Experiment 14

Single Slit Diffraction Experiment

Aim of the experiment: To study the diffraction pattern produced by a diode laser light passes through a single narrow slit. And hence determine the width of the slit using the Fraunhofer diffraction formula.

Equipment, apparatus, devices required: Diode laser (λ≈650 nm) and its power supply, single slit (micrometer adjustable), optical bench with mounts, graph-sheet on pin-board to serve as screen, meter scale, Vernier callipers, stand and holders

Principle: When a parallel beam of monochromatic light from a diode laser is incident on a narrow slit whose width is comparable to the wavelength of light, diffraction takes place. The diffraction pattern consists of a central bright maximum flanked by alternate dark and bright fringes of decreasing intensity.
For single slit Fraunhofer diffraction, the intensity distribution is given by:

$$I = I_0 \left(\frac{\sin\beta}{\beta}\right)^2$$

where,

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

here,
d = width of the slit
λ = wavelength of the laser light
θ = angle of diffraction

Condition for Minima
$d \sin\theta = m\lambda \;\; m = 1, 2, 3, \ldots..$

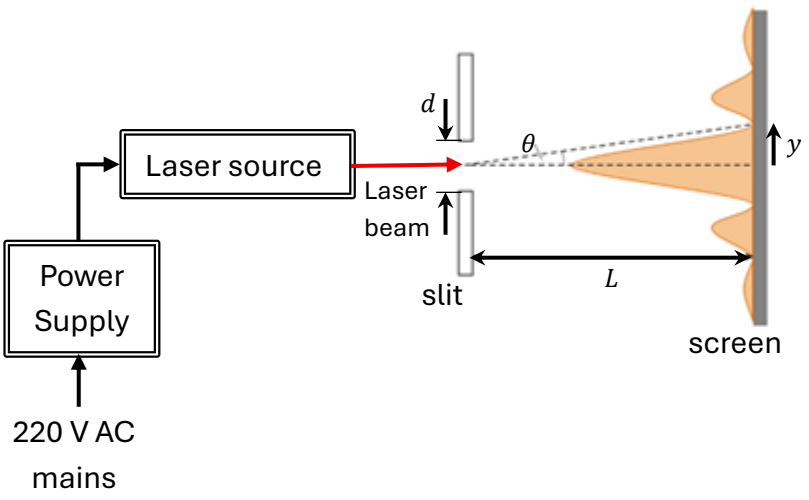
For small angles,

$$\sin\theta \approx \tan\theta = \frac{y}{L}$$

Hence,

$$d = \frac{m\lambda L}{y}$$

where,
y = distance of the mth dark fringe from the central maximum
L = distance between slit and screen



Procedure and precautions:

1. Mount the laser diode on the optical bench and align it horizontally. The laser beam should not be viewed directly.
2. Place the single slit in front of the laser beam perpendicularly. The slit should be clean. Dust on edges of the slit may scatter the light falling on it.
3. Keep the screen at a distance D (1–2 m) from the slit and measure it.
4. Switch on the laser and adjust alignment to obtain a clear diffraction pattern. A graph-sheet may be used to serve as the screen. This helps in marking the positions of the maxima and minima accurately.
5. In case of an adjustable slit, adjust its width. Narrower the slit wider is the spread of the diffracted pattern.
6. Mark the position of the central bright maximum.
7. Measure the distance x between the central maximum and successive minima on either side.
8. Take readings for different orders m.
9. Calculate the slit width using the formula.
10. Take the average value of slit width.
11. Slit to screen distance 'L', should be measured accurately.
12. Error in locating exact position of minima.
13. Imperfect slit edges.
14. Repeat the experiment by recording the diffraction pattern for at least three different slit widths.
15. Measure the distance between the first two minima and record it as $2y$.
16. Calculate the width of the slit using the formula
17. Please note that the distance of the laser source to the slit does not matter and hence need not be recorded.

Observations:

Wavelength of diode laser,

$$\lambda = 650\ nm$$

Distance between slit and screen,

$$D = \_\_\_\_\_ m$$

Table-1:

Order (m)	Distance between symmetric minima $2y$	y	Slit width d
	(cm)	(cm)	(mm)

Calculations:

Slit width for different orders is calculated using the relation:

$$a = \frac{m\,\lambda\,D}{x}$$

The mean slit width

$$a = \_\_\_\_\_ \, mm$$

Results and Discussion:
The width of the single slit as determined using
diffraction of light is = _____ mm
The width of the same slit measured using
a travelling microscope is = _____ mm

The experimentally observed diffraction pattern confirms the wave nature of light. The central maximum is wider and brighter compared to secondary maxima, in agreement with Fraunhofer diffraction theory.

Single slit diffraction using a diode laser was successfully studied, and the slit width was determined experimentally with reasonable accuracy.

Viva Questions:

- How does diffraction differ from interference?
- What is Fraunhofer diffraction?
- How can you say that the single slit diffraction experiment is an example of Fraunhofer diffraction?
- Why is a laser preferred in diffraction experiments?
- What difference would it make if a wire is kept in place of the slit?
- What difference would it make if sodium light is used in place of laser?
- Why is the central maximum the brightest?
- What is the effect of increasing slit width on diffraction pattern?
- In what way is the experiment useful in the present context of science and technology?