Interference

Ken Intriligator's week 9 lecture, Nov.28, 2013

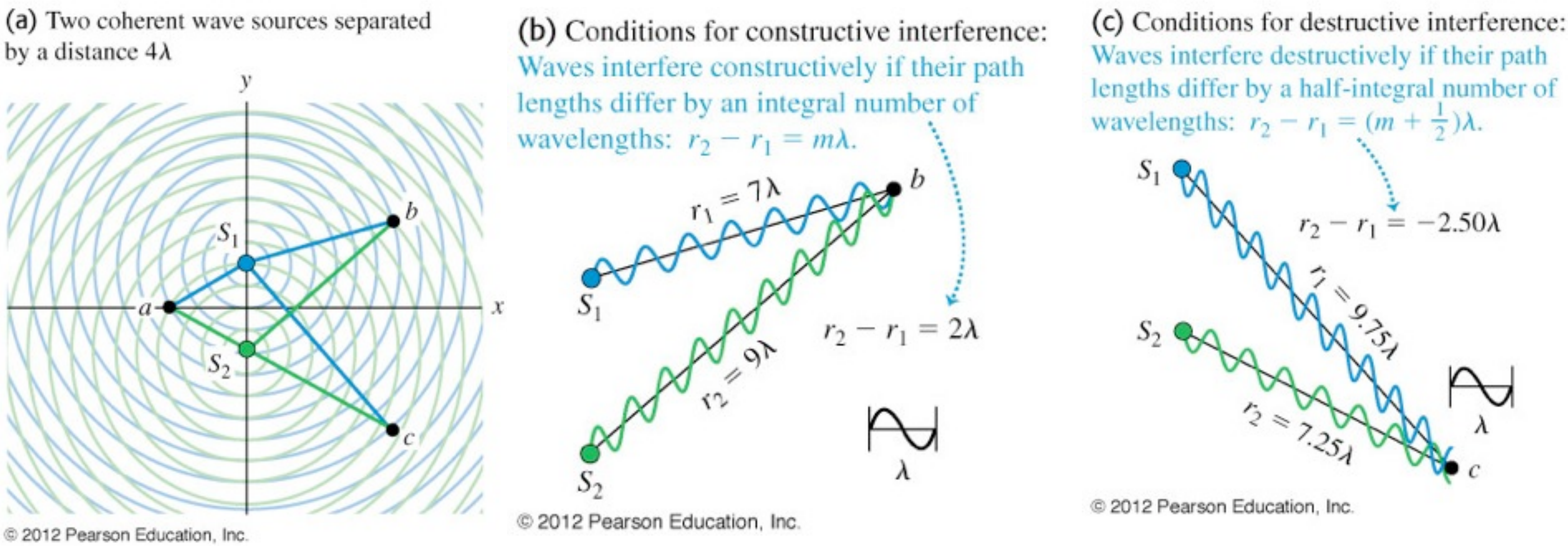
Same as with sound

Superposition with light: Maxwell's equations are linear equations for E and B, so we can simply add the E and B of different sources to get the total E and B. Do this for light sources. Intensity is proportional to E-squared. Depending on the location, sources can either add or subtract: i.e. constructive or destructive interference.

Constructive: E's peaks from two sources aligned.

Destructive: E's peaks from two sources anti-align.

Example:

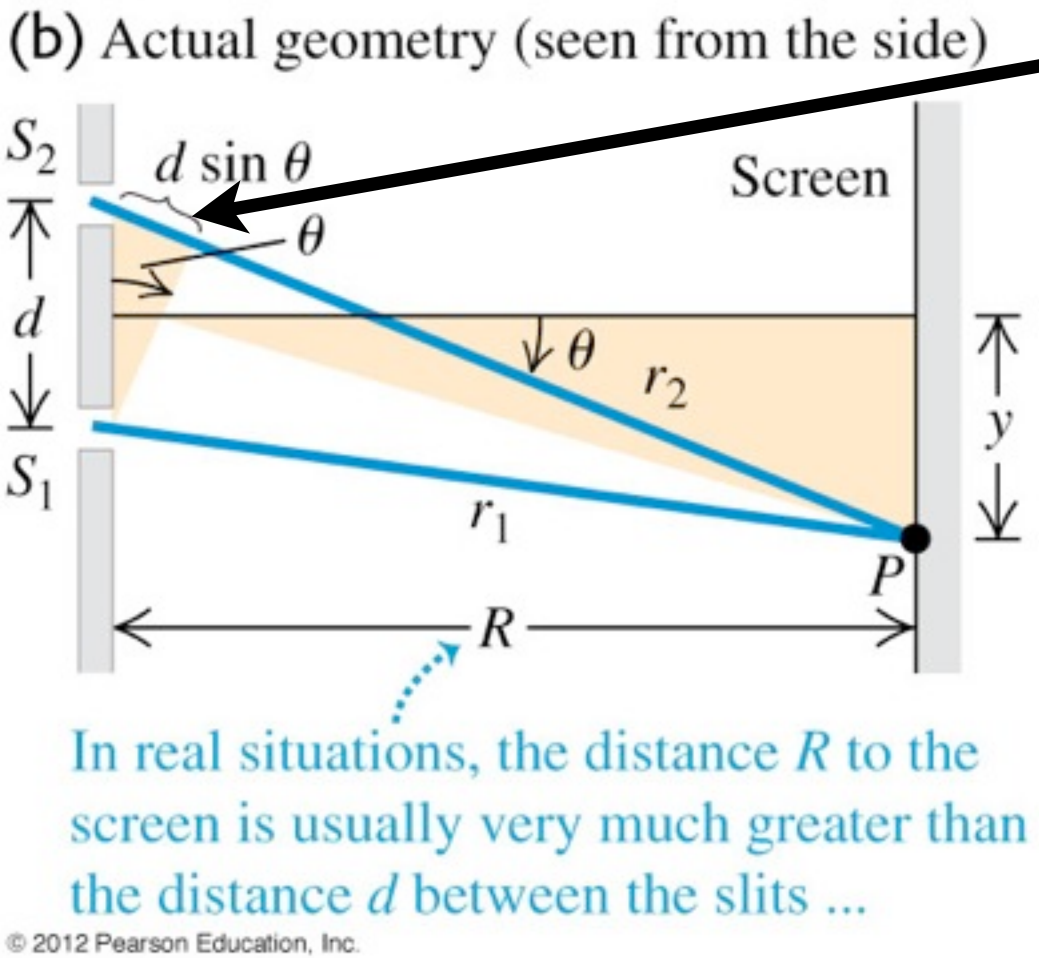


Constructive: $\Delta L = m\lambda$

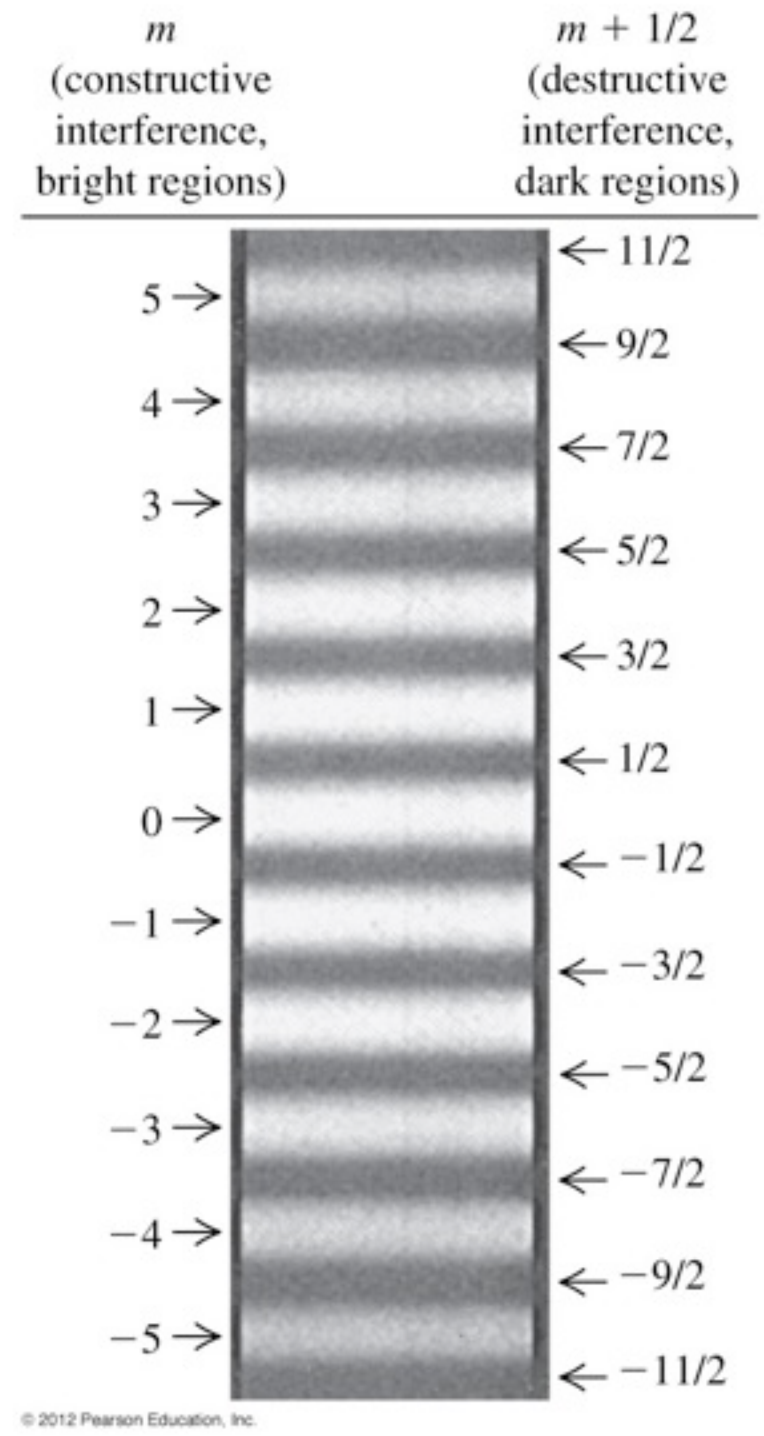
Destructive: $\Delta L = (m + \frac{1}{2})\lambda$

$$m = 0, \pm 1, \pm 2, \ldots$$

Two source geometry



$$\Delta L \approx d \sin\theta$$



Bright: $d \sin\theta = m\lambda$

Dark: $d \sin\theta = (m + \frac{1}{2})\lambda$

2 sources intensity

(coherent)

$$I \sim \langle E_{tot}^2 \rangle$$

(Time averaged)

Recall trig identity:

$$\cos a + \cos b = 2\cos(\frac{a+b}{2})\cos(\frac{a-b}{2})$$

source 1 wave   source 2 wave

$$E_{tot}/E_0 = \cos(kL - \omega t) + \cos(kL' - \omega t) = 2\cos(\frac{k\Delta L}{2})\cos(kL_{ave} - \omega t)$$

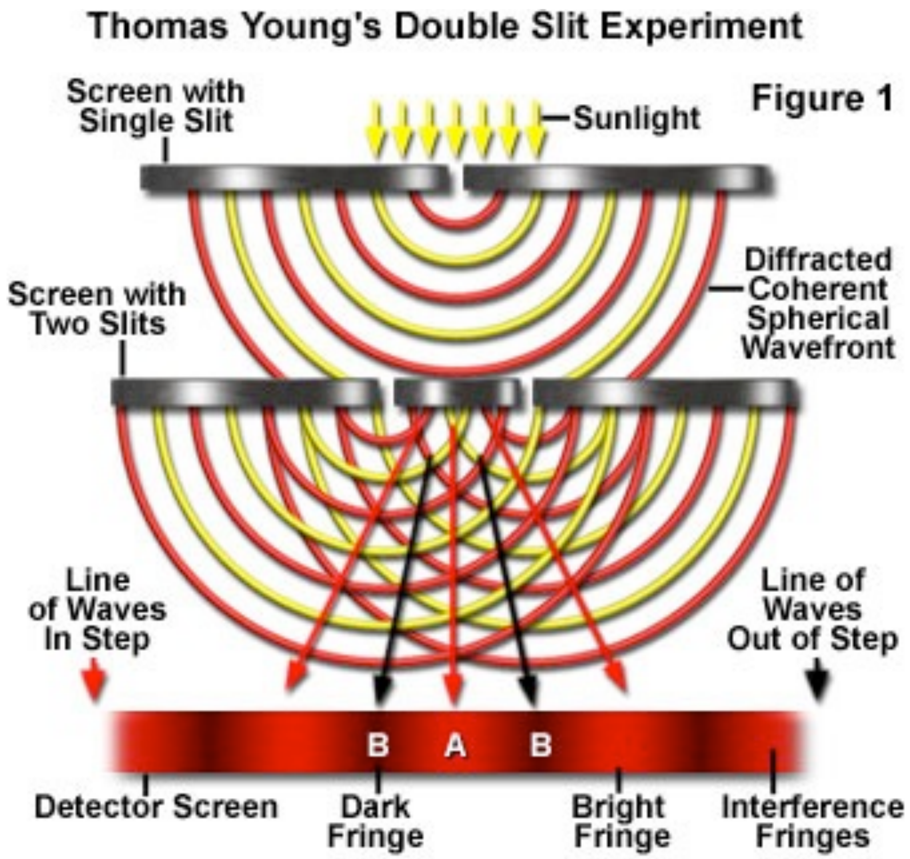
interference amplitude, square it for intensity.

