O_6: Study of the intensity distribution of Fraunhofer diffraction pattern due to a double slit

Theory: If monochromatic light of wavelength λ impinges on a system of parallel and equidistant slits, the luminous intensity I of the beams diffracted in the direction φ is given through:

$$I(\varphi) \propto b^2 \frac{sin^2(\frac{\pi}{\lambda} bsin\varphi)}{(\frac{\pi}{\lambda} b\, sin\varphi)^2} \cdot \frac{Sin^2(\frac{p\pi}{\lambda}\, g\, sin\varphi)}{sin^2(\frac{\pi}{\lambda}\, g\, sin\varphi)} \quad (1)$$

where b = width of the slit, g = distance between slits, p = number of slits

The first factor in (1) gives the intensity distribution for a single slit, the second factor describes the modification of the diffraction intensity due to the combined effect of p slits. For a double slit (p=2), equation (1) yields:

$$I(\varphi) \propto b^2 \frac{Sin^2(\frac{\pi}{\lambda} bsin\varphi)}{(\frac{\pi}{\lambda} b\, sin\varphi)^2}\ 4\, cos^2(\frac{\pi}{\lambda}\, gsin\varphi) \quad (2)$$

If one considers only a single slit, this gives minimum intensity when the numerator of the first factor becomes zero. This always is the case when the following applies:

$$sin\varphi_k = \frac{k\lambda}{b};\ (k = 1, 2, 3, \ldots\ldots) \quad (3)$$

For the secondary peaks one obtains approximately:

$$sin\varphi_k^* = \frac{2k^* + 1}{2} \cdot \frac{\lambda}{b}\ ;\ (k^* = 1, 2, 3, \ldots\ldots) \quad (4)$$

If several slits act together, supplementary minima appear whose location is determined by the points at which the second factor becomes zero. If p = 2, (2) yields:

$$4cos^2\,(\frac{\pi}{\lambda} gsin\varphi\,) = 0 \quad (5)$$

This expression becomes zero if

$$sin\varphi_h = \frac{2h+1}{2} \cdot \frac{\lambda}{g};\ (h = 0, 1, 2, 3, \ldots\ldots) \quad (6)$$

Supplementary peaks appear when

$$4cos^2(\frac{\pi}{\lambda} gsin\varphi) = \pm 1 \quad (7)$$

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This condition is fulfilled if

$$sin\varphi_h^* = h^* . \frac{\lambda}{g} \; ; (h^* = 0, 1, 2, ...) \qquad (8)$$

From (1) and (7), it follows that the intensity of the main peak is four times that of the intensity obtained with the corresponding single slit.

Apparatus/Equipment:

i) Laser, He-Ne 1.0 mW, 220 V AC ($\lambda = 633\ nm$)

ii) Universal measuring amplifier

iii) Optical profile bench, $l = 150\ cm$

iv) Lens holder, Object holder

v) Lens, ($f = +20\ mm$ & $f = +100\ mm$)

vi) Photodiode (Photocell), Multimeter

vii) Double slit (b = 0.1 mm and g = 0.25 mm), Diaphragm holder

viii) Connecting wires, etc.

Fig.1 Experimental set-up for the investigation of the diffraction intensity due to double slit.

(***Caution: Never look directly into a non-attenuated laser beam)***

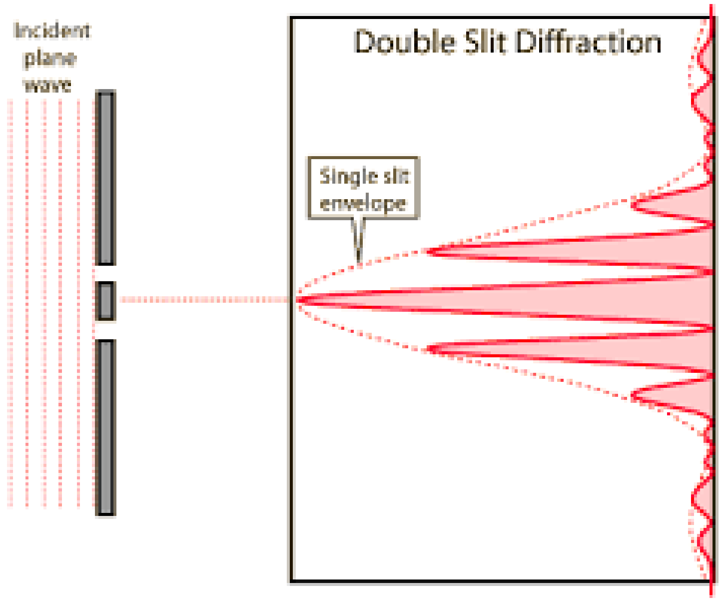

Fig. 2 Intensity distribution pattern for Fraunhofer diffraction double slit experiment

Procedure:

i) Arrange optical experimental set-up as shown in figure 1.

ii) The laser and the measurement amplifier should be warmed up for about 15 minutes before the experimental work.

iii) A broadened and parallel laser beam obtained with lenses f = 20 mm and f =100 mm, must impinge centrally on the photocell. The photocell is situated at the center of its shifting range.

iv) The slit diaphragm is set onto the photocell and the diaphragm with double slit is set into the diaphragm support. It must be made sure that the slit which is to be investigated is placed centered and perpendicularly to the beam.

iv) Connect the photodiode to the measurement amplifier by connecting wire.

vi) Multimeter should be kept in the range 20 or 200 mA.

vi) Collect the diffraction intensity data for the double slit (b = 0.1 mm and g = 0.25 mm) by shifting the photodiodes within step of 0.5 mm (rotate screw sliding device).

vii) Draw a graph with Current, I (along vertical axis) and Distance, x (along horizontal axis).

Data Collection:

Table: Data for double slit (b = 0.1 mm and g = 0.25 mm)

Distance, x (mm)	Current, I (mA)	Distance, x (mm)	Current, I (mA)	Distance, x (mm)	Current, I (mA)
0.0		….		….	
0.5		….		….	
1.0		….		….	
1.5		….		….	
2.0		….		….	
2.5		….		….	
3.0		….		….	
3.5		….		….	
4.0		….		….	
4.5		….		….	
5.0		….		….	
5.5		….		….	
6.0		….		….	
6.5		….		….	
7.0		….		….	

Results:

i) Plot Current (I) versus Distance (x) in a graph paper.

ii) Observe the diffraction intensity distribution due to a double slit.

Discussion: