FRAUNHOFER DIFFRACTION OF SINGLE SLIT AND DOUBLE SLIT

PROJECT REPORT

Submitted by

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B.Sc. Physics

PROJECT REPORT

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Year of Work: 2022-'23

This is to certify that this project "FRAUNHOFER DIFFRACTION OF SINGLE SLIT AND DOUBLE SLIT " is the work done by Sangeetha Lal.

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Date:

Examiners:

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CERTIFICATE

This is to certify that the project entitled " FRAUNHOFER DIFFRACTION OF SINGLE SLIT AND DOUBLE SLIT " is an authentic work done by **SANGEETHA LAL**, St Teresa's College, Ernakulam ,under any supervision at Department of Physics, St Teresa's College, Ernakulam,for the partial requirements for the award of Degree of Bachelor of Science in Physics during the academic year 2022-23.The work presented in this dissertation has not been submitted for any other university.

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DECLARATION

I,SANGEETHA LAL,final year B.Sc Physics students,Department of Physics. St.Teresa’s College,Ernakulam do hereby declare that the project work entitled **‘FRAUNHOFER DIFFRACTION OF SINGLE SLIT AND DOUBLE SLIT’** had been originally carried out under the guidance and supervision of SREEJA.VG Assistant Professor, Department of Physics, St. Teresa's College (Autonomous), Ernakulam in partial fulfillment for the award of the degree of Bachelor of Physics. I further declare that this project is not partially or wholly submitted for any other purpose and the data included in the project is collected from various sources and is true to the best of my knowledge.

PLACE: ERNAKULAM
DATE: 19/5/2020

ACKNOWLEDGEMENT

For any accomplishment or achievement the prime requisite is the blessing of the Almighty and it is the same that made this work possible. I bow to the lord with a grateful heart and prayfull mind.

It is with this great pleasure that I express my gratitude to my beloved teacher Dr Sreeja V G Dept. Of Physics, St. Teresa's College, for her inspiring valuable guidance, keen interest throughout the progress of this work and for her overwhelming support, motivation and encouragement.I also thank the first year PG seniors of Physics department,Union Christian college for their valuable time and guidance.

I would like to thank all the faculty members of the Department,our HOD Smt Dr. Priya Parvathi Ameena Jose ma'am and my friends who helped us directly and indirectly through their valuable suggestions and self criticisms, which went a long way in ensuring that this project becomes a success.

FRAUNHOFER DIFFRACTION OF SINGLE SLIT AND DOUBLE SLIT

CONTENTS

ABSTRACT

In this project, the diffraction pattern of fraunhofer diffraction is observed using fraunhofer single slit and fraunhofer double slit apparatus .The slit width of the single slit and double slit Apparatus is determined using the diffraction of laser light by varying the distance between the screen and slit .The diffraction pattern is drawn on the graph and the value for the thickness of the slit is determined through calculations.The obtained results are then validated by comparing with the existing values.

OBJECTIVES OF THE PRESENT WORK

The experiment aimed to explore the Fraunhofer diffraction pattern of single slit and double slit and to determine the slit width of the single slit and double slit using diffraction of laserlight by varying the distance between screen and the slit.

CHAPTER 1

INTRODUCTION

1.1 DIFFRACTION

When light passes through a narrow aperture or obstacle, it spreads out into the geometric shadow of the aperture or the obstacle. This spreading of light around the edge of an aperture or obstacle is called the diffraction. Diffraction of a sound wave is larger than light waves as a wavelength of sound is larger than a wavelength of light.The light passing through a narrow slit produces a diffraction pattern consisting of a broad, intense central band called the central maximum and a series of narrower less intense bands called secondary maxima.Diffraction is a phenomenon of all electromagnetic radiation, including radio waves; microwaves; infrared, visible, and ultraviolet light; and x-rays. The effects for light are important in connection with the resolving power of optical instruments.

Diffraction may be noticed when the size of the aperture is proportional to the wavelength of light. If the aperture is substantially bigger than the wavelength of light, the bending will be imperceptible. The amount of bending is significant and visible to the human eye if both are of equal or similar size.

Diffraction occurs with all waves, including water, sound, and electromagnetic waves. It happens when light waves travel through a hole, slit, or even a corner that should be smaller or the same size as the light's wavelength. Sun rays originating from clouds, light bending around the edges of windows and doors, and so on are instances of light diffraction.

1.2TYPES OF DIFFRACTION

There are two main classes of diffraction

• Fraunhofer diffraction

• Fresnel diffraction

1.2.1 FRAUNHOFER DIFFRACTION

In Fraunhofer Diffraction, the diffraction pattern is obtained successfully at unlimited or limitless distance from the diffracting system. The diffraction pattern is generated by using a convex lens. When the distance between two points is extended,the outgoing diffraction pattern wave becomes linear or horizontal. Consider the plane wavefront. The following sections describe the key points for Fraunhofer Diffraction :

• The distance between the screen and the source is unlimited.

• On the diffracting obstruction, the incident wavefronts are horizontal or plane.

• A convex lens connects the plane or horizontal wavefront to form a diffraction pattern.

