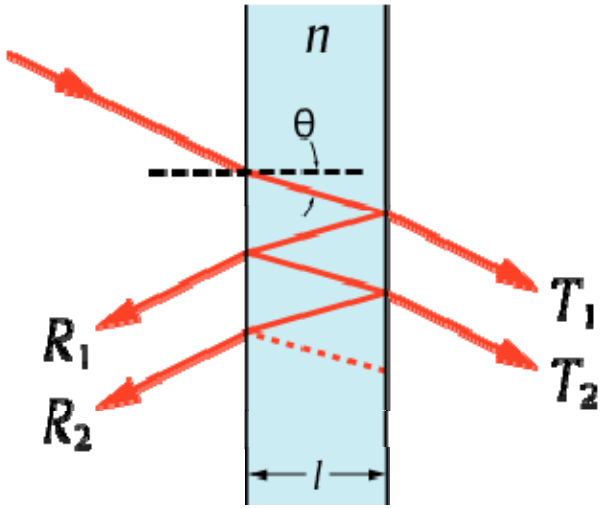
Interferometric Spectroscopy

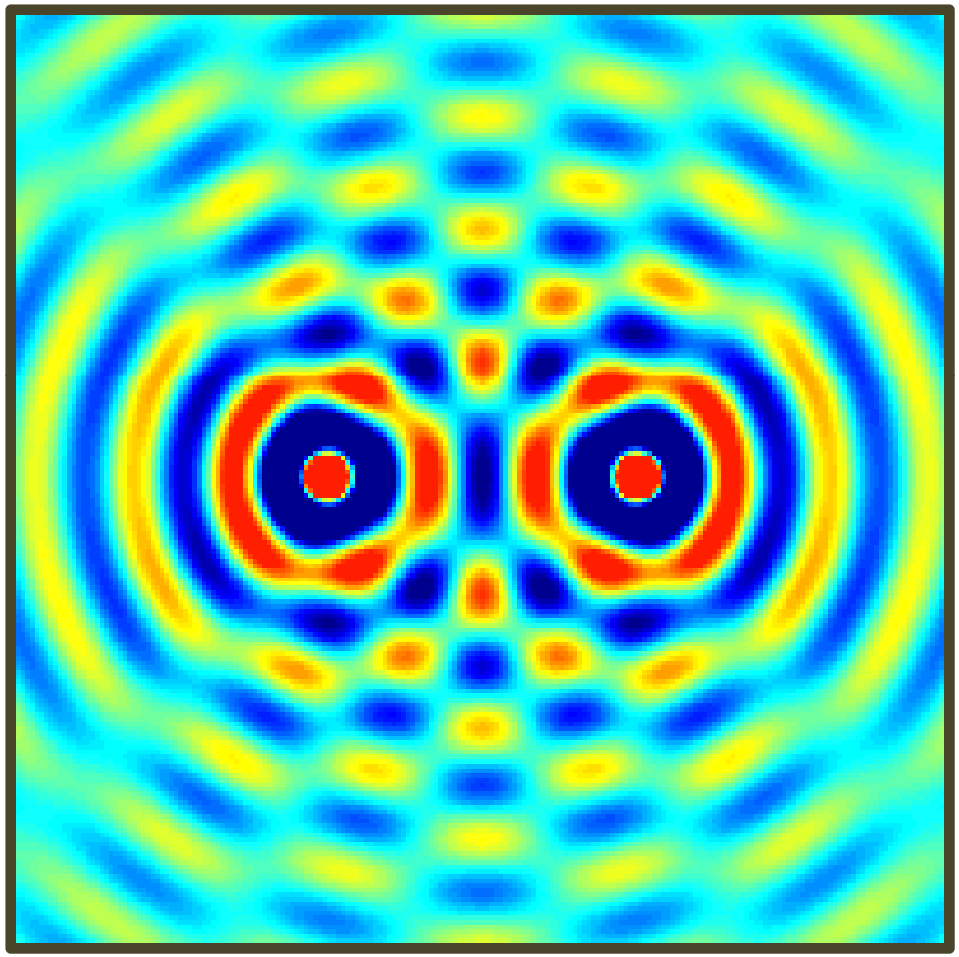
Week of April 5, 2010



Modern Physics Laboratory
(Physics 6180/7180)

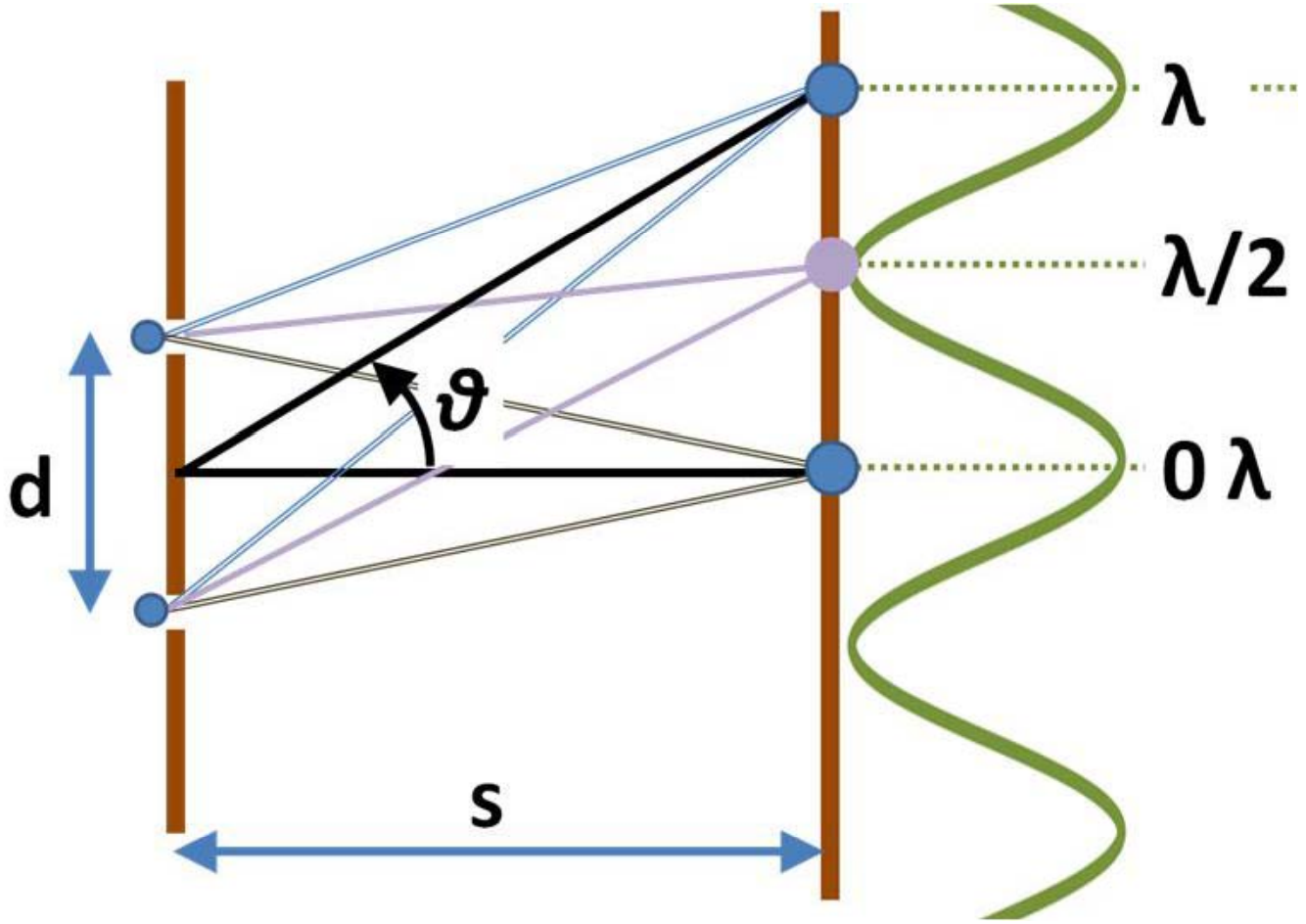
The University of Toledo
Instructor: Randy Ellingson

