EXPERIMENT 8: Single Slit Diffraction

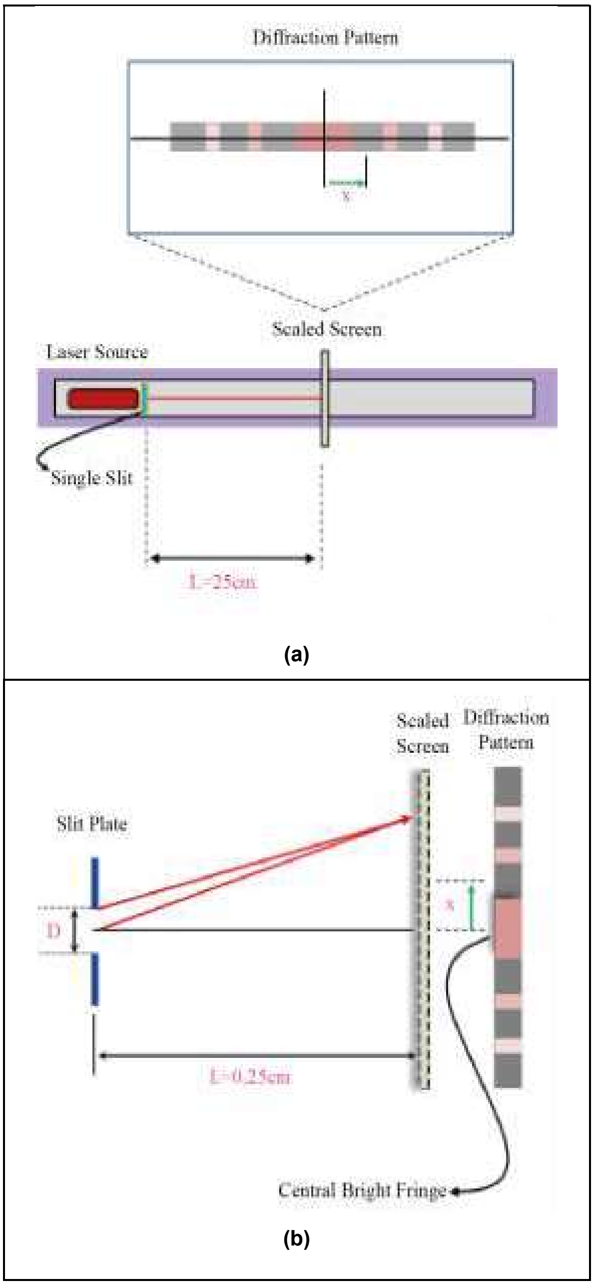


Figure-45: Experimental set-up for single slit diffraction **(a)** and position of central bright fringe at diffraction pattern **(b)**.

1. Laser source, single slit plate and scaled screen are placed on optics track (**Figure-45a**).

1.1. In experiment of single slit diffraction, slit of which width is smallest is chosen.

CAUTION

Please, don't look at laser beam directly.

1.2. Wavelength of laser source used in experiment is $\lambda = 650nm$.

1.3. Rectangular slit is put on its holder horizontally (or vertically) and it is placed in front of laser source by means of its holder so that they are close to each other.

1.4. Distance between slit and screen is adjusted to;

- $L = 25\ cm.$

This value is noted as distance of screen.

2. Laser source is opened.

2.1. Diffraction pattern formed by laser source, i.e. bright and dark fringes, is observed on scaled screen.

2.2. Central bright fringe's width and brightness is observed. ***(Scaled screen used in experiment has latitudinal and longitudinal metric ruler.)***

If a monochromatic light beam of which wavelength is λ pass from a single slit of which width is D, central bright fringe is seen on screen. Intensity of light of bright fringes on screen declines as it is approached to sides of screen. So, it is seen that intensity of light is maximum at central bright fringe and decreases at sides of screen.

3. At single slit diffraction pattern, distance (x) between center of central bright fringe and center of first dark fringe (m=1) is measured (**Figure-45b**).

3.1. Slit width is calculated, using wavelength of laser ($\lambda = 650\ nm$), distance between slit plate and screen ($L = 25\ cm$) and measured distance (x):

$$x_m = L\frac{m\lambda}{D}$$

4. Experiment is repeated for different slit width and different screen distance.

5. Why minimum and maximum intensity of light form at diffraction pattern is explained.

6. Which condition should be satisfied for occurring diffraction at light wave?.

> When slit width is equal to or smaller than wavelength of light passing from slit, diffraction phenomenon occurs.

7. How does fringe width (Δx) change when slit width (D) is decreased at single slit diffraction?.

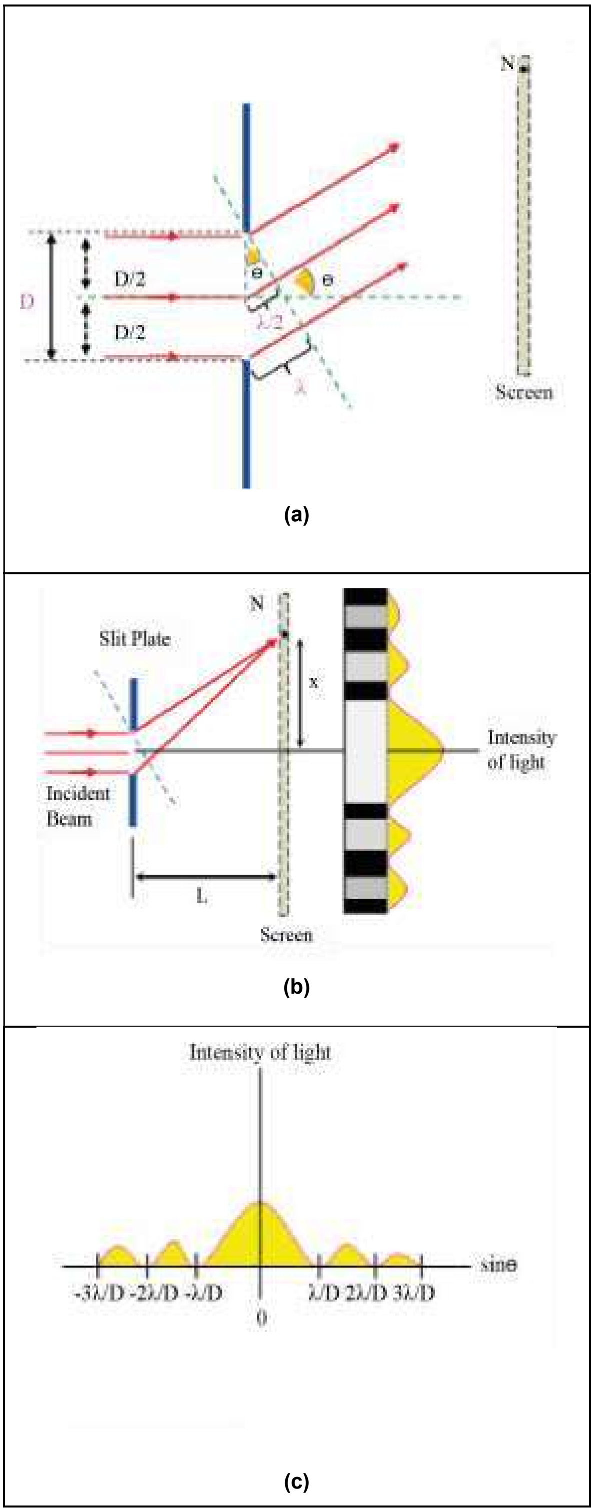
> Fringe width on screen increases.

8. What is relation of fringe width (Δx)?.

9. If wavelength of light (λ) used at single slit diffraction is increased, How does fringe width on screen (Δx) change?.

> If wavelength of light used at single slit diffraction is increased, fringe width on diffraction pattern increases.

7. Diffraction of Light Wave



(a)

(b)

(c)

Figure-32: Single slit diffraction **(a)**, formation of diffraction pattern **(b)**, and change of intensity of light at diffraction pattern **(c)**.

After waves pass from side of an obstacle or a narrow gap, it changes its direction. This phenomenon is called diffraction. While monochromatic light beam incident on single slit pass from slit gap, it propagates through every direction as light waves. When these waves interfere with each other, some waves destruct with each other by causing that region is dark whereas some waves construct with each other and bright regions emerge.

In Figure-(32a), a monochromatic light beam with a wavelength "λ" incident on a slit with width "D" is shown. A monochromatic light beam from gap of which width is "D" meets at point N on the screen at the distance L. difference between beam passing from lower side of the slit and beam passing from the center will be λ/2. Since distance difference to point N is λ/2, waves from slit interfere destructively at point N and they emerge dark (minima) fringe. For dark fringe, the following relation is found:

$$\sin\theta = \frac{\lambda/2}{D/2} \tag{61}$$

$$\sin\theta = \frac{\lambda}{D} \tag{62}$$

$$\boxed{D\sin\theta = m\lambda} \qquad m=\pm1, \pm2, \pm3, \ldots \tag{63}$$

Intensity of light is maximum at θ = 0° and minimum at given angle θ.

Bright (maxima) fringe at point N;

$$\boxed{D\sin\theta = (m+\frac{1}{2})\lambda} \qquad m=1, 2, 3, \ldots \tag{64}$$

Single slit diffraction pattern formed by light passing from slit and incident on screen is shown in Figure - 32b. Bright fringes formed at diffraction pattern weaken through sides of screen. Figure-32c indicates that distribution of intensity of light as a function of value of sinθ.