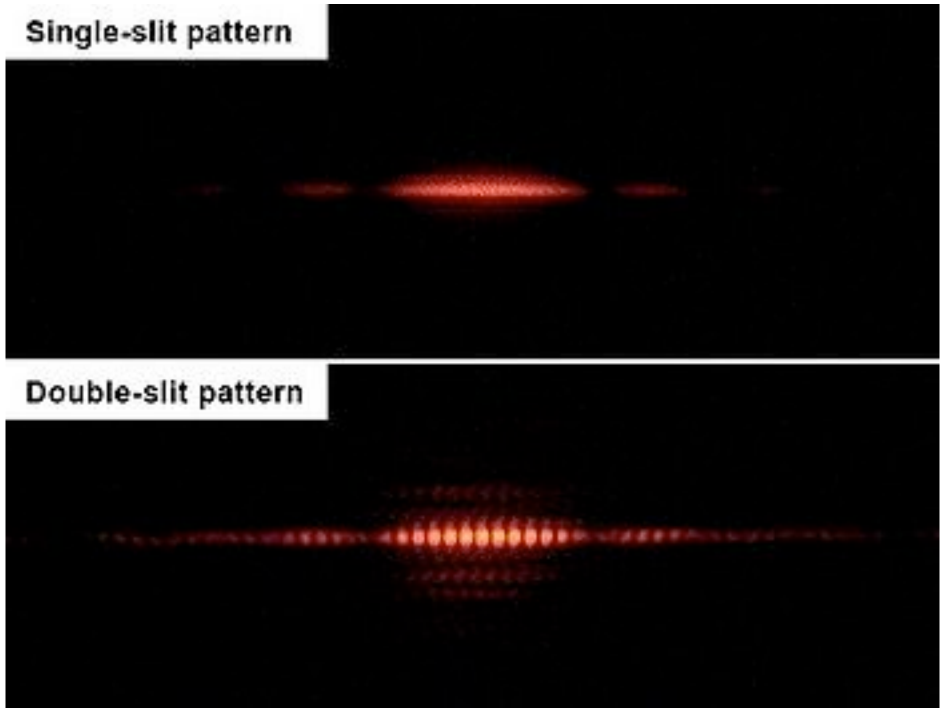
$$I_2 = 4I_1\cos^2(\frac{1}{2}k\Delta L) = 4I_1\cos^2(\pi\Delta L/\lambda)$$

Constructive intensity peaks from 2 sources is 4 times that of a single source. Averaging over space gives

$\overline{I_2} = 2I_1$ since $\overline{\cos^2\theta} = \frac{1}{2}$ Makes sense.

Young expt. (1801)





