Single Slit Diffraction

Aim:

To study the intensity distribution due to diffraction from single slit and to determine the slit width (d).

Apparatus :

Optical bench, He-Ne Laser, screen with a rectangular slit, photo cell, micro ammeter

Formula Used:

Slit width ‘ d’ is given by

$$\mathbf{d} = \frac{2D\lambda}{\beta}$$

where D = is the distance of screen from slit

λ = Wave length He-Ne laser (632.8 nm)

β = width of central maxima

First minima on either side of Central maxima is given by condition for diffraction minima. viz, $d \sin\theta = m\lambda$. with m = 1

Theory:

DIFFRACTION OF LIGHT:

Light travels in a straight line. However, when light passes through a small hole, there is a certain amount of spreading of light. Similarly, when light passes by an obstacle, it appears to bend round the edges of the obstacle and enters its geometrical shadow.

The phenomenon of bending of light around the corners of small obstacles or apertures and its consequent spreading into the regions of geometrical shadow is called diffraction of light.

The effect of diffraction is more pronounced if the size of the aperture or the obstacle is of the order of the wavelength of the light. As the wavelength of visible light $(\sim 10^{-6} m)$ is much smaller than the size of the objects around us, so diffraction of light is not easily seen. On the other hand sound waves have large wavelength $(\sim 10^{1} m)$ so sound waves easily exhibit diffraction by the objects around us.

Here we study the Fraunh offer class of diffraction in which light source is at infinite distance from obstacle, to ensure this source S of monochromatic light is placed at the focus of a convex lens L_1. A parallel beam of light and hence a plane wave front WW’ gets incident on a narrow rectangular slit AB of width d.

The incident wave front disturbs all parts of the slit AB simultaneously. According to Huygens theory all parts of the slit AB will become source of secondary wavelets, which all start in same phase. These wavelets spread out as rays in all directions, thus causing diffraction of light after it emerges through slit AB. Suppose the diffraction pattern is focused by a convex lens L_2 on a screen placed in its focal plane.

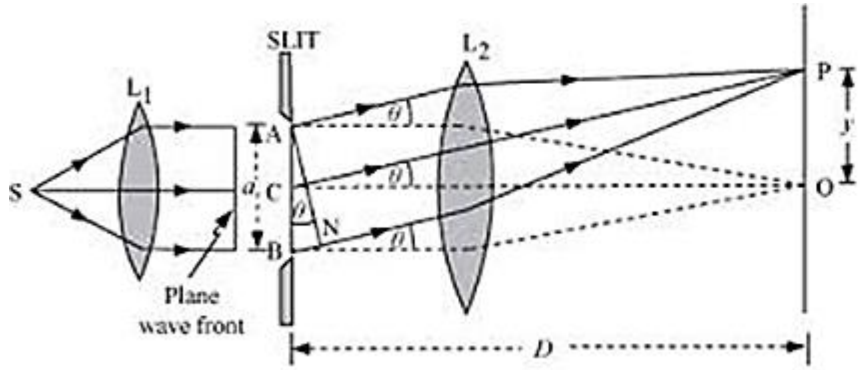


Figure 1 Diffraction through single slit

Calculation of path difference :
Suppose the secondary wavelets diffracted at an angle θ are focused at point P. The secondary wavelets start from different parts of the slit in same phase but they reach point P in different phases. The path difference (p) b/w the wavelets from A & B will be

p = BP-AP = BN = AB sin θ = d sin θ

Central Maxima:
All the secondary wavelets going straight across the slit AB are focused at the central point O of the screen. The wavelets from any two corresponding points of the two halves of the slit reach the point O in the same phase, they add constructively to produce a central bright fringe, whose width is decided by the first minima on either side.

Positions of minima :
Let the point P be so located on the screen that the path difference $p = \lambda$ and the angle be θ_1. Then from the above equation, we get

$$d \sin\theta_1 = \lambda$$

we can divide the slit AB into two halves AC & CB. Then the path difference b/w the wavelets from A & C will be $\lambda/2$. Similarly corresponding to every point in the upper half AC, there is a point in the lower half CB for which the path difference is $\lambda/2$. Hence they interfere destructively so as to produce a minimum.
Thus the condition for first minima is

$$d \sin\theta_1 = \lambda$$

similarly the condition for second minima is

$$d \sin\theta_2 = 2\lambda$$

Hence the condition for n^{th} minima can be written as

$$d \sin\theta_n = n\lambda$$

Now lets calculate the width of central maxima

The directions of 1st minima on either side of central maximum are given by

$$\theta_1 \approx \sin\theta_1 = 1.\frac{\lambda}{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Angle θ_1 is called half angular width of central maximum.

$\therefore$ Angular width of central maximum $\qquad 2\theta_1 = \frac{2\lambda}{d}$

If D is the distance of the screen from the single slit, For the lens L_2 kept close to the slit $D \approx f_2$ then the linear width of central maximum will be

$$\beta = D * 2\theta_1 = \frac{2D\lambda.}{d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Intensity of secondary maxima decreases with the order of the maximum. The reason is that the intensity of the central maximum is due to the constructive interference of wavelets from all parts of the contribution of wavelets form one third part of the slit (wavelets from remaining two parts interfere destructively), the second secondary maximum is due to the contribution of wavelets from the one fifth part only (the remaining four interfere destructively) and so on. Hence the intensity of secondary maximum decreases with the increase in the order 'n' of the maximum.

