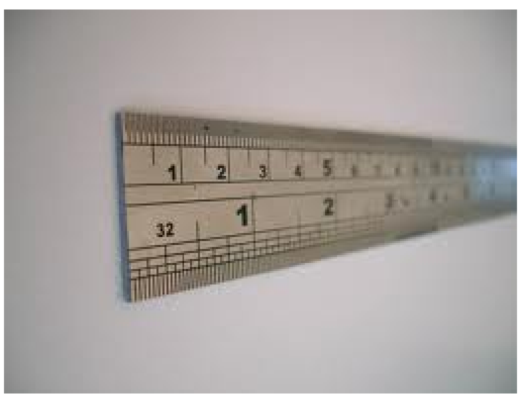
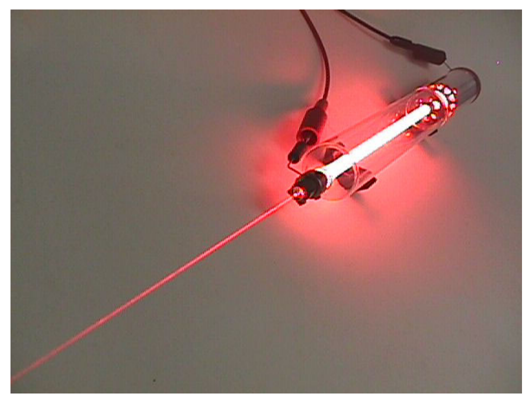
Lab 2: Wave length of light

PURPOSE

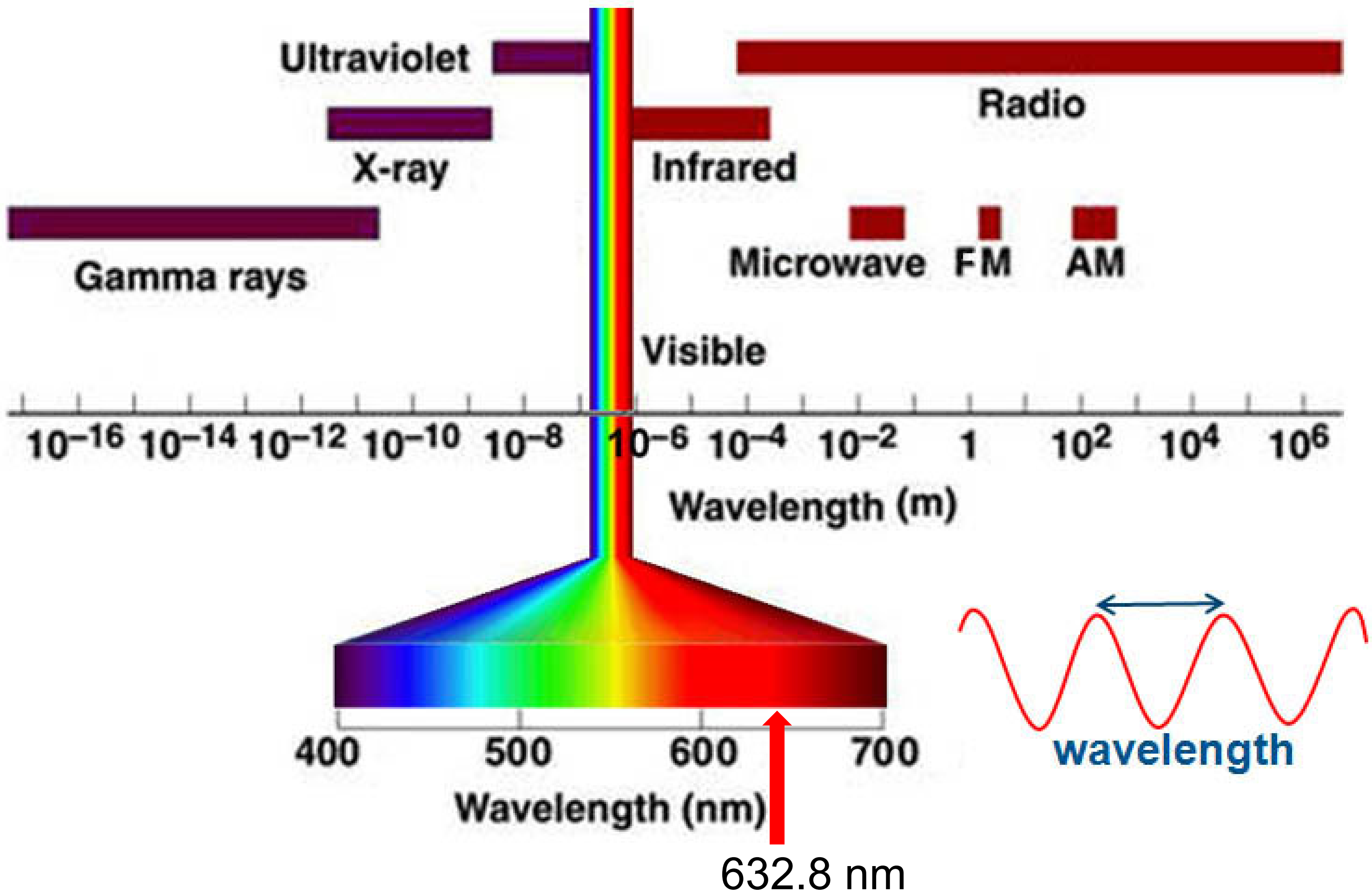
The purpose of this lab is to measure the wavelength of light from a He-Ne Laser using a steel ruler and a meter stick.