$$I_2 = 4I_1 \cos^2(\frac{1}{2}k\Delta L) = 4I_1 \cos^2(\pi \Delta L/\lambda)$$

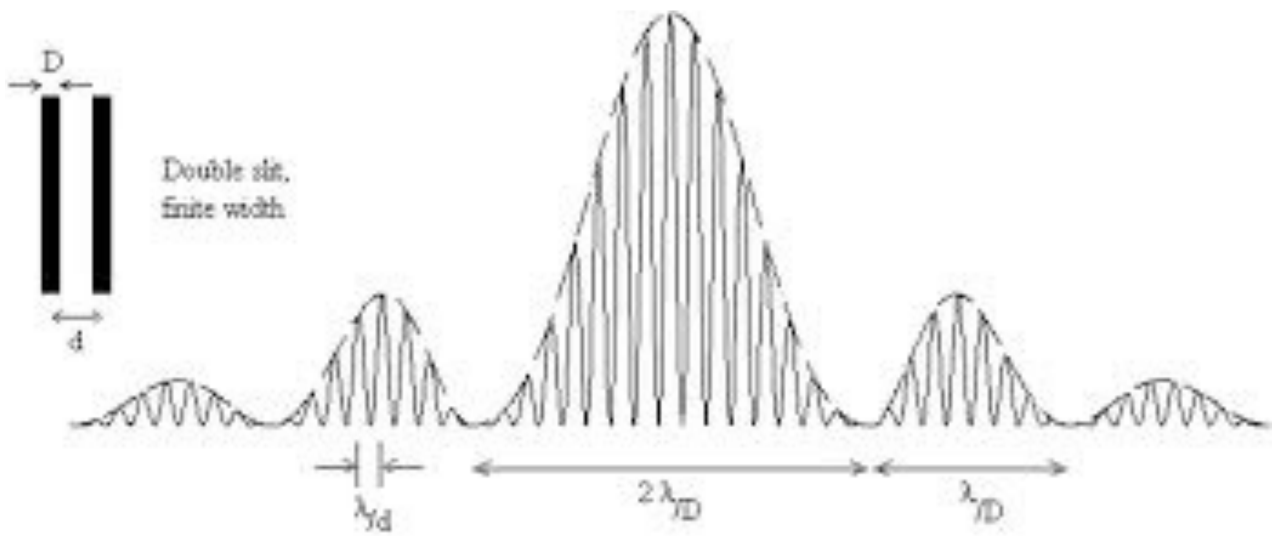
$$\Delta L = d \sin\theta$$

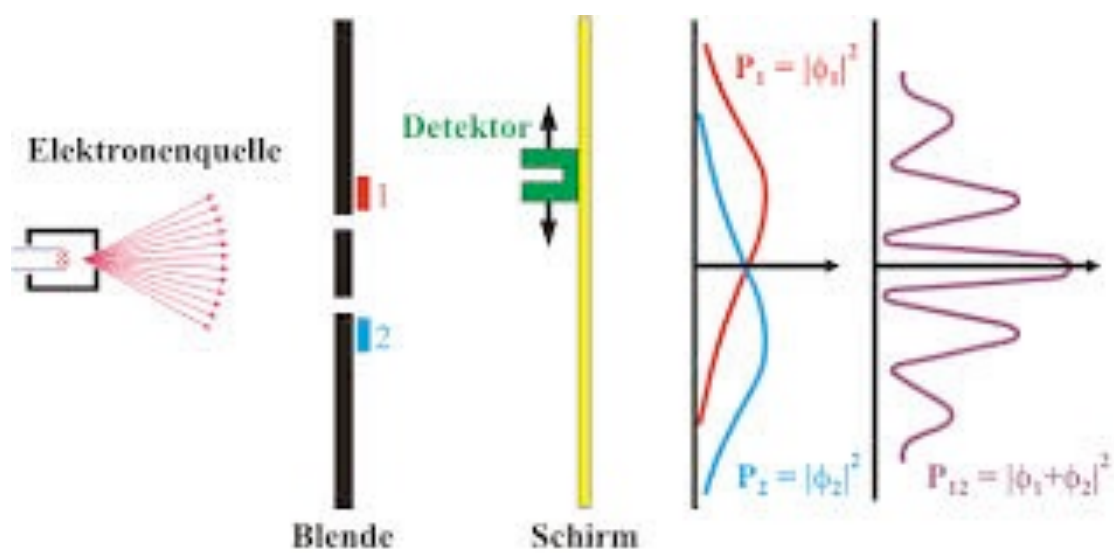
$$I(\theta) \propto \cos^2(\pi d \sin\theta/\lambda)$$

Shows light is a wave!

Actually small particles (e.g. electrons) behave same way (QM)!

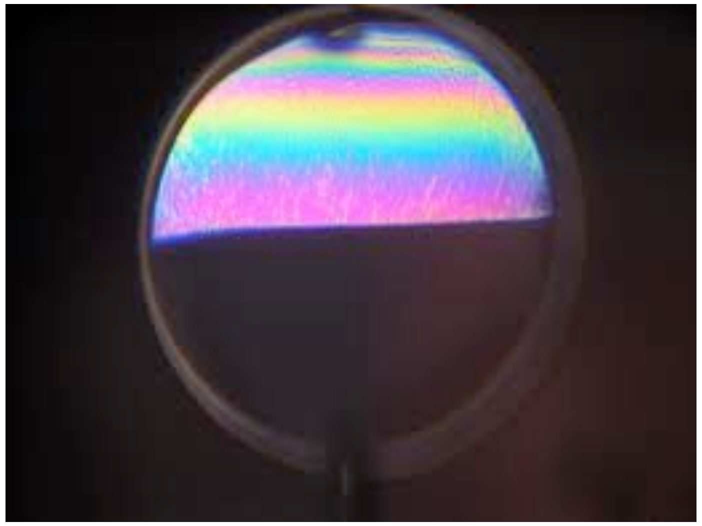
Double slit intensity

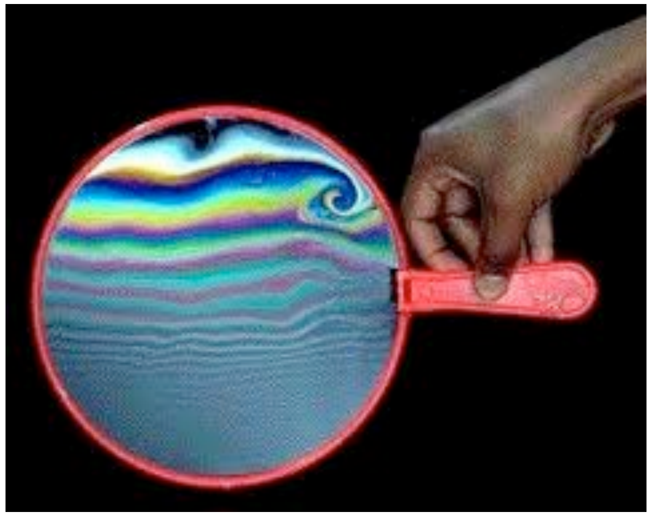


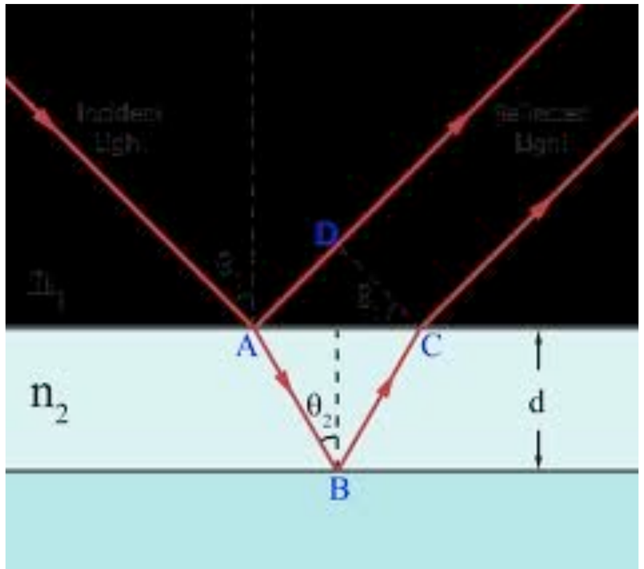


Actually small particles (e.g. electrons) behave same way (QM)!

thin films

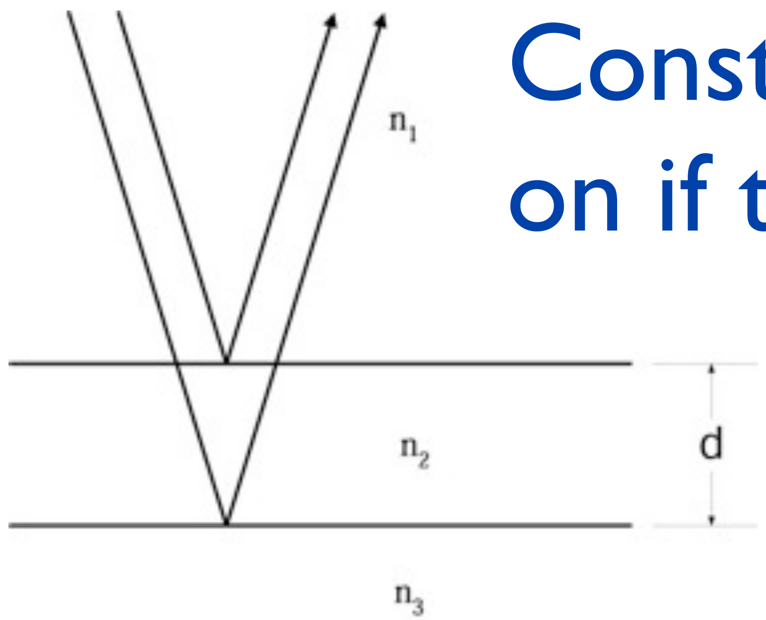






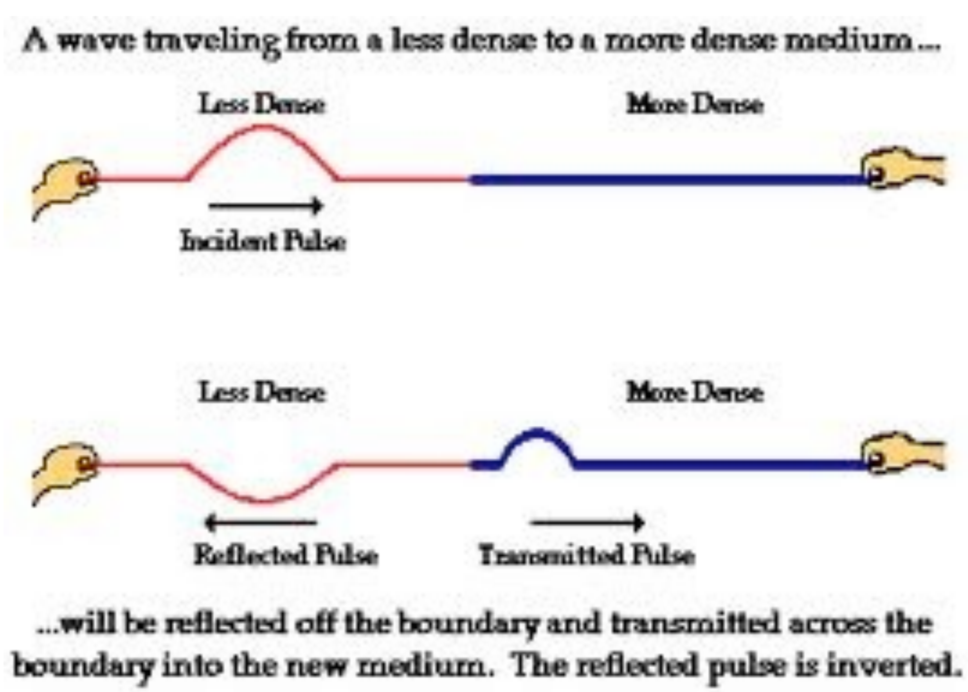
even some critters!

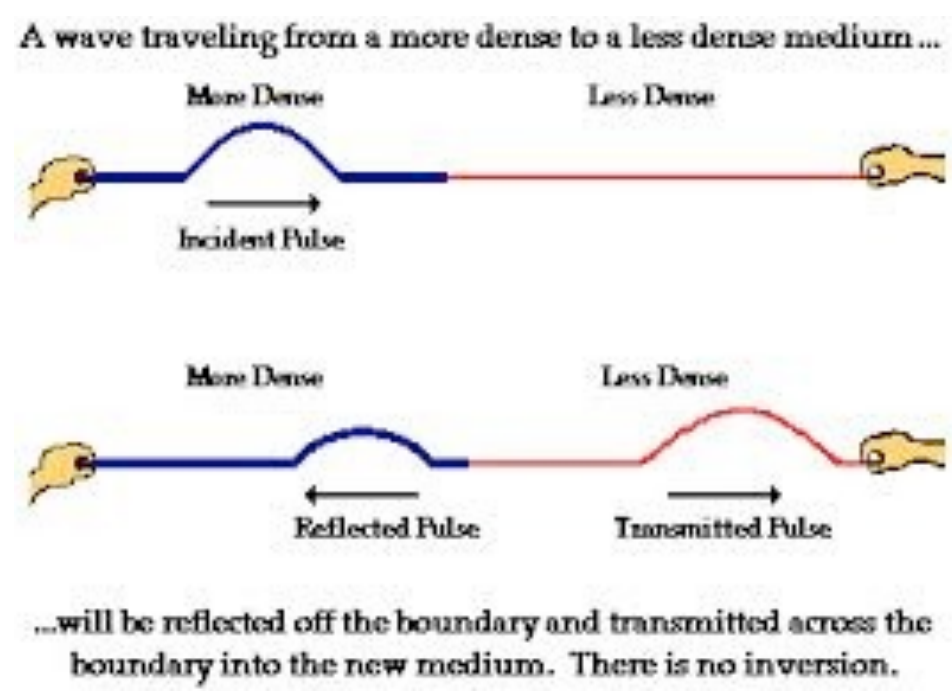
thin film interference



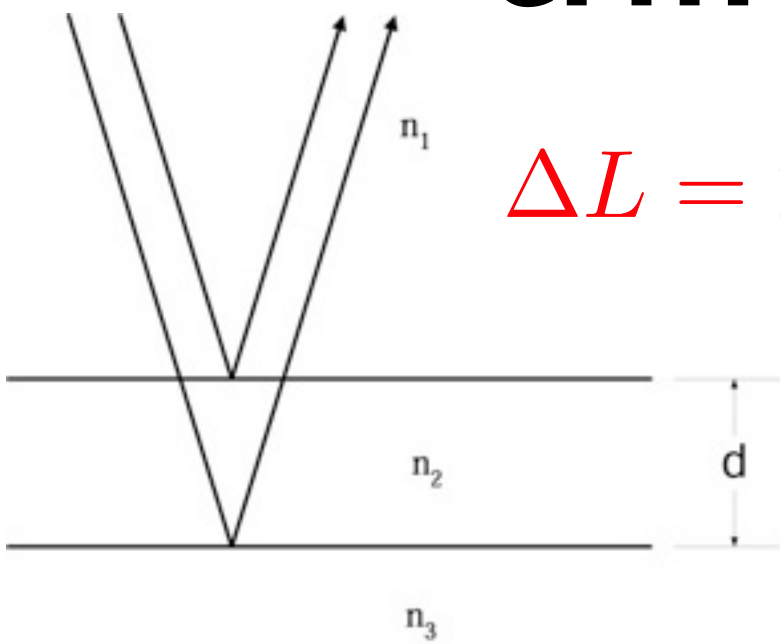
Constructive / destructive depending on if two waves are in / out of phase.

RPS: Reflected wave gets upside-down phase shifted if it hits bigger index n.





thin films, cont.



$\Delta L = 2d$ Length difference of two rays.

$\lambda_{n_2} = \lambda_{vac}/n_2$ in material 2

m= integer.

$$\Delta L = m\lambda_{n_2}$$

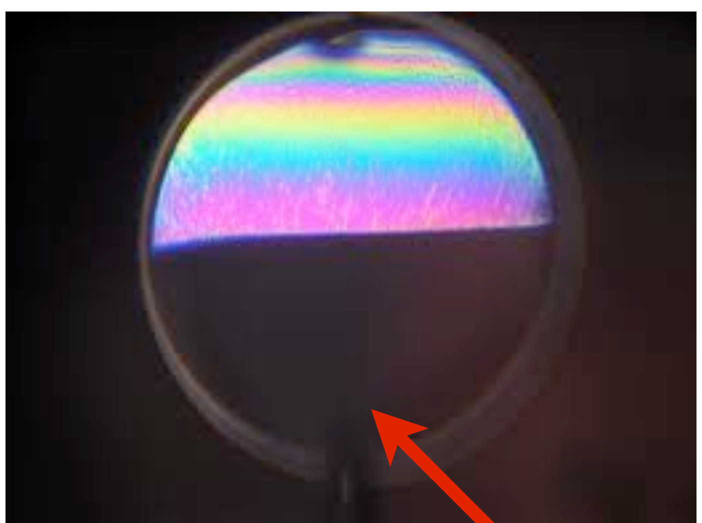
Constructive interference if 0 or 2 RPS's,
or destructive interference if 1 RPS.

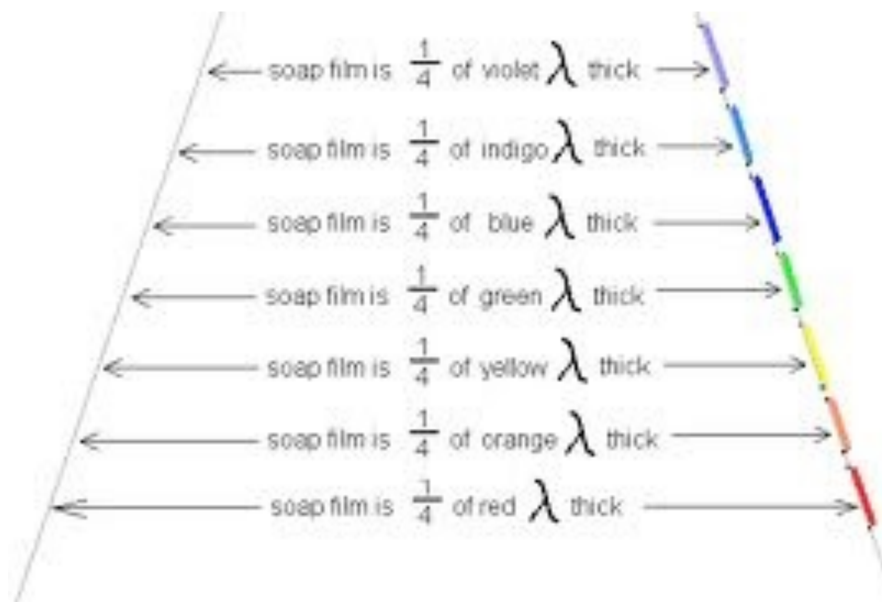
$$\Delta L = (m + \frac{1}{2})\lambda_{n_2}$$

Destructive interference if 0 or 2 RPS's,
or constructive interference if 1 RPS.

e.g. soap bubble

RPS from outer surface, not from inner surface.

