Fabry Perot Interferometer

Marija Kotur
Optics Rotation
Stony Brook Univerity
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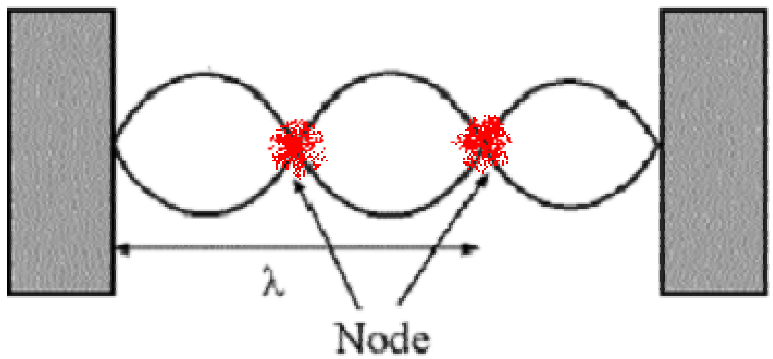
Motivation

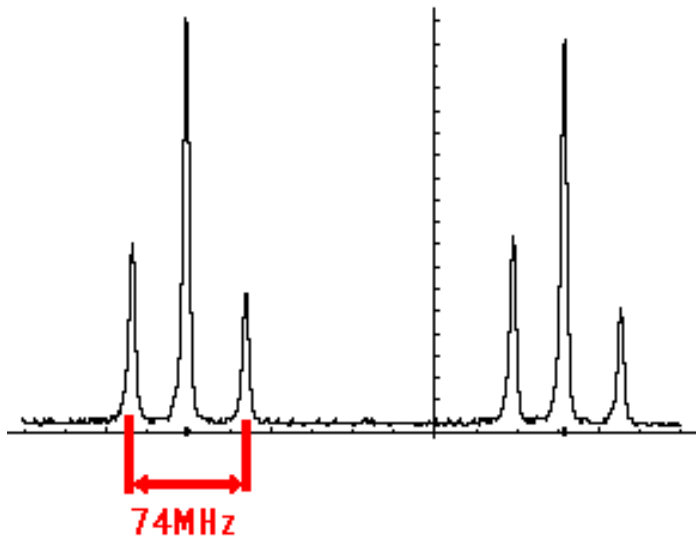
- Goal: build a Fabry Perot for use in the lithography experiment

- Need a single frequency ω_a of light to form a standing wave in the cell – two or more frequencies would lead to a travelling wave

- Atoms will concentrate around the nodes; the size of the region determines the precision or lithograhy

- Possible other frequencies: ω_a-*52MHz* and ω_a+*22MHz*





Properties of Fabry-Perot

- Two opposing highly reflecting surfaces
- Transmission is a function of wavelength
- Phase build-up for a round trip is:

$$\delta = \frac{4\pi n l \cos(\theta)}{\lambda}$$

- Transmission:

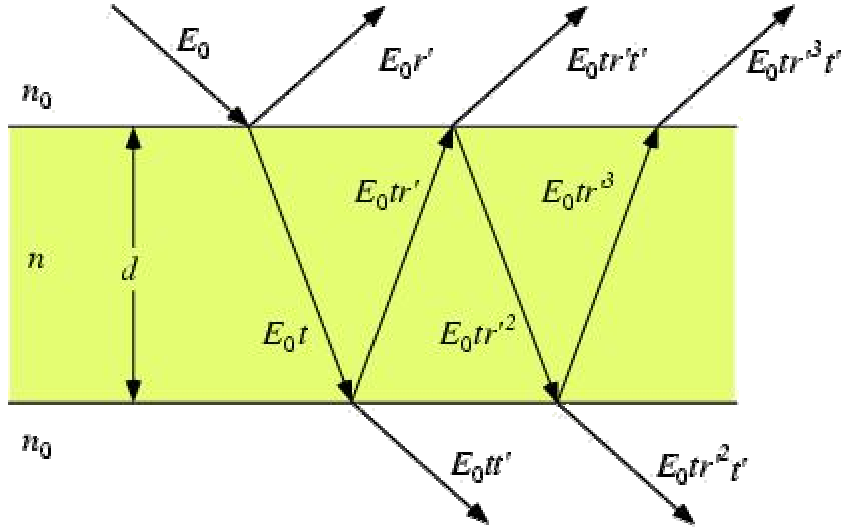
$$\frac{I_t}{I_i} = \frac{(1-r)^2}{(1-r)^2 + 4r\sin(\delta/2)}$$