Interference



http://en.wikipedia.org/wiki/Interference_(wave_propagation)

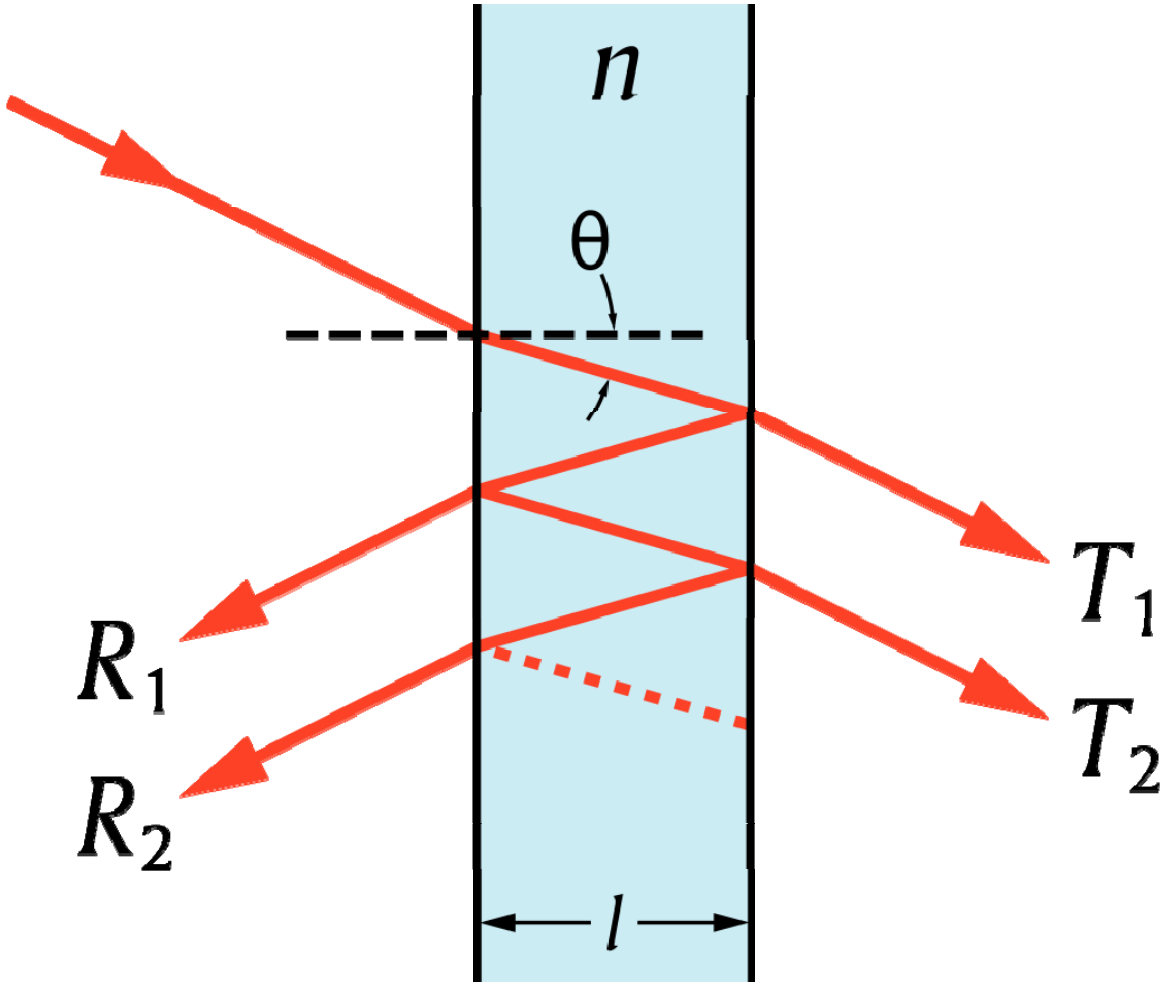
Interference (double-slit)



$$d \sin\theta = m\lambda \qquad d \sin\theta = \left(m + \tfrac{1}{2}\right)\lambda$$

http://en.wikipedia.org/wiki/File:Interferometer_path_differences.JPG

Fabry-Pérot Interferometer



Light enters a Fabry-Perot interferometer and undergoes multiple internal reflections.

