermopile Detector

A thermopile is an electronic device that converts thermal energy into electrical energy. It is composed of several thermocouples connected usually in series or, less commonly, in parallel.

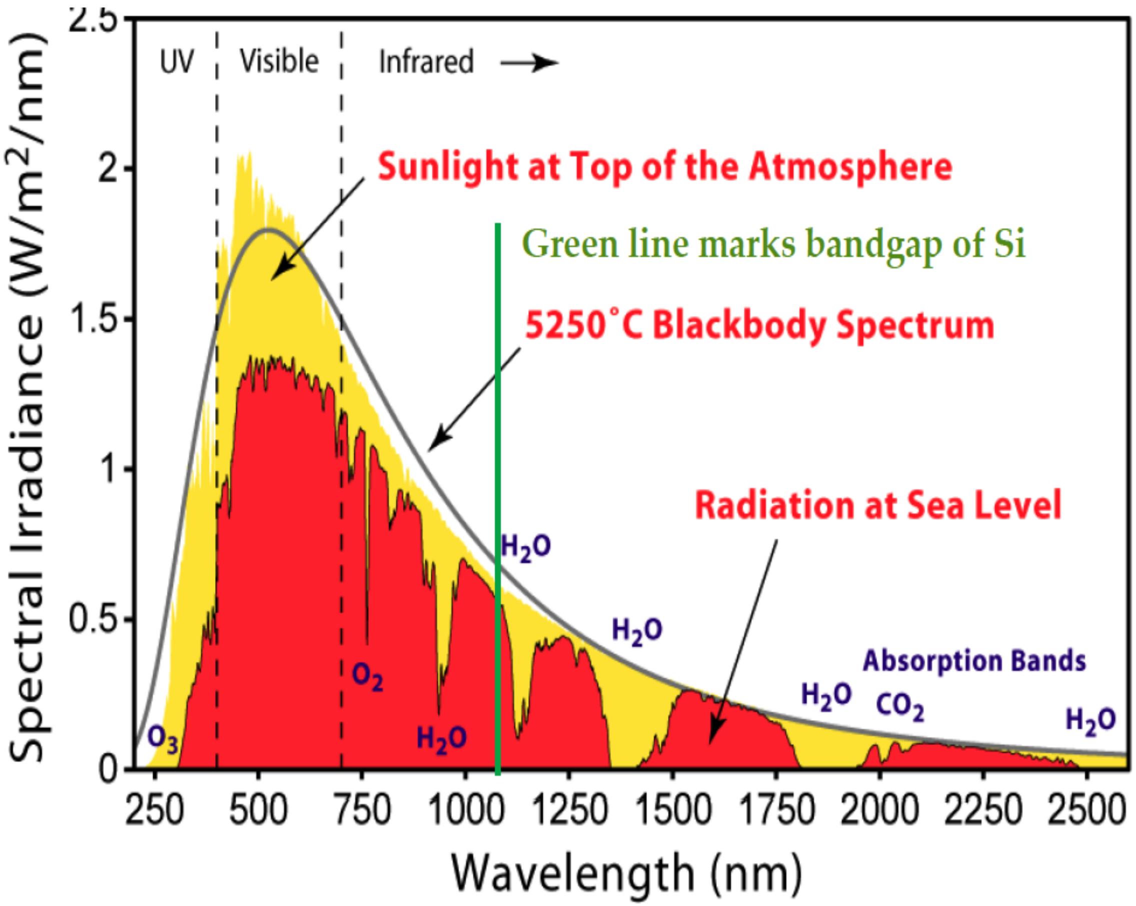
Dexter 2M detector

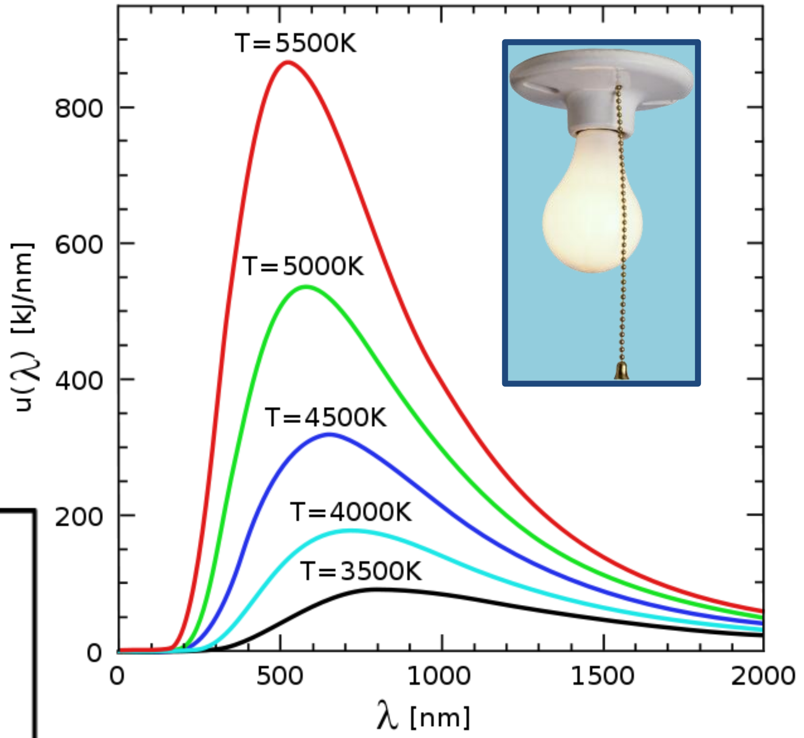
Thermopiles do not respond to absolute temperature, but generate an output voltage proportional to a local temperature difference or temperature gradient.

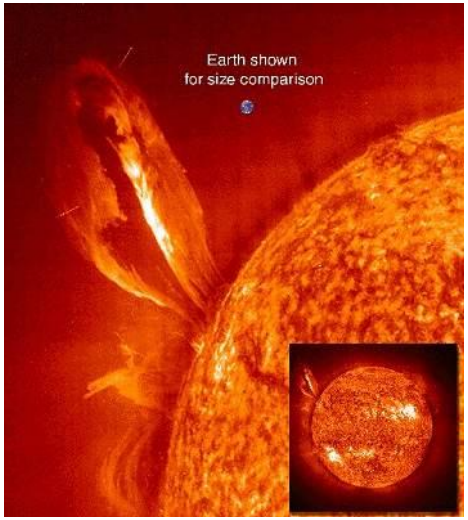
Thermopiles are often used to provide a voltage output in response to temperature as part of a temperature measuring device, such as the infrared thermometers widely used by medical professionals to measure body temperature. They are also used widely in heat flux sensors. The output of a thermopile is usually in the range of tens or hundreds of millivolts.