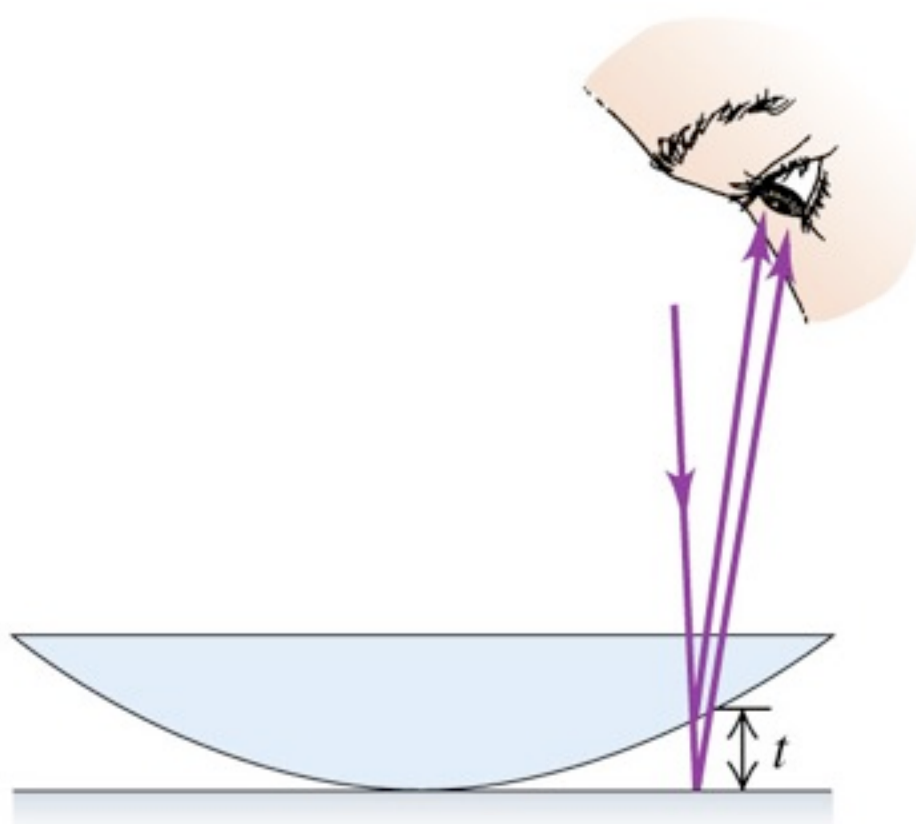




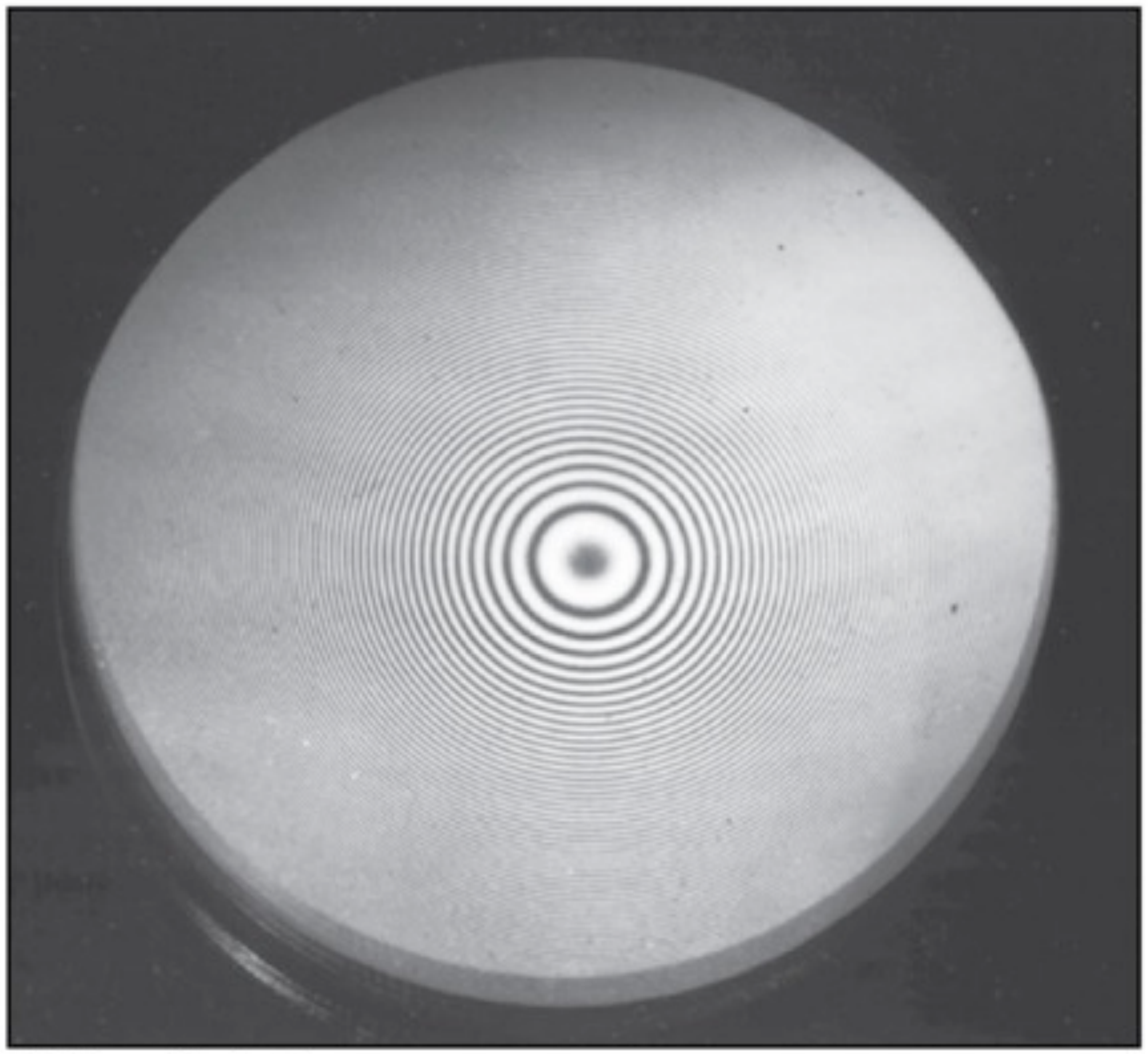
(Constructive interference outside of visible range here.)

Newton's rings

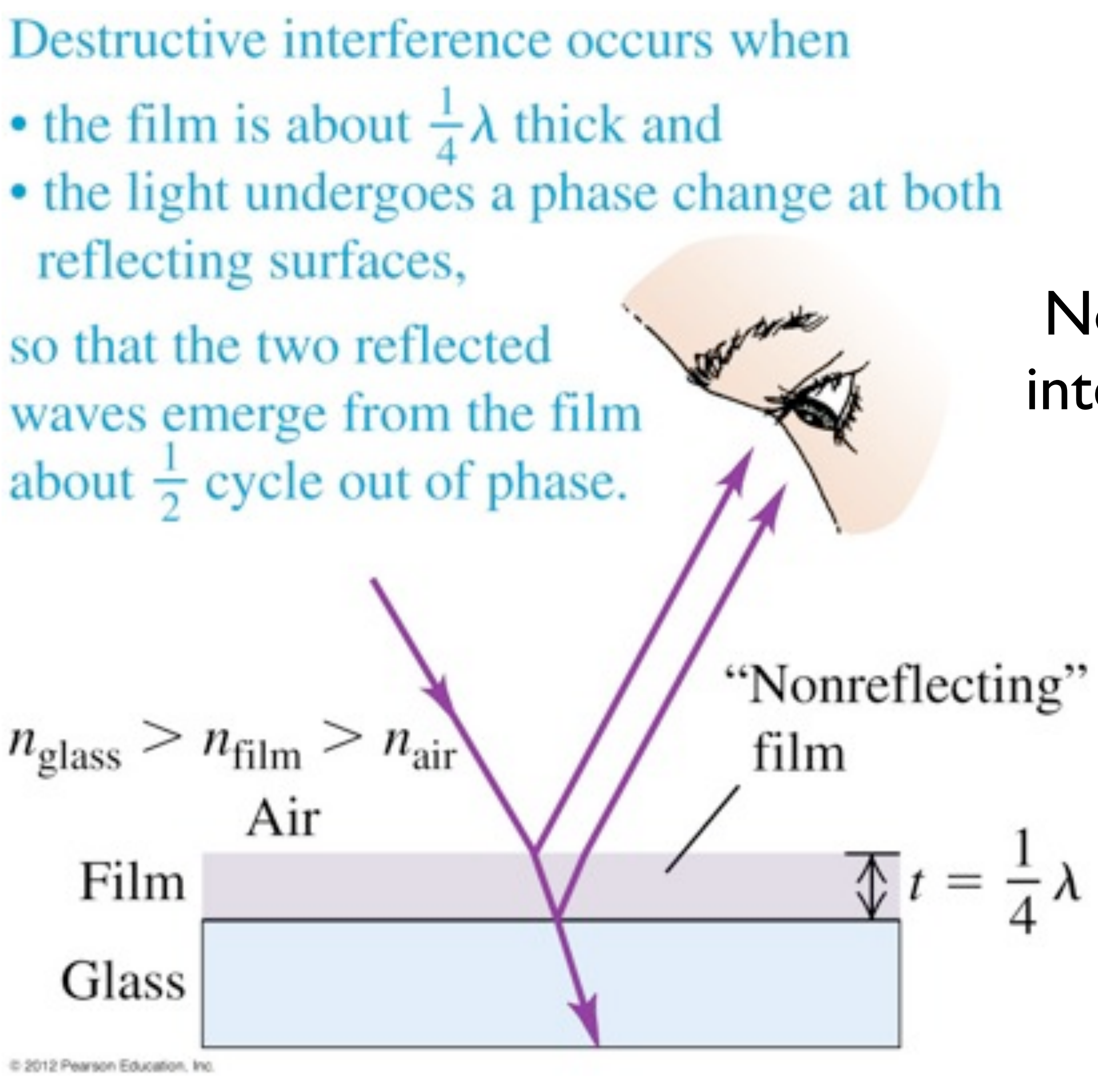
(a) A convex lens in contact with a glass plane



