Lecture 4: Optics – Diffraction

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Chapter 18, Fraunhofer Diffraction I

18.1 Introduction
18.2 Single-slit Diffraction Pattern
18.3 Diffraction by Circular Aperture

What is diffraction?

Do shadow have sharp boundary?

Shadow of a zinc oxide crystal illuminated by electrons

Shadow of a hand illuminated by a Helium Neon laser (light)

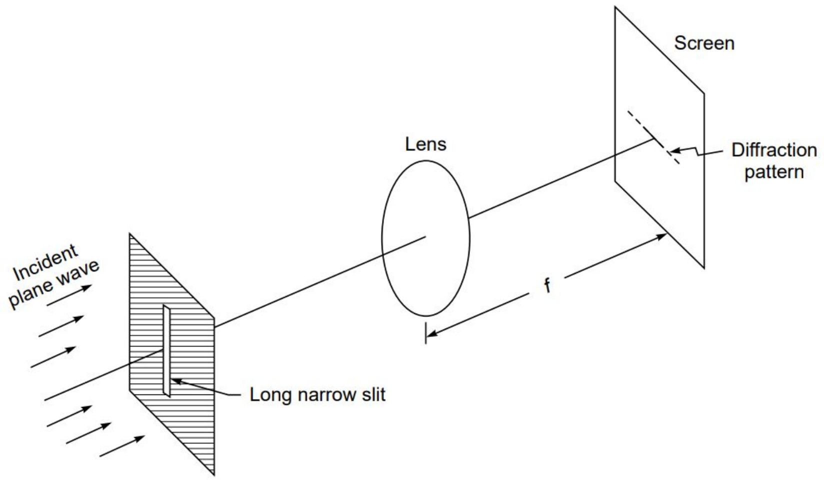
Light does not always travel in a straight line. It tends to bend around the objects. This tendency is called **diffraction.**

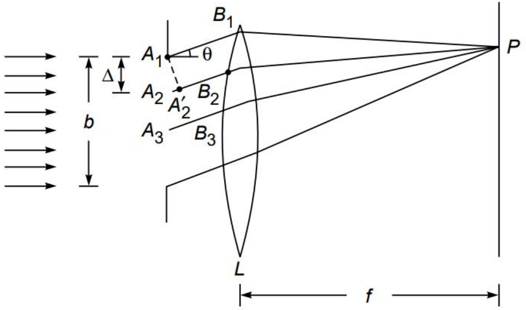
Any wave will do this, including matter waves and acoustic waves.

If the width of the slit is reduced, the diffracted light is more spread out

Heisenberg uncertainty principle

Single slit diffraction pattern





Electric field distribution:

$$E = A\frac{\sin\beta}{\beta}\cos(\omega t - \beta)$$

$$\beta = \frac{\pi b\sin\theta}{\lambda}$$

θ is angle the diffracted rays make an angle with the normal to the slit.

b: width of slit

λ: wavelength

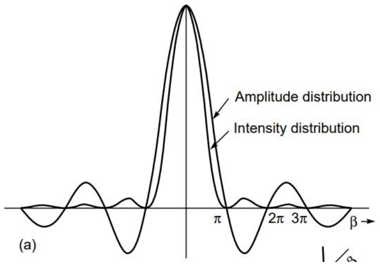
A: amplitude of wave

Intensity distribution:

$$I = I_0\frac{\sin^2\beta}{\beta^2}$$

where I_0 represents the intensity at $\theta = 0$.

Intensity distribution:



Condition for minimum

$$b\sin\theta = m\lambda;\ m = \pm 1, \pm 2, \pm 3, \ldots \text{ (minima)}$$

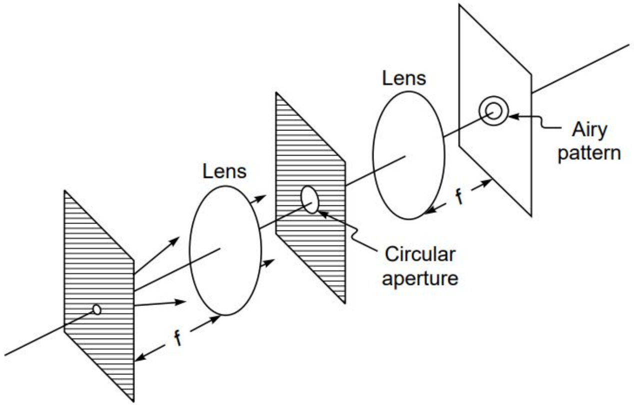
Passing light though apertures

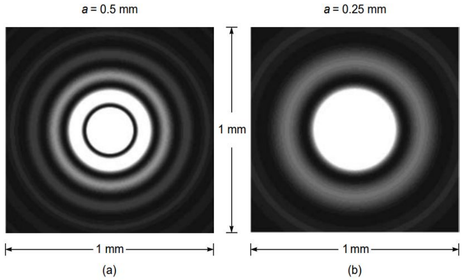
For a circular aperture…

How much small light beam cross-section is possible?

How best focus of light
we can get?

Diffraction by circular aperture





Computer-generated Airy patterns; (a) and (b) correspond to a = 0.5 and 0.25 mm, respectively, at the focal plane of a lens of focal length 20 cm (λ = 0.5 μm).

Airy pattern describes <u>best-focused spot of light</u> that a perfect lens with a circular aperture can make, limited by the diffraction of light.

<u>Intensity distribution of Airy pattern:</u>

$$I = I_0 \left[\frac{2J_1(v)}{v} \right]^2 \qquad \textbf{(19)}$$

where

$$v = \frac{2\pi}{\lambda} a \sin\theta \qquad \textbf{(20)}$$

a being the radius of the circular aperture, λ the wavelength of light, and θ the angle of diffraction; I_0 is the intensity at $\theta = 0$ (which represents the central maximum) and $J_1(v)$ is known as the Bessel function of the first order.

Diffraction limits spot-size of light beam