EXPT- 1

DIFFRACTION OF LASER LIGHT USING VARIOUS APERTURES

Submitted By

Gayatri P
2211185
Int. M.Sc. (B22)

Objectives :

1. To determine the wavelength of laser light from single-slit diffraction pattern.
2. To determine the thickness of a fine wire from its diffraction pattern.
3. compare the thickness of the wire with the single slit width that forms the same diffraction pattern
4. To understand the diffraction pattern due to the double slit and determine the slit width and the width of the opaque gap between the two slits.

Theory

When a coherent light beam is passed through a thin wire or slit with thickness comparable to its wavelength, diffraction occurs. This diffraction pattern is caused by secondary waves from emerging beam's wavefront which have a constant phase difference as they arrive at the screen after travelling different distances.

The particular type of diffraction in which the light source, the screen and the slit are all practically at infinite distance from each other is called Franhouffer diffraction.

(A) Single Slit Diffraction

For single-slit diffraction, the intensity of transmitted light on screen is given by:

$$I = I_0 \frac{\sin^2\beta}{\beta^2} \quad , \quad \beta = \frac{\pi b \sin\theta}{\lambda} \qquad — (1)$$

where b = width of the slit.

For a minima, we need $\beta = m\pi$, $m \in \mathbb{Z}$. Hence the condition for a minima is,

$$\pi b \sin\theta = m\lambda\pi \quad \Rightarrow \quad b\sin\theta = m\lambda$$

for small θ, (i.e. large distance between slit and the screen,

$\theta \approx \sin\theta \approx \tan\theta = \frac{x}{2D}$, where x = distance b/w m^{th} minima on both sides of the principle maxima.

& D = distance b/w the slit and screen.

Hence, we get

$$\boxed{x_m = \frac{2Dm\lambda}{b}} \quad -(2)$$

or $\lambda = \dfrac{x_m b}{2mD}$

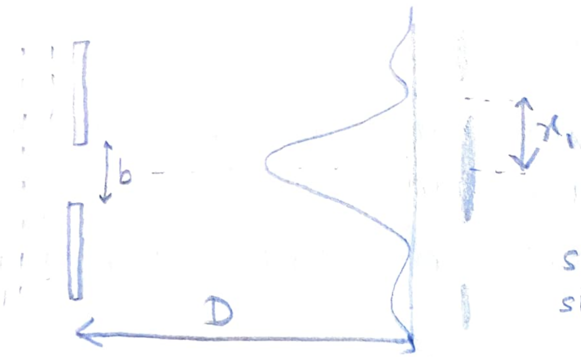


Fig 1
schematics for single slit diffraction

(B) Diffraction by a thin wire

A similar diffraction pattern to that of a single-slit is obtained on screen when the slit is replaced by a wire that blocks the light with equal amount of intensity as the slit. The following relation ship still holds b/w m & x_m,

$$x_m = \frac{2Dm\lambda}{b} \quad -(3)$$

This general rule, known as Babinet's principle is illustrated by the fact that Fraunhoffer diffraction pattern caused by an obstruction is identical to that of an opening of the same dimension. This can be tested by replacing the wire with a single slit and adjusting the width unit the pattern is identical to the one ~~befor~~ with the wire and then comparing their widths.

(C) Double ~~slit~~ slit Diffraction and Interference

Here we have two parallel slits each of width b separated by an opaque space of width c, such that the distance b/w the center of two openings is d ($d = c+b$). The diffraction patterns from two slits interfere on the screen corresponding intensity function is given by,

$$I = |U_p|^2 = U_p U_p^*$$

where U_p is the corresponding wave expression,

$$U_p = c\int e^{ikr}\,dA = c'\left[\int_0^b e^{ikx\sin\theta}\,dx + \int_d^{d+b} e^{ikx\sin\theta}\,dx\right]$$

$$= \frac{c'}{ik\sin\theta}\left(e^{ikb\sin\theta} - 1\right)\left(1 + e^{ikd\sin\theta}\right)$$

Let $\beta = \dfrac{bk\sin\theta}{2}$ & $\gamma = \dfrac{kd\sin\theta}{2}$

Thus, U_p simplifies to,

$$U_p = c'' e^{i\beta} \frac{\sin \beta}{\beta} e^{i\gamma} \cos \gamma$$

$$\therefore \quad I \propto \frac{\sin^2 \beta}{\beta^2} \cdot \cos^2 \gamma \quad \text{— (4)} \qquad \text{where} \quad \beta = \frac{\pi b \sin\theta}{\lambda}$$

$$\& \quad \gamma = \frac{\pi d \sin\theta}{\lambda}$$

where $\sin^2\beta / \beta^2$ represents the diffraction pattern produced by the single slit & $\cos^2 \gamma$ represents the interference produced by two beams of equal intensity and phase difference γ. The overall pattern consists of diffraction fringes each broken into narrow interference fringes. The conditions for minim are–

$$d \sin\theta = \left(p + \tfrac{1}{2}\right)\lambda \quad \& \quad b \sin\theta = m\lambda$$

When maxima of ~~infe~~ interference fringes falls on the minima of diffraction fringes, we get $I = 0$, which essential leads to missing orders in the interference pattern. Hence it might be difficult to determine the correct order number, so we will consider the difference b/w n consecutive minima, $\Delta x_p = x_{p+n} - x_p$. Hence to determine b & d, ($\sin\theta \approx \theta$)

$$\theta \approx \frac{x_p}{D} = d = \frac{n\lambda D}{\Delta x_p} \quad \& \quad \theta \approx \frac{x_m}{D} \Rightarrow b = \frac{n\lambda D}{\Delta x_m} \quad \text{— (5)}$$

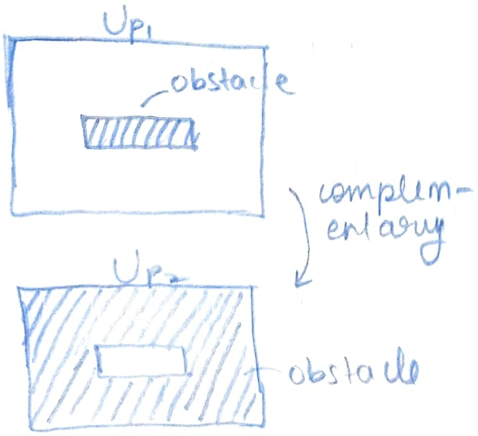


Fig 2: Representation of babinet's principle

Here, $U_{p_1} + U_{p_2} = 0$

$\Rightarrow U_{p_1} = -U_{p_2}$ (phase diff of π)

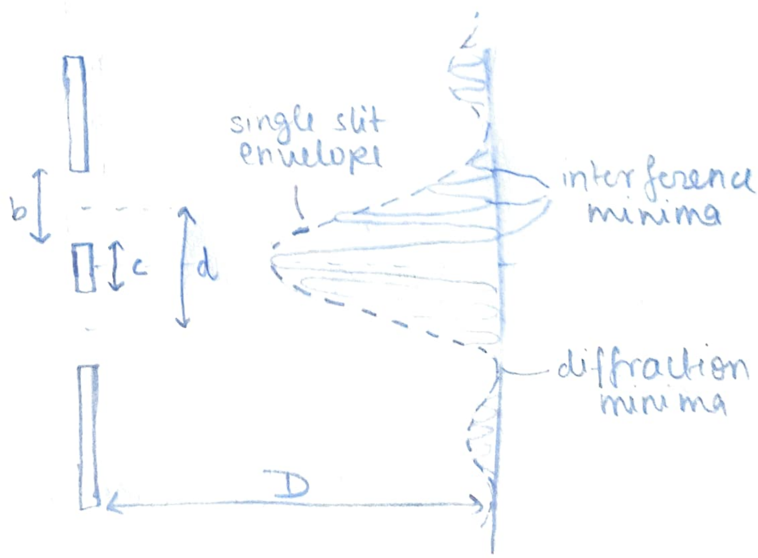


Fig 3: Schematics for double slit diffraction

Instruments Required

1. Laser source
2. Screen
3. Graph paper
4. Thin wire
5. Variable single & double slits
6. Measuring tape
7. Travelling microscope

Observations & Calculations

(A) ~~Single Slit~~ Diffraction using a thin wire

Table 1: Finding thickness of wire using diffraction pattern $D = 1.6m$

order (x_i)	Left Fringes a^l_1 (cm)	a^l_2 (cm)	a^l (cm)	Right Fringes a^r_1 (cm)	a^r_2 (cm)	a^r (cm)	$x_m = a^l \sim a^r$ (y_i) (mm)	x_i^2	$x_i y_i$ (mm)
1	13.5	13.6	13.6	15.3	15.4	15.4	9	1	9
2	12.6	12.8	12.7	16.2	16.3	16.3	18	4	36
3	11.8	12.0	11.9	17.0	17.1	17.1	26	9	77
4	10.9	11.1	11.0	17.8	18.0	17.9	35	16	138
5	10.6	10.2	10.1	18.7	18.9	18.8	44	25	218
6	9.1	9.4	9.3	19.6	19.8	19.7	53	36	314
7	8.3	8.5	8.4	20.5	20.8	20.7	62	49	429
8	7.3	7.5	7.4	21.3	21.5	21.4	70	64	560
9	6.5	6.8	6.7	22.1	22.4	22.3	78	81	702
10	5.6	6.0	5.8	23.0	23.3	23.2	87	100	868
11	4.8	5.1	5.0	23.9	24.2	24.1	96	121	1051
$\Sigma = 66$							$\Sigma = 574$	$\Sigma = 506$	$\Sigma = 4400$

Here the center of the ~~interference~~ diffraction pattern, $= \frac{13.6 + 15.3}{2} = 14.45$ cm

& $\sigma_{y_i} = 0.1cm = 1mm$

Least count of graph paper used for measurement $= 0.1cm = 1mm$

~~slit~~ wire width ditermined using a travelling microscope, (table attached at the end), $\underline{b = 0.21mm}$

Least square fitting for x_m vs m plot

From eq^n 3, we can find b using $b = \frac{2m\lambda D}{x_m}$.

