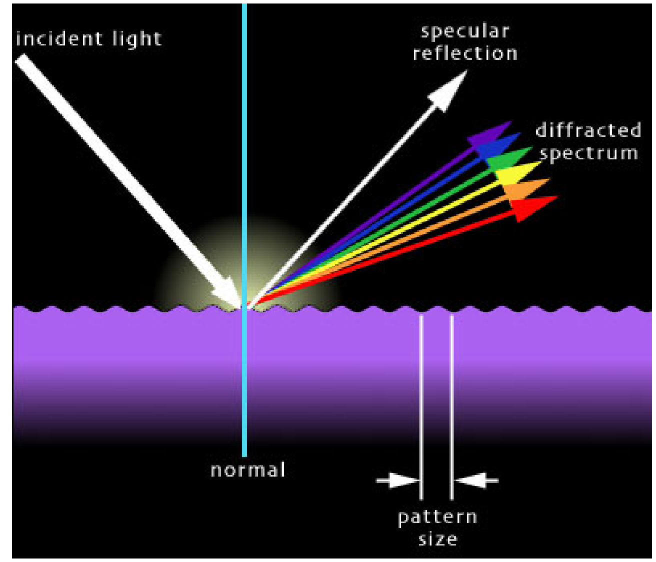
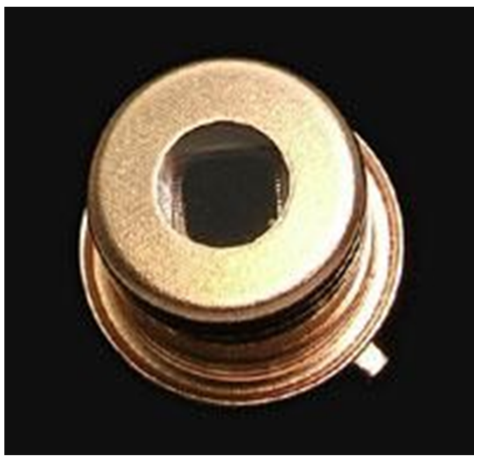
Grating Spectrometers, Thermopile Detectors, and Lock-In Detection

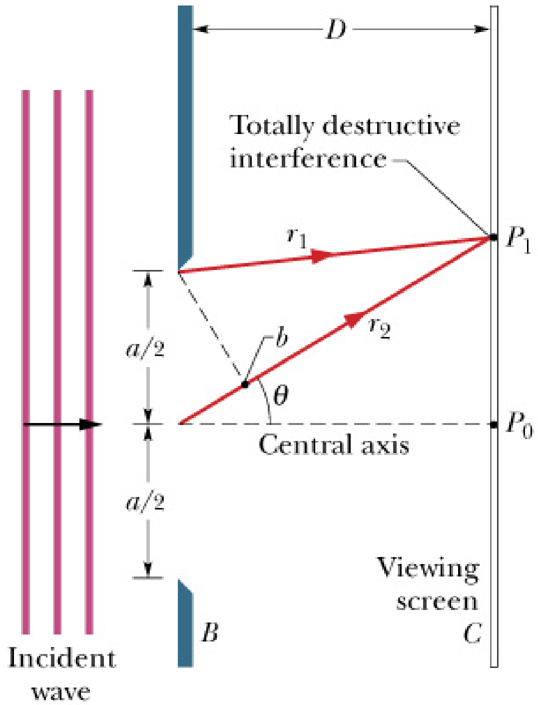


September 13, 2011

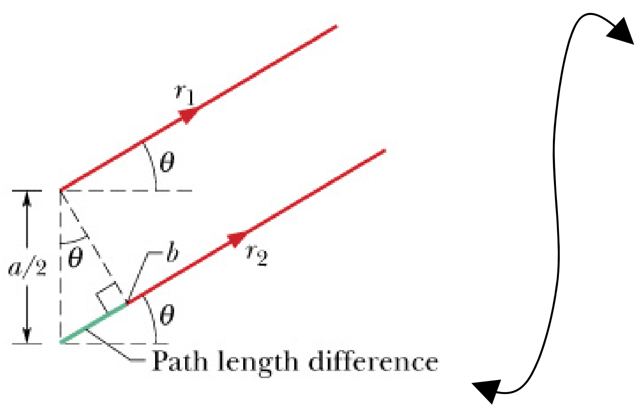


The University of Toledo
R. Ellingson and M. Heben

Diffraction by a Single Slit: Locating the *Minima*



(*a*)