After *Wikipedia and Dexter Research*

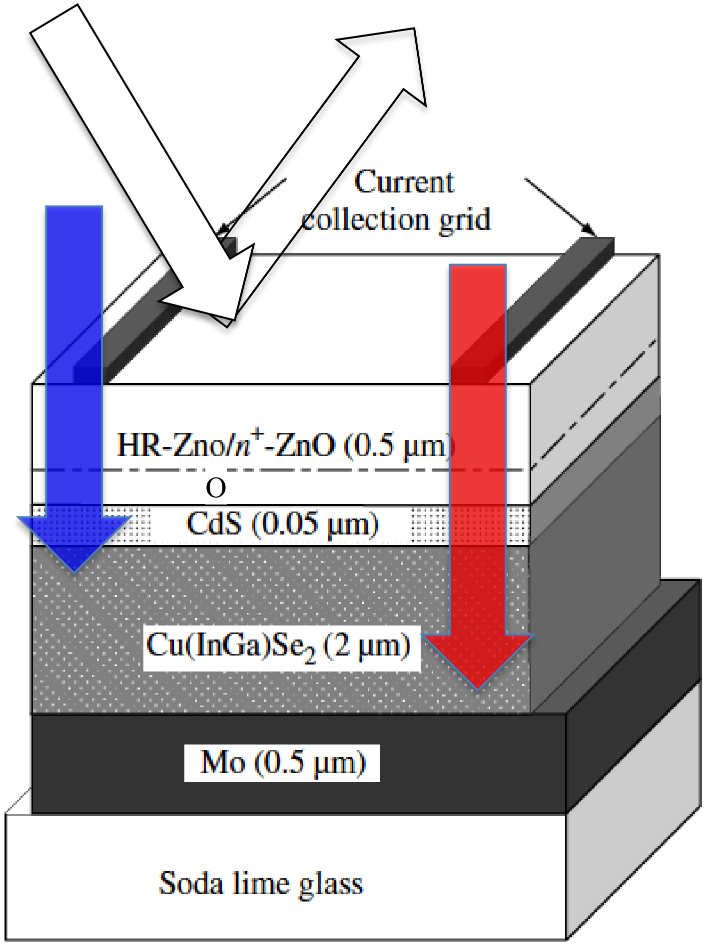
Our Sun, and other Blackbody light sources, emit more than one wavelength of light.



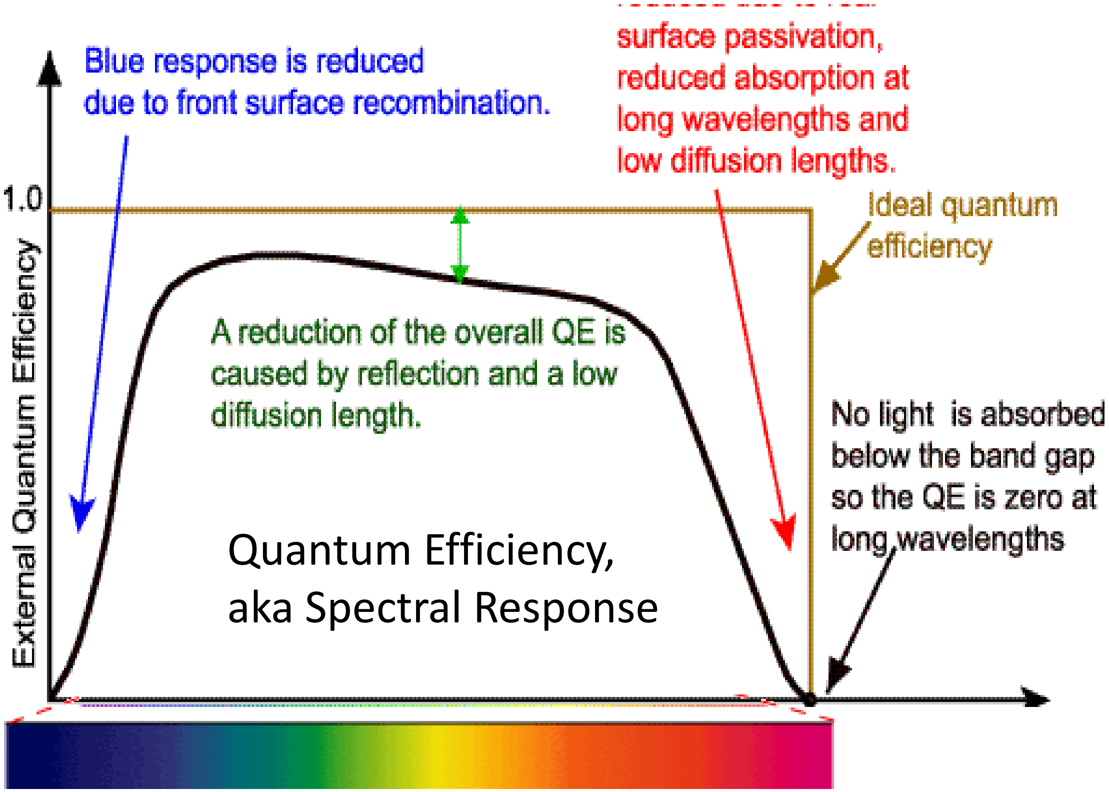




Wavelength Dependent Response of PV Materials and Devices



Schematic cross section of a typical Cu(InGa)Se_2 solar cell



Blue response is reduced due to front surface recombination.

surface passivation, reduced absorption at long wavelengths and low diffusion lengths.