Here, we plot x_m vs m st. $x_m = \left(\frac{2\lambda D}{b}\right) m$ is of the form $y = ax + c$.

By defining $\chi^2 = \sum_i \left(\frac{y_i - ax_i - c}{\sigma_{y_i}^2} \right)^2$ and minimizing χ^2 w.r.t. a and c, we get the eq^{n}s,

$$cS + aS_x = S_y$$
$$cS_x + aS_{xx} = S_{xy},$$

where $S = \sum_i \frac{1}{\sigma_{y_i}^2}$, $S_x = \sum_i \frac{x_i}{\sigma_i}$, $S_y = \sum_i \frac{y_i}{\sigma_{y_i}^2}$

$S_x = \sum_i \frac{x_i^2}{\sigma_{y_i}^2}$, $S_{xy} = \sum_i \frac{x_i y_i}{\sigma_i^2}$

Solving for a & c, we get

$$a = \frac{S S_{xy} - S_x S_y}{\Delta} \quad (6) \quad \& \quad c = \frac{S_{xx} S_y - S_x S_{xy}}{\Delta} \quad (7)$$

$[\Delta = S_{xx} S - (S_x)^2]$

For table 1, $\Delta = 1210$

$$a = \frac{11 \cdot 4400 - 66 \cdot 574}{1210} = 8.673$$

$$c = \frac{506 \cdot 574 - 66 \cdot 4400}{1210} = 0.168$$

$$\left[\begin{array}{l} S_x = 66 \\ S_{xx} = 506 \\ S_y = 574 \\ S_{xy} = 4400 \end{array} \right]$$

$\Rightarrow x_m = (8.673) m + 0.168$

$\therefore$ Equating $a = \frac{2\lambda D}{b}$, $b = \frac{2\lambda D}{a}$

using $D = 1.6m$

& $\lambda = 6.328 \times 10^{-07} m$,

$$b = \frac{2 \times 6.328 \times 10^{-7} \times 1.6}{8.673 \times 10^{-3}} = 0.23 \times 10^{-3} m$$

$\underline{b = 0.23mm}$

(B) Single Slit Diffraction

Table 2: Determination of wavelength of light using diffraction pattern

$D = 3.5\,m$

Order (x_i)	Left fringes a_1^l (cm)	a_2^l (cm)	a^l (cm)	Right fringes a_1^r (cm)	a_2^r (cm)	a^r (cm)	$x_m = a^l - a^r$ (y_i) (mm)	$x_i y_i$ (mm)	x_i^2
1	10.9	11.0	11.0	15.3	15.4	15.4	22	22	1
2	8.9	9.1	9.0	16.7	16.8	16.8	39	77	4
3	7.0	7.2	7.1	18.6	18.8	18.7	58	174	9
4.	5.1	5.4	5.3	20.6	20.8	20.7	77	309	16
5	3.2	3.6	3.4	22.7	22.9	22.8	97	485	25
6	1.5	1.8	1.7	24.7	25.1	24.9	116	698	36
$\Sigma = 21$							$\Sigma = 409$	$\Sigma = 1765$	$\Sigma = 91$

where the center of the diffraction pattern was found to be at $x = \frac{11.0 + 14.7}{2} = 12.85\,cm$ & $\sigma_{y_i} = 1\,mm$

Using the travelling microscope, the width of the slit was found to be $0.246\,mm$ ($\sim 0.25\,mm$) $= b$

Least square fitting for x_m vs. m plot

Eqn (1) can be rewritten to be $x_m = \left(\frac{2D\lambda}{b}\right) m$ which is of the form $y = ax + c$.

Similar to the process followed in (A), we can find a & c using eqns (6) & (7).

From table (2),

$S_x = 21$, $S_{xx} = 91$, $S_y = 409$, $S_{xy} = 1765$ & $S = 6$.

$\Rightarrow \Delta = S S_{xx} - (S_x)^2 = 105$

$$\& \quad a = \frac{S S_{xy} - S_x S_y}{\Delta} = \frac{6 \cdot 1765 - 21 \cdot 91}{105} = 19.007$$

$$c = \frac{S_{xx} S_y - S_x S_{xy}}{\Delta} = \frac{91 \cdot 409 - 21 \cdot 1765}{105} = 1.683$$

$\therefore \; x_m = (19.007)\,m + 1.683$

Equating $a = \frac{2D\lambda}{b} \Rightarrow \lambda = \frac{ab}{2D}$

$\therefore$ we can determine the value of λ to be,

$$\lambda = \frac{19.007 \times 10^{-3} \times 0.246 \times 10^{-3}}{2 \times 3.5} = 669.775 \times 10^{-9}$$

$$\Rightarrow \lambda = 670\,nm$$

(C) Verifying Babinet's principle (comparing slit width & wire thickness)

After obtaining the ~~on~~ diffraction pattern used in part (A), the wire was replaced with a single slit and its width was adjusted to reproduce the wire's pattern as close as possible (by using marked graph papers).