• The diffraction object produces wavefronts that are also straight or flat.

1.2.2 FRESNEL DIFFRACTION

In Fresnel Diffraction, the diffraction pattern is obtained successfully at a restricted or finite obtained successfully at a restricted or finite distance from the diffracting device. As an example, consider spherical or cylindrical wavefronts. The following points explain the main aspects of Fresnel Diffraction:

• The screen and the source are close together. They are restricted in number or distance.

• Incident wavefronts have spherical or cylindrical forms.

• The wavefronts leave behind spherical objects.

• The convex lens is not required to join the spherical wavefronts.

1.3 DIFFERENCE BETWEEN SINGLE SLIT AND DOUBLE SLIT DIFFRACTION

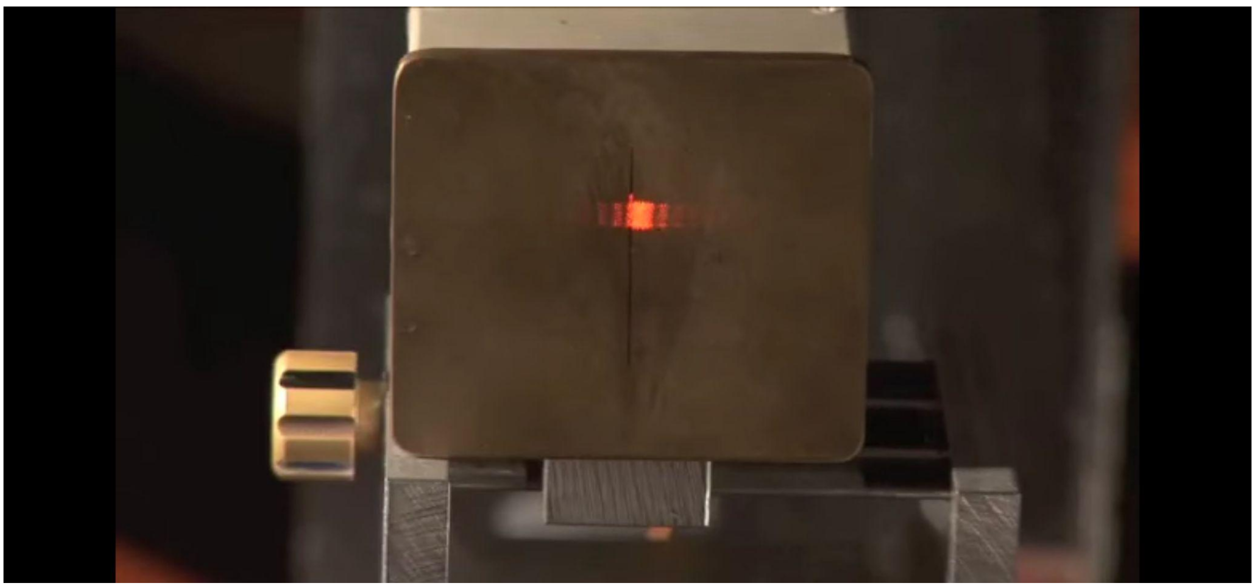
The following table shows the difference between single and double slit diffraction

Sr.No	Single slit diffraction	Double slit diffraction
1.	Light outstretches in a perpendicular line to the slit in single slit diffraction	Light diffracts while passing through the slits in double slit diffraction
2.	The central maximum in a single slit diffraction pattern is greater than the maxima on each side.Hence, the intensity diminishes fast on either side.	Light going through a double slit, on the other hand,generates equally spaced lines that fade steadily on each side of the center

CHAPTER 2

2.THEORY

2.1 DIFFRACTION OF LASER LIGHT THROUGH A SINGLE SLIT



SINGLE SLIT APPARATUS

Diffraction is caused by bending of light waves around an object while encountering it.For diffraction to occur the obstacle should have a sharp edge or the light should pass through small slit.Fraunhofer diffraction is observed using a single slit and laser source of light- The intensity of the diffracted light.Single slit apparatus generally has a narrow opening in the form of an adjustable slit as shown in Fig- The opening is 10mm long and Its width is adjustable from 0.5mm to 5mm. The diffraction pattern comprising alternate bright and dark fringes can be observed even by an unaided eye.

$$\sin \theta m = m\lambda/d$$

where 'd' is the slit width of single slit apparatus A is the wavelength of laser source