Ideal quantum efficiency

A reduction of the overall QE is caused by reflection and a low diffusion length.

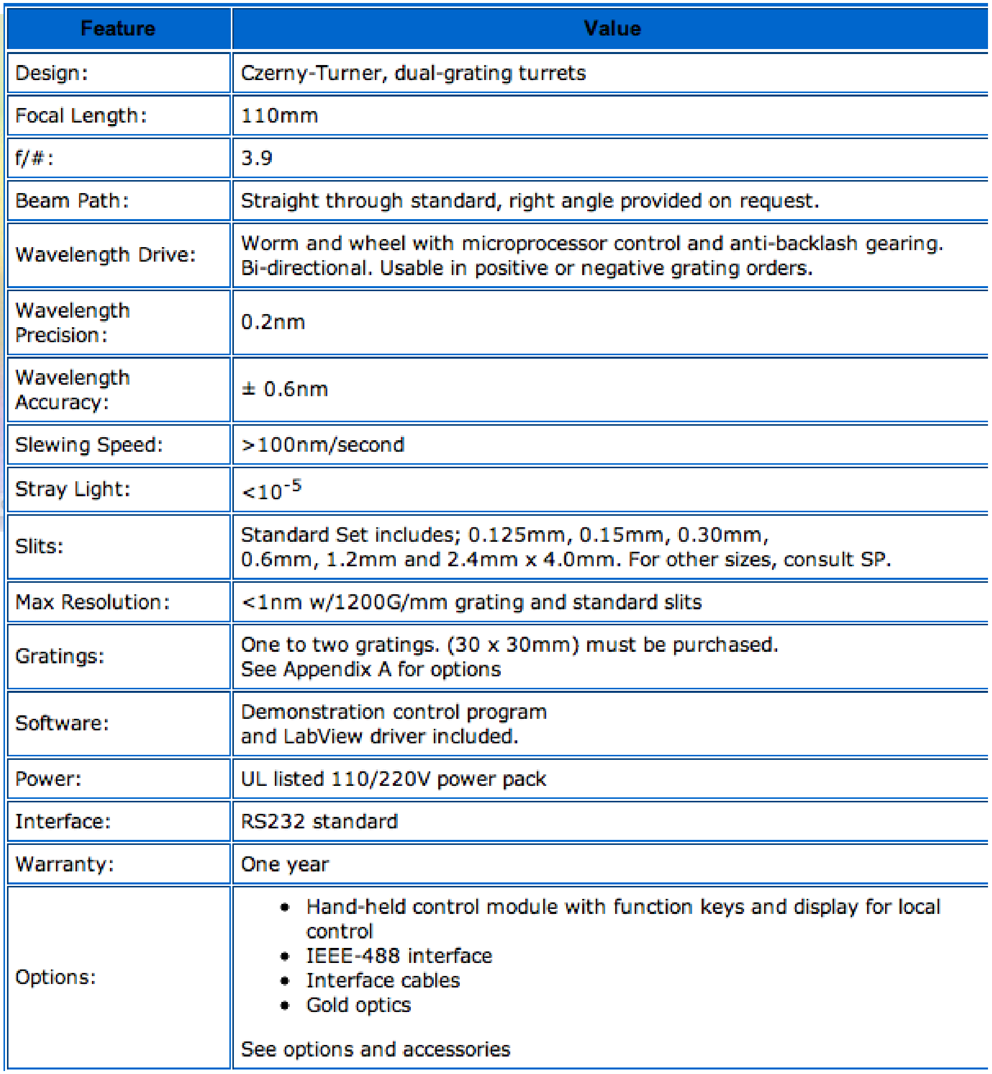
No light is absorbed below the band gap so the QE is zero at long wavelengths