The width of the wire obtained from part (A) is $b_w = 0.23\,mm$. The width of the equivalent slit was measured using a travelling microscope [Table 4(c)] and was found out to be $b_s = 0.24\,mm$.

$\therefore$ b_w & b_s are ~~almost equal~~ very close (within 0.1mm) and hence Babinet's principle is verified.

(D) Double ~~slit~~ slit Diffraction and Interference (D = 3.8m)

Table 3: Determination of b & d using diffraction pattern

(a) Diffraction fringes

Order (x_i)	Left Fringes a_1^l (cm)	a_2^l (cm)	a^l (cm)	Right Fringes a_1^r (cm)	a_2^r (cm)	a^r (cm)	X_m (y_i) (mm)	$x_i y_i$ (mm)	x_i^2
1	23.9	23.2	23.6	~~32~~ 27.9	28.5	28.2	23	23	1
2	20.8	21.6	21.2	30.1	30.7	30.4	46	92	4
3	18.5	18.2	18.4	32.3	33.1	32.7	72	215	9
4	16.1	17.1	16.6	34.6	35.5	35.1	92	369	16
5	14.6	13.8	14.2	36.9	37.8	37.4	116	579	25

6	11.4	12.4	11.9	~~40.5~~ 39.3	40.0	39.7	139	833	36
7	9.0	10.1	9.6	41.5	42.6	42.1	163	1138	49
8	6.7	7.7	7.2				187	1496	64
9	4.3	5.4	4.9				211	1895	81
10	1.9	3.1	2.5				234	2340	100
$\Sigma = 55$							$\Sigma = 1282$	$\Sigma = 8979$	$\Sigma = 385$

(b) Interference fringes (Δx_p instead of x_p for reasons mentioned previously)

order	Left Fringes					Right Fringes				
	a_1^l (cm)	a_2^l (cm)	a^l (cm)	Δx_p (cm)	d (mm)	a_1^r (cm)	a_2^r (cm)	a^r (cm)	Δx_p (cm)	d (mm)
0	25.4	25.5	25.5			~~27.5~~	~~26~~ 27.5	27.5		
1	24.7	24.8	24.8	0.70	0.34	28.2	28.3	28.25	0.75	0.32
2	23.9	23.9	23.9	1.55	0.31	28.9	28.9	28.9	1.40	0.34
0	23.2	23.2	23.2			29.8	29.8	29.8		
1	22.4	22.5	22.5	0.75	0.32	30.5	30.6	30.6	0.75	0.32
2	21.6	21.6	21.6	1.60	0.30	31.2	31.2	31.2	1.40	0.34
0	20.8	20.8	20.8			32.0	32.0	32.0		
1	20.1	20.0	20.1	0.75	0.32	32.7	32.8	32.8	0.75	0.32
2	19.3	19.3	19.3	1.50	0.32	33.5	33.5	33.5	1.50	0.32
0	18.5	18.5	18.5			34.4	34.4	34.4		
1	17.7	17.8	17.9	0.75	0.32	35.2	35.2	35.1	0.70	0.34
2	17.1	17.1	17.1	1.40	0.34	35.7	35.7	35.7	1.30	0.37
0	16.1	16.1	16.1			36.8	36.8	36.8		
1	15.4	15.4	15.4	0.75	0.34	37.5	37.6	37.6	0.75	0.32
2	14.6	14.6	14.6	1.50	0.32	38.1	38.1	38.1	1.50	0.37
0	13.9	13.9	13.9			39.0	39.0	39.0		
1	13.1	13.2	13.2	0.75	0.32	39.7	39.8	39.8	0.75	0.32
2	12.5	12.5	12.5	1.40	0.34	40.5	40.5	40.5	1.40	0.32
0	11.4	11.4	11.4			41.3	41.3	41.3		
1	10.7	10.8	10.8	0.65	0.37	42.0	42.1	42.1	0.75	0.32
2	10.1	10.1	10.1	1.30	0.37	42.7	42.7	42.7	1.40	0.34
0	9.1	9.1	9.1			43.7	43.7	43.7		
1	8.4	8.5	8.5	0.65	0.37	44.3	44.5	44.4	0.70	0.34
2	7.8	7.8	7.8	1.30	0.37	45.0	45.0	45.0	1.30	0.37
0	6.8	6.8	6.8							
1	6.1	6.2	6.2	0.65	0.37					
2	5.5	5.5	5.5	1.30	0.37					

0	4.5	4.5	4.5		
1	3.7	3.9	3.8	0.7	0.34
2	3.2	3.2	3.2	1.3	0.37
0	2.1	2.1	2.1		
1	1.5	1.3	1.2	0.7	0.34
2	0.8	0.8	0.8	1.3	0.37

Here the center of the interference + diffraction pattern was found at $\frac{27.9+23.9}{2} = 25.9\,cm$

and d was calculated for each Δx_p using the formula,

$$d = \frac{\lambda D m}{\Delta x_p} \quad , D = 3.8m \quad \lambda = 632.8\,nm$$

From the 37 different sets in the table above, the mean value of d came out to be, $\boxed{d = 0.34\text{ mm}}$

From the diffraction pattern, we can create a x_m vs. m plot similar to parts (A) & (B).