(b) Newton's rings: circular interference fringes

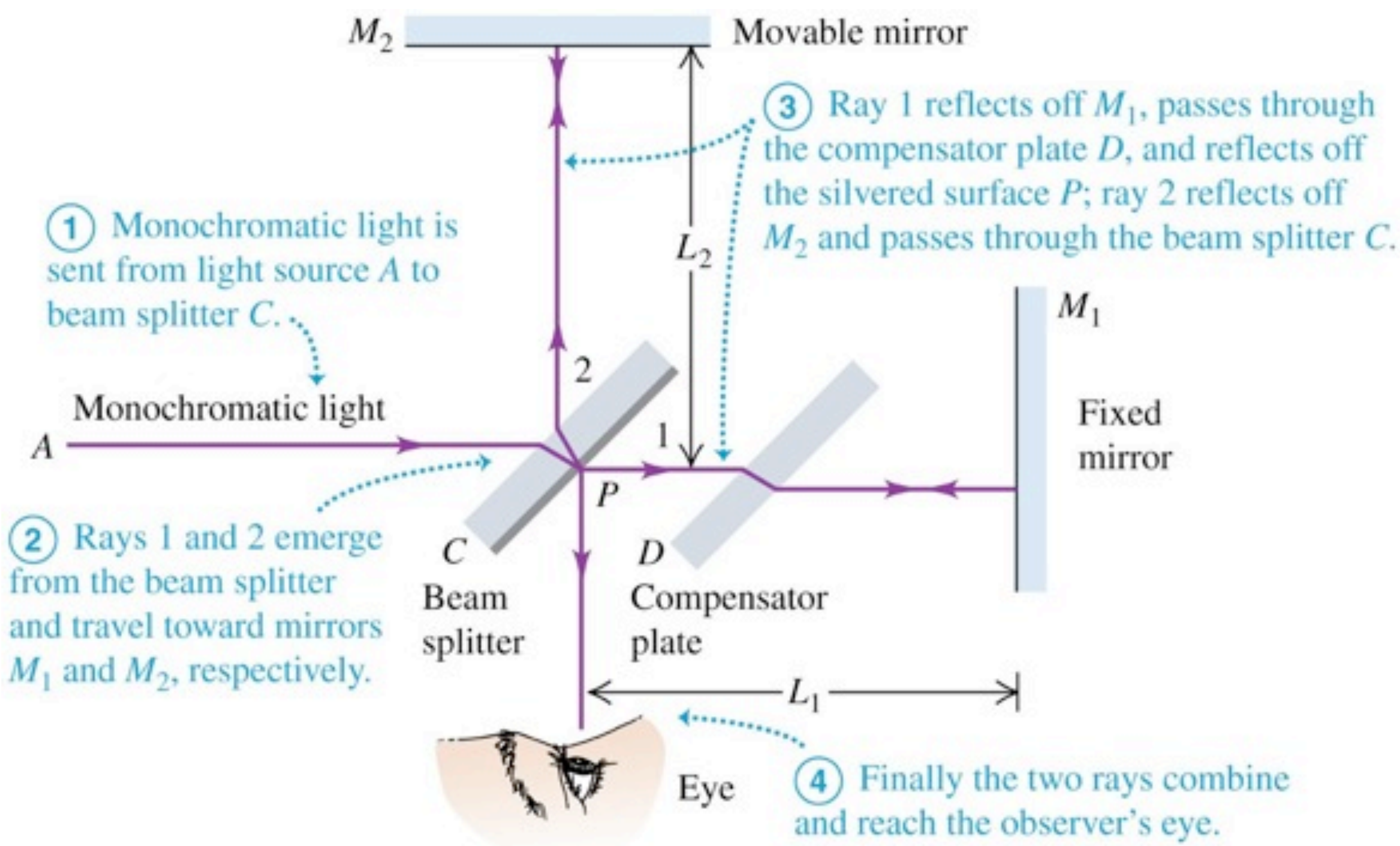


nonreflective coatings

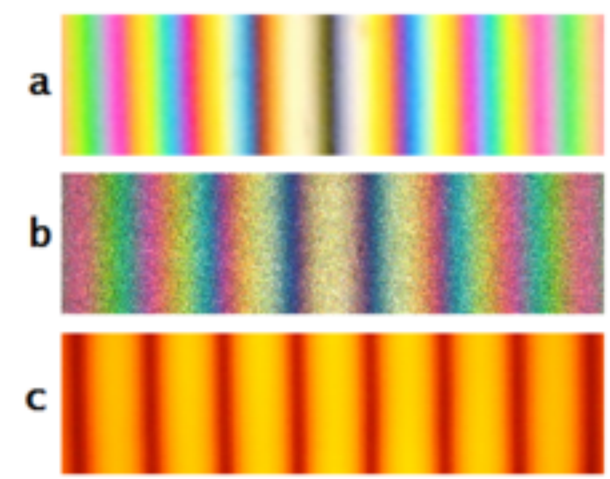


Note both reflections give a RPS, so destructive interference when the length difference is an odd number of half wavelengths.

Michelson interferometer



Two paths interfere, based on their length difference. If the lengths are changed, find interference fringes move. Can measure lengths, and wavelengths very accurately this way.



E.g. LIGO

Huge laser interferometer, looking for tiny length changes from gravitational waves. Hope to get a new view of the sky, using gravitational wave detectors in addition to electromagnetic wave (light) telescope detectors. Fantastically difficult, because gravity is so much weaker than electromagnetism. Hope to see for example strong gravity effects, from sources like black holes and maybe some special events, like black hole collisions, and also in the early universe.

Michelson Morley Expt:

1887. Used Michelson's interferometer to try to see the effect of earth's motion through the "ether". "Ether" was the imagined stuff, filling all space, which allows light to propagate. Thought to be analogous to how sound waves require a medium, i.e. the air.

They did a careful experiment and found a negative result: no evident effect on the light from the earth's motion. Was explained by Einstein's 1905 theory of special relativity: there is no ether, and light's speed is unaffected by motion of the observer or source.