Quantum Efficiency, aka Spectral Response

From "Cu(InGa)Se_2 Solar Cells", by Shafarman and Stolt and *PVEducation.org*

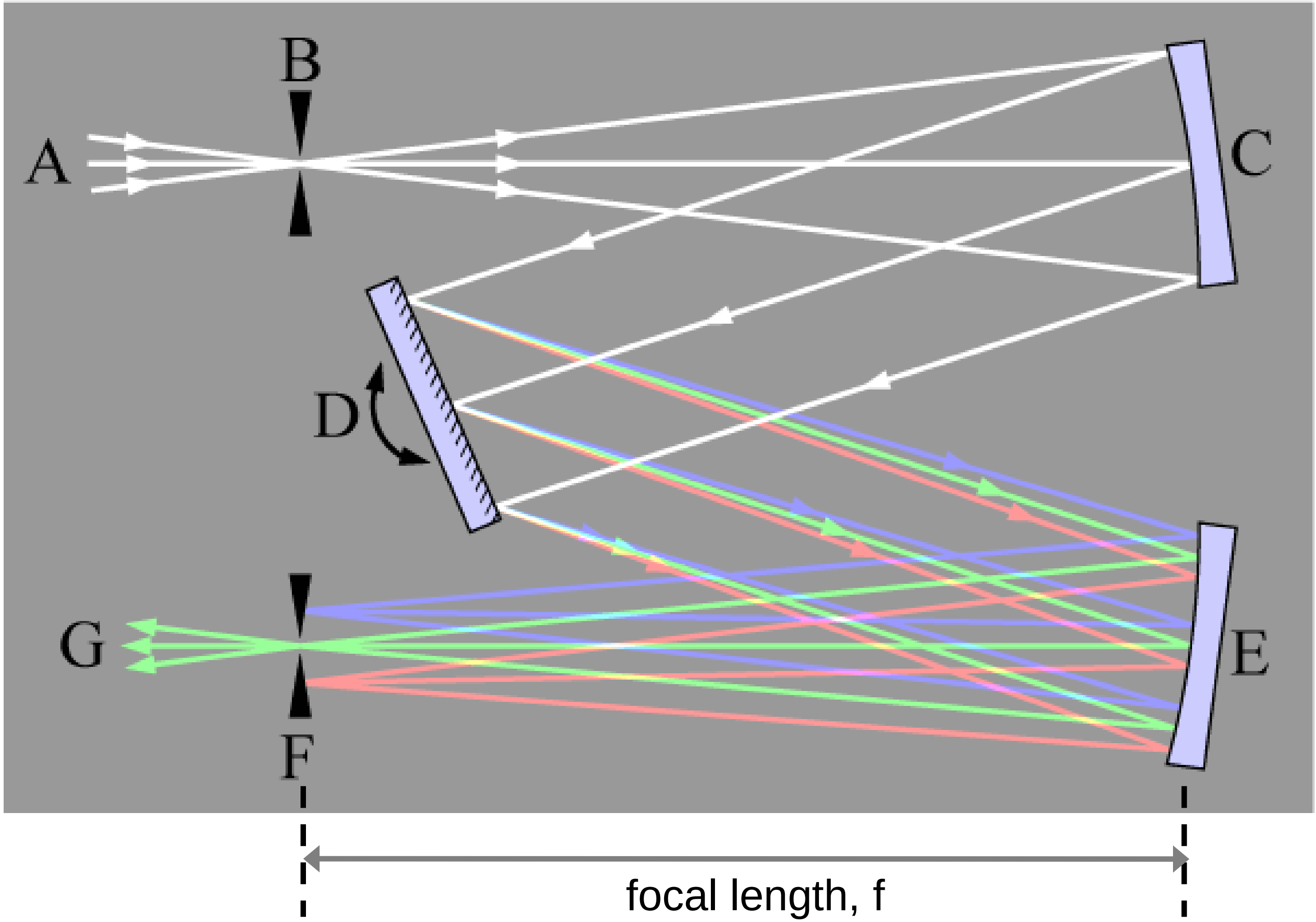
Spectral Products, CM110 1/8th meter monochromator