What is light?

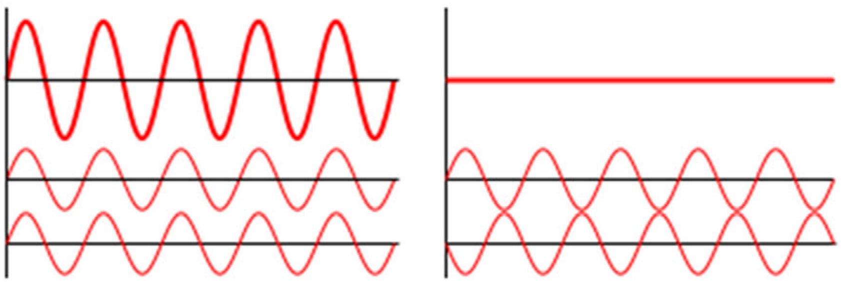
Wavelength of light (E&M wave)

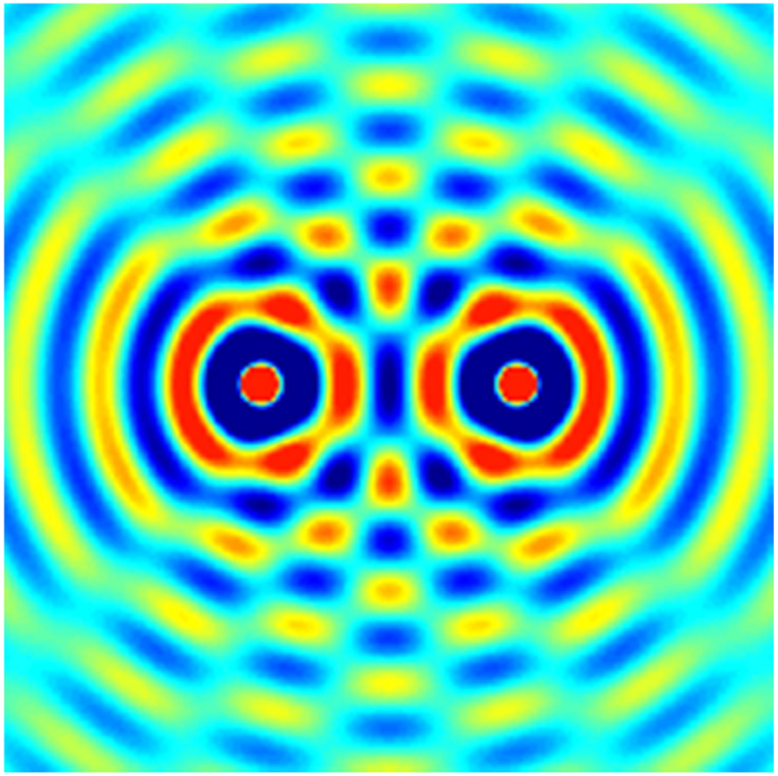


How to measure such a small length with a steel ruler and a meter stick?

Interference of waves

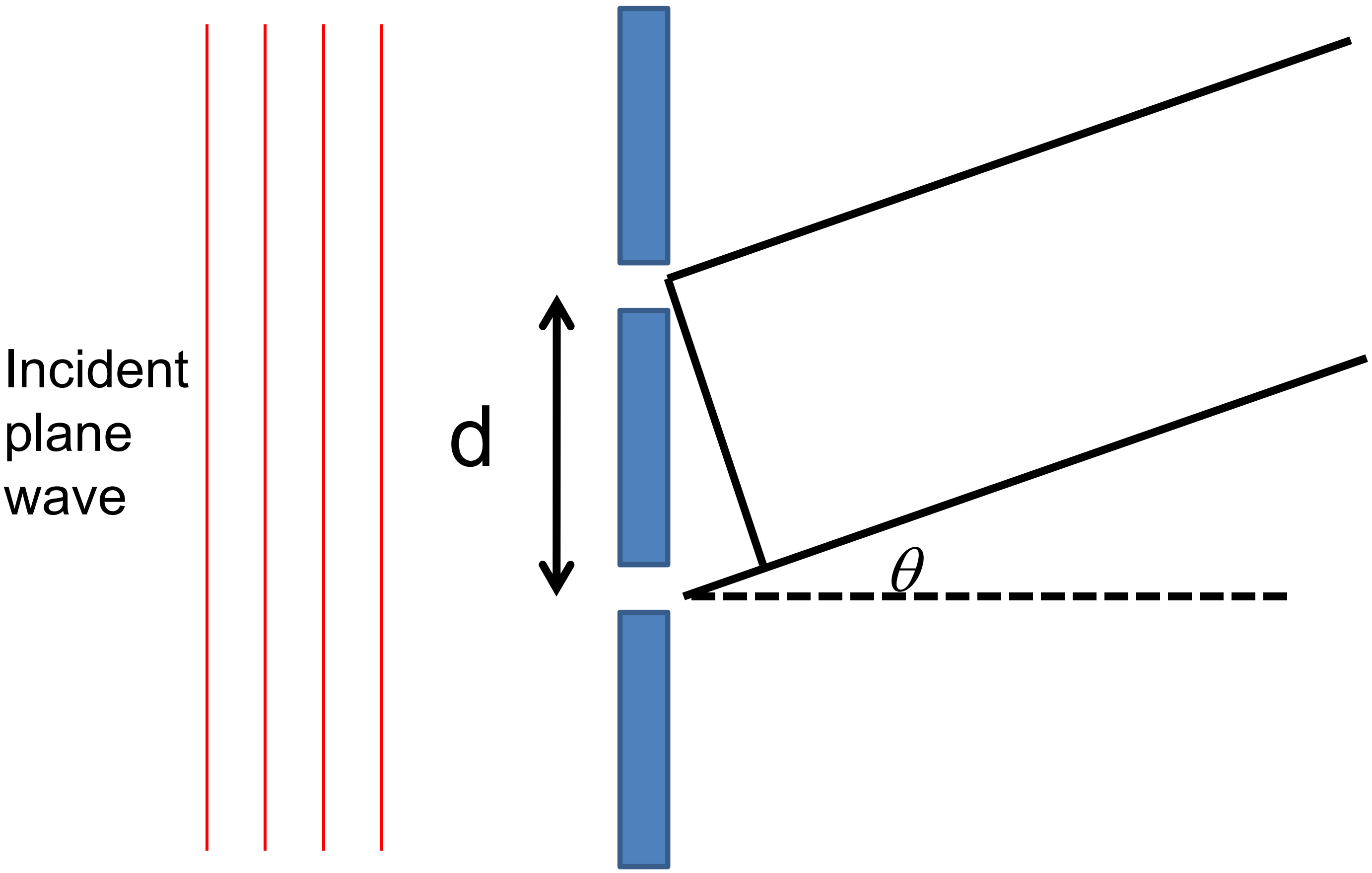
Interference: superposition of 2 propagating waves with the same frequency.