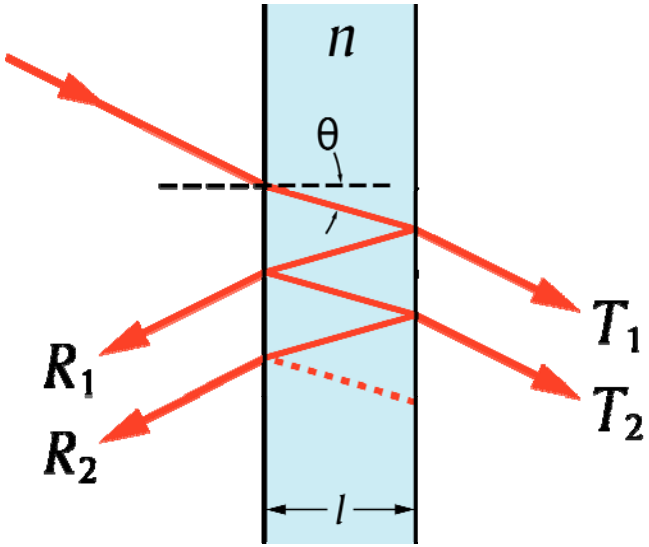
http://en.wikipedia.org/wiki/Fabry%E2%80%93P%C3%A9rot_interferometer

Fabry-Pérot Interferometer

Phase difference between successive reflections off the same surface:

$$\delta = \left(\frac{2\pi}{\lambda}\right) 2nl\cos\theta$$

(optical path difference between successive transmitted beams)



When both reflecting surfaces have reflectance R, the transmission of the etalon is given by:

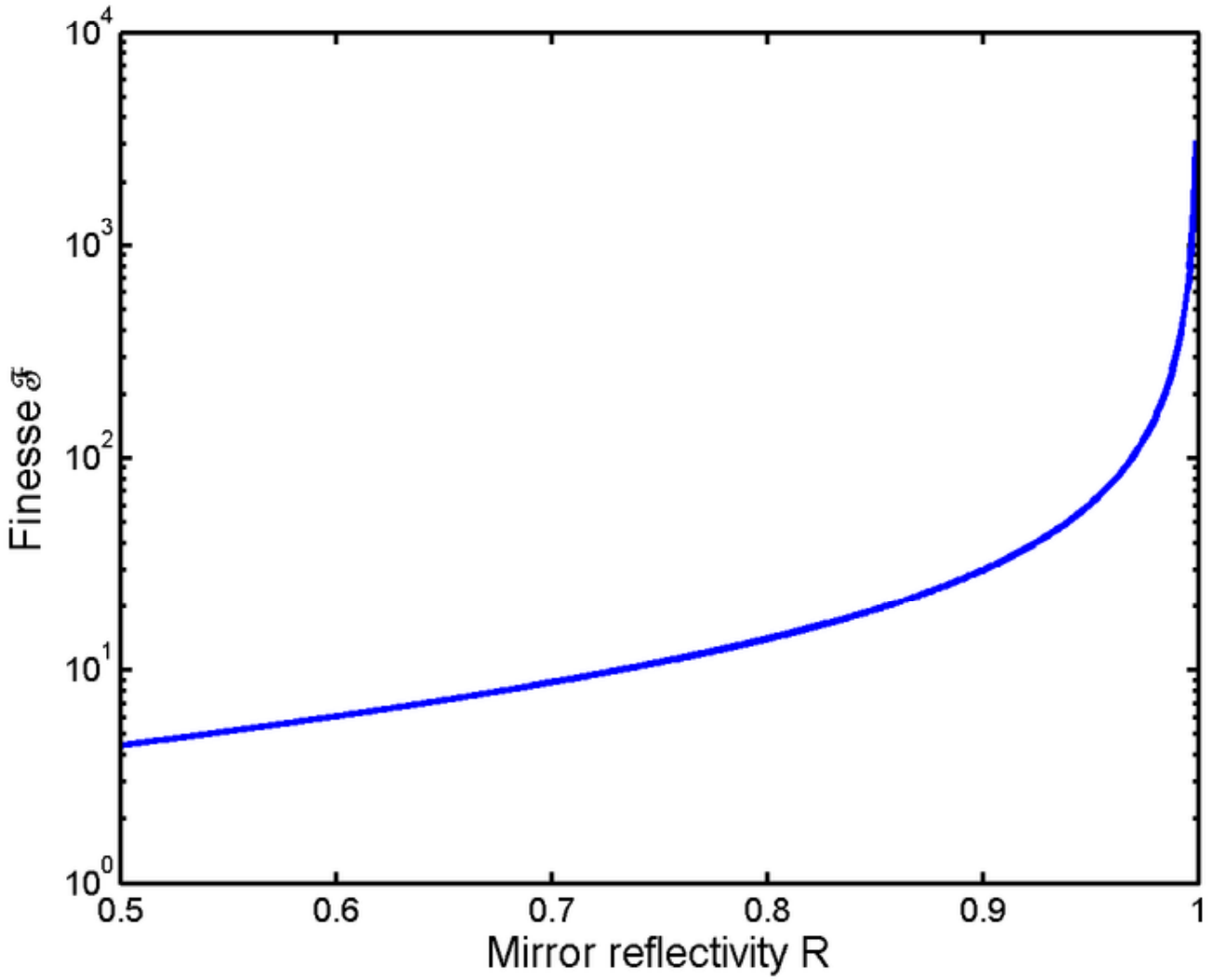
$$T = \frac{(1-R)^2}{1+R^2-2R\cos(\delta)} = \frac{1}{1+F\sin^2\left(\frac{\delta}{2}\right)}$$

where $F = \frac{4R}{(1-R)^2}$

F is the *coefficient of finesse* (not the same as the *finesse*).

http://en.wikipedia.org/wiki/Fabry%E2%80%93P%C3%A9rot_interferometer

Cavity (or Etalon) Finesse

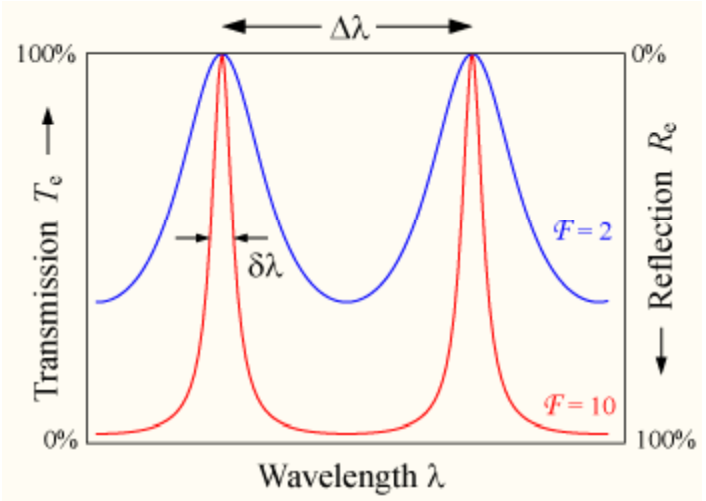


$$F = \frac{4R}{(1-R)^2}$$

http://en.wikipedia.org/wiki/Fabry%E2%80%93P%C3%A9rot_interferometer

Fabry-Pérot Interferometer

With no absorption, $R = 1 - T$



The wavelength spacing between successive transmission peaks is called the *free spectral range* (FSR):

$$\Delta\lambda = \frac{\lambda_0^2}{2nl\cos\theta + \lambda_0} \approx \frac{\lambda_0^2}{2nl\cos\theta}$$