Serial commands sent from computer to CM110 via USB



Feature	Value
Design:	Czerny-Turner, dual-grating turrets
Focal Length:	110mm
f/#:	3.9
Beam Path:	Straight through standard, right angle provided on request.
Wavelength Drive:	Worm and wheel with microprocessor control and anti-backlash gearing. Bi-directional. Usable in positive or negative grating orders.
Wavelength Precision:	0.2nm
Wavelength Accuracy:	± 0.6nm
Slewing Speed:	>100nm/second
Stray Light:	$<10^{-5}$
Slits:	Standard Set includes; 0.125mm, 0.15mm, 0.30mm, 0.6mm, 1.2mm and 2.4mm x 4.0mm. For other sizes, consult SP.
Max Resolution:	<1nm w/1200G/mm grating and standard slits
Gratings:	One to two gratings. (30 x 30mm) must be purchased. See Appendix A for options
Software:	Demonstration control program and LabView driver included.
Power:	UL listed 110/220V power pack
Interface:	RS232 standard
Warranty:	One year
Options:	• Hand-held control module with function keys and display for local control • IEEE-488 interface • Interface cables • Gold optics See options and accessories

Czerny-Turner Monochrometer

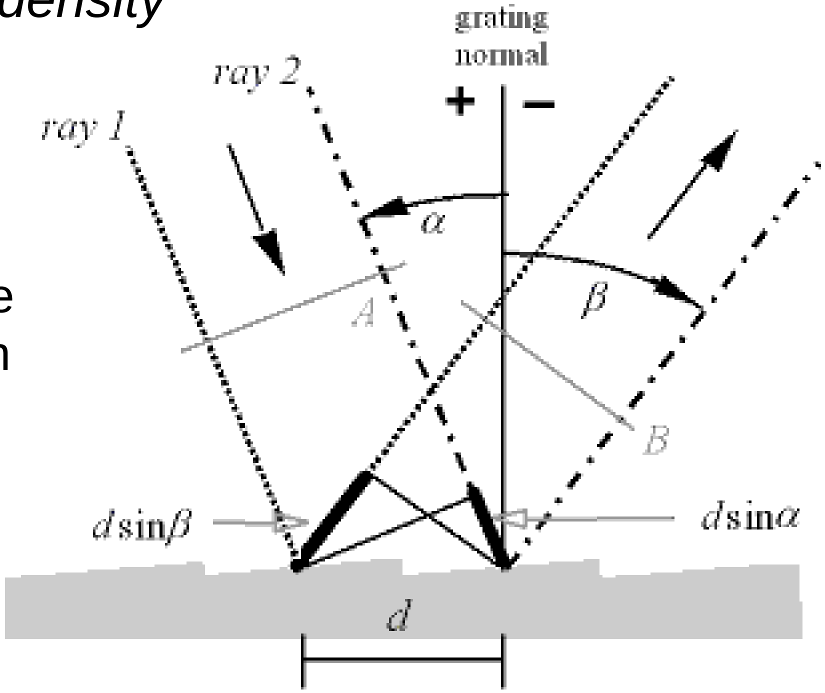


Constructive Interference and the Grating Equation

$m\lambda = d(\sin\alpha + \sin\beta)$; or $Gm\lambda = \sin\alpha + \sin\beta$

Where m is the diffraction order and G = 1/d is the groove frequency or density

Reflective diffraction grating



$\mathrm{Sin}(\beta) = -\mathrm{Sin}(-\beta)$

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://gratings.newport.com/information/handbook/chapter2.asp#2.2