From the table, ($\sigma_{yi} = 1$ mm)

$S_x = 55$, $S_{xx} = 385$, $S_y = 1282$, $S_{xy} = 8979$, $S = 10$

$\Rightarrow \Delta = SS_{xx} - (S_x)^2 = 825$

Using eqⁿs 6 & 7,

$$a = \frac{SS_{xy} - S_xS_y}{\Delta} = \frac{10 \cdot 8979 - 55 \cdot 1282}{825} = 23.38$$

$$\text{intercept} = \frac{S_{xx}S_y - S_xS_{xy}}{\Delta} = \frac{385 \cdot 1282 - 55 \cdot 8979}{825} = -0.43$$

$\therefore$ The eqⁿ $x_m = \left(\frac{2D\lambda}{b}\right) m$ can be written as,

$$x_m = 23.38m - 0.43$$

using $D = 3.8m$ & $\lambda = 632.8\,nm$, we get $\boxed{b = 0.10\text{ mm}}$

Now, since $d = b + c$, $\boxed{c = 0.24\text{ mm}}$

Error Analysis

(A) Diffraction using a thin wire (to determine width of the wire)

By minimising a & c wrt. y_i we can find the uncertainities, we can find uncertainities in a & c respectively as,

$$\sigma_a^2 = \frac{S}{\Delta} = \frac{11}{1210}$$

$$\Rightarrow \sigma_a = \sqrt{\frac{11}{1210}} = 0.10 \text{ mm}$$

$$\& \ \sigma_c^2 = \frac{S_{xx}}{\Delta} \Rightarrow \sigma_c = \sqrt{\frac{506}{1210}} = 0.65 \text{ mm}$$

∴ The corrected eq^n is,

$$x_m = (8.67 \pm 0.10)\, m + (0.17 \pm 0.65)$$

since $b = \frac{2\lambda D}{a}$,

$$\frac{\sigma_b}{b} = \sqrt{\left(\frac{\sigma_D}{D}\right)^2 + \left(\frac{\sigma_a}{a}\right)^2}$$

putting $\sigma_D = 0.01\,m$,

$$\sigma_b = 0.23\sqrt{\left(\frac{0.01}{1.6}\right)^2 + \left(\frac{0.10}{8.673}\right)^2} = \cancel{0.003 \text{ mm}}\ 0.0029 \text{mm}$$

$$= 2.9 \times 10^{-3} \text{ mm}$$

$$\therefore \ b = (0.23 \pm 2.9\times10^{-3}) \text{ mm}$$

(B) single slit Diffraction (to determine wavelength of source light)

Similarly to part (A),

$$\sigma_a = \sqrt{\frac{S}{\Delta}} = \sqrt{\frac{6}{105}} = 0.24 \text{ mm}$$

$$\sigma_c = \sqrt{\frac{S_{xx}}{\Delta}} = \sqrt{\frac{91}{105}} = 0.93 \text{ mm}$$

∴ The eq^n becomes, $x_m = (19.01 \pm 0.24) + (1.68 \pm 0.93)$

~~that~~ since $\lambda = \frac{ab}{2D}$, the uncertainity σ_λ is given by,

$$\frac{\sigma_\lambda}{\lambda} = \sqrt{\left(\frac{\sigma_a}{a}\right)^2 + \left(\frac{\sigma_b}{b}\right)^2 + \left(\frac{\sigma_D}{D}\right)^2}$$

using $\sigma_D = 0.001\,m$, $\sigma_b = 0.01\,mm$,

$$\sigma_\lambda = 670\sqrt{\left(\frac{0.24}{19.01}\right)^2 + \left(\frac{0.01}{0.246}\right) + \left(\frac{0.01}{3.5}\right)^2}$$

$$= 28\ nm$$

$$\therefore\ \sigma_\lambda = (670 \pm 28)\,nm$$

(D) Double slit Diffraction & Interference

For the diffraction pattern, uncertainities in slope & intercept,

$$\sigma_a = \sqrt{\frac{S}{\Delta}} = \sqrt{\frac{10}{825}} = 0.11\ mm$$

$$\sigma_{int.} = \sqrt{\frac{S_{xx}}{\Delta}} = \sqrt{\frac{385}{825}} = 0.68\ mm$$