The finesse $\Im$ is the ratio of the FSR to the width of any one transmission peak ($\delta\lambda$):

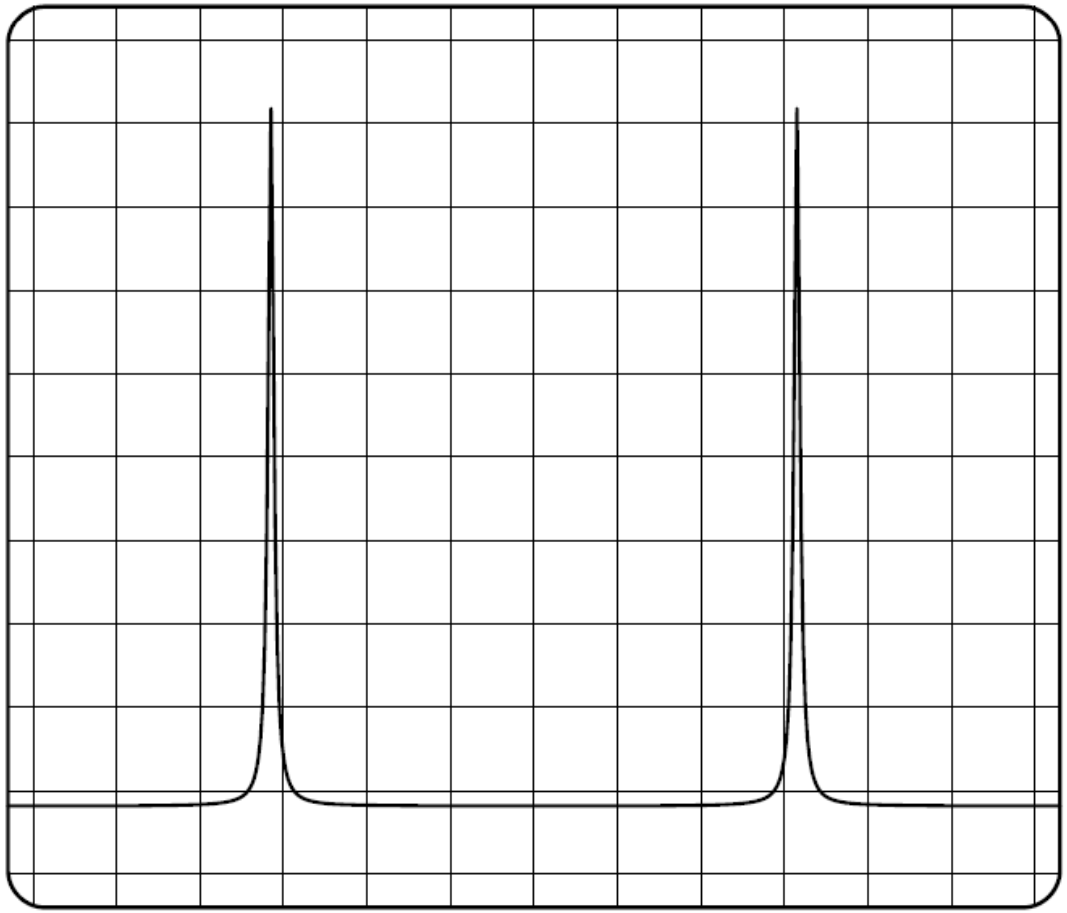
$$\Im = \frac{\Delta\lambda}{\delta\lambda} = \frac{\pi}{2\arcsin\left(1/\sqrt{F}\right)}$$

