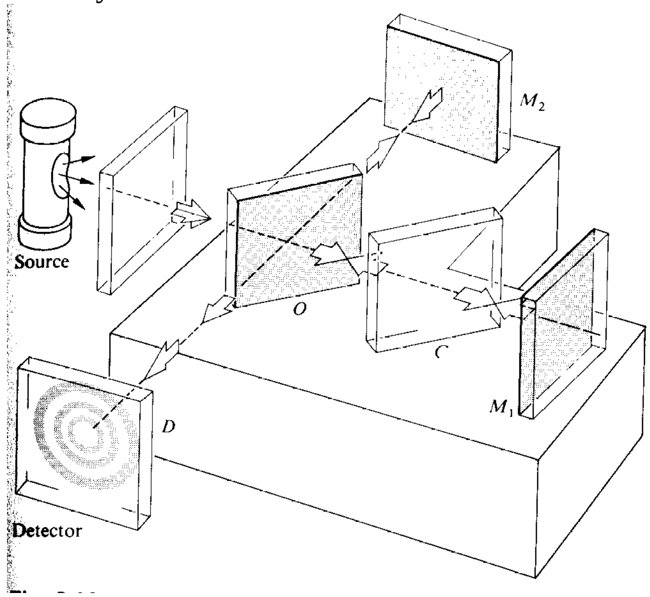
Lab 4 Comments
Michelson Interferometer (MI)

Alignment of the MI is the key!



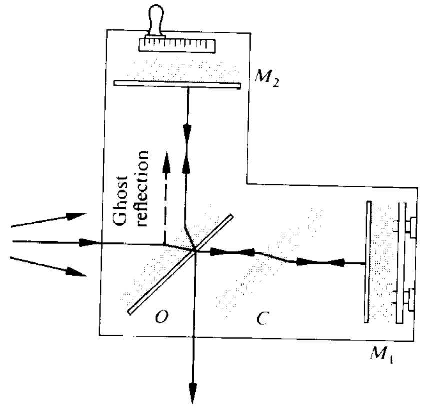
Make sure to retro-reflect the laser beam. Use the two knobs on the back of the mirror mounts to do fine alignments. You must both retroreflect the beam and center the beam on the moveable mirror in the MI.

Be very careful with the knobs on the stationary mirror in the MI. Very small changes can send the interference pattern off the screen!

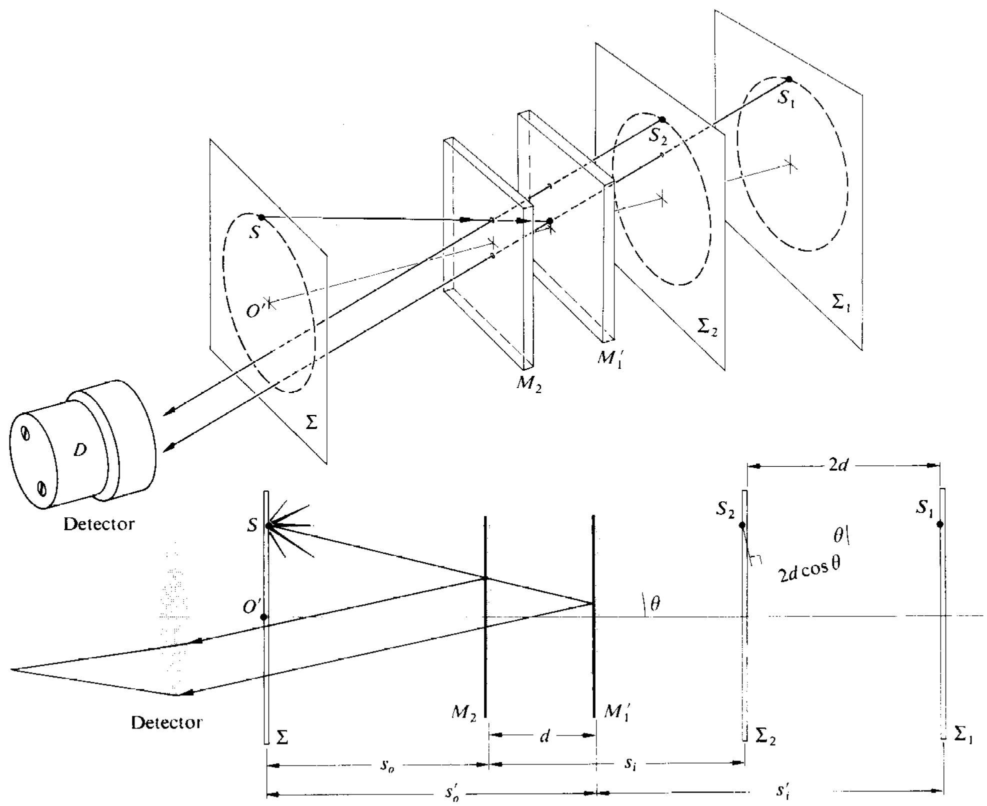
Take a Fast Fourier Transform (FFT) of your fringe data. This offers another way to find the fringe passage rate.

Note that the laser has a limited longitudinal coherence length. Therefore, interference patterns are most easily seen when the two arms of the interferometer are of nearly equal length.

Be careful not to leave the motor running and drive the translation stage to its limit!



Extra spots appear from unwanted reflections



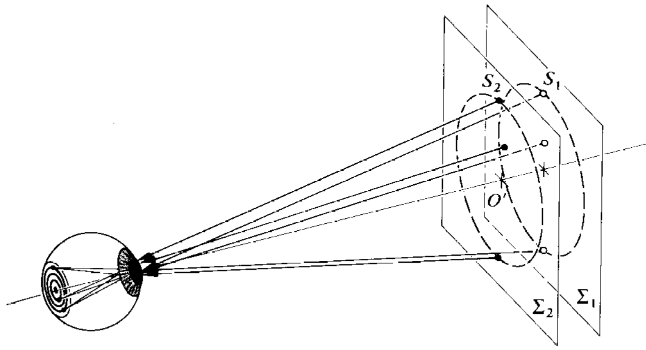
Destructive interference occurs when the path length difference is an integer number of wavelengths:

$$2d\cos(\theta_m) = m\lambda$$

where m is an integer. (It is not $\lambda/2$ because of an additional phase shift acquired in the interferometer by the two beams. There is a π phase difference between a wave that is externally reflected (O-M1) from the beam splitter compared to the one that is internally reflected (O-M2) on the same surface.) [Check out the Stokes relations: P^3, pages 184-185]

For the central fringe, $\theta_m = 0$, so

$$2d = m\lambda$$



Interference of Waves With a Single Frequency

If two waves simultaneously propagate through the same region of space, the resultant electric field at any point in that region is the vector sum of the electric field of each wave. This is the principle of superposition. (We assume all waves have the same polarization). If two beams emanate from a common source, but travel over two different paths to a detector, the field at the detector will be determined by the optical path difference, which we will denote by $\Delta x = x_2 - x_1$. A related quantity is the phase difference, $\Delta\varphi$, given by

$$\Delta\varphi = \frac{2\pi}{\lambda}\,\Delta x = k\Delta x\,, \qquad (1)$$

where k is the wavenumber. Constructive interference occurs when

$$\Delta\varphi = 2m\pi,\ \ m = 0, \pm1, \pm2, \pm3, \ldots. \qquad (2)$$

Destructive interference occurs when

$$\Delta\varphi = \pm(2m+1)\pi,\quad m = 0, 1, 2, 3, \ldots. \qquad (3)$$

Interference of Waves with Two Frequencies

We will now consider the case of two frequencies with wavenumbers k_1 and k_2 that together follow two different paths with a difference of Δx. The sum of the waves with different amplitudes at point x along the x-axis is given by:

$$E_T = \left(e^{ixk_1} + e^{i(x+\Delta x)k_1}\right)E_1 + \left(e^{ixk_2} + e^{i(x+\Delta x)k_2}\right)E_2 \qquad (4)$$

If we let $a = E_2/E_1$ and define $\delta k = (k_1 - k_2\,)/2$, after a lot of algebra, we can write the intensity ($E_T^* E_T$) as:

$$E_T^* E_T = 2\left(1 + a + a^2 + \mathrm{a}\cos(2\,\delta k\,\Delta x) + (1+a)\big(cos(k_1\,\Delta x) + a\,cos(k_2\,\Delta x)\big)\right) \qquad (5)$$

The figure below shows the expected signal, which consists of a fast oscillation as well as a slow oscillation characteristic of δk.