$\therefore$ eqn becomes $x_m = (23.38 \pm 0.11)\,m\ \mp\ (0.43 \mp 0.68)$

since $b = \frac{2D\lambda}{a}$,

$$\sigma_b = b\sqrt{\left(\frac{\sigma_D}{D}\right)^2 + \left(\frac{\sigma_a}{a}\right)^2} = 0.10\sqrt{\left(\frac{0.01}{3.8}\right)^2 + \left(\frac{0.11}{23.38}\right)^2} =$$

$$= 0.00055 = 5.5\times10^{-4}\ mm$$

$$\therefore\ \boxed{b = (0.10 \pm 5.5\times10^{-4})\,mm}$$

From the interference pattern, we can find σ_d as the std. deviation in all the d values,

$$\sigma_d = \sqrt{\frac{1}{N-2}\sum_i [d_i - d]^2} \approx 0.06\ mm$$

$$\therefore\ \boxed{d = (0.34 \pm 0.06)\,mm}$$

Hence, $\sigma_c = \sqrt{(\sigma_d)^2 + (\sigma_b)^2} \approx 0.06\,mm$

$$\therefore\ \boxed{c = (0.24 \pm 0.06)\,mm}$$

Observations

Table 4: Determination of ~~slit~~ 'b' using travelling microscope

(B) Single slit Diffraction (Determination of b) (L.C. = 0.01mm)

S.no.	Left edge (a_l)			Right edge (a_r)			$b = a_l \sim a_r$	Mean b
	MSR (mm)	VSR	Tot (mm)	MSR (mm)	VSR	Tot (mm)	(mm)	(mm)
1	20.0	40	20.40	20.0	15	20.15	0.25	
2	19.5	45	19.95	20.0	20	20.20	0.25	0.246 ~0.25
3	19.5	49	19.99	20.0	23	20.23	0.24	
(A) Wire Diffraction (Determination of b)								
	~~41.0~~	~~27~~	~~41.27~~	~~41.5~~	~~5~~	~~41.55~~	~~0.28~~	
	~~41.0~~	~~30~~	~~41.30~~	~~41.0~~	~~3~~	~~41.03~~	~~0.27~~	
	~~40.5~~	~~37~~	~~40.87~~	~~40.5~~	~~10~~	~~40.60~~	~~0.27~~	
	~~40.5~~	~~3~~		~~40.5~~	~~28~~		~~0.25~~	
1	40.5	0		40.5	22		0.22	
2	40.5	2		40.5	23		0.21	0.213 ~0.21
3	40.5	15		40.0	44		0.21	
(C) Verification of Babinet's Principle (width of equivalent slit)								
1	43	15	43.15	42.5	42	42.92	0.23	
2	43	12	43.12	42.5	36	42.86	0.26	0.24
3	42.5	46	42.96	42.5	23	42.73	0.23	

02/09/24

Table 5: Determination of b & d using travelling microscope

	Left edge (mm)			Right edge (mm)			Width (mm)	Mean width (mm)
	msr (mm)	usr	tot (mm)	msr (mm)	usr	tot (mm)		
Slit-1	41	3	41.03	40.5	40	40.90	0.13	
	41	4	41.04	40.5	44	40.94	0.10	b ~
slit-2	40.5	21	40.71	40.5	12	40.62	0.09	0.11
	40.5	21	40.71	40.5	10	40.60	0.11	
slit-1 +wire	41.0	20	41.20	40.5	34	40.84	0.36	
	41.0	25	41.25	40.5	35	40.85	0.40	d ~
slit-2 +wire	41.0	20	41.20	40.5	37	40.87	0.33	0.35
	40.5	5	40.55	40.0	24	40.24	0.31	

P. [illegible]
03/09/24

Results & Discussion

We we successfully able to observe and study diffraction patterns created by laser light when it interacts with a thin single slit, thin wire and a double slit. By fixing the distance between the slit and the screen, we able to mark the diffraction pattern to measure the wavelength of light as well as the dimensions of the wire / slit.

Using single slit diffraction, we were able to determine the wavelength of the source to be,

$$\lambda = (670 \pm 28) \text{ nm}$$

which is just slightly outside the error bar compared to the literature value of $\lambda = 632.8$ nm. We also note that while taking measurements, we only consider the positions of minima & not maxima. This is because unlike the central maxima, the secondary maxima are not located precisely halway between the minima. The reason for this can be shown analytically:-

for the diffraction pattern $I = I_0 \left(\frac{\sin\beta}{\beta}\right)^2$, the maxima can be found by putting $\frac{dI}{d\beta} = 0$. This gives us an eq^n of the form $\tan\beta = \beta$ which can be solved analytically to find solutions, $\beta = 0, 4.493$ rad; 7.725 rad ... $\because$ Using $\beta = (m+\frac{1}{2})\pi$, we get $\beta = 0, 4.712$ rad, 7.853 rad, ...; which are close but ~~not~~ do not exactly correspond to the real sol^{n}s. This is because $(m+1/2)\pi$ is not a sol^n of $\tan\beta = \beta$.

For the second part of the experiment we were able to determine the width of a wire from analyzing its diffraction pattern, which came out to be,

$$b = (0.23 \pm 2.9\times10^{-3}) \text{ mm}$$

which is quite close to the width measured using a travelling microscope, $b = (0.21 \pm 5.7\times10^{-3})$ mm.

