# 6 - DOUBLE-SLIT DIFFRACTION

## OBJECTIVE

- To investigate the phenomenon of diffraction using a double slit.

## EQUIPMENTS

- **White Light Source,**
- **Laser**
- **Filter**
- **Coherence Slit**
- **Lens**
- **Photodiode**
- **Double Slit**
- **Viewfinder**

## GENERAL INFORMATION

We know that the intensity distribution of the interference pattern obtained with a double slit system, where the slit width is a and the distance between the slits is d, is given by the equation:

$$I = 4I_s cos^2\beta \qquad (1)$$

Here, θ is the observation angle and, where

$$\beta = \left(\frac{\pi b}{\lambda}\right) sin\theta \qquad (2)$$

Here, it is assumed that the intensity Is from each slit is constant. For a single slit system with slit width a, the intensity distribution of the diffraction pattern is given by $\alpha = \pi\, a\, \frac{\sin\theta}{\lambda}$, where:

$$I_s = I_0 \left[\frac{sin\alpha}{\alpha}\right]^2 \qquad (3)$$

In a double-slit system, since both interference and diffraction effects can be observed simultaneously, the intensity distribution of the resulting illumination pattern is given by the product of the interference term $cos^2\beta$ and the diffraction term $\left[\frac{sin\alpha}{\alpha}\right]^2$, where:

$$I = 4I_s \left[\frac{sin\alpha}{\alpha}\right]^2 cos^2\beta \qquad (4)$$

In the expression above, the diffraction factor, as shown in Figure 1, determines the envelope curve of the interference fringes.

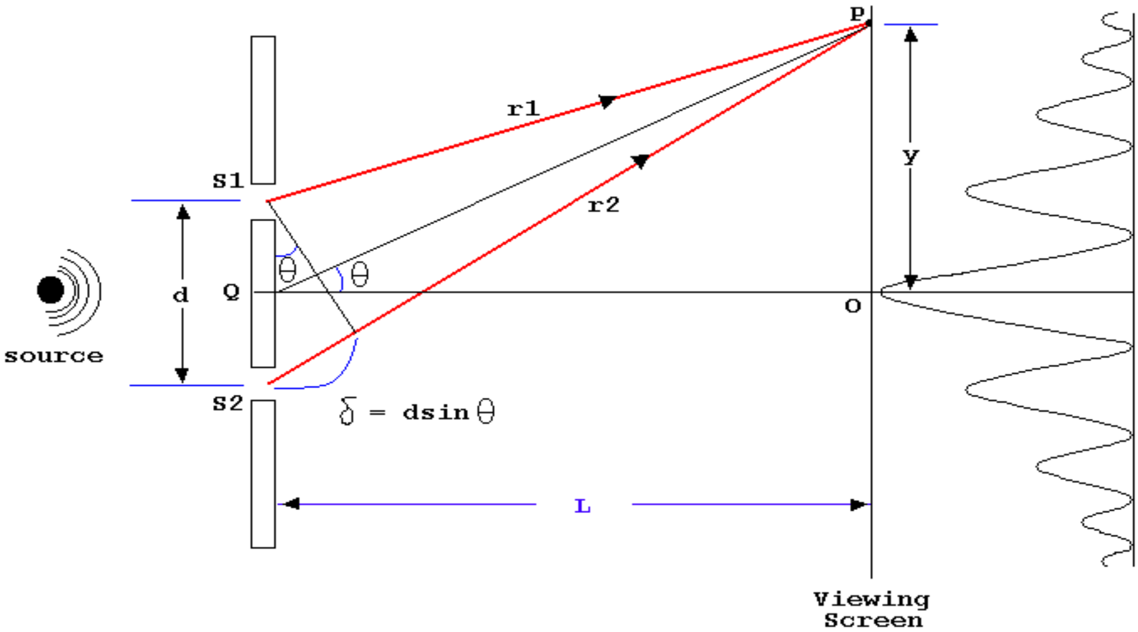


**Figure 1:** Double-Slit Diffraction

Interference minimum:

$$\beta = \left(m + \tfrac{1}{2}\right)\pi \qquad m = 0,1,2,3\ldots \qquad (4)$$

Interference maxima :

$$\beta = m\pi \qquad m = 0,1,2,3\ldots \qquad (5)$$

If the distance between the slits and the screen, L, is much larger than the distance between the slits, b, then for θ approximately:

$$sin\theta \approx tan\theta = \frac{y}{L} \qquad (6)$$

The distance between all consecutive maxima and minima is given by

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

## EXPERIMENT PROCEDURE

The experiment is conducted in two stages:

1. **First Stage:** A white light source is used. Conditions are set with the appropriate elements to observe the illumination pattern of the double-slit system.
2. **Second Stage:** A laser light source is used to obtain the illumination pattern of the double-slit diffraction and to determine the intensity distribution.

