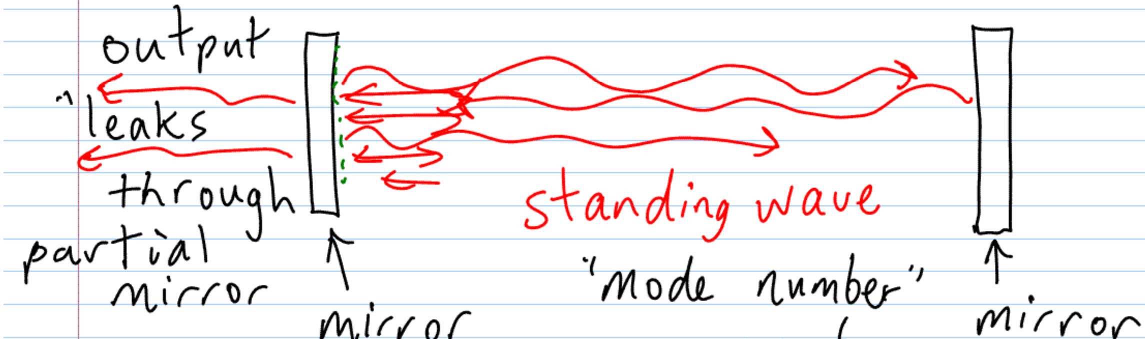
PHY138Y1Y, Physics for the Life Sciences I

Waves Quarter - Lecture 6 — November 22, 2006

Wave Interference. Beats

LASER : invented in 1960's

$\longrightarrow$ based on standing waves



$\sim m \approx 10^6$

(partially silvered: $\sim 5\%$ transmission, 95% reflection

Output: Very strong, single frequency, narrow beam of light. $\rightarrow$ "in phase" $\rightarrow$ "coherent light" $\leftarrow$ Useful!

Interference. basics:

$$D_1 = a \sin(kx - \omega t + \phi_{10})$$

$$+ \quad D_2 = a \sin(kx - \omega t + \phi_{20})$$

Different phase constants $\phi_{10} \neq \phi_{20}$

$$D_1 + D_2 = a \sin(\cdots + \phi_{10}) + a \sin(\cdots + \phi_{20})$$

$\vdots$

trig identities, algebra

$$D_1 + D_2 = \underbrace{2a\cos\left(\frac{\Delta\phi}{2}\right)}_{\substack{\text{New} \\ \text{Amplitude} \\ = A}} \cdot \underbrace{\sin\left(kx - \omega t + \left(\frac{\phi_{10}+\phi_{20}}{2}\right)\right)}_{\text{Another sinusoidal wave}}$$

A depends on phase difference,

$$\boxed{\Delta\phi = \phi_{20} - \phi_{10}}$$

Special cases: $\Delta\phi = \pi + (2\pi n)$

$n =$ any integer

"perfect destructive interference"

$A = 0$

$\Delta\phi = 2\pi n$ ($n =$ any integer)

$A = 2a$ "perfect constructive interference".

- Headphones exist which contain a microphone which reads sound, adds π phase difference, and immediately plays it.
  - → this creates "anti-sound" which cancels sound you hear by destructive interference.
  - → Used by travelers to reduce engine noise.

In 2-D or 3-D, wave fronts mark "crests" and are circles or spheres which spread away from the source

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Beats Two waves, same amplitude, a, same phase constant, ϕ_0, slightly different frequencies

$$\omega_1 \simeq \omega_2 \quad \text{but} \quad \omega_1 \neq \omega_2$$

set $x = 0$ and examine temporal (time interference) (set $\phi_0 = \pi$)

$$D_1 = a \sin(-\omega_1 t + \pi)$$

$$D_1 = a \sin(\omega_1 t)$$

$$D_2 = a \sin(\omega_2 t)$$

$$D_1 + D_2 = a \sin(\omega_1 t) + a \sin(\omega_2 t)$$

$$\text{Result} = \underbrace{2a \cos(\omega_{mod} t)}_{\text{time varying amplitude.}} \cdot \underbrace{\sin(\omega_{avg} t)}_{\text{another sinusoidal wave}}$$

(blue wiggly line)

$$\omega_{mod} = \frac{\omega_1 - \omega_2}{2} \leftarrow \text{"Modulation Freq."}$$

$$\omega_{avg} = \frac{\omega_1 + \omega_2}{2} \leftarrow \text{"Average freq."}$$

$\omega_{avg} \gg \omega_{mod}$ ← ω_{avg} = fast wiggles times low frequency modulation.