We were also able to verify Babinet's principle, by adjusting the width of a slit ~~to~~ such that the diffraction pattern matches the one we saw using the thin wire. As the width of the wire was found to be around 0.23 mm, the width of the ~~comparable~~ equivalent single slit was found to be $(0.24 \pm 5.7\times10^{-3})$ mm. The ~~our~~ discrepancies here could be attributed to the fact that the similarity between the diffraction patterns were judged ~~quite roughly~~ using a graph paper and was not ~~really~~ very precise.

In the final part of the experiment, we analysed light passing through two parallel slits each of width 'b' separated by an opaque space 'c'. The values of b & c were calculated from the diffraction pattern, which came out to be,

$$b = (0.10 \times 5.5\times10^{-4})\,\text{mm}$$
$$d = (0.34 \pm 0.06)\,\text{mm}$$

and hence, $c = d - b = (0.24 \pm 0.06)$ mm.

These values are in agreement with the values obtained using the travelling microscope: $b = (0.11 \pm 0.01)$ mm & $d = (0.35 \pm 0.01)$ mm.

In the diffraction pattern observed, we saw single slit diffraction fringes broken down into narrow maxima & minima of interference fringes. This highlights the primary difference between diffraction — bending of light around opaque edges — opposed to interference — superposition of 2 or more wavefronts. The interference fringes hence were observed to have equal widths and all the maxima have the same intensity, which is not the case for diffraction fringes.

This experiment also demonstrates the concept of missing orders — when a diffraction minimum coincides with an interference maximum, which is why we measured Δx_p instead of x_p.

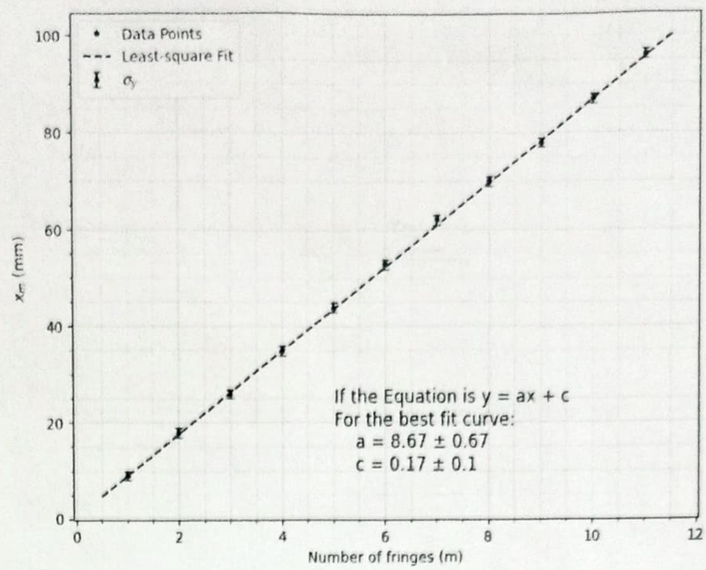
Precautions & Sources of Error

1. Make sure that the laser path is perpendicular to the screen
2. Mark the diffraction pattern on a graph paper carefully as to not miss any fringes
3. Turn the knob of the travelling microscope only in one direction to avoid any backlash

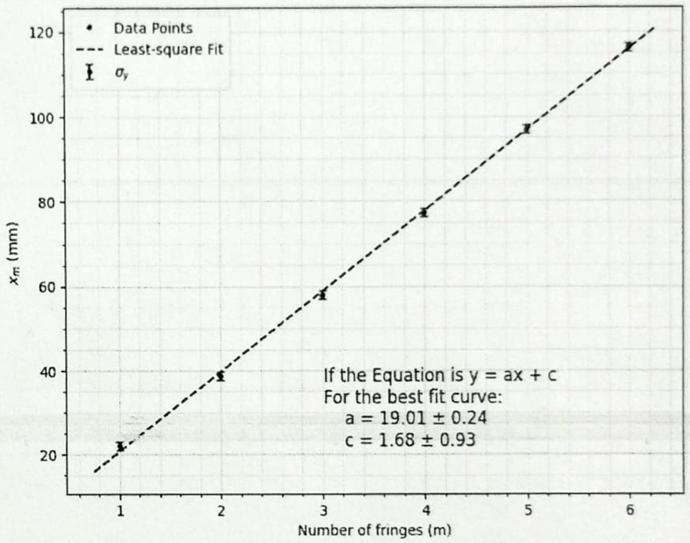
Plots

$\sigma_{y_i} = 1mm$

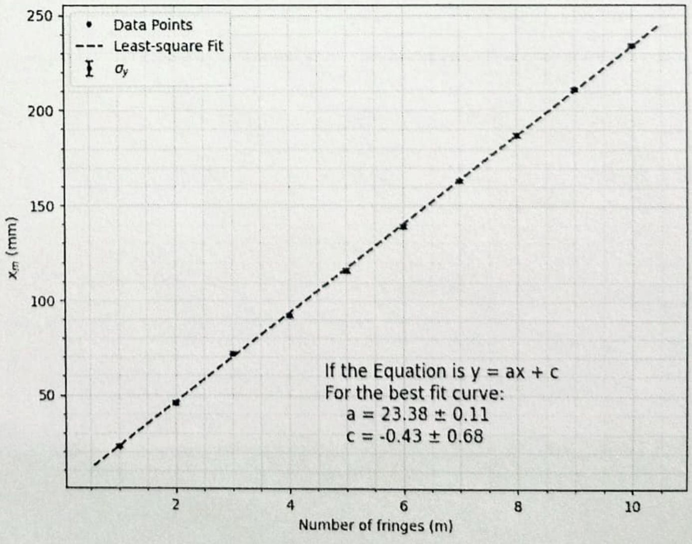
(A) x_m vs. m plot for diffraction using a thin wire (Table 1)