'm' is the order of the diffraction pattern Calculating and knowing wavelength of laser source we could find slit width of single slit apparatus

$$d=m\lambda/ \sin \theta m$$

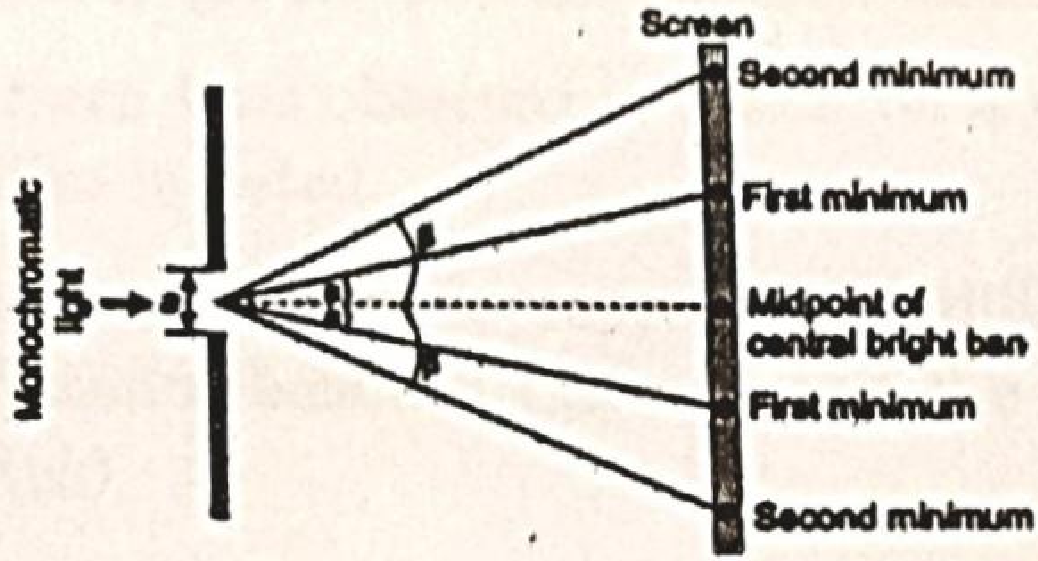
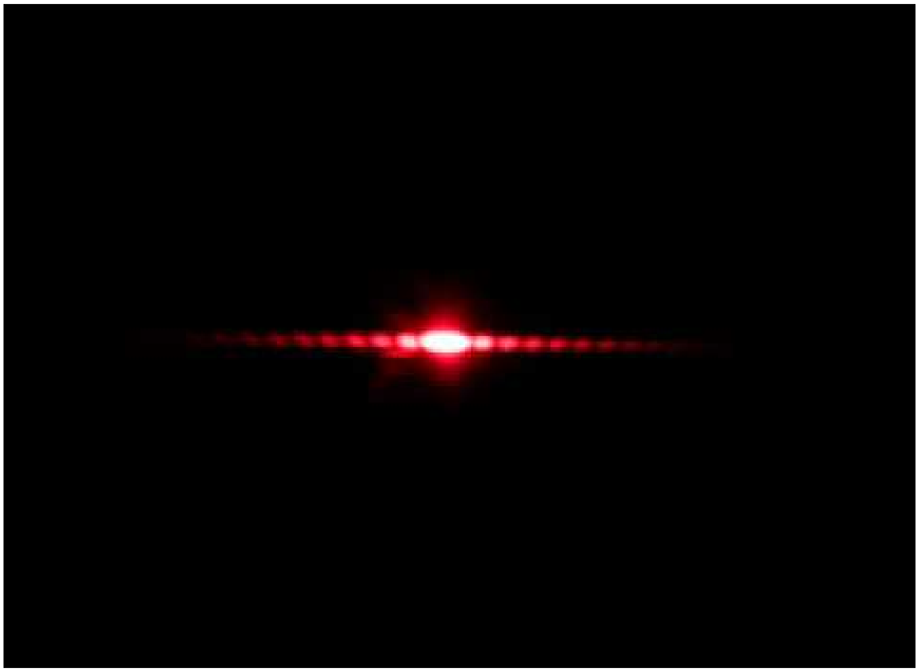
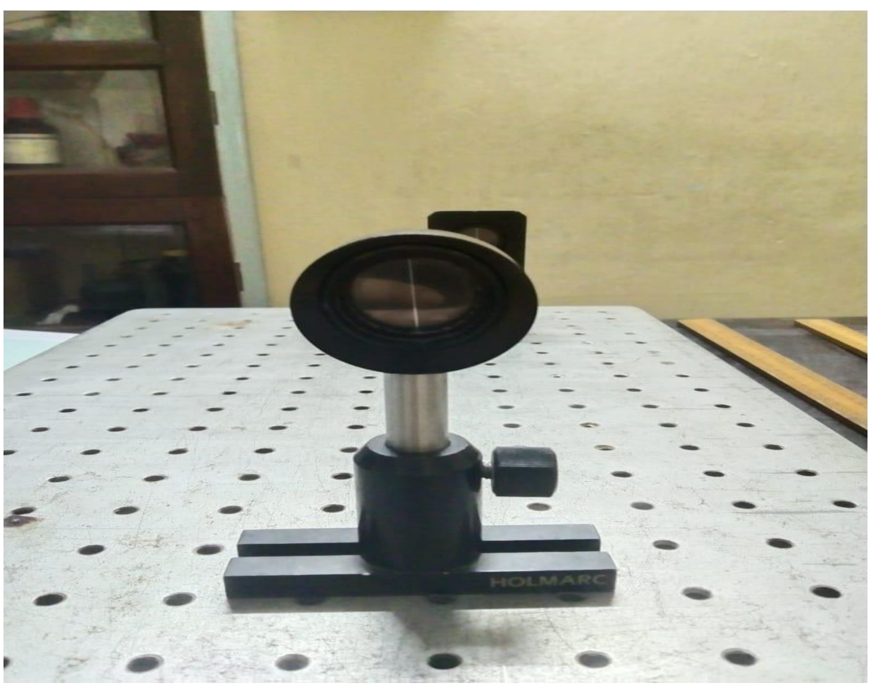