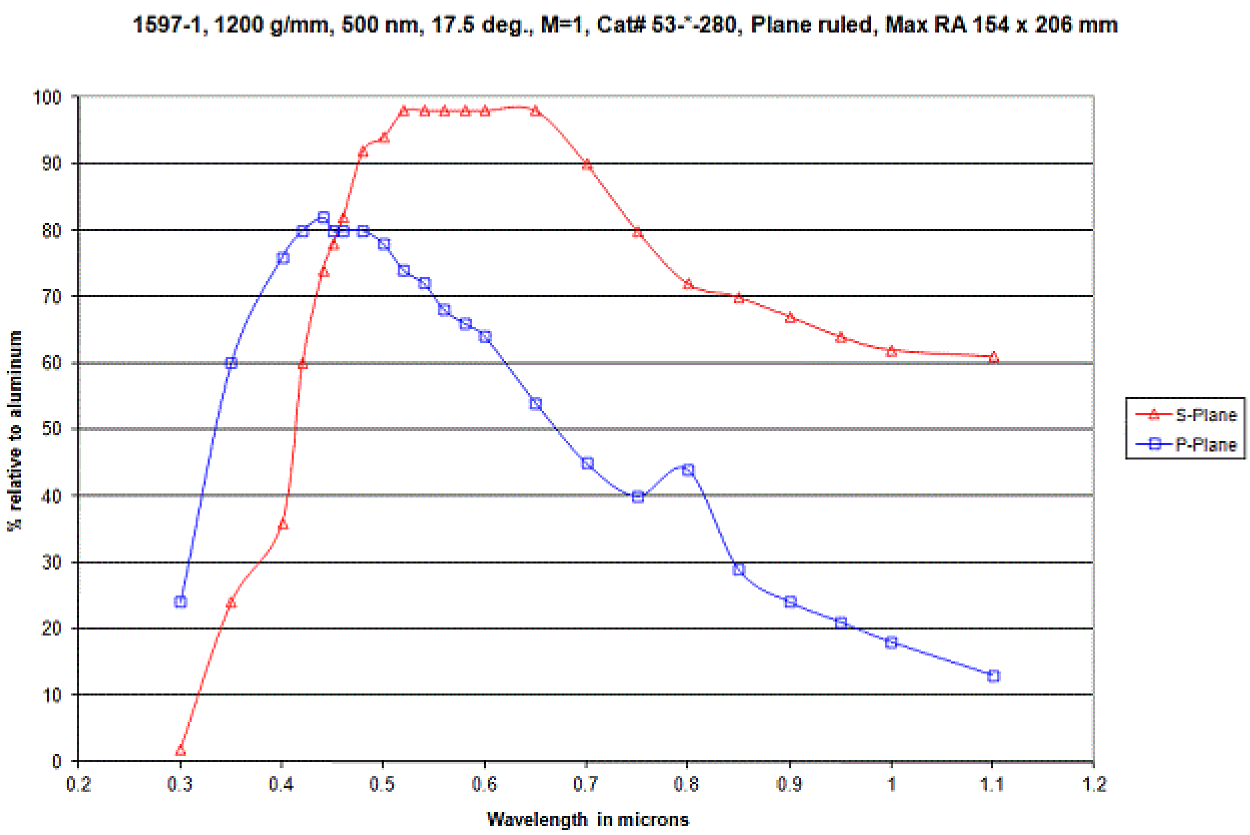
http://www.pariss-hyperspectral-imaging.com/GratingOrders_Movie/GratingOrders_Movie.html

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 6.52 nm/mm.