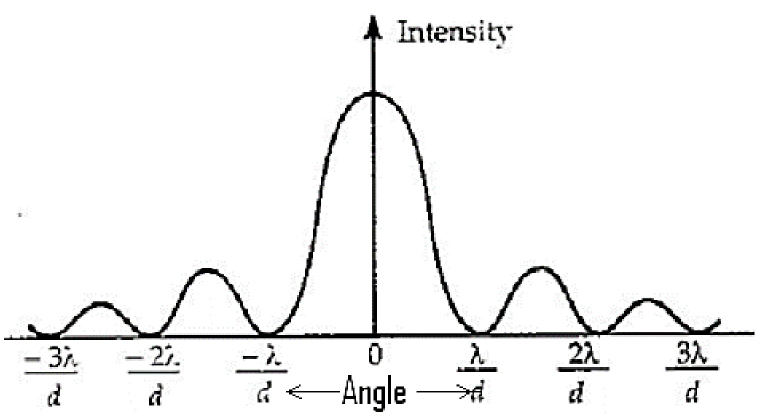


Figure 2 Diffraction pattern obtained through single slit

Set-up and Procedure

1. Switch on the laser source about 15 minutes before the experiment is due to start. This ensures that the intensity of light from the laser source is constant.

2. Allow the laser beam to fall on a slit formed in the screen provided. The photo detector is secured to a mount and is kept as far behind the slit as possible.

3. Try to observe the diffraction pattern by putting a screen (paper) in front of photo detector. After getting diffraction pattern on the screen (paper) remove it.

4. Adjust the position of photo detector somewhere around second minima & keep on recording the current with the position of photo detector moving it towards central maxima and continue in same direction till second minima on other side is obtained . The intensity distribution of the diffraction pattern is measured with the help of a photo detector connected to a microammeter.

5. Measure the distance between slit & photo detector.

6. Plot a graph (position of detector) vs (current). It will be of shape shown in fig.(3). Now measure the distance (β) between two first minima on either side of central maxima from graph. This is the width of central maxima 'β '. Now calculate width of slit using eq. (2).

7. Repeat the procedure for a different position of photo detector.

<u>Observation table</u>

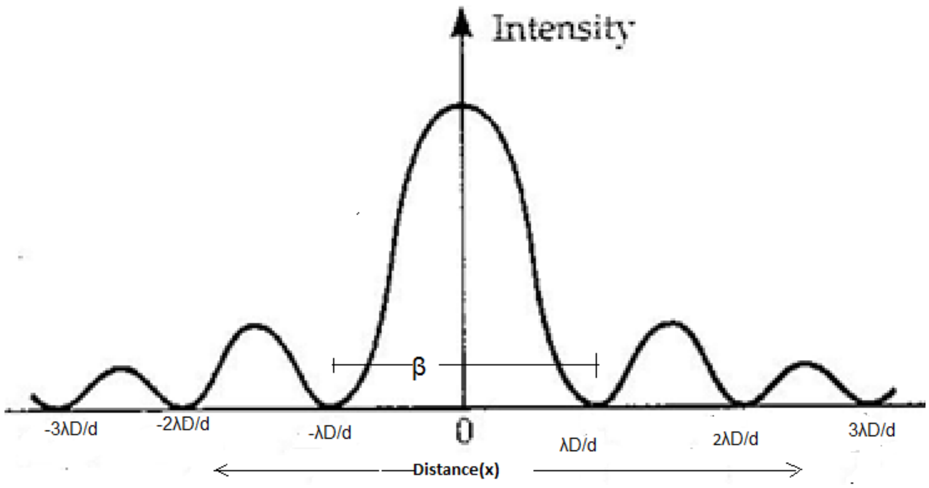
Wave length He-Ne laser λ=632.8nm
Position of Slit = ….. cm

<u>Table : 1</u>

S.No.	Position of the detector (cm)	Current in ammeter (μamp)
1		
2		
3		
..		
..		
..		
..		

<u>Table : 2</u>

S.No.	Distance between two first minimum on either side of central maxima (β *in cm*) (from graph)	Distance between the detector & slit (D in cm)	Slit width (microns) d= $\frac{2D\lambda}{\beta}$
1			
2			



Result:

1. The intensity distribution due to diffraction at a single slit was studied.
2. The width of central maxima 'β '=……mm
3. The width of the single slit is……..microns.

Precautions

1. The laser beam should not penetrate into eyes as this may damage the eyes permanently.
2. The photo detector should be as away from the slit as possible.
3. The laser should be operated at a constant voltage 220V obtained from a stabilizer. This avoids the flickering of the laser beam.
4. Laser should be started at least 15 minutes before starting the experiment.
5. Scale of vernier should be rotated slowly.