constructive	destructive
$\Delta l = n\lambda$	$\Delta l = \left(n + \frac{1}{2}\right)\lambda$
Intensity=max.	Intensity=0

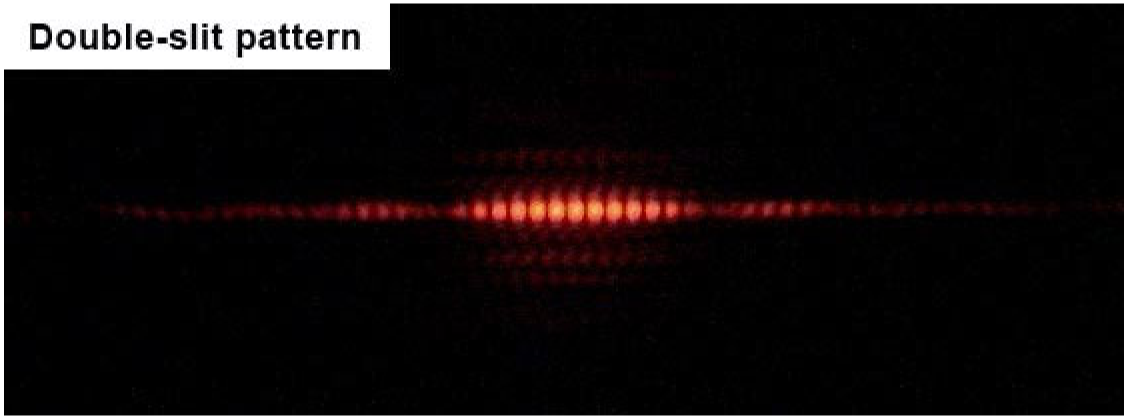
Young's double-slit experiment



destructive (dark): $\Delta l = d \sin\theta = \left(n + \tfrac{1}{2}\right)\lambda \Rightarrow \sin\theta_n = \dfrac{\left(n + \tfrac{1}{2}\right)\lambda}{d}$

what is the largest possible value of θ_n ?