Here, angle θ determines position of a point on the screen.

If single slit diffraction is investigated;

1. If λ **<< D,** then diffraction does not occur. While a wave travels on linear path, bright point is seen on screen.
2. If λ **≈ D,** it is started to observe diffraction. Light propagates at all directions after it passes from slit.
3. If **D <<** λ**,** diffraction is observed clearly. Light beam incident on single slit brings about many point wave sources at slit separation. Therefore, light beam from different points on slit separation interfere constructively and destructively and so diffraction pattern is formed.

Intensity of light of bright fringes at diffraction pattern decreases as sides of screen is gone (**Figure-32b**).

Figure-(32c) gives distribution of light intensity of bright fringes as a function of sinθ. Here, angle θ is angle that determines position of a point on screen.

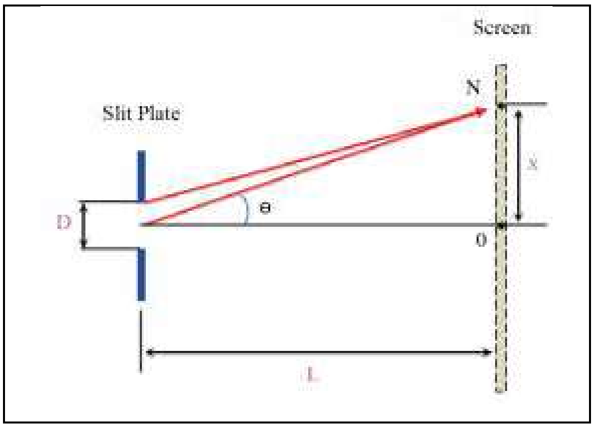


Figure-33: Distance between a dark fringe formed at single slit diffraction pattern and central bright fringe.

If at single slit diffraction (**Figure-33**), distance between m^{th} dark fringe and central bright fringe is x_m, the following relation is written:

$$\boxed{x_m = L\frac{m\lambda}{D}} \qquad \textbf{(Experimental)} \quad (65)$$

Here;

$x_m(m)$: Distance between dark fringe and central bright fringe.

$L(m)$: Distance between slit plane and screen.

$\lambda(m)$: Wavelength of light source.

$D(m)$ Width of slit

In this equality, distance between central bright fringe and first dark fringe (x_1) is wanted to find, m will be 1.

Fringe width (Δ**x**) is distance between two sequent bright or two sequent dark fringe. Wavelength is found in terms of fringe width as below;

$$\lambda = \frac{D\Delta x}{L} \qquad (66)$$

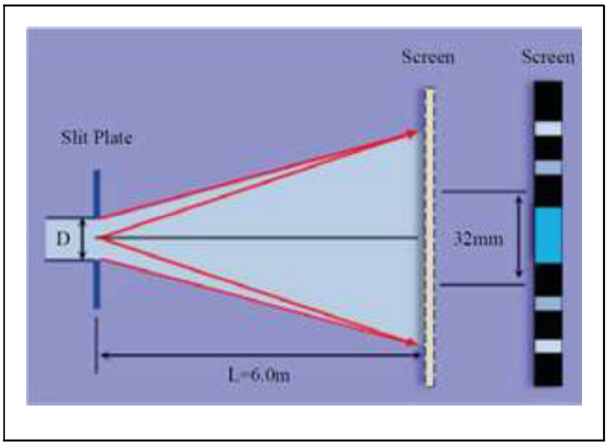


Figure 34: Diffraction pattern of beams passing from single slit on screen.

As an example, a laser beam with λ=633nm used in the experiment of single slit and diffraction pattern emerges on screen at distance L=6 m. On screen, distance between centers of first dark fringes except for central bright fringe is calculated as 32 mm (see **Figure-34**).

If slit width is calculated from these data;

- m=1 is taken for distance between central bright fringe and first dark fringe.
- Distance between central bright fringe and first dark fringe is;

$$x_1 = \frac{32mm}{2} = 16\ mm.$$

Single Slit

Wavelength	Distance of screen	Distance of first dark fringe	Slit width
λ (nm)	L (m)	x_1 (m)	D(mm)
633	6	$16\text{x}10^{-3}$	. . . . .

From here, it is found that;

$$x_m = L\frac{m\lambda}{D}$$

$$x_1 = L\frac{\lambda}{D}$$

$$D = L\frac{\lambda}{x_1} = \frac{(6m)(633\times10^{-9}\,m)}{16\times10^{-3}\,m}$$

$$D = 2.4\times10^{-4}\,m = 0.24mm$$