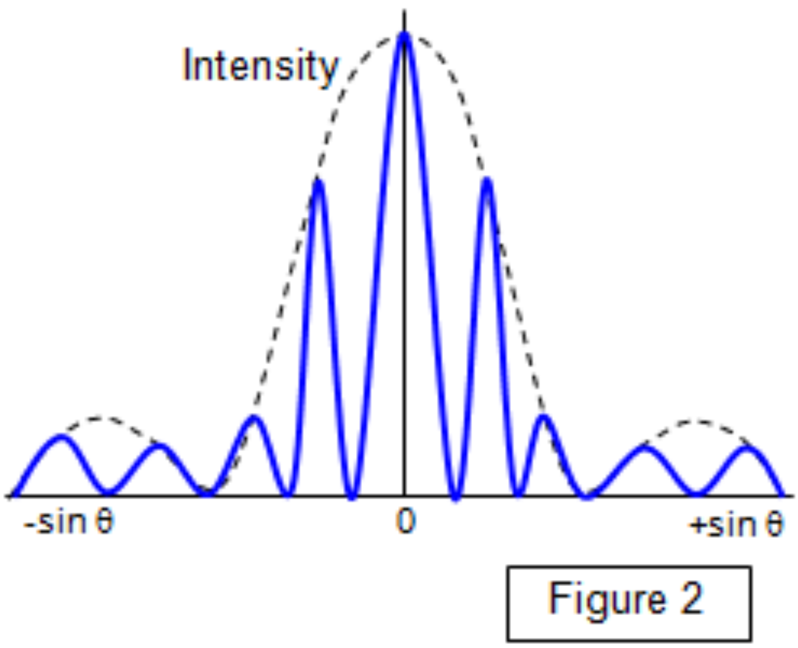


**Figure 2:** Intensity distribution of double-slit diffraction.

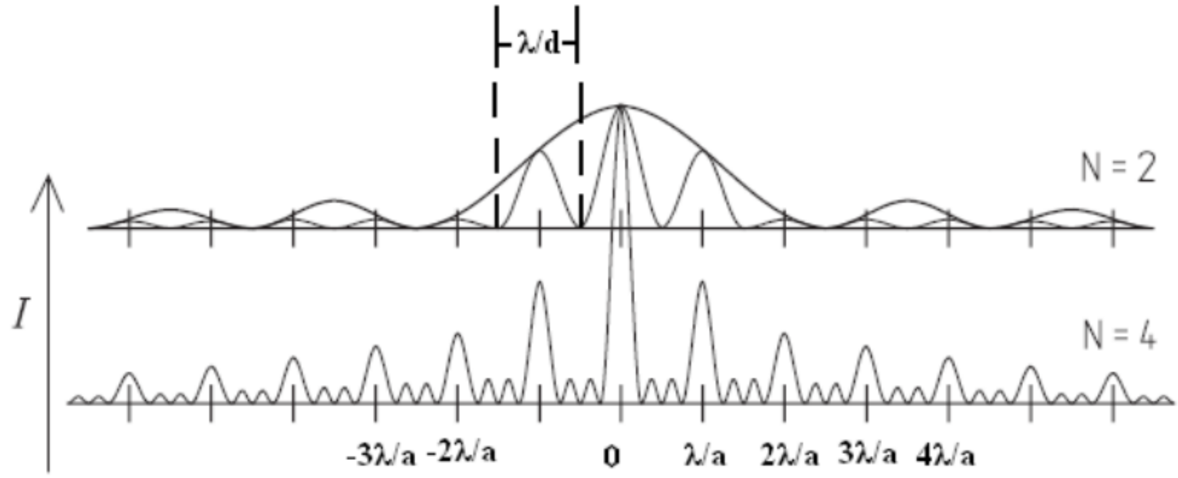


**Figure 3:** Variation of the intensity distribution of double-slit diffraction with the number of slits in the barrier.

At this stage, light rays from a point source, a white light source S, are passed through a single slit and a filter to ensure coherence of the light before being directed onto the double-slit system. To observe the diffraction and interference pattern on the screen, the most suitable slit width and slit-to-screen distance are determined. In the first phase of the experiment, no measurements will be taken; only the illumination pattern will be observed.

## Phase 1:

Light rays emitted from a point source, S, undergo diffraction at the diffraction slit when the elements are arranged appropriately, creating an illumination pattern on the screen (Figure 4)

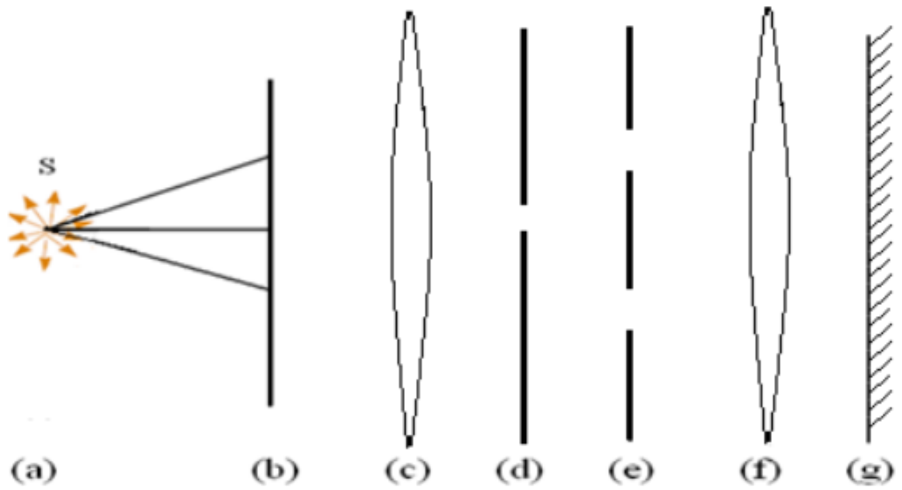


**Figure 4:** Double slit experimental setup. (a) Light source, (b) Filter, (c) Thin-edged lens, (d) Coherence slit, (e) Diffraction slit, (f) Thin-edged lens, (g) Screen.

## Phase 2:

1. The experimental setup is arranged as shown in Figure 4. The components are placed and fixed in the optical path to achieve the best illumination pattern: Laser = 2.5 cm; f = +20 mm; lens = 14.5 cm; f = +100 mm; lens = 27.5 cm; plate with the slit systems = 33 cm, photodiode = 147.5 cm. The wavelength of the laser source used is $\lambda$ = 632.8 nm.

2. An expanded laser beam is created with the help of lenses. This laser beam is directed onto the photodiode through a single slit. The plate is placed with a holder. Ensure that the slits being examined are perpendicular to the holder and that they are properly illuminated.

3. To prevent unwanted variations in intensity (such as fluctuations), the laser and measurement amplifier should be warmed up approximately 15 minutes before starting the measurements. Connect the photodiode to the measurement amplifier (amplifier factor ($10^3$ - $10^5$) x $10^4$ ohms). When changing the amplifier factor, check and, if necessary, adjust the zero point of the measurement amplifier with the photodiode covered.

4. Light intensity values are measured with the photodiode in 0.1 mm to 0.2 mm steps for the double slit systems.

5. The illumination pattern for the double-slit system is observed. Minima in the interference pattern, where diffraction maxima are observed, occur under the conditions specified in the following expression:

$$sin\varphi_m = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}; \qquad m = 0,1,2,3\ldots$$

   The d values for minima at different orders, i.e., different mmm values, are found and averaged. The measurements and calculations are recorded in Table 1.

**Table 1:** Results of the Double-Slit Diffraction Experiment

| | $\Delta x$ | $\sin\varphi_m = \frac{\Delta x}{L}$ | $d(mm)$ |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| $d_{avg} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots mm$ | | | |
| $\lambda = 632.8\ nm = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots mm$ | | $L = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots cm$ | |