Date :

2. Single Slit Diffraction

Background

Interference
Diffraction
Fresnel Diffraction
Fraunhofer Diffraction

Aim of the experiment

To plot the intensity distribution of the Fraunhofer diffraction pattern by a slit and to measure the width of the slit.

Apparatus required

Laser, He-Ne 1.0 mw
220 V AC photocell
Multirange meter with amplifier
Adjustable slit
Screen

Theory

If a beam of monochromatic light of wavelength λ falls normally on the surface of a narrow vertical slit AB of width *b*, a number of dark and bright diffraction fringes on the either side of central maximum is observed.

Let θ be the angle between fringes on the left or on the right of the central maximum w.r.t central maximum (angle between the diffracted ray and normal to the slit).

$$\alpha = \frac{\pi . b . \sin\theta}{\lambda} \qquad \ldots(1)$$

where

for dark fringes $\alpha = \pm\pi, \pm 2\pi, \pm 3\pi, \ldots\ldots = \pm m\pi$ …(2)
for bright fringes $\alpha = 1.430\pi, 2.459\pi, 3.471\pi, 4.477\pi \ldots\ldots$ …(3)

The intensity of the diffraction pattern is given by

$$I(\theta) = I_0 \sin^2\alpha / \alpha^2$$

Procedure

1. Place the photocell at the center of the shifting range at the one end of the optical bench. Connect the photocell to the multimeter. The laser is mounted on the opposite end of the bench. Align the laser source on the optical bench to get collimated laser beam

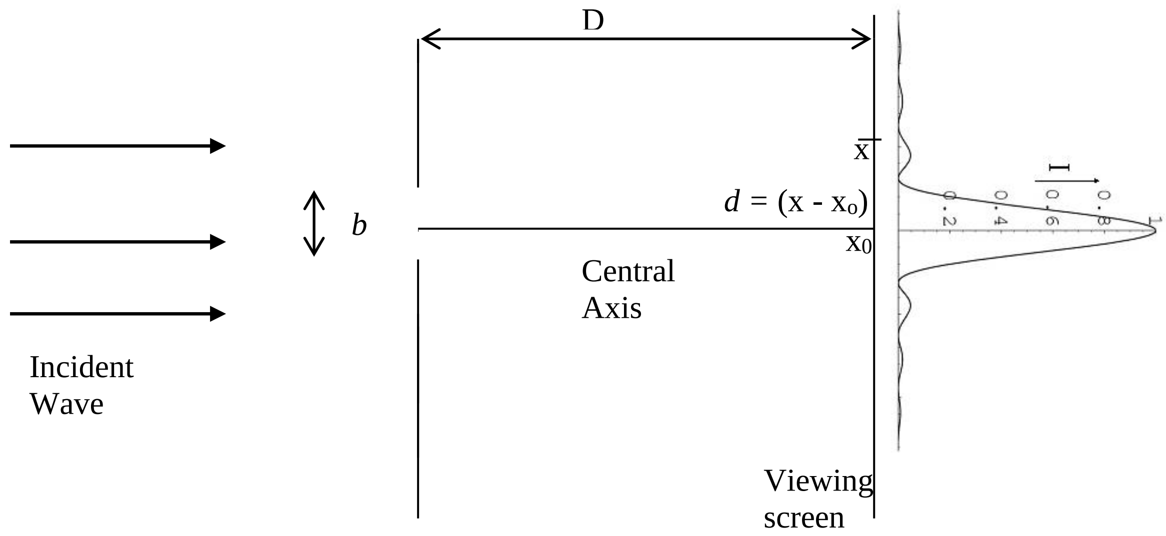

Fig. 1

2. (A broadened and parallel laser beam, obtained with the lenses f= 20 mm and f=100 mm, must impinge centrally the photocell. To achieve this the distance between the laser and the lens f=20mm is kept 11.5 cm whereas the distance between the lenses f=20mm and f=100mm is adjusted to 13 cm.)

3. Place the single slit perpendicular to the beam at a distance of 5 to 6 cm from the lens f=100mm. This makes a separation about 1m between the slit and the photocell.

4. Place the screen on the optical bench as far as possible from the single slit. Adjust the width of the slit to get bright and distinct fringes on the screen.

5. Measure the micrometer constant of the scale attached to the photocell detector. Remove the screen and place the photocell at one end of the fringe system. You should include 2-3 secondary maxima on either side of the central maximum. Turn the circular scale attached at the base of the cell in equal intervals and note that the intensity of the fringes using a multimeter. Reach the other end of the fringe system this way noting down many readings of the intensities in between. Repeat your readings moving in reverse direction.

6. Measure the distance, *D*, separation between slit and the detector, using the scale on the optical bench.

7. Calculate angular deviation for all above positions and plot two separate graphs in θ vs. intensity (as shown in Fig. 2), one for left to right and another for right to left observations. Calculate the slit width from both graphs.

8. Determine the vernier constant of the traveling microscope and measure the width *b* of the slit at several position, and find the mean *b*, by illuminating the single slit from behind.

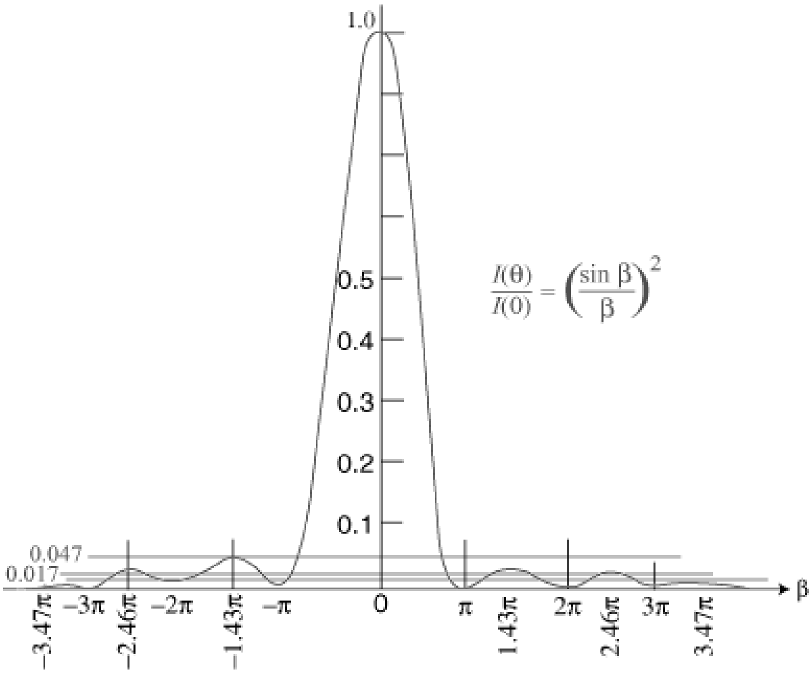

Fig. 2 Intensity distribution for single slit diffraction pattern

Observations

Wavelength of the light (λ) = ……………… cm

Distance of the slit from the detector, D = …………..cm

TABLE – 1

Intensity distribution of the single slit diffraction pattern (x_0 corresponds to position of the central maximum). Readings of the photocell current.

Position (x cm)	$\theta_{lr} = (x-x_0)/D$	Left to right l(amp)	Position (x cm)	$\theta_{rl} = (x-x_0)/D$	Right to left r(amp)

Continued

Position (x cm)	**$\theta_{lr} = (x-x_0)/D$**	**Left to right l(amp)**	**Position (x cm)**	**$\theta_{rl} = (x-x_0)/D$**	**Right to left r(amp)**

Position (x cm)	**$\theta_{lr} = (x-x_0)/D$**	**Left to right l(amp)**	**Position (x cm)**	**$\theta_{rl} = (x-x_0)/D$**	**Right to left r(amp)**

<u>TABLE – 2</u>

Vernier constant of the microscope:

<table>
<tr><th rowspan="3">No. of obs.</th><th colspan="6">Readings corresponding to</th><th rowspan="3">Width of the slit $b = R \sim L$ (cm)</th><th colspan="2">Width of the slit obtained from</th></tr>
<tr><th colspan="3">left edge of the slit</th><th colspan="3">Right edge of the slit</th><th rowspan="2">Microscope measurement (cm) mean b</th><th rowspan="2">Diffraction expt. (from bright/dark fringes) (cm)</th></tr>
<tr><th>Main scale (cm)</th><th>Vernier scale (cm)</th><th>Total L (cm)</th><th>Main scale (cm)</th><th>Vernier scale (cm)</th><th>Total R (cm)</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Results and Calculations

1. Plot Intensity distribution of the diffraction as a function of θ parallel to the plane of the slit.

2. Find the width of given slit from the plot and compare this width with that measured by microscope .

Error calculation

We have for dark fringes

$$b = \frac{2D\lambda}{d}; \qquad \text{where } d = (x - x_o)$$

Therefore, $$\frac{\delta b}{b} = 2\frac{\delta D}{D} + 2\frac{\delta d}{d}$$

Here, λ is supplied. The '2' factor that appear with $\frac{\delta D}{D}$ and $\frac{\delta d}{d}$ terms in the above expression is related to the fact that *D* and *d* are obtained as a difference of two scale readings, each with an error equal to the least count of the instrument.

Precautions

(i) Adjustment of lens, slit, laser must be made properly so that fringes are bright and distinct.

(ii) Since the linear shift *d* is proportional to *D*, it should be fairly large. A value of *D* of about 1.0 metres is preferable.

(iii) Make sure that a strong monochromatic source of light is used.

Questions

1. What do you understand by diffraction of light?
2. How does diffraction differ from interference?
3. When does the diffraction become appreciable?
4. How many classes of diffraction are there?
5. Distinguish between Fresnel and Fraunhofer diffraction.
6. In present experiment what kind of diffraction occurs and how?
7. What will happen if the width of the slit is increased?
8. What is the difference between a single slit and double slit fringe systems?
9. What is the source you are using in your experiment? How does it work?

References

1. Fundamental of Optics by F. Jenkins and H. White 535 JEN/F
2. Optics by A.Ghatak 535 GHA/O
3. Optics by E. Hecht 535 HEC/O

Graph : Single Slit Diffraction