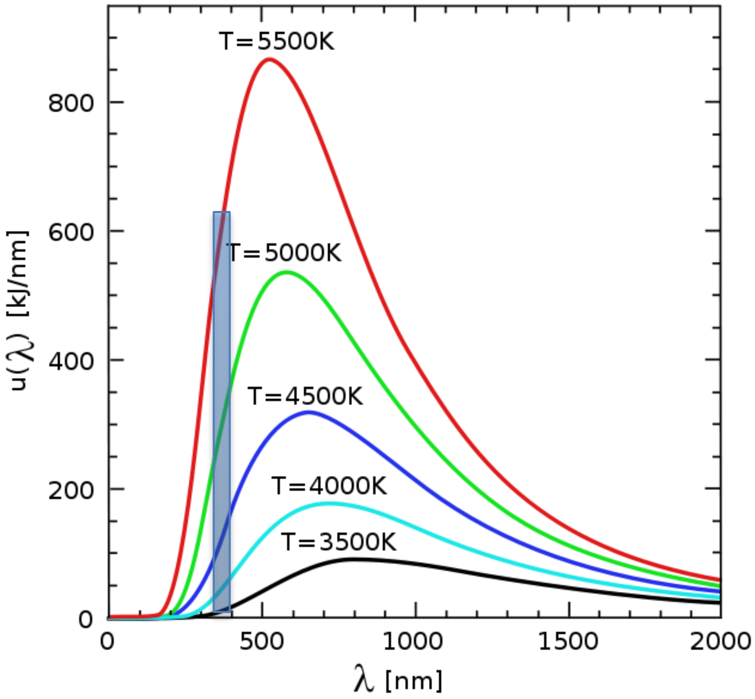
Therefore, when using the 0.15 mm slits, the spectral band pass of the CM 110 is:

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

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

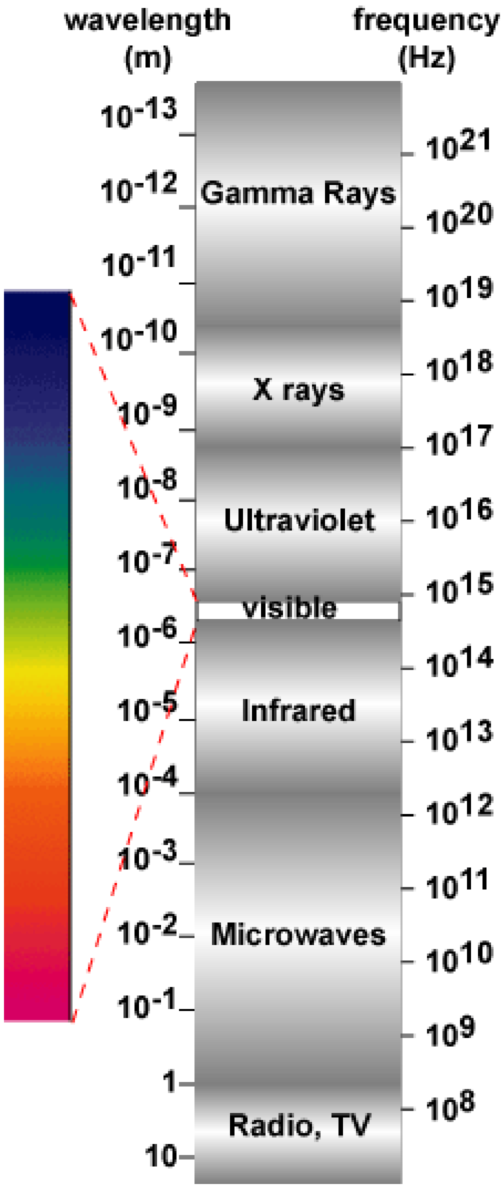
- Single measurements as f(λ)
- Step through wavelengths
- Also a function of the slit-width:

  - 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:

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

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

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

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

Spectral irradiance can be expressed in units of:

W/(m^2-nm)

or eV/(s-m^2-nm)

or # of photons/(s-m^2-nm)

Where:

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

LabVIEW Training Videos

http://www.ni.com/academic/students/learn/