Figure 2: Process of diffraction at single slit

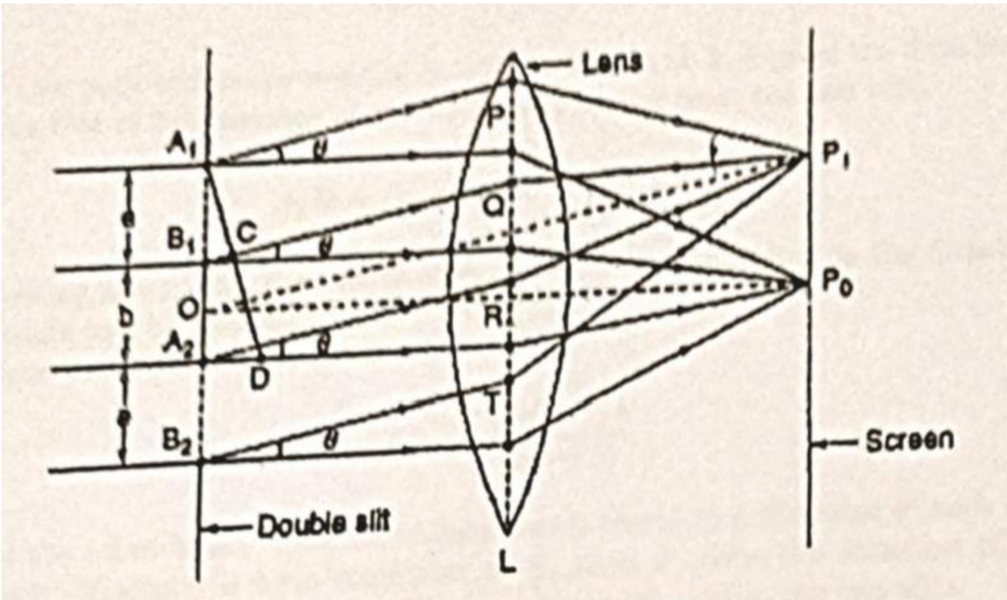


SINGLE SLIT DIFFRACTION PATTERN

2.2 FRAUNHOFER DIFFRACTION OF DOUBLE SLIT



FRAUNHOFER DOUBLE SLIT APPARATUS



DOUBLE SLIT

In The Figure, A1B1, and A2B₂ are two rectangular slits parallel to one another and perpendicular to the plane of the paper. The width of each slit is a and the width of the opaque portion is b. L is a collecting lens and MN is a screen perpendicular to the plane of the paper. Po is a point on the screen such that OP is perpendicular to the screen. Let a plane wave front be incident on the surface of XY. All the secondary waves traveling in a direction parallel to OP come to focus at Po. Therefore, Po corresponds to the position of the central bright Maximum.

In this case, the diffraction pattern has to be considered In two parts

(i).the interference phenomenon due to the secondary waves emanating from the cor- responding points of the two slits and

(ii).the diffraction pattern due to the secondary waves from the two slits individually. For calculating the positions of interference maxima and minima, the diffraction angle is denoted as θ and for the diffraction maxima and minima it is denoted as ϕ. Both the angles refer to the angle between the direction of the secondary waves and the initial direction of the incident light.

2.2.1 Interference maxima and minima:

Let us consider the secondary waves traveling in a direction incline at an angle θ with the initial direction.

In the triangle A2A1,D[Fig: 2]

$\sin\theta = A2D/A1A2 = A2D/a+b$

$$A2D = (a+b)\sin\theta \qquad (2)$$

If this path difference is equal to odd multiples of $\lambda/2$, θ gives the direction of minima due to interference of the secondary waves from the two slits.

$$A2D = (a+b)\sin\theta = (2n+1)\ \lambda/2 \qquad (3)$$

Putting n = 1,2,3,... the values of $\theta1,\theta2,\theta3$. corresponding to the directions of minima can be obtained.

From this equation we have

$$\sin\theta=(2n+1)\ \lambda / [2(a+b)] \qquad (4)$$

On the other hand, if the secondary waves travel in a direction θ' such that the path difference is even multiples of $\lambda/2$, then θ' gives the direction of the maxima due to interference of light waves emanating from the two slits.

$$A2D =(a+b)\sin \theta n' =2n\ \lambda/2 \qquad 5)$$

$$\sin\theta n' = n[\lambda/(a+b)] \qquad (6)$$

Putting n = 1,2,3….θ1',θ2',θ3' , corresponding to the direction of the maxima can be obtained. The slit width is obtained by the terin (a+b). So the equation to calculate slit width of a given double slit apparatus is

$$d=n[\lambda/\sin\theta n] \quad (7)$$

Where n gives the order of maxima, d = (a+b), the slit width, and λ is the wavelength of the light used.