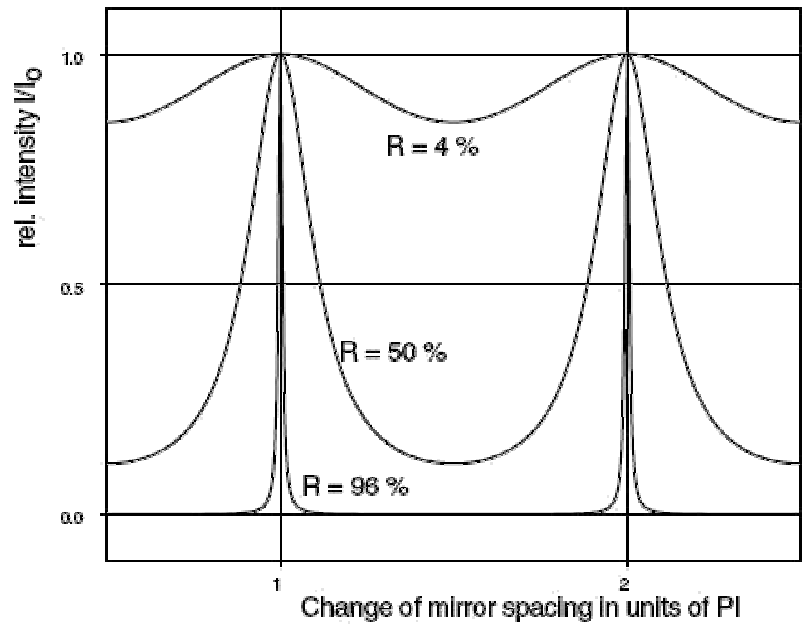
$$\frac{I_t}{I_i} = 1 \quad \text{for } \delta = 2m\pi \quad \text{or } \nu_m = \frac{mc}{2nl\cos\theta}$$

- Free spectral range:

$$\Delta\nu = \nu_{m+1} - \nu_m = \frac{c}{2nl\cos\theta}$$

- Finesse: $F = \frac{\Delta\nu_{FWHM}}{\Delta\nu} = \frac{\pi\sqrt{r}}{1-r}$





Geometry and Stability

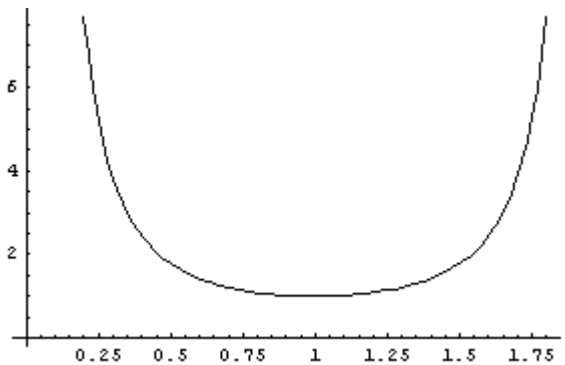
- Stability condition: $0 \le \left(1-\frac{L}{R_1}\right)\left(1-\frac{L}{R_2}\right) \le 1$

$$g_1 = 1-\frac{L}{R_1} \qquad g_2 = 1-\frac{L}{R_2}$$

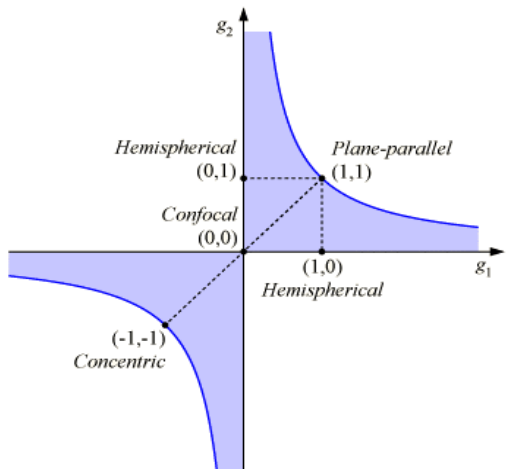
- The resonator is stable only inside of the shaded region

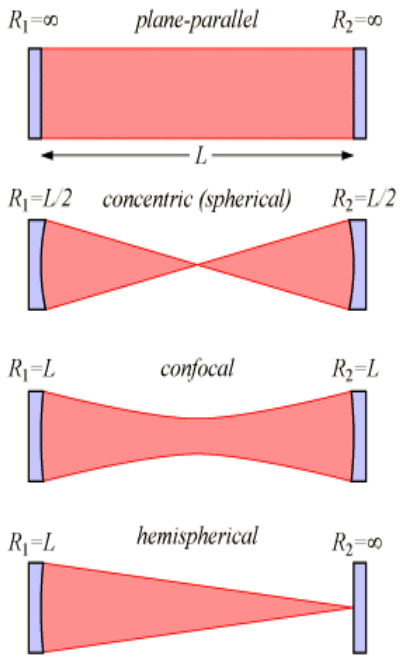
- The aim is to minimize diffraction loses, e. g. energy “spill over” the mirror edges