(*b*)

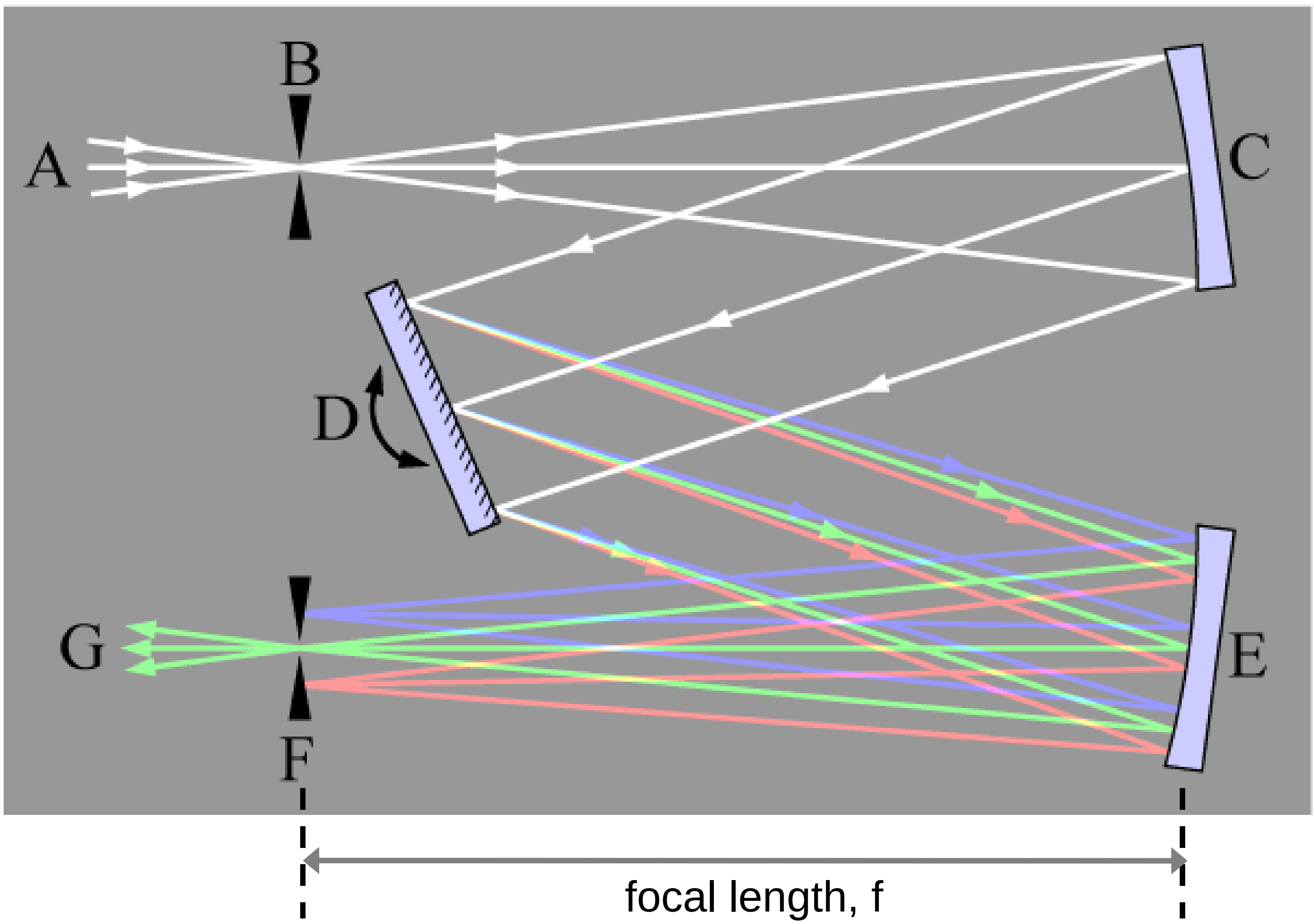
When the path length difference between rays r_1 and r_2 is $\lambda/2$, the two rays will be out of phase when they reach P_1 on the screen, resulting in destructive interference at P_1. The path length difference is the distance from the starting point of r_2 at the center of the slit to point *b*.