(B) x_m vs. m plot for single slit diffraction (Table 2)

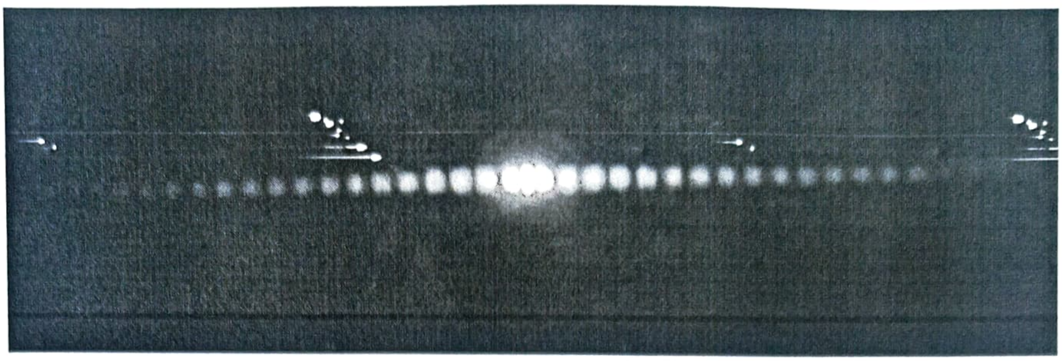


(C) x_m vs. m plot for ~~dif~~ double slit diffraction (Table 3a)

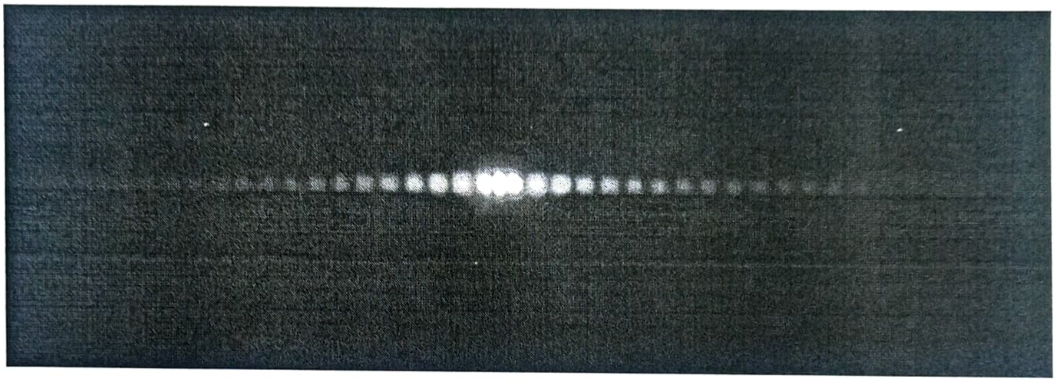


Observed Diffraction Patterns

(A) Diffraction using thin wire

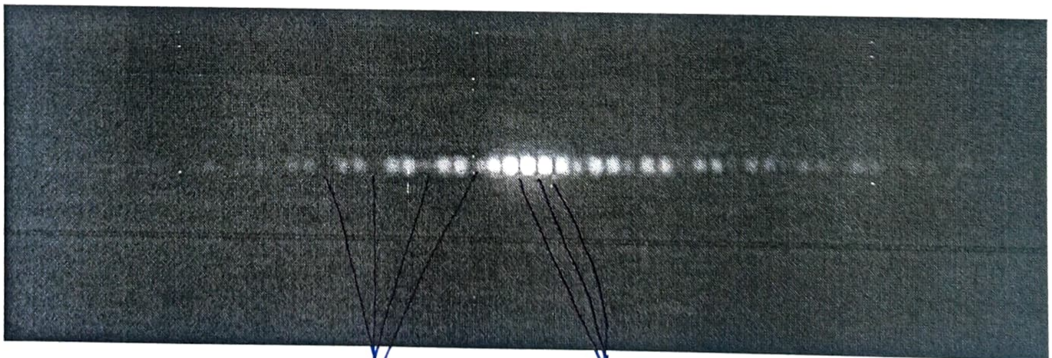


(B) Diffraction using single slit



Here (A) & (B) are practically the same pattern, as a result of Babinet's principle.

(C) Double slit diffraction.



~~Here~~

diffraction minima

interference minima

Here, one can see the diffraction maxima evenly split into several interference maxima & minima.