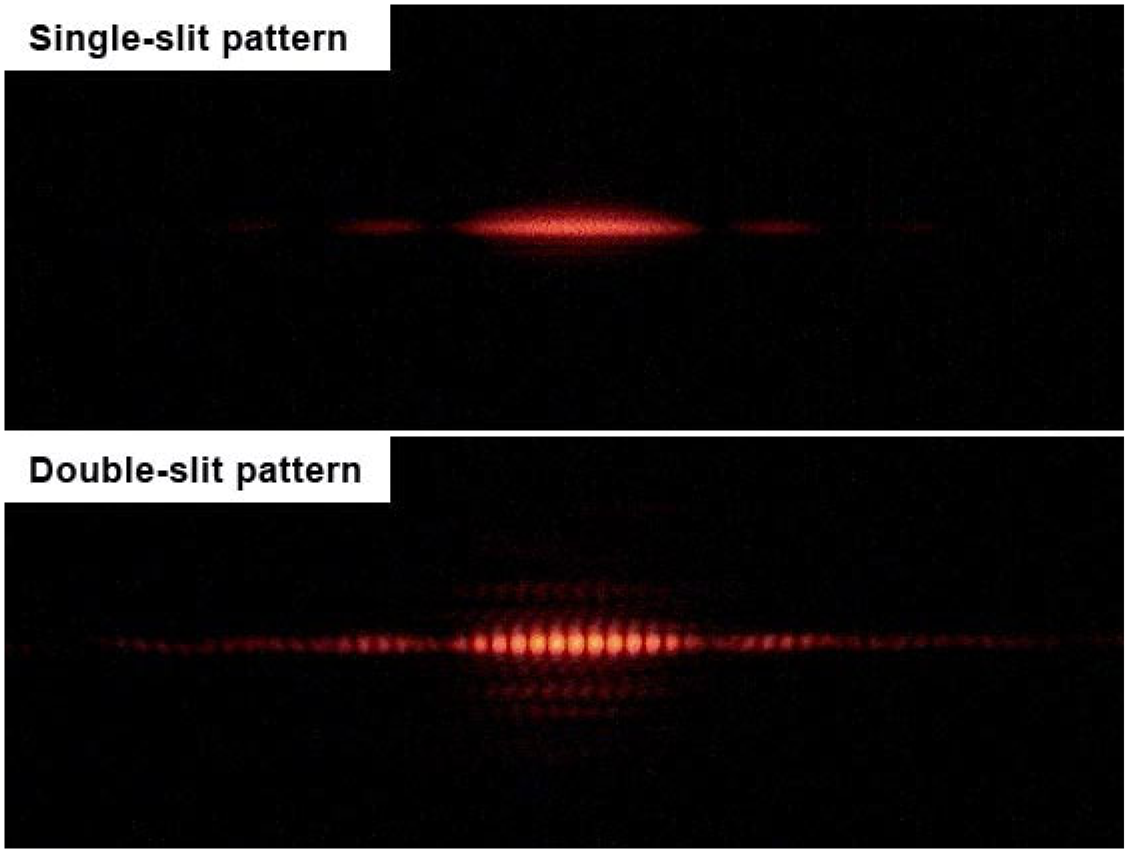
Experimental observation



$$\sin\theta_n = \frac{\left(n + \frac{1}{2}\right)\lambda}{d}$$

http://en.wikipedia.org/

Experimental observation

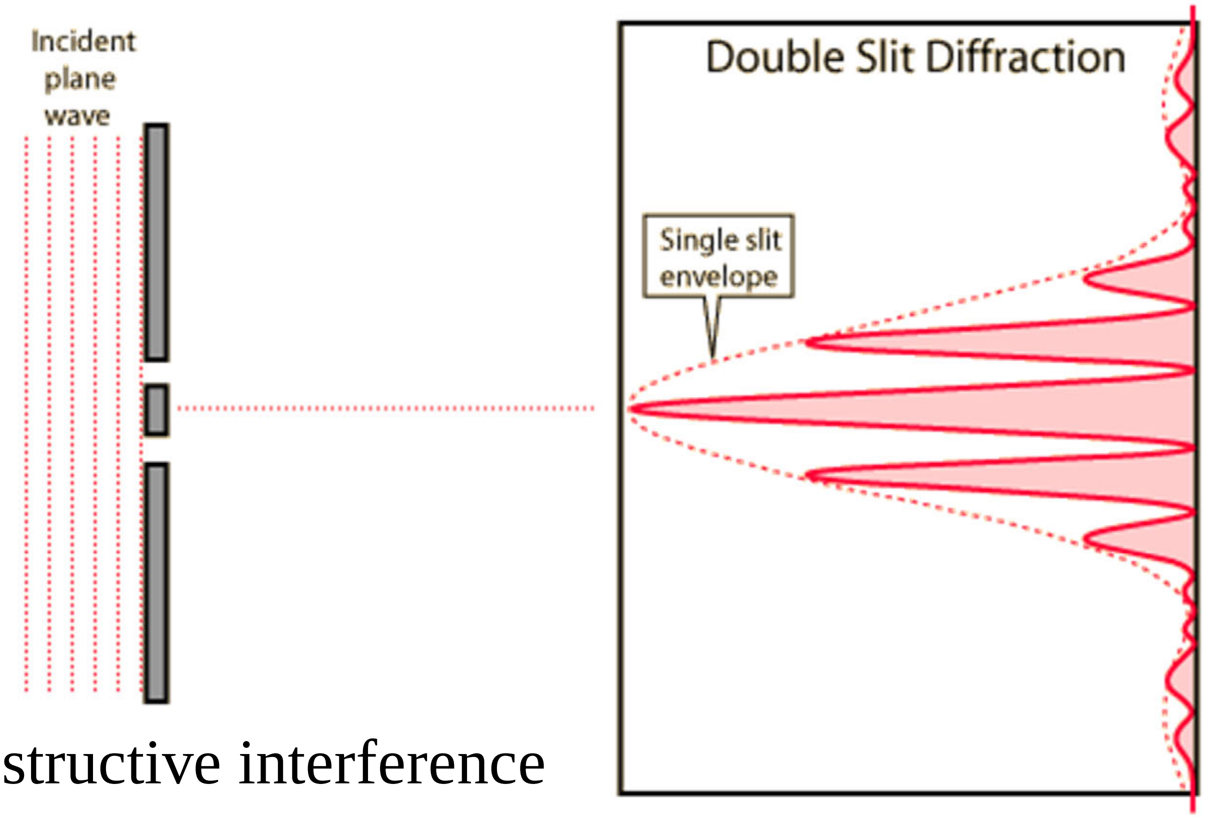


$$\sin\theta_n = \frac{\left(n+\frac{1}{2}\right)\lambda}{d}$$

http://en.wikipedia.org/

Double-slit diffraction

Diffraction (of 1 slit) “×” Interference (of 2 slits)

