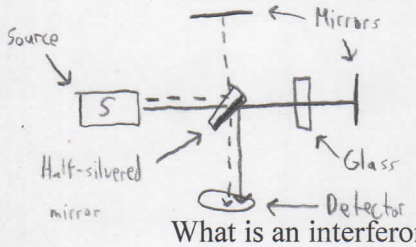
PH202-1G
Spring 2014

Worksheet March 31

Interferometer

Describe how an interferometer works. Draw a diagram to supplement your explanation.



Light from a source is split into two beams by a half-silvered mirror. The two beams reflect from mirrors and are combined by the half-silvered mirror, causing interference at a detector. The glass corrects the path length of the ray represented by the solid line.

What is an interferometer used for?

Moving one of the mirrors causes a path length difference. The interferometer can precisely measure wavelength.

Diffraction

What is diffraction? What physical aspect of a system determines whether diffraction occurs?

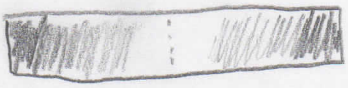
Diffraction is the bending of light around an edge. The ratio of the wavelength of the wave to the width of the opening $\left(\frac{\lambda}{w}\right)$ determines whether diffraction occurs. Large $\frac{\lambda}{w} \Rightarrow$ diffraction

Describe the pattern produced on a screen by the diffraction of light passing through a single slit.

Wide central bright fringe with subsequent bright fringes that are narrower and less intense.

How does this pattern differ from the pattern produced by light passing through a single slit which does not exhibit diffraction?

For a single slit, one bright fringe is observed.



How does this pattern differ from the pattern produced by the interference of light passing through two slits?

For two slits, the bright fringes have the same width and intensity.

Give a mathematical expression for the angles from the midline that produce dark fringes for single-slit diffraction.

$\sin\theta = m\frac{\lambda}{W}$ where m is a positive integer and W is the width of the slit.

Resolving power

What is resolving power?

Resolving power is the ability to distinguish between two objects.

What is the Rayleigh criterion for resolution?

Two objects are resolved when the first dark fringe of one object falls on the central maximum of the second object.

What angle will produce the first dark fringe for light passing through a circular opening?

$\sin\theta = 1.22\frac{\lambda}{D}$ where D is the diameter of the opening.

For small angles, $\theta \approx 1.22\frac{\lambda}{D}$ since $\sin\theta \approx \theta$

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Diffraction grating

What is a diffraction grating?

Material containing many small, closely-spaced parallel slits.

Describe the pattern produced on a screen by light passing through a diffraction grating.

Narrow principal maxima, which do not decay with distance, separated by low-intensity secondary maxima,

How does this pattern differ from the pattern produced by the interference of light passing through two slits?

Maxima are wider; no secondary maxima.

Give a mathematical expression for the angles from the midline that produce maxima from a diffraction grating.

$\sin\theta = m\frac{\lambda}{d}$ where m is a positive integer and d is the separation between slits (often given as lines·cm^{-1}, i.e. $\frac{1}{d}$)

Problems

1. A green laser (wavelength 520 nm) shines through a single slit with width 4.0 μm onto a screen. The width of the central maximum on the screen is 12 cm. a) What is the distance between the slit and the screen? b) If the single slit was replaced with a diffraction grating, what should the separation between the slits of the diffraction grating to produce a maximum at a distance of 9.0 cm away from the midline on the screen?

a) First find angle using $\sin\theta = m\frac{\lambda}{W}$. The central bright fringe is between the first dark fringes, so $m = 1$.

$$\theta = \arcsin\left(\frac{\lambda}{W}\right) = \arcsin\left(\frac{520\text{ nm}}{4.0\,\mu\text{m}}\right) = 7.470^\circ$$

The distance to the first dark fringe is half the width of the central maximum.

$$L = \frac{y}{\tan\theta} = \frac{12\text{ cm}}{2\tan 7.470^\circ} = \boxed{0.46\text{ m}}$$

b) $$\theta = \arctan\left(\frac{y}{L}\right) = \arctan\left(\frac{0.090\text{ m}}{0.46\text{ m}}\right) = 11.13^\circ$$

$$d = \frac{\lambda}{\sin\theta} = \frac{520\text{ nm}}{\sin 11.13^\circ} = \boxed{2.7\,\mu\text{m}}$$

2. A person is looking at a sign located about 200 m away. If the letters on the sign are 2.0 cm apart, what is minimum diameter of the person's pupil that will allow the letters to be resolved? Assume that the wavelength of the light is 500 nm.

$$\theta_{min} \approx 1.22\frac{\lambda}{D}$$

$$D \approx \frac{1.22\lambda}{\theta} = \frac{1.22 \cdot 500\text{ nm}}{\arctan(0.020\text{ m} / 200\text{ m})} = 1.065\cdot 10^{-4} \approx \boxed{0.11\text{ mm}}$$