For $D \gg a$, the path length difference between rays r_1 and r_2 is $(a/2) \sin\theta$.

Spectral Products, CM110 1/8th meter monochromator

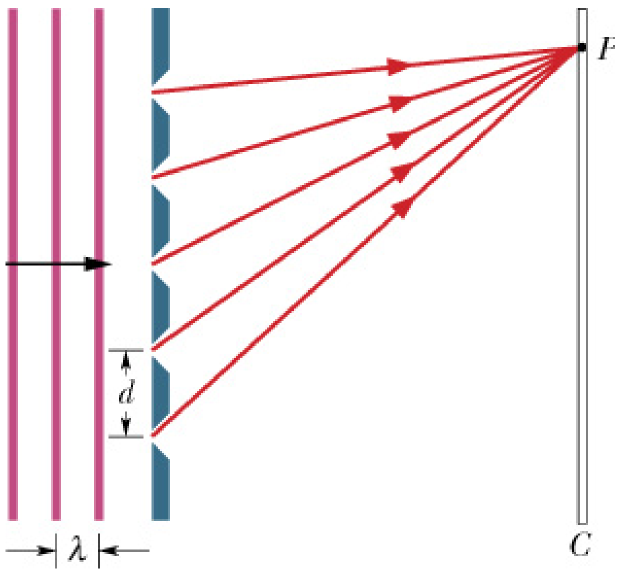
Feature	Value
Design:	Czerny-Turner, dual-grating turrets
Focal Length:	110mm
f/#:	3.9
Beam Path:	Straight through standard, right angle provided on request.
Wavelength Drive:	Worm and wheel with microprocessor control and anti-backlash gearing. Bi-directional. Usable in positive or negative grating 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

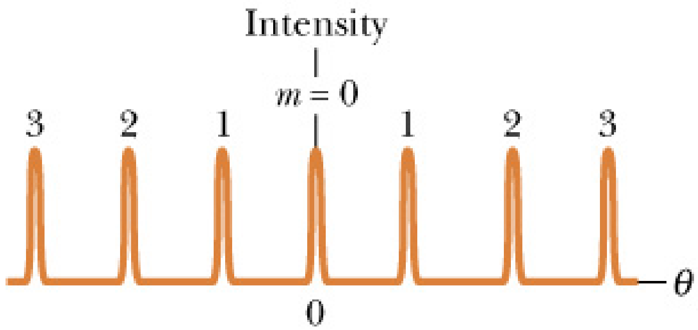
Czerny-Turner Monochrometer



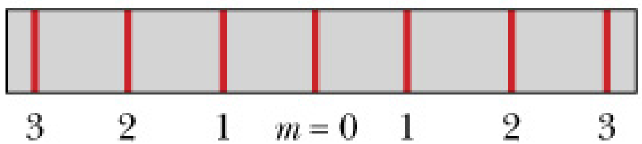
Diffraction Gratings

Device with *N* slits (rulings) can be used to separate different wavelengths of light that are contained in a single beam. How does a diffraction grating affect monochromatic light?





(a)