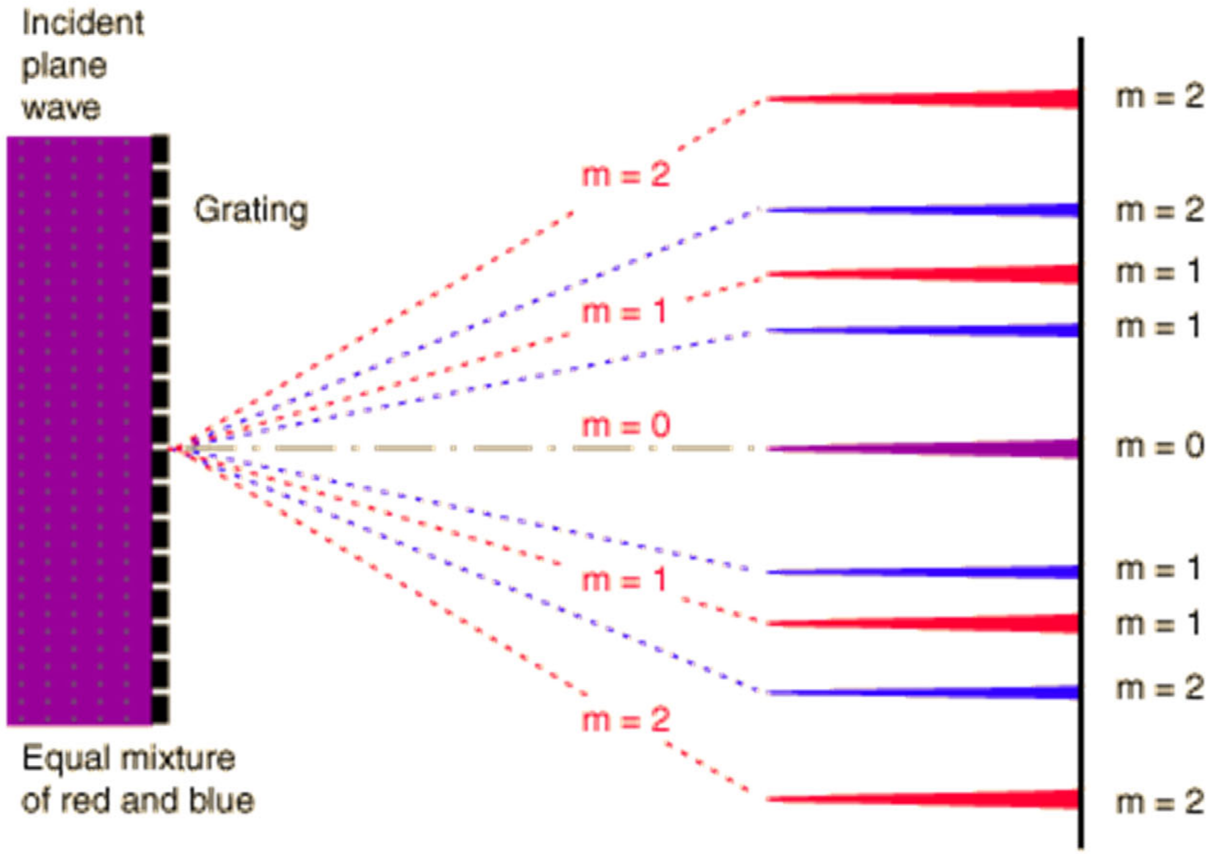


destructive interference

double slit: $\Delta l = d\sin\theta = \left(n+\tfrac{1}{2}\right)\lambda$

single slit: $\Delta l = \dfrac{w}{2}\sin\theta = \left(n+\tfrac{1}{2}\right)\lambda$

