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INDIAN INSTITUTE OF TECHNOLOGY

PHYSICS DEPT.

NO. 19100079 CLASS BATCH P14/1

NAME NABH AGRAWAL

EXPT. No. 1 LABORATORY

DATE 05/08/2019

AIM

To observe the intensity pattern generated by diffraction of a laser beam when passed through a double slit and to measure the size of diffracting element.

APPARATUS

i) Optical Rail.
ii) Diode Laser (wavelength 650 nm).
iii) Kinematic Laser Mount.
iv) Power Supply for LASER.
v) Cell Mount with Diffraction Cell.
vi) Pin hole detector.
vii) Output Measurement Unit
viii) Linear Translational Stage
ix) Slit Box.

THEORY & FORMULAE USED

Light Rays, when partially obstructed tend to show certain wave like properties that include diffraction and interference (in case of overlapping of waves). This bending of Light was explained by Huygen's Principle which treated every point on wave front

as another source of Light.

1) For a diffraction by Single slit, intensity is given by

$$\boxed{I(\theta) = I_0 \left(\frac{\sin\beta}{\beta}\right)^2}$$ where $\beta = \left(\frac{\pi d}{\lambda}\right)\sin\theta$.

Thus, for a maxima, $\beta = 0$ & $\pm (2m+1)\pi/2$; $m = 1, 2, \ldots$

$\theta = 0$ & $\pm \sin^{-1}\left[(2m+1)\lambda/2d\right]$.

for a minima, $\beta_m = \pm m\pi$; $m = 1, 2, \ldots$

$\theta_m = \pm \sin^{-1}\left(\frac{m\lambda}{d}\right)$.

$\therefore$ From the positions of minima, we can find out the slit width using $\boxed{d = m\lambda/\sin\theta_m}$, where θ_m could be experimentally calculated using $\boxed{\tan\theta_m = y_m/D}$.

y_m = y-position of Minima.
D = distance between slit & screen.
d = Slit width.
λ = wavelength used.

2) In Case of Interference & Diffraction by Double Slit:

$$\boxed{I(\theta) = I_0 \cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)\left[\frac{\sin\beta}{\beta}\right]^2}$$ where $\beta = (\pi a/\lambda)\sin\theta$.

a = Slit width
d = Slit separation.

$\therefore$ for a maxima $d\sin\theta = m\lambda$, $m \in Z$.

for a minima $d\sin\theta = (m + 1/2)\lambda$, $m \in Z$.

Here $d > a$, and from positions of maxima, we can easily find the slit separation : $\boxed{d = \frac{m\lambda}{\sin\theta_m}}$ where $\boxed{\theta_m = \tan^{-1}(y_m/D)}$

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3) Diffraction of Light by Pin hole.

$$I(\theta) = I_0 \left[\frac{2 J_1(ka\sin\theta)}{ka\sin\theta} \right]^2$$ where $k = 2\pi/\lambda$ &

J_1 = Bessel Function of first kind of order one.

Bright rings appear around the central maxima (called Airy Disc.)

Minima occurs at zeroes of J_1 at $ka\sin\theta = 3.83, 7.0156, \ldots$

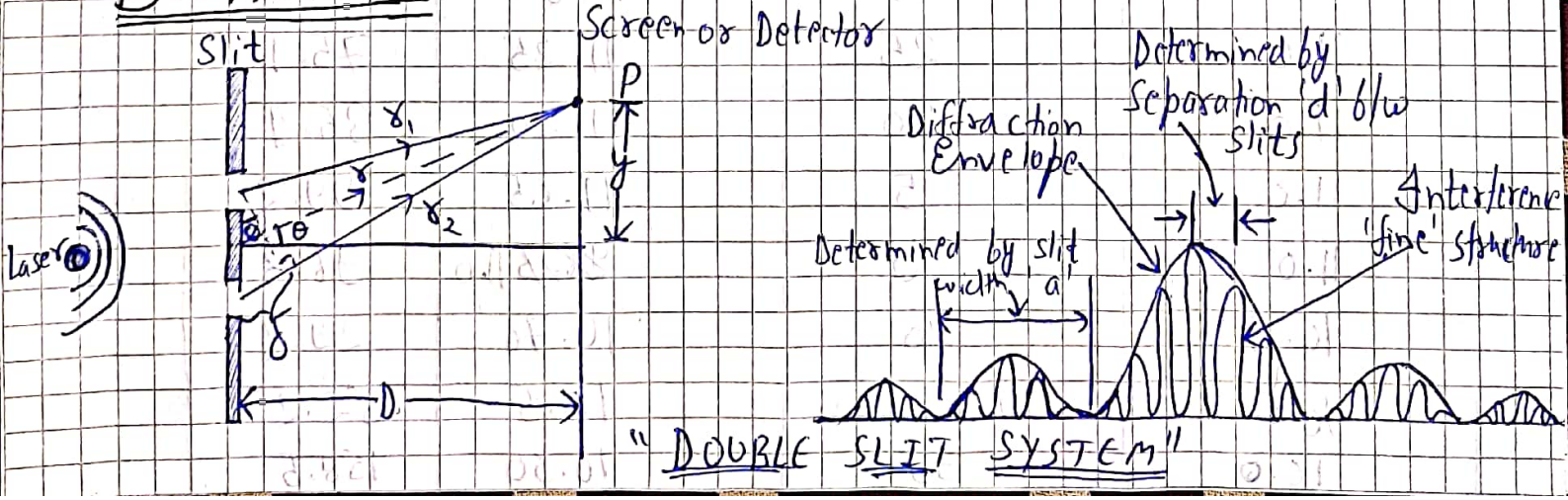
and for first minima, $\sin\theta = 1.22\lambda/a$.