For R > 0.5, $\Im$ is often approximated by:

$$\Im \approx \frac{\pi\sqrt{F}}{2} = \frac{\pi R^{1/2}}{1-R}$$

http://en.wikipedia.org/wiki/Fabry%E2%80%93P%C3%A9rot_interferometer

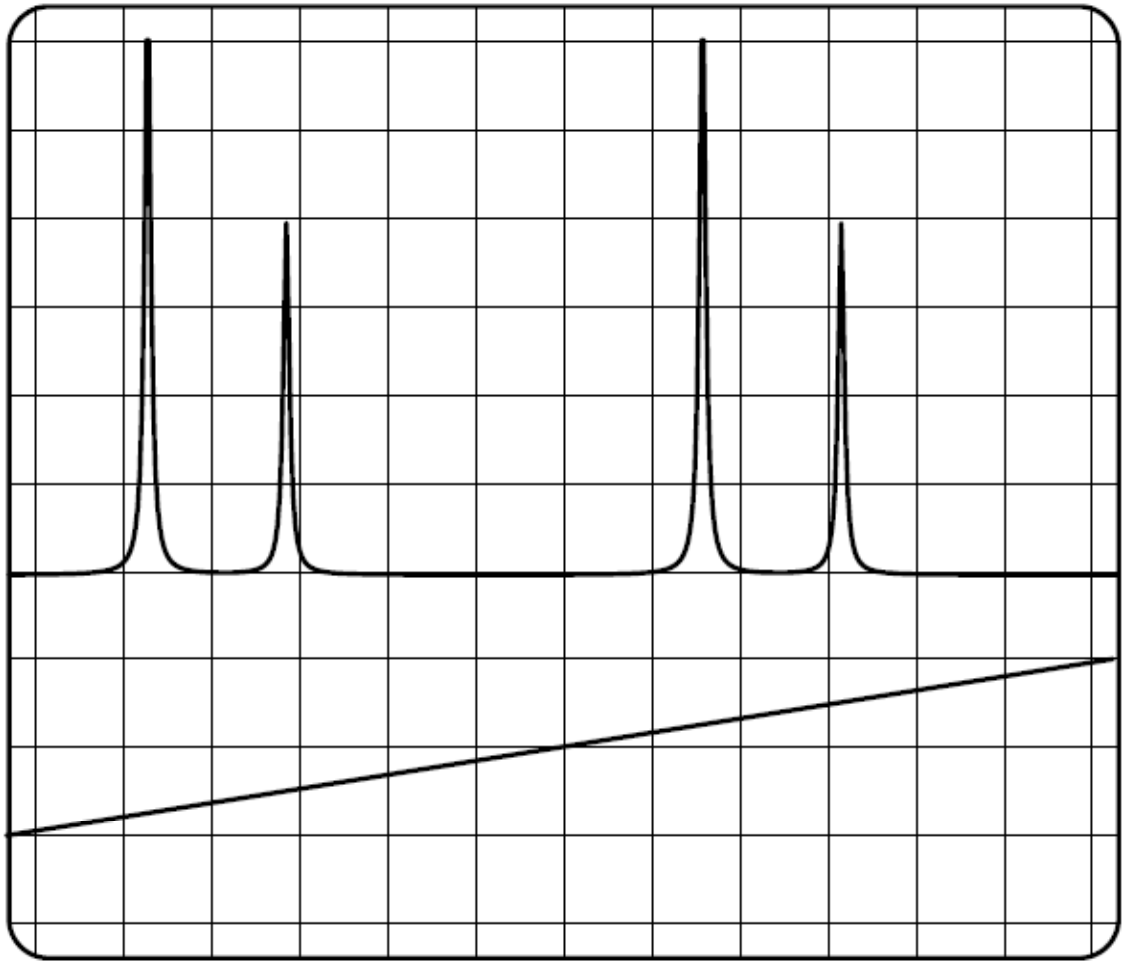
Typical Fabry-Perot interferogram (single mode)



Transmission signal on an oscilloscope with a periodic variation of the mirror distance *d*.

http://repairfaq.ece.drexel.edu/sam/MEOS/EXP03.pdf

Two-mode laser operation



Example of a scan of a two mode laser. The lower trace shows the change in length of the F-P.

http://repairfaq.ece.drexel.edu/sam/MEOS/EXP03.pdf