# Lecture 29

## Michelson's Interferometer

Interferometer - device that can measure lengths or changes in length w/ great accuracy by using interference fringes.

(show slides)

- Light leaves point P on extended source S.
- It then encounters a beam splitter, which transmits half of incident light & reflects other half.

- At beamsplitter M, light divides into two waves.
- one part goes toward mirror $M_1$
- other part goes toward mirror $M_2$
- waves are then entirely reflected @ mirrors & sent back along directions of incidence.
- Observer sees a pattern of curved or approximately straight interference fringes (show slides)

Question: what is difference in path length traveled by two light waves when they recombine @ telescope?

Answer: $2d_2 - 2d_1$

Anything that changes this path length difference causes a change in phase difference between two observed waves.

- For example, suppose mirror $M_2$ is moved a distance $\frac{1}{2}\lambda$. What is change in path length difference?

$\lambda$

Then causes fringe pattern to shift by one fringe.

- Shift in fringe pattern can also be caused by insertion of thin transparent material into optical path of one of the mirrors.

- If material has thickness $L$ + index of refraction $n$, then # of wavelengths along light's to-and-fro path through material is

$$N_m = \frac{2L}{\lambda_n} = \frac{2Ln}{\lambda}$$

# of wavelengths in same thickness $2L$ of air is

$$N_a = \frac{2L}{\lambda}$$

phase change in terms of # of wavelengths is

$$N_m - N_a = \frac{2Ln}{\lambda} - \frac{2L}{\lambda}$$

$$= \frac{2L}{\lambda}(n-1)$$

- Can then use this & fringe pattern change in pattern to measure thickness L of material in terms of $\lambda$. (count # of fringes through which material causes pattern to shift.)

- This type of measurement is so precise that it is now used as the standard for the meter (expressed in terms of # of wavelengths of monochromatic red light)

# Ch. 36 - Diffraction

- We previously learned that interference + diffraction occur when light is incident on a double slit (Young's interference experiment)
- Now we learn about another effect when there is a single slit (or a sharp edge).
- diffraction occurs whenever light encounters edge of an object.

Goal is now to figure out location of minima from a single slit.

(show figure from slides)

- Suppose light has wavelength $\lambda$ & slit has width $\underline{a}$

- When diffracted light reaches screen, it produces ~~a~~ diffraction pattern of bright + dark fringes on the screen.

- Before doing anything, note that central bright fringe comes about b/c all points in slit travel about same distance + are thus in phase (show slides)

## Strategy for locating minima:

- pair up all rays coming through the slit + then find conditions that cause them to cancel

1) Divide slit into two zones of equal widths $a/2$.
2) Extend light rays $r_1$ + $r_2$

Want wavelets from these two points to cancel eachother.

We should compute path length difference:

To produce 1st dark fringe, rays $r_1$ + $r_2$ should be out of phase by $\lambda/2$.

- Simplify calculation by allowing screen separation D to be much longer than slit width a.

- use approximation from before (rays $r_1$ + $r_2$ are approx. parallel)

(show slides for approx.)

- path length difference by simple geometry is $\frac{a}{2} \sin\theta$

- can repeat this analysis for any other pairs of rays @ corresponding points in two zones + extending to $P_1$.

- Each such pair of rays has same path length difference: $\frac{a}{2} \sin\theta$.

Setting common path length difference to $\frac{\lambda}{2}$ (for dark fringes)

then gives

$$\frac{a}{2} \sin\theta = \frac{\lambda}{2}$$

$$\Rightarrow \quad a \sin\theta = \lambda \quad \text{(locating 1st minimum)}.$$

gives angle $\theta$ of 1st dark fringe above + below central axis.

---

- Now we want to find second minima.

- Divide slit into 4 zones of equal width.

(show slides)

path length differences between $r_1, r_2$ + $r_2, r_3$ + $r_3, r_4$ should all = 0.

Approximate $D >> a$ as before

(show slides)

- path length diff. between $r_1$ & $r_2$ is

$\frac{a}{4} \sin\theta$.

same for other pairs.

Dark fringes then occur @

$$\frac{a}{4} \sin\theta = \frac{\lambda}{2}$$

↑ corresponding to destructive interference.

$\Rightarrow$ $a \sin\theta = 2\lambda$

Can continue this to find all higher order minima. (dividing into smaller zones)

then we get that minima are @ $a \sin\theta = m\lambda$

for $m = 1, 2, 3, \ldots$

In a single slit diffraction experiment, dark fringes are produced where path length differences between top & bottom rays are equal to $\lambda, 2\lambda, 3\lambda, \ldots$

Question: Suppose diffraction pattern is produced by sending blue light through narrow slit.

Do minima move away from or toward center when shifting to blue light

if we (a) shift to yellow light

(b) decrease slit width?

(both expand)