Least Count = (Smallest Division on Main Scale) / (No. of Division on circular Scale.)

= 0.05 cm / 50 = 0.001 cm.

Micrometer Reading = M.S.R + (No. of Div. on Circular Scale) × L.C.

DIAGRAM



"DOUBLE SLIT SYSTEM"

OBSERVATIONS

Diffraction Pattern by Double Slit.

Main Scale Reading	Circular Scale Reading	Total Reading (mm)	Intensity (uA)
~~18.0~~	0	~~17~~	09.0
~~16~~.5	0	~~16~~.5	04.1
~~16~~.0	0	~~16~~.0	04.1
~~15~~.5	0	~~15~~.5	05.1
~~15~~.0	0	~~15~~.0	~~03~~.8
~~14~~.5	0	~~14~~.5	03.5
~~14~~.0	0	~~14~~.0	03.7
~~13~~.5	0	~~13~~.5	08.5
~~13~~.0	32	~~13~~.32	09.7
~~13~~.0	0	~~13~~.0	05.8
~~12~~.5	20	~~12~~.70	04.0
~~12.0~~ 12.5	0	~~12~~.5	03.5
~~12~~.0	0	~~12~~.0	05.0
~~11~~.5	0	~~11~~.5	20.1
~~11~~.0	40	~~11~~.40	39.6
~~11~~.0	30	~~11~~.30	62.6
~~11~~.0	25	~~11~~.25	75.1
~~11~~.0	20	~~11~~.20	85.9
~~11~~.0	5	~~11~~.05	99.2
~~11~~.0	0	~~11~~.0	96.3
~~10~~.5	20	~~10~~.70	29.2
~~10~~.5	0	~~10~~.5	52.2
~~10~~.0	30	~~10~~.30	158.5

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Main Scale Reading	Circular Scale Reading	Total Reading (mm)	Intensity (uA)	
10.0	0	10.0	172.0	max
9.5	5	9.55	30.0	min
9.5	0	9.5	37.2	↑
9.0	15	9.15	82.5	max
9.0	0	9.0	66.3	
8.0	0	8.0	03.0	min
7.5	0	7.5	03.2	
7.0	0	7.0	11.3	
6.5	40	6.90	11.8	max
6.5	0	6.50	04.2	
6.0	10	6.10	02.1	min
5.5	0	5.5	02.3	
5.0	15	5.15	02.4	
5.0	5	5.05	03.2	
5.0	0	5.0	03.6	
4.5	25	4.75	05.0	max
4.5	0	4.5	03.7	
4.0	0	4.0	02.3	

S. Bhui 05.08.2019

(a) ✓ $D = 1100\ mm - 435\ mm = 665\ mm.$

PRECAUTIONS

1) Do not touch the inner surface of diffraction cell.
2) Avoid Backlash Error while moving the micrometre Screw.
3) Take care while handling all the equipments.
4) Avoid looking directly into the laser beam.

CALCULATIONS

y_0 Position of Central Maxima = 10.00 mm

Positions of 1st Maxima = 11.05 mm & 9.15 mm ~~& 8.75 mm~~

Positions of 2nd Maxima = 13.32 mm & 6.90 mm

Positions of 3rd Maxima = 15.50 mm & 4.75 mm

$\therefore y_1 = 11.05 - 10.00 = 1.05$ mm ; $y_1' = 10.00 - 9.15 = 0.85$ mm

$y_2 = 13.32 - 10.00 = 3.32$ mm ; $y_2' = 10.00 - 6.90 = 3.10$ mm

$y_3 = 15.50 - 10.00 = 5.50$ mm ; $y_3' = 10.00 - 4.75 = 5.25$ mm

Also, $D = 665$ mm.

Now, using $\theta_n = \tan^{-1}\left(\frac{y_n}{D}\right)$. we have,

$\theta_1 = 0.0904$. ; $\theta_1' = 0.0732$.

$\theta_2 = 0.2860$. ; $\theta_2' = 0.2670$.

$\theta_3 = 0.4738$. ; $\theta_3' = 0.4523$.

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Now using $d = \frac{m\lambda}{\sin\theta_m}$ we have,

$d_1 = 411.972\ \mu m$; $d_4 = 508.774\ \mu m$.

$d_2 = 260.436\ \mu m$. ; $d_5 = 278.969\ \mu m$.

$d_3 = 235.812\ \mu m$. ; $d_6 = 247.021\ \mu m$.

$$\therefore d_{avg} = \frac{\sum d_i}{6} = \frac{411.972 + 508.774 + 260.436 + 278.969 + 235.812 + 247.021}{6}$$

$$= 323.830\ \mu m.$$

$$\delta d = \sqrt{\frac{\sum (d_i - d_{avg})^2}{6}} = \sqrt{\frac{7769.0121 + 34204.2831 + 4018.7992 + 2012.5093 + 7747.1688 + 5899.6224}{6}}$$

$$= \sqrt{10275.2324}.$$

$$= 101.3668\ \mu m$$

(10)

RESULT

Slit Width = $d_{avg} \pm \delta d$

$= 323.830\ \mu m \pm 101.3668\ \mu m.$

Diffraction Pattern by Double Slit

SCALE :-
x: 1 Smallest Box = 0.1 mm.
y: 1 Smallest Box = 1 μA.