Diffraction grating: a lot of slits

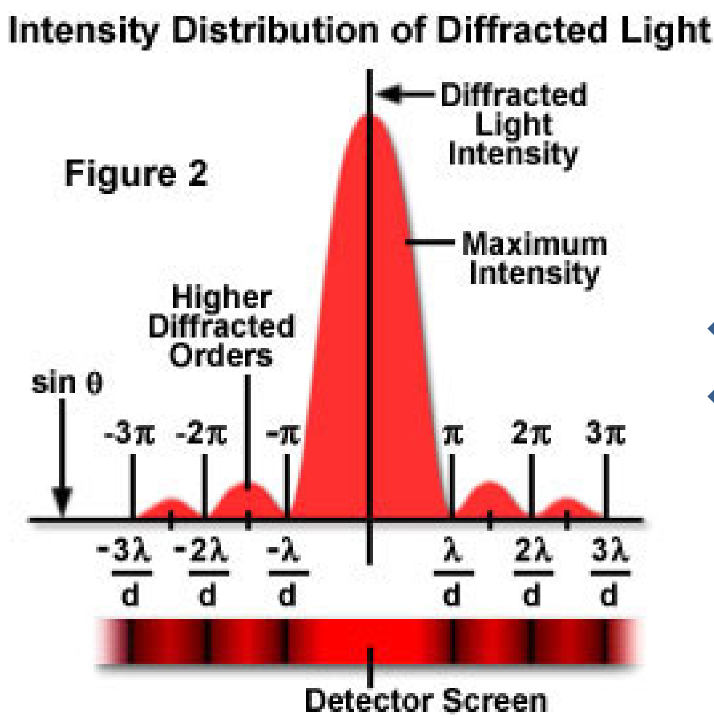


constructive interference: $\Delta l = d \sin\theta_m = m\lambda$

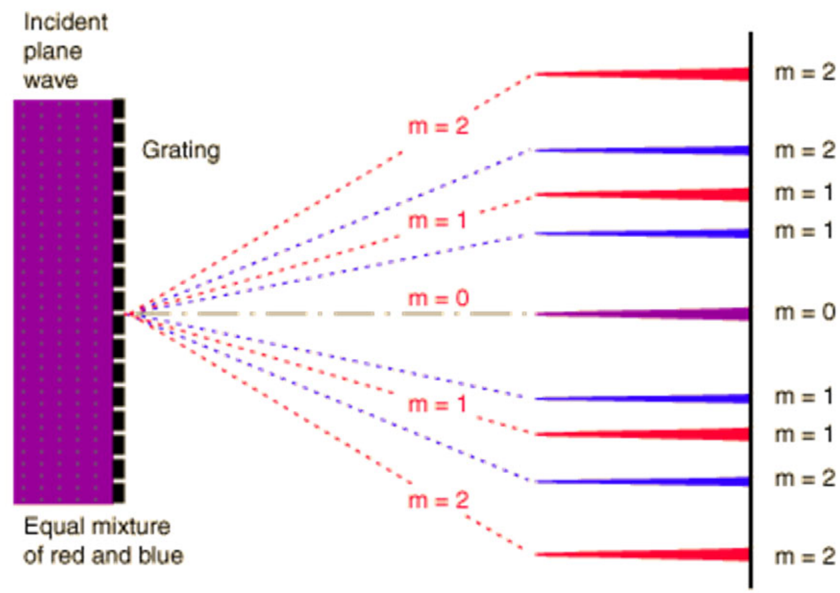
Same as the double-slit case

Diffraction grating: a lot of slits

Pattern of diffraction grating: Diffraction “×” Interference



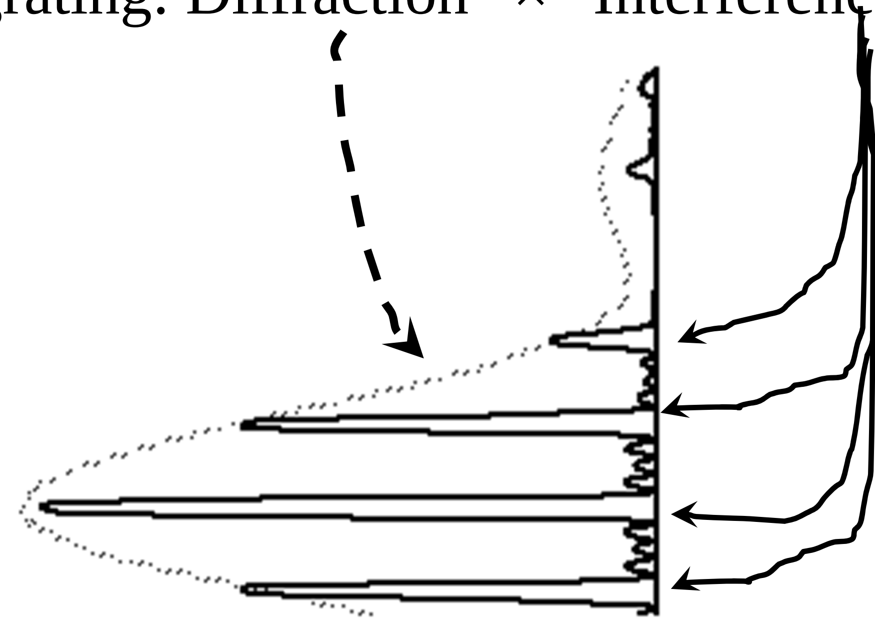
“Envelope”