- Flat mirrors not suitable – beam size would increase steadily, also cannot be manufactured to required precission



- The spot size on the mirrors is minimal in the confocal configuration, $L=R_1=R_2=R$

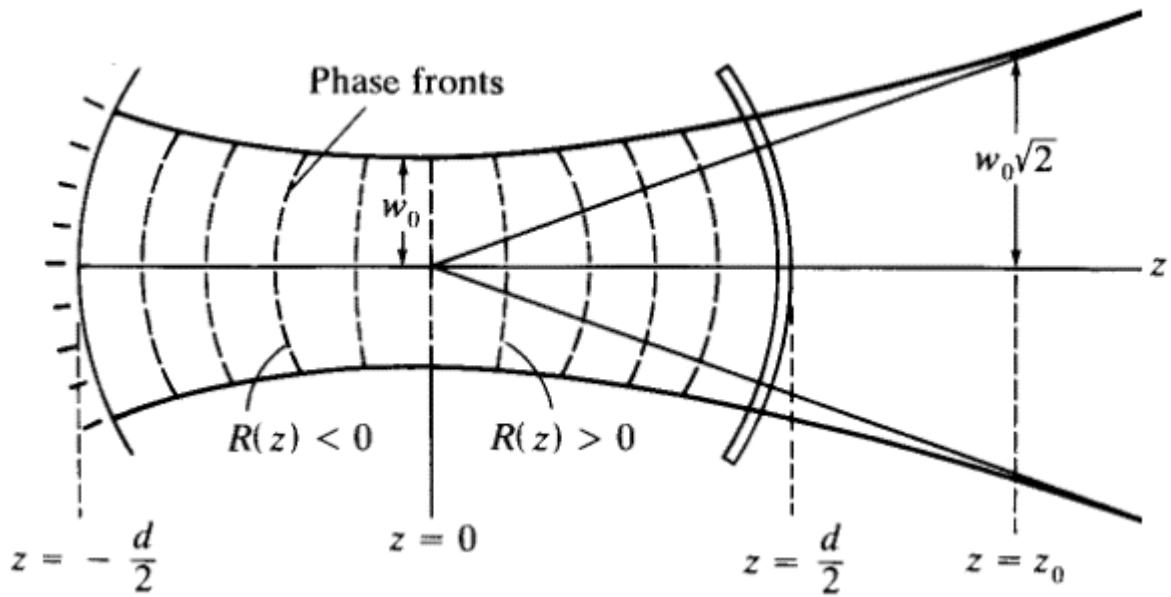




Confocal Fabry-Perot

- The radii of curvature of mirrors are chosen to be the same as those of the beam wavefronts

- Then there is no change in the transverse profile



- For a symmetrical resonator:

$$z_0^{\,2} = \frac{(2R - l)l}{4} \qquad \omega_0 = \sqrt{\frac{\lambda z_0}{n\pi}}$$

$$\omega_{spot} = \left(\frac{\lambda z_0}{n\pi}\right)^{1/2} \left(\frac{2R^2}{l(R - l/2)}\right)^{1/4}$$

- For the confocal geometry, these reduce to:

$$z_0 = R/2 \qquad \omega_0 = \left(\frac{\lambda R}{2n\pi}\right)^{1/2} \qquad \omega_{spot} = \left(\frac{\lambda R}{n\pi}\right)^{1/2}$$

Materials

- A rigid tube – $\Delta L << \lambda / 2$

  $\frac{\lambda}{2L\Delta T} \approx 7 \cdot 10^{-6} K^{-1}$ or $\alpha << 10K^{-1}$ at

  $\Delta T = 1K$

- Two mirrors coated appropriately, *r>0.99*, geometric finesse *F>300*

- Epoxy (cures w/o shrinking)

- PZT translator, at least *1μm* sweep

  $\Delta L \approx d_{31} \cdot L \cdot \frac{U}{d}$, $d_{13}=-200pm/V$

  for *L=0.5”, d=0.03”, V~300V*

- High voltage supply (with negative feedback, as PZTs show hysteresis)