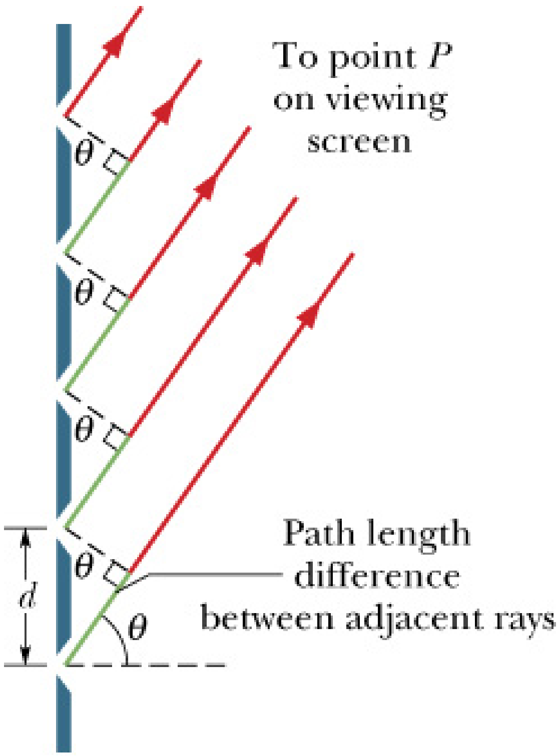


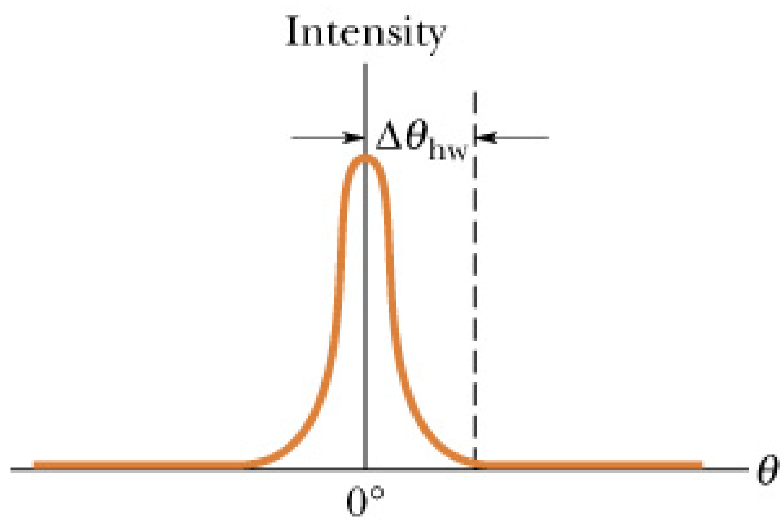
(b)

$$d \sin\theta = m\lambda \quad \text{for } m = 0, 1, 2\ldots \quad \text{(maxima-lines)}$$

Width of Lines

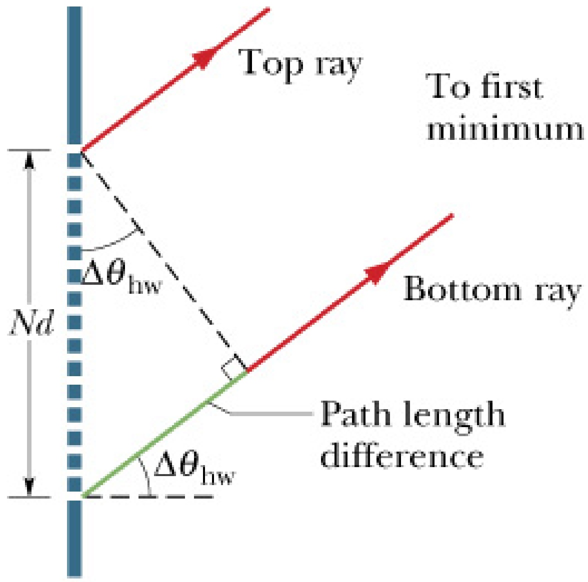
The ability of the diffraction grating to resolve (separate) different wavelengths depends on the width of the lines (maxima)





Width of Lines, cont'd

A wave is roughly defined as any longitudinal wave (energy moving along the direction of wave propagation).