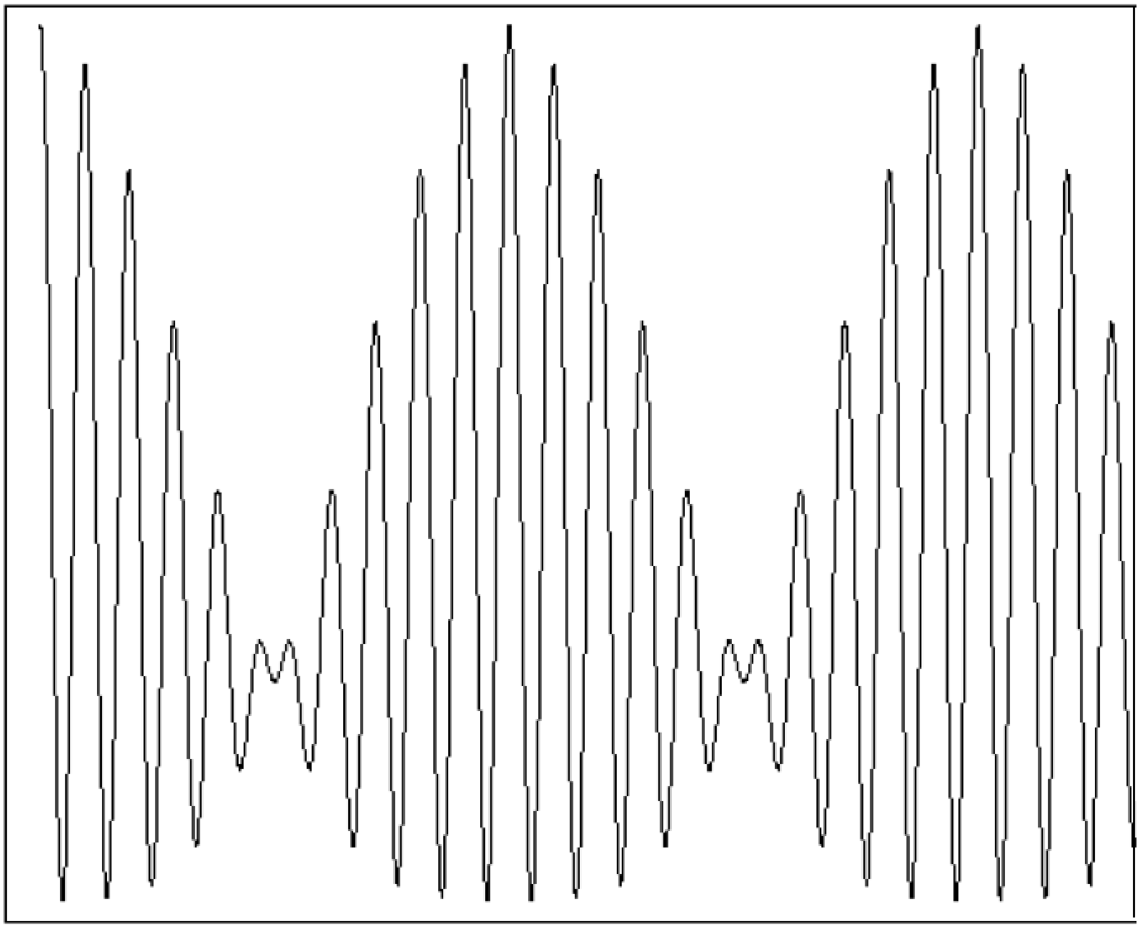


Figure: Beat signal from two input frequencies into a Michelson interferometer