Interference

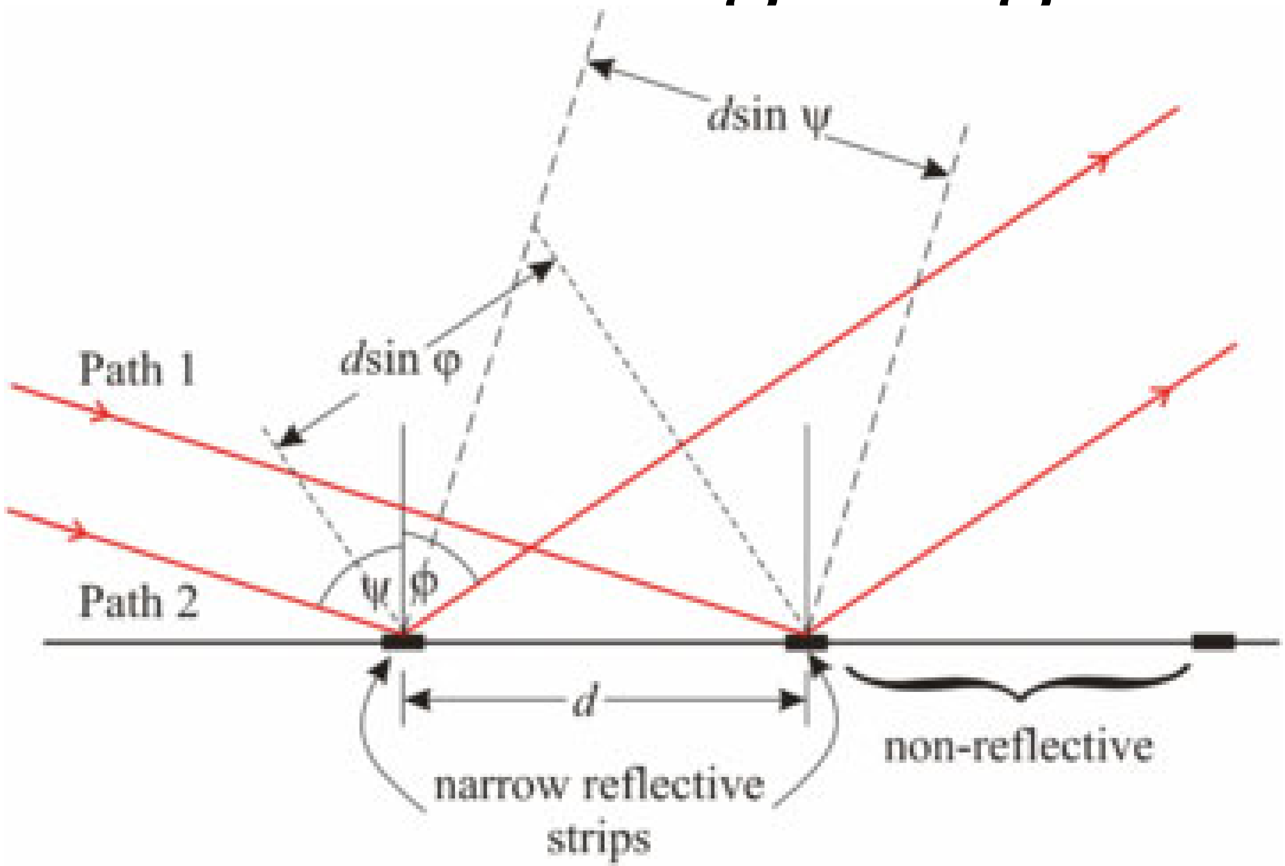
Diffraction grating: a lot of slits

Diffraction grating: Diffraction “×” Interference



http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/gratint.html

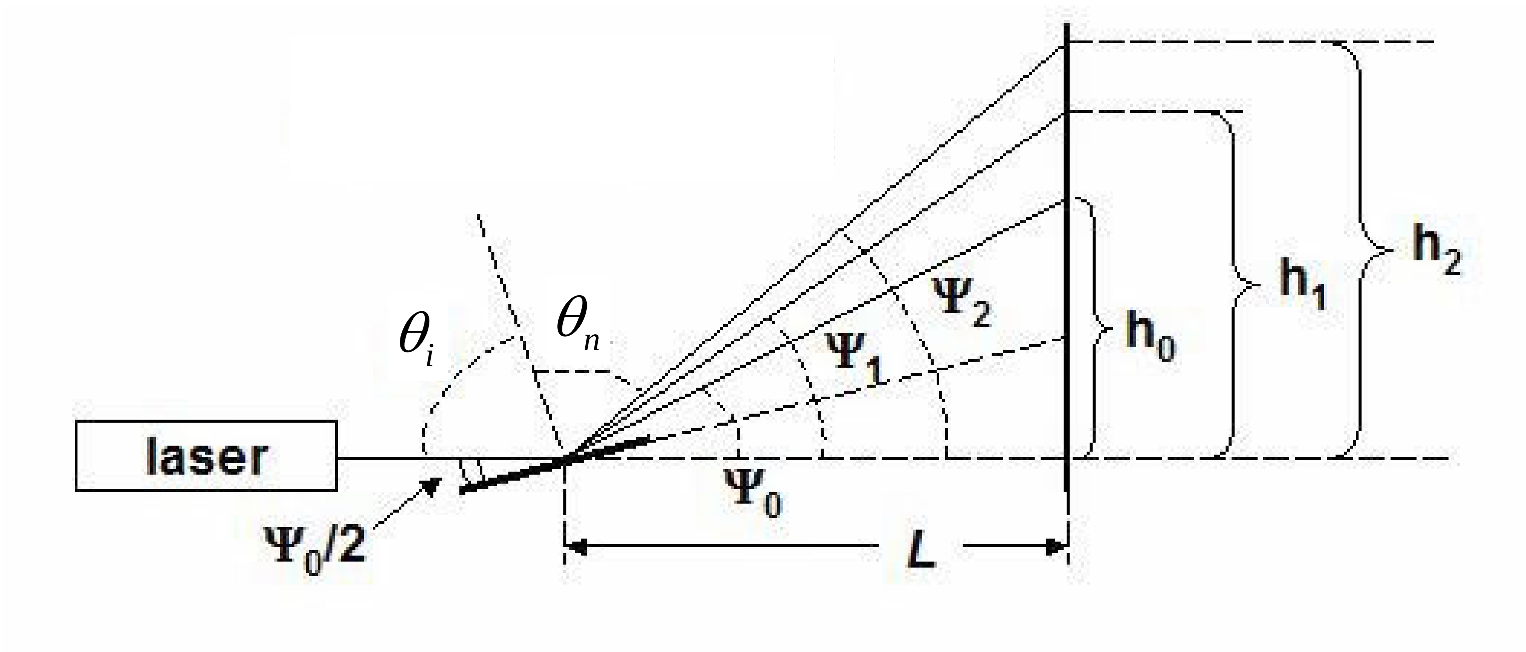
Reflection grating



$$d\left(\sin\psi - \sin\varphi\right) = n\lambda$$

D Nikolić and Lj Nešić, *Eur. J. Phys.* **33** 1677 (2012).