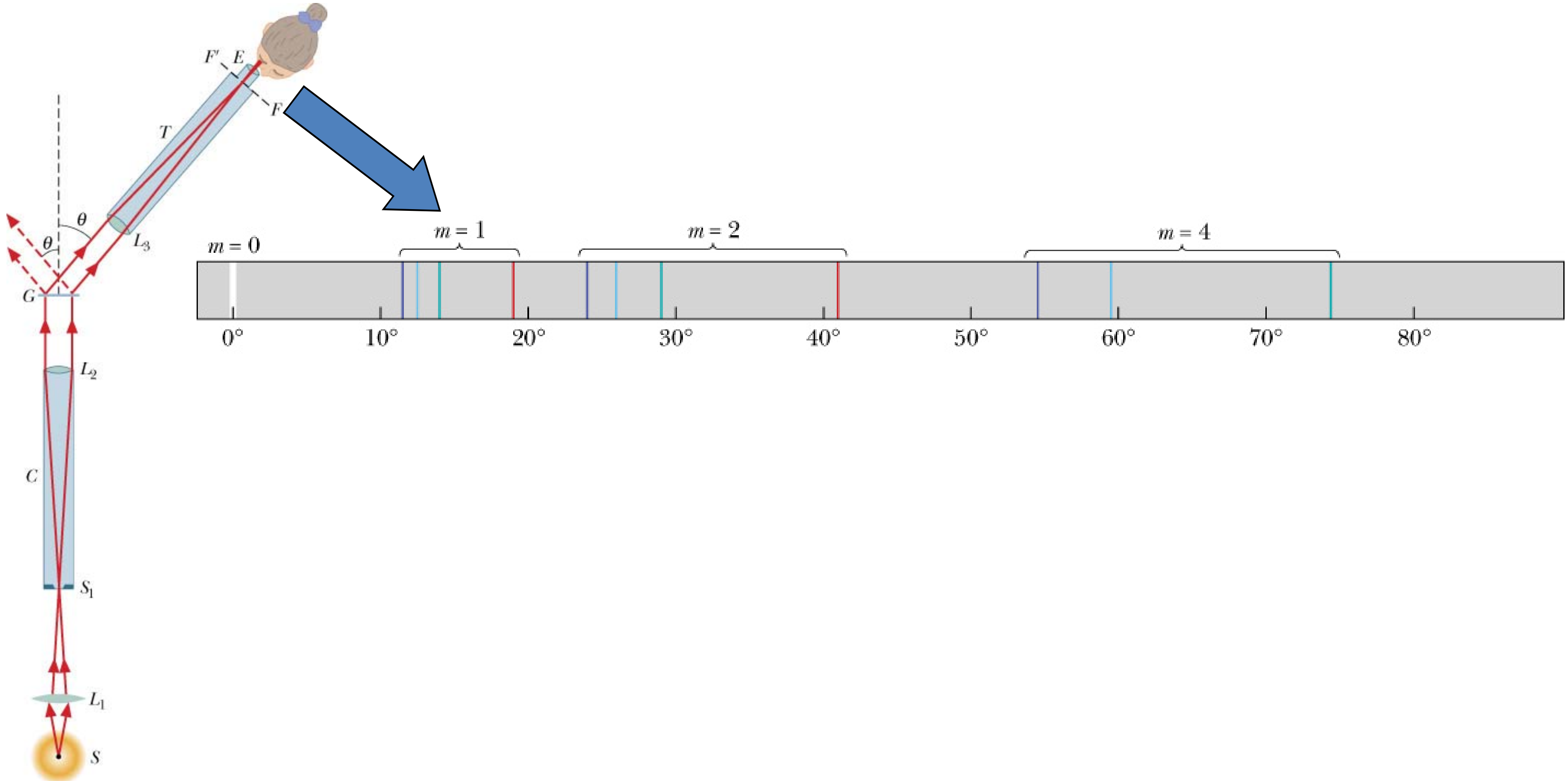
$$Nd \sin \Delta\theta_{\text{hw}} = \lambda \quad , \qquad \sin \Delta\theta_{hw} \approx \Delta\theta_{hw}$$

$$\Delta\theta_{\text{hw}} = \frac{\lambda}{Nd} \quad \text{(half width of central line)}$$

$$\Delta\theta_{\text{hw}} = \frac{\lambda}{Nd\cos\theta} \quad \text{(half width of line at } \theta\text{)}$$

Grating Spectroscope

Separates different wavelengths (colors) of light into distinct diffraction lines (this image shows a transmission diffraction grating, while most spectrometers use reflective diffraction gratings).



Grating equation

http://www.cis.rit.edu/class/simg401/DiffractionGratingEquation.pdf

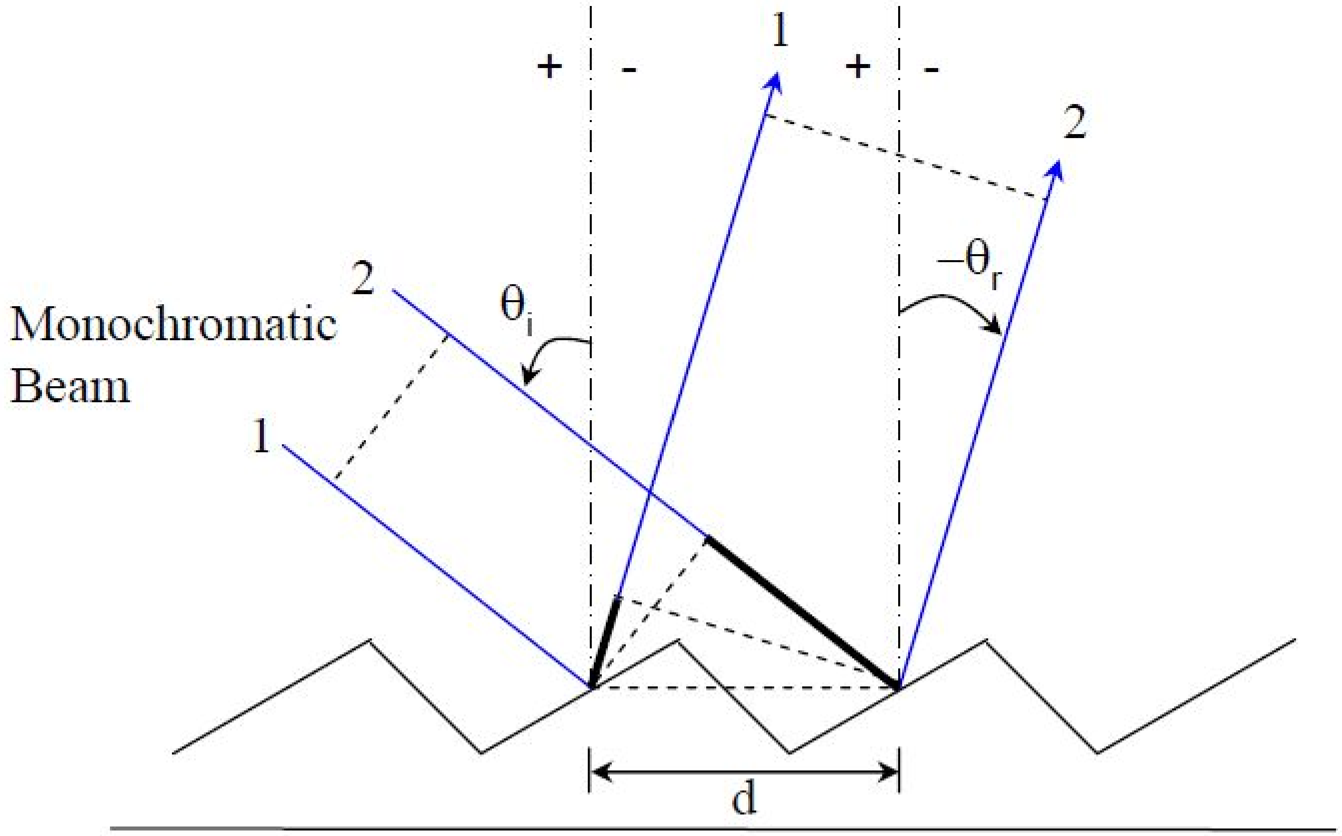
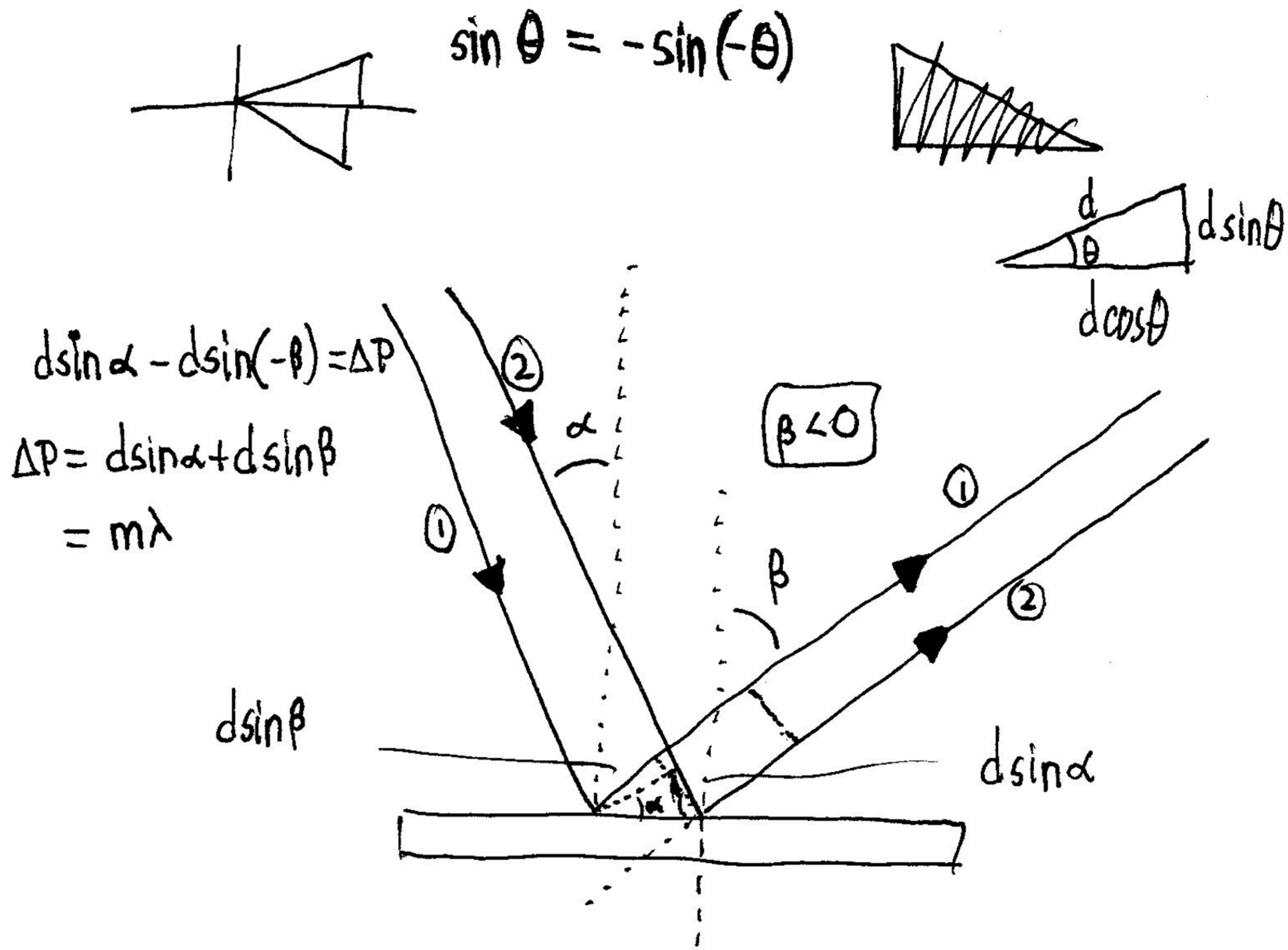