2.2.2 DIFFRACTION MAXIMA AND MINIMA

Let us consider the secondary waves traveling in a direction inclined at an angle ϕ

with the initial direction of the incident light.

If the path difference B1C is equal to λ , the wavelength of the light used, then ϕ will give the direction of the diffraction minimum. This is, the path difference between secondary waves emanating from the extremities of a slit (points A1 and B1) is equal to λ . Considering the wave front in A1B1 to be made up of the two halves, the path difference between the corresponding points of the upper and lower halves is equal to ϕ. The effect at P' due to the wave front incident on A1B1 is zero.Similarity,for the same direction of the secondary waves,the effect at P' due to the wave front incident on the slit A1B1 is also zero.In general,

$$A\sin\phi n = n\lambda \quad (8)$$

Putting n=1,2,3….the values of ϕ1,ϕ2,ϕ3….. Corresponding to the direction of diffraction minima can be obtained.

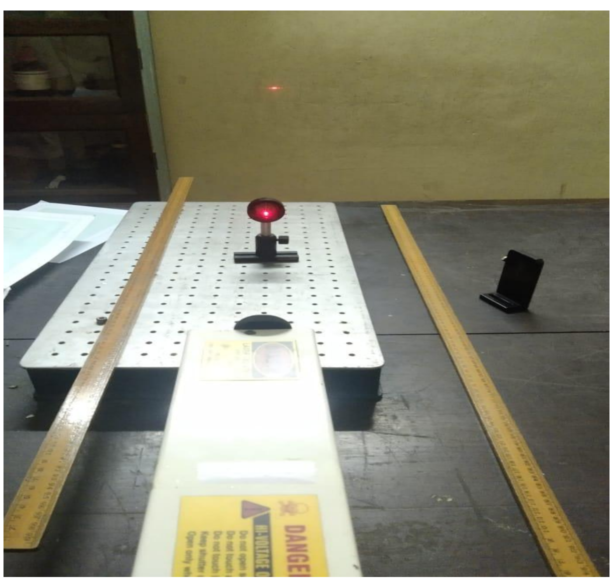
CHAPTER 3

EXPERIMENTAL SETUP

The main content of fraunhofer diffraction of single slit and double slit diffraction is to observe diffraction patterns of single slit and double slit and to determine the slit width.

This experiment usually consist of;

- Laser Beam
- Single slit apparatus
- Double slit apparatus
- Graph paper
- Meter scales



APPARATUS

3.1 LASER BEAM

A laser emits a beam of electromagnetic radiation that is always monochromatic, collimated and coherent in nature.The wavelength of the laser is λ=638.5nm

3.2 SINGLE SLIT APPARATUS

Single slit apparatus is used in this experiment for the single slit diffraction pattern. A monochromatic light is passed through one slit of finite width and a similar pattern is observed on the screen.

3.3 DOUBLE SLIT APPARATUS

The double-slit experiment is a demonstration that light and matter can display characteristics of both classically defined waves and particles.

3.4 METER SCALE

The meter scale is a device for measuring the length of any object

CHAPTER 4

EXPERIMENTAL PROCEDURE

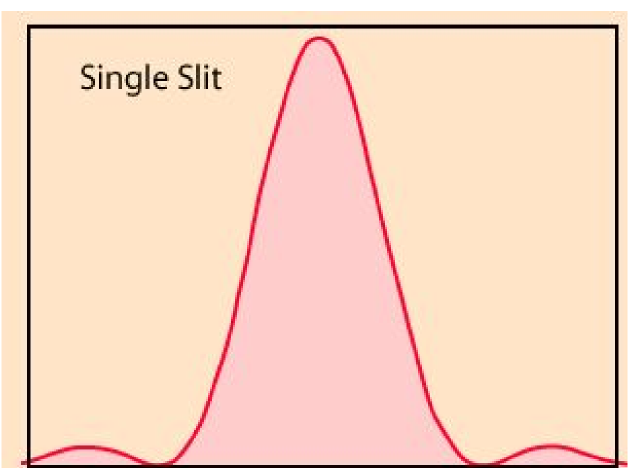
4.1 SINGLE SLIT

- The laser beam is made to fall on the wall(screen)
- Now the single slit apparatus is kept in front of the laser beam at a specific distance from the wall(screen) where the single slit pattern becomes clearly visible.
- The pattern thus observed is drawn on a graph paper.Radius is noted.
- The same procedure is repeated for different distances(distance between the wall and the single slit apparatus).

PRECAUTIONS:

1. The laser beam should not penetrate into eyes as this may damage the eyes permanently.
2. The detector should be as away from the slit as possible.
3. The laser should be operated at a constant voltage 220V obtained from a stabilizer. This avoids the flickering of the laser beam.

GRAPH



4.2DOUBLE SLIT EXPERIMENT

- The laser is switched on and placed on the table so that the light is allowed to fall on a wall or screen.
- The double slit is placed in front of the laser beam and the beam is adjusted to fall exactly on the two slit opening of the apparatus.
- Diffraction pattern is observed.
- To determine the width of the slit, distance D (Distance between the screen and slit) and Y. (Distance between the central maximum and nth minimum in the intensity distribution of the diffraction pattern) are measured directly.
- Thus the angle **θ** , can be measured which when substituted in the equation[7]
- gives the slit width of the double slit apparatus.
- The interval between two consecutive minima positions of the detector should be small enough, so that the adjacent maxima/minima of the intensity distribution are missed.

PRECAUTIONS:

1. The laser beam should not penetrate into eyes as this may damage the eyes permanently.
2. The detector should be as away from the slit as possible.
3. The laser should be operated at a constant voltage 220V obtained from a stabilizer. This avoids the flickering of the laser beam.

CHAPTER 5

EXPERIMENTAL OBSERVATIONS OF FRAUNHOFER DIFFRACTION

5.1 SINGLE SLIT DIFFRACTION EXPERIMENT

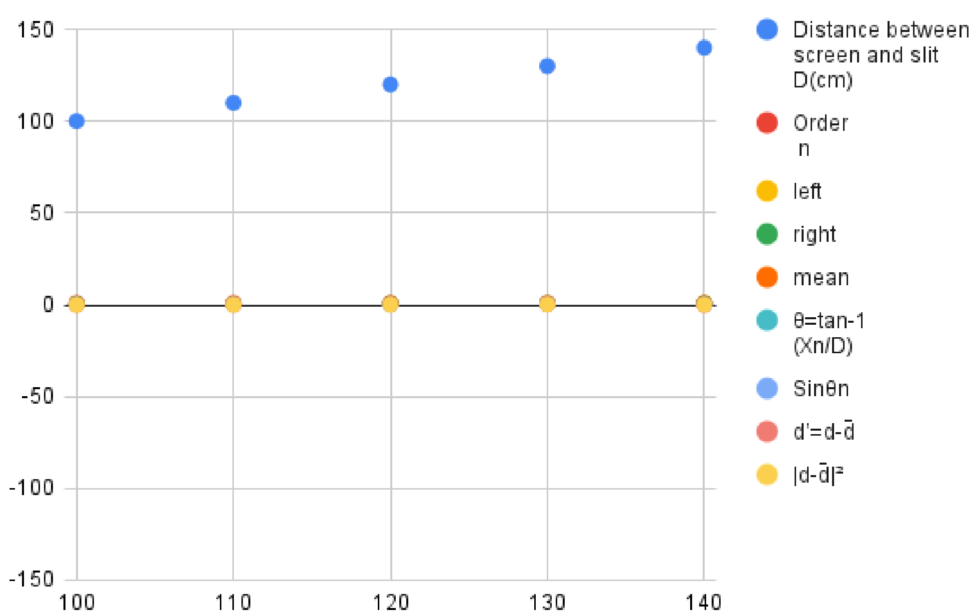
OBSERVATIONS

Distance between screen and slit D(cm)	Order n	Distance between central maximum and minimum(Xn) (cm)			θ=tan-1 (Xn/D)	Sinθn	d=nλ/Sinθn	d=mean a-a	d^2
		left	right	mean					
100	1	0.65	0.65	0.65	0.3724	6.494×10^{-3}	9.82×10^{-5}	0.098	0.0096
	2	1.3	1.3	1.3	0.7446	0.0130	9.82×10^{-5}	0.098	0.0096
	3	2	2	2	1.1458	0.0200	9.57×10^{-5}	0.348	0.1211
	4	2.6	2.65	2.625	1.5037	0.0262	9.74×10^{-5}	0.178	0.0316
110	1	0.7	o.7	0.7	0.3646	6.363×10^{-3}	10.03×10^{-5}	0.112	0.0125

	2	1.4	1.45	1.425	0.7422	0.0130	9.82×10^{-5}	0.098	0.0096
	3	2.1	2.1	2.1	1.0937	0.0191	10.02×10^{-5}	-0,102	0.0104
	4	2.85	2.9	2.875	1.4972	0.0261	9.78×10^{-5}	0.138	0.0190
120	1	0.8	0.8	0.8	0.3820	6.667×10^{-3}	9.57×10^{-5}	0.348	0.1211
	2	1.6	1.55	1.575	0.7520	0.0131	9.74×10^{-5}	0.348	0.1211
	3	2.35	2.3	2.325	1.1100	0.0194	9.87×10^{-5}	0.048	0.0023
	4	3.05	3	3.025	1.4440	0.0252	$10..13\times10^{-5}$	-0.212	0.0449
130	1	0.9	0.85	0.875	0.3856	6.730×10^{-3}	$9,48\times10^{-5}$	0.438	0.1918
	2	1.6	1.7	1.65	0.7272	0.0126	10.13×10^{-5}	-0.212	0.0449
	3	2.45	2.45	2.45	1.0797	0.0188	10.18×10^{-5}	-0.262	0.0686
	4	3.25	3.25	3.25	1.4321	0.0250	10.21×10^{-5}	-0.292	0.0852