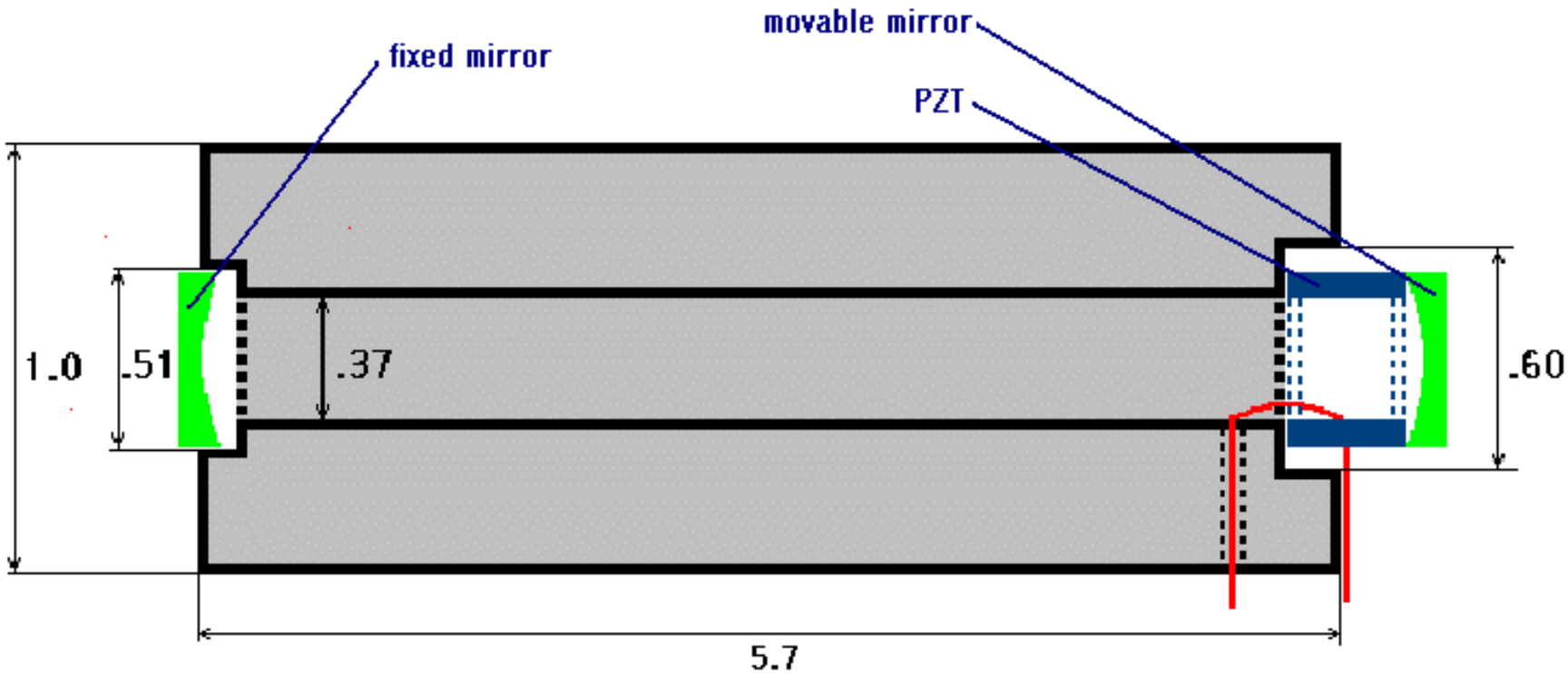
Material	α [K^{-1}]
metals	10-20
Glass	3
Invar	1
Diamond	1
Fused quartz	0.6

- Length *L=15cm*
- $\Delta\nu_{FSR} \approx 500MHz$
- $\omega_0 = 0.16mm$
- $\omega_{spot} = 0.23mm$