Figure 1: Monochromatic beam incident on (blazed) diffraction grating at angle θ_i and diffracted at angle $-\theta_r$. The blaze spacing is d.

Grating equation



Spectral Products, CM110 1/8th meter monochromator

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

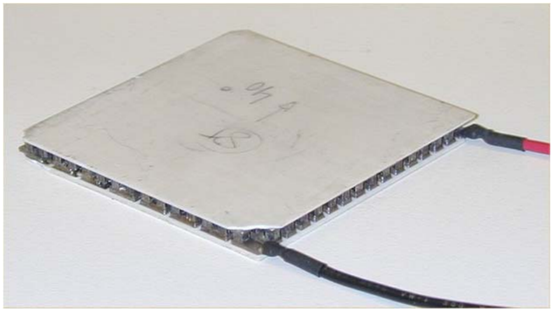
Thermopile Detector

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.

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

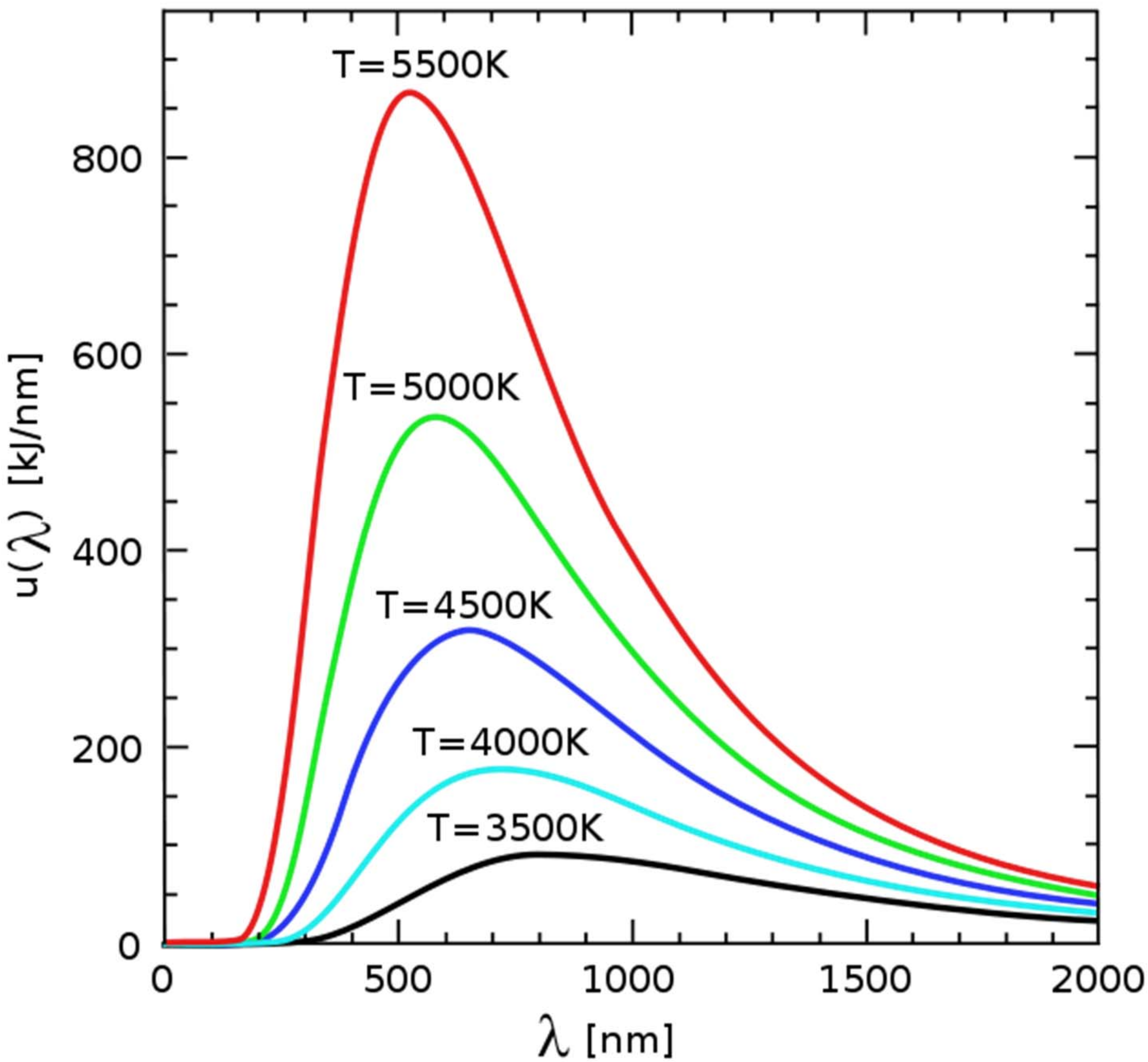
Thermopiles are used to provide an output in response to temperature as part of a temperature measuring device, such as the infrared thermometers widely used by medical professionals to measure body temperature. They are also used widely in heat flux sensors. The output of a thermopile is usually in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

Dexter 2M detector



After *Wikipedia and Dexter Research*

Spectrometer sensitivity calibration: black body radiation, grating efficiency, PMT sensitivity



Goals of this Unit

1)Build an optical set-up to permit development of a LabView program to acquire (directly into the DAQ board), plot, and store signals from the thermopile detector. The detector is to be excited by the chopped output of the CM110 monochromator. Determine the time constant of the detector, and identify the gas used for packaging. Useful resources are under “Effects of Encapsulation Gas on Thermopile Detectors” and “Thermopile Time Constant Determination” at the
http://www.dexterresearch.com/?module=Page&sID=technical-library

2)Acquire plot and store data from the thermopile using the lock-in technique. Compare to data from (1), and understand how the measured voltage relates to the thermopile’s response.

3)Develop a program to measure, plot and store the output of the monochromator, in terms of # of photons/nm, as function of wavelength, for various lamp powers, and several slits widths.

- How does measured spectrum compare to Black Body spectrum?
- How does measured spectrum compare to AM 1.5 spectrum
- Develop a correction file to convert measured spectrum into either BB or AM 1.5 spectrum using Igor Pro.

Resources:

http://gratings.newport.com/information/handbook/toc.asp

http://www.thinksrs.com/products/SR510530.htm

http://www.dexterresearch.com/?module=Page&sID=technical-library