Lab 2 (reflection grating)



$$\theta_i = \frac{\pi}{2} - \frac{\Psi_0}{2} \quad \theta_n = \frac{\pi}{2} - \Psi_n + \frac{\Psi_0}{2} \quad \tan\Psi_0 = \frac{h_0}{L} \quad \tan\Psi_n = \frac{h_n}{L}$$

$$d\left(\sin\theta_i - \sin\theta_n\right) = n\lambda$$

Some approximations

$$n\lambda = d\left[\sin\left(\frac{\pi}{2}-\frac{\Psi_0}{2}\right)-\sin\left(\frac{\pi}{2}-\Psi_n+\frac{\Psi_0}{2}\right)\right] \quad \Rightarrow \quad n\lambda = d\left[\cos\left(\frac{\Psi_0}{2}\right)-\cos\left(\Psi_n-\frac{\Psi_0}{2}\right)\right]$$

Applying Taylor expansion: $\cos x \approx 1-\frac{x^2}{2}$

$$n\lambda \approx \frac{d}{2}\left[\left(\Psi_n-\frac{\Psi_0}{2}\right)^2-\left(\frac{\Psi_0}{2}\right)^2\right]=\frac{d}{2}\Psi_n\left(\Psi_n-\Psi_0\right)$$

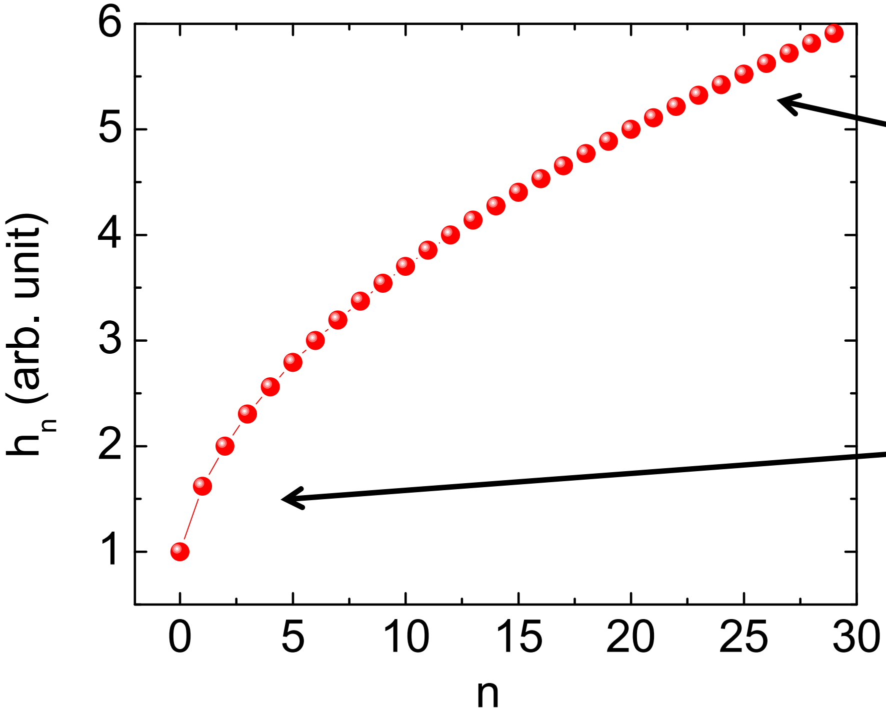
Applying Taylor expansion once more: $\tan x \approx x$

$$n\lambda = \frac{d}{2}\tan\Psi_n\left(\tan\Psi_n-\tan\Psi_0\right)=\frac{d}{2}\frac{h_n}{L}\left(\frac{h_n}{L}-\frac{h_0}{L}\right)=\frac{d}{2L^2}h_n\left(h_n-h_0\right)$$

$$\boxed{n\lambda = \frac{d}{2L^2}\left[\left(h_n\right)^2-h_nh_0\right]}$$

What to expect?

$$d\left(\sin\theta_i - \sin\theta_r\right) = n\lambda \quad \Rightarrow n\lambda = \frac{d}{2L^2}\left[\left(h_n\right)^2 - h_n h_0\right]$$



$$h_n \propto \sqrt{n} \quad h_0 << h_n \quad \left(\Psi_0 << \Psi_n\right)$$

$$h_n - h_0 \propto n \quad h_0 \sim h_n \quad \left(\Psi_0 \sim \Psi_n\right)$$

$$\lambda = 632.8 \text{ nm} = 6.328\times10^{-7}\text{m}, \; d = \frac{1}{32}\text{inch} = 0.794 \text{ mm} = 7.94\times10^{-4}\text{m}$$

Some estimations

How big should the angles Ψ_n be?

$$n\lambda \approx \frac{d}{2}\Psi_n\left(\Psi_n - \Psi_0\right) \quad \rightarrow n\lambda \approx \frac{d}{2}\Psi_n^2$$

$$\lambda \approx 0.001d \quad \Rightarrow \quad \Psi_n \approx \sqrt{0.001n} \approx 0.03\sqrt{n} = 1.8^\circ \times \sqrt{n}$$

How precise should these angles θ_n be? i.e. fractional error?

How to realize such a precision of angle measurements?

How about systematic errors?