Design

Highly simplified design – increased stability

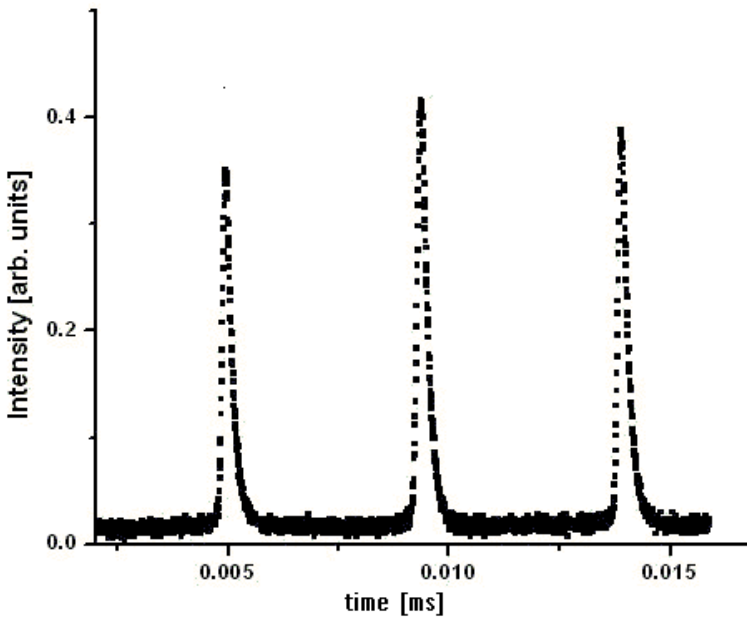
FSP is fixed - no flexibility



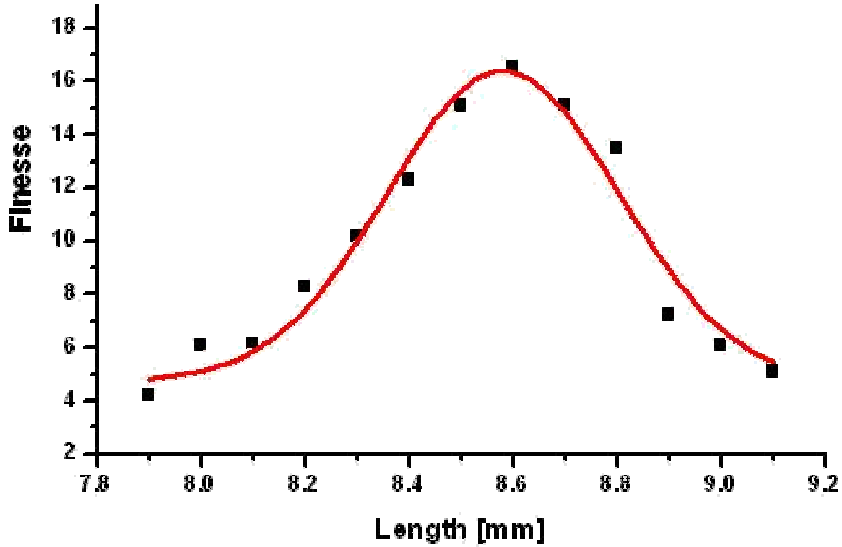
Preliminary Measurements

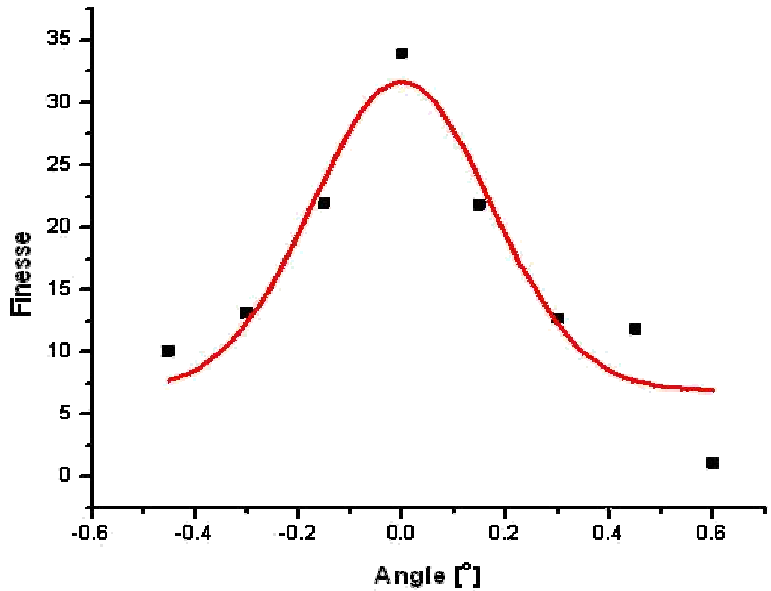
Length sweep (Gaussian fit):
R^2=0.96, W=0.44

Angle sweep (Gaussian fit):
R^2=0.89, W=0.34



Oscilloscope trace (peaks were produced by sweeping the laser frequency)





Literature:

[1] http://scienceworld.wolfram.com/physics/Fabry-PerotInterferometer.html

[2] http://en.wikipedia.org/wiki/Invar

[3] H. J. Metcalf, Laser Cooling and Trapping, Springer (1999).

[4] P.W. Milonni, J.H. Eberly, Lasers, John Wiley & Sons, New York, NY (1998)

[5] A. Yariv, P. Yev, Photonics, Oxford University Press (2006)