140	1	0.9	0.9	0.9	0.3683	6.428×10^{-3}	9.93×10^{-5}	-0.012	0.0001
	2	1.75	1.7	1.725	0.7059	0.0123	10.38×10^{-5}	-0.462	0.2134
	3	2.75	2.6	2.675	1.0946	0.0191	10.02×10^{-5}	-0.102	0.0104
	4	3.6	3.45	3.525	1.4423	0.0252	10.13×10^{-5}	-0.212	0.0449

CALCULATIONS



Mean a= 9.9185 x10^{-6}m

Mean variances d^2/n = 0.05413 Standard errors

Standard deviation = 0.2326

Standard error = $\sigma/\sqrt{n-1}$= 0.2326/$\sqrt{19}$ = 0.0533

D= 1m

Order n=1

Xn=0·65

$\theta = \tan^{-1}(0.65\text{x}10^{-2}/1) = 0.3724$

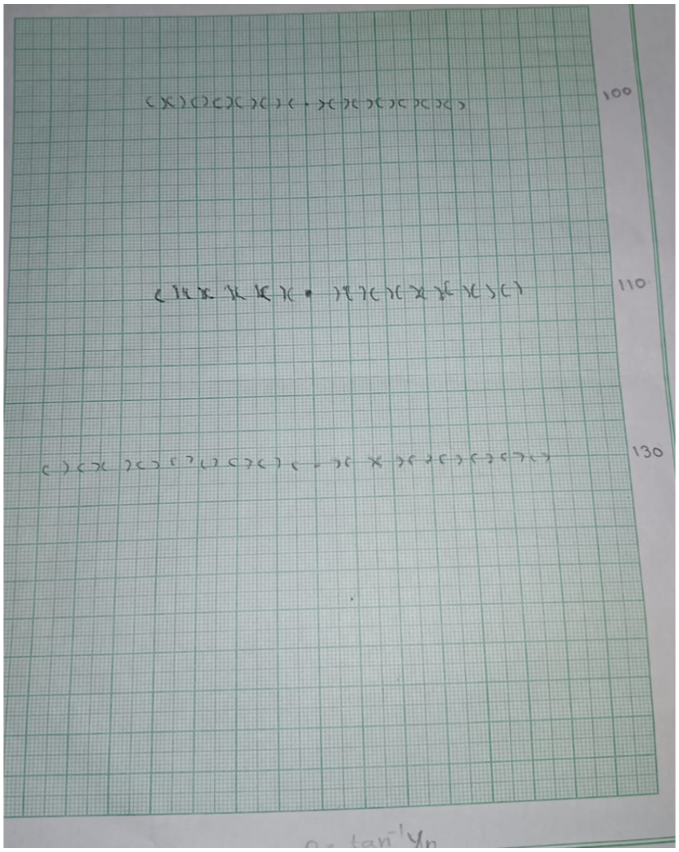
$\text{Sin}\theta n = \text{Sin}(0.3724) = 6.499\times10^{-3}$

$a = n\lambda/\text{Sin}\theta n = 1\text{x}638.5\text{x}10^{-9}/6.499\times10^{-3} = 98.24\text{x}10^{-6}\text{m}$

$d = 99.185\text{x}10^{-6} - 98.2\text{x}10^{-6} = 0.0985\text{m}$

$d^2 = |0.098|^2 = 0.0097\text{m}$

GRAPH



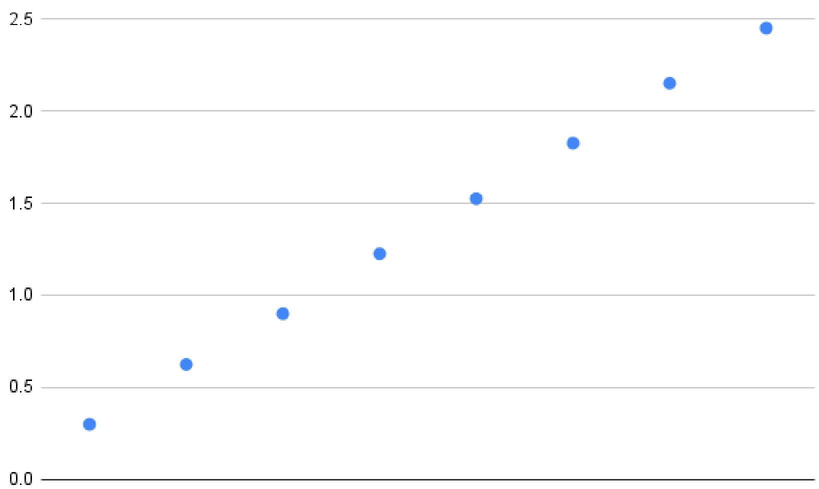
RESULT

The single slit diffraction pattern is observed and the slit width of the single slit apparatus is calculated

Mean slit width=$(99.185 \pm 0.0533)\times 10^{-6}$m

5.2DOUBLE SLIT DIFFRACTION EXPERIMENT

OBSERVATIONS



Order(n)	Distance between screen and slit D(cm)	Distance between central maximum and minimum(Yn)(cm)	θ=tan-1 (Yn/f)	Sin θn	d=nλ/Sinθn (μm)
1	100	0.3	0.1718	0.0029	212.83
2	100	0.625	0.3581	0.0063	204.32
3	100	0.9	0.5156	0.0090	212.84
4	100	1.225	0.7018	0.0122	208.50
5	100	1.525	0.8737	0.0153	209.37
6	100	1.825	1.0455	0.0182	209.95
7	100	2.15	1.2317	0.0215	207.93
8	100	2.45	1.4035	0.0245	208.55

Order(n)	Distance between screen and slit D(cm)	Distance between central maximum and minimum(Yn) (cm)	θ=tan-1(Yn/f)	Sin θn	d=nλ/Sinθn (μm)
1	140	0.45	0.1842	0.003	212.83
2	140	0.9	0.3683	0.006	212.83
3	140	1.25	0.5115	0.008	214.54
4	140	1.775	0.7263	0.0126	202.70
5	140	2.175	0.8900	0.0155	205.96
6	140	2.625	1.0741	0.0187	204.86
7	140	3.025	1.2378	0.0216	206.92
8	140	3.475	1.4218	0.0248	205.97

Mean d= 208.806μm

ERROR ANALYSIS

Sl no.	d (μm)	|d-d'| (μm)	|d-d'|²
1	212.83	4.024	1.619×10^{-11}
2	204.32	4.486	2.012×10^{-11}

3	212.84	4.034	1.627×10^{-11}
4	208.50	0.306	0.009×10^{-11}
5	209.37	0.564	0.031×10^{-11}
6	209.95	1.144	0.131×10^{-11}
7	207.93	0.876	0.076×10^{-11}
8	208.55	0.256	0.006×10^{-11}
9	212.83	4.024	1.619×10^{-11}
10	212.83	4.024	1.619×10^{-11}
11	214.54	5.734	3.287×10^{-11}
12	202.70	6.106	3.728×10^{-11}
13	205.96	2.846	0.809×10^{-11}
14	204.86	3.946	1.557×10^{-11}
15	206.92	1.886	0.035×10^{-11}
16	205.97	2.836	0.804×10^{-11}

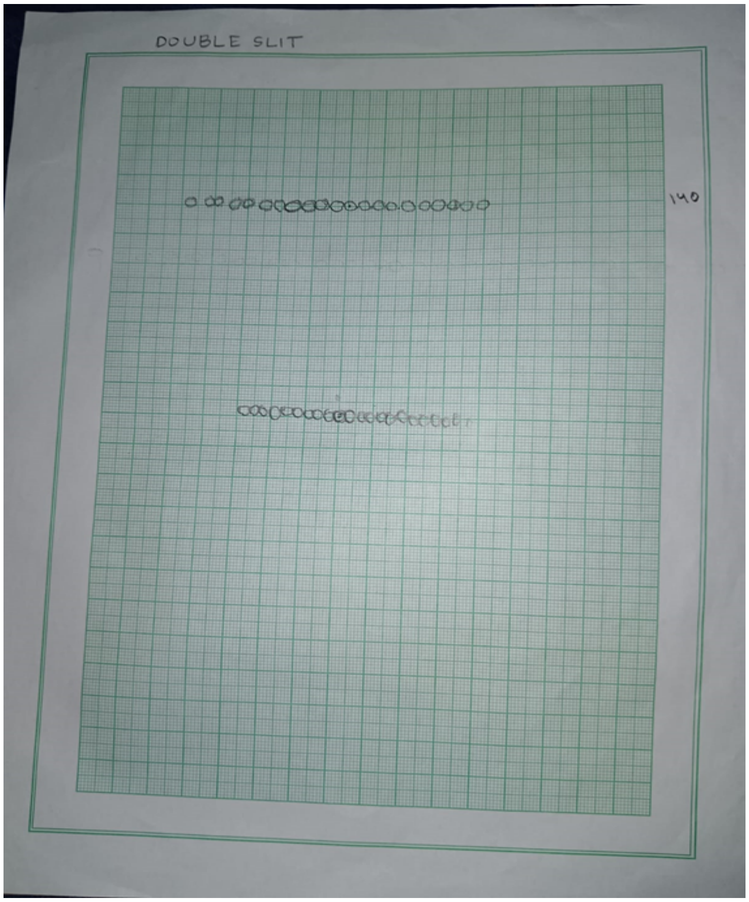
CALCULATIONS

Mean variance $\sigma^2 = 1.185\times10^{-11} m^2$
$\sigma = 3.442x10^{-6} m$

Standard Deviation = $\sigma/\sqrt{n-1} = 3.442x10^{-6} \backslash \sqrt{15} = 0.8887x10^{-6}$

$= 0.8887 \mu m$

GRAPH



RESULT

The double slit diffraction pattern is observed and the slit width of the double slit apparatus is calculated

Mean slit width=(208.806 ±888)µm

CONCLUSION

In conclusion, the determination of the slit width of single slit and double slit by fraunhofer diffraction helps to observe the diffraction pattern and help us to know more about the diffraction happening when a monochromatic light passes through the slits.Thus, we were able to observe the diffraction pattern and successfully estimated the width of the single slit and double slit by fraunhofer diffraction.

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