Optics

Day 11

Mar 7th, 2017 P1/3

Today

I Last time

II A Brief Tour of Interferometers

III Thin Wedge or Fizeau Fringes

I • Superposition: Coherent

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$

constructive for $I_1 = I_2 = I_0$, $\delta = 0$

$$I = 2I_0 + 2I_0\cos(0) = 4I_0$$

deconstructive $\delta = 180^\circ = \pi$

$$I = 2I_0 + 2I_0\cos\pi = 0$$

Incoherent for N waves

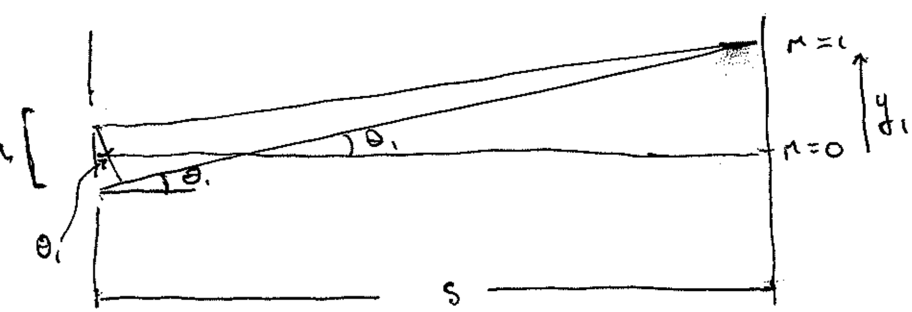
$$I = I_1 + I_2 + \cdots + I_N.$$

• Young's double slit

$$y_m = \frac{s}{a} m\lambda \quad \text{or} \quad \theta_m = \frac{m\lambda}{a}$$

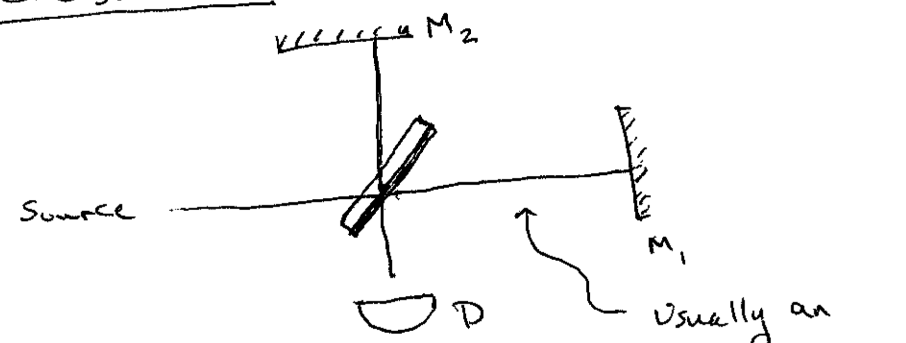
so that $\Delta y = \frac{s}{a}\lambda$. Also

$$I = 4I_0\cos^2\left(\frac{ya\pi}{s\lambda}\right)$$



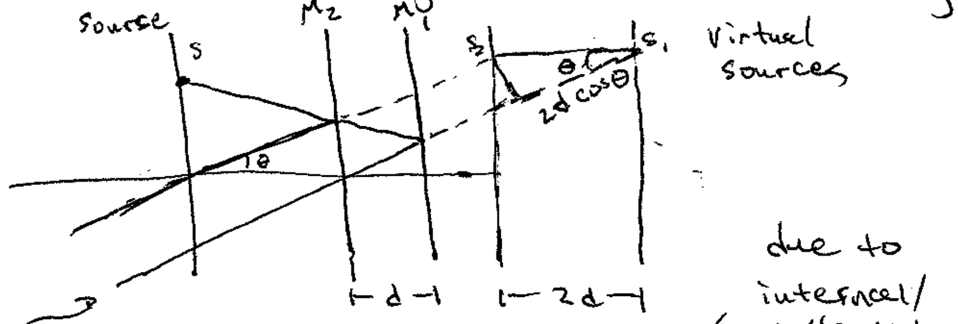
II There are many interferometers based on mirrors and beam splitters.

<u>Michelson Int</u>



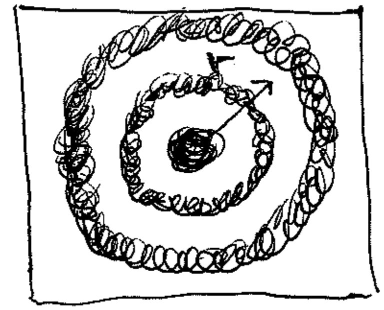
The central ray interferes with its split partner just based on the difference in OPL, but...

... off center rays are more interesting



relative phase $= k(2d\cos\theta) - \pi$

If you put a lens in front of the outgoing rays, with focal length f, you get a circular interference pattern



$$\theta \approx \frac{r}{f}$$

This interferometer is quite sensitive to changes in d. It is at the heart of the LIGO detectors that recently performed the first measurements of gravitational waves. We also use it in the Modern physics lab to measure

nair.

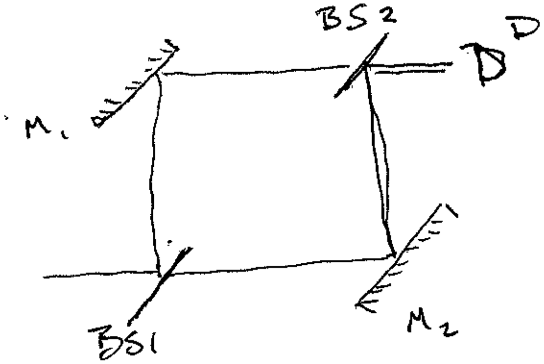
<u>Mach-Zehnder Interferometer</u>: A simple setup used in measuring gas flow patterns and in single photon quantum experiments.

The fringes move outwards as you increase d,

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

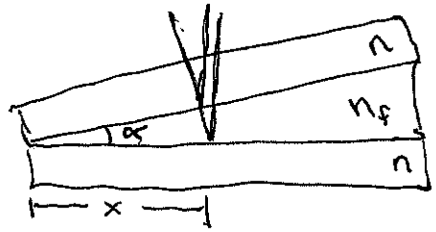
as $d\uparrow$, $\cos\theta_m\downarrow$ to maintain $m\lambda$.

$\Rightarrow$ θ_m increases.



or in a <u>Sagnac interferometer</u> you replace BS2 by a mirror. This configuration is used in a fascinating way to measure rotational motion of the interferometer.

III In nature a common way to encounter interference is through thin films. As a simple model consider



The excess distance travelled by the beam entering the film is $2d = 2x\alpha$. There is also a difference of π phase in the two types of reflection (happens whenever $n_i < n_r$) and so

$$\delta \approx \frac{4\pi}{\lambda_0} n d - \pi$$

or

$$\left(m+\frac{1}{2}\right)\lambda_0 = 2 n_f d_m$$

$$\doteq 2 n_f \alpha x_m$$

$$\Rightarrow \boxed{x_m = \left(\frac{m+1/2}{2\alpha}\right)\lambda_f}$$

This sort of interference shows up in bubbles, gas on water, microscope slides and birds' feathers.