BISHOP MOORE COLLEGE

MAVELIKARA

PROJECT REPORT ON

"STUDY OF DIFFRACTION EMPLOYING SINGLE SLIT, DOUBLE SLIT AND GRATING"

By

ANANTHU MURALI : **REG NO: 23019101003**

KEERTHI MADHU : **REG NO: 23019101012**

CERTIFIED GENUINE

Signature of lecturer in charge *SIGNATURE OF EXAMINERS*

1.

2.

Date:

Department of Physics

Bishop Moore College, Mavelikara

CERTIFICATE

This is to certify that the dissertation entitled **"Study of diffraction employing Single Slit, Double Slit and Grating"** submitted by **Ananthu Murali (Reg no: 23019101003) and Keerthi Madhu (Reg no: 23019101012)** for the award of the **Degree of Bachelor of Science** in **Physics** is an authentic work done under my guidance and supervision during the period from **2019-2022**.

Also certified, that the dissertation represents an independent work on the part of the candidate.

Dr. Tintu K Kuruvilla

Assistant Professor

Department of Physics

Bishop Moore College, Mavelikara

DECLARATION OF ORGINALITY

We, hereby declare that thesis entitled **"Study of diffraction employing Single Slit, Double Slit and Grating"** submitted in partial fulfilment for the Degree of **Bachelor of Science** in Physics in Bishop Moore College, Mavelikara under University of Kerala, is a result of my original and independent work carried out under the guidance of Dr. Tintu K Kuruvilla, Assistant Professor, Bishop Moore College, Mavelikara, Kerala, and that it has not been submitted for the award of any degree of any University or Institution.

Ananthu Murali

Keerthi Madhu

ACKNOWLEDGEMENT

Foremost, we would like to express my sincere gratitude to our guide **Dr Tintu K Kuruvila,** Assistant Professor, **Bishop Moore College, Mavelikara** for her continuous support, patience, motivation, enthusiasm and most knowledge. She was always a source of inspiration to us. Her guidance helped in all the time of research and writing this project. We could not imagine having a better advisor and mentor for our research. The work could not have been possible without her worthy suggestions and constant co-operation.

Besides our advisor, we are also thankful to **Dr. D. Sajan**, Head of the department and Assistant professor, Bishop Moore College, Mavelikara for the help and guidance he provided to us for the initiation of this project. His dynamism, vision, sincerity and motivation have deeply inspired us. Our heart is fulfilled with deep sense of thankfulness and obeisance to our teachers for their valuable suggestions. We also express our thanks to all faculty members of Bishop Moore College, Mavelikara for their constant support.

We are grateful to our parents for their love, caring and sacrifices. We also thank our friends for giving us strength.

Ananthu Murali

Keerthi Madhu

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ABSTRACT

The bending of light rays around the corners of a obstacles is known as diffraction. With a laser as a light source, an experimental investigation of diffraction was carried out utilising single slit, double slit, and grating. Each experiment's calculations and observations were recorded, and the findings were tabulated. The diffraction patterns of each slit were documented during the experiment, and graphs were plotted. The result of the present study gives information about the effect of diffraction under various conditions and probable outputs, which is valuable for gaining mechanistic insights into the results of such experiments**.**

CHAPTER – 1
INTRODUCTION

Light can be defined as a stream of photons, which are massless packets of energy that travel at the speed of light with wave-like qualities. The smallest quantity, the photon, travels in discrete quanta. There are numerous different types of light, with sunlight being the most common, besides laser, fluorescence etc which are other useful methods for light generation. Due to various properties exhibited by light, it can be subjected to research and study of various experiments. In this project, principle of light based on diffraction properties were evaluated using a laser source.

1.2 PHENOMENA OF LIGHT

1.21 FEATURES OF LIGHT

Light consists of packets of energy called photons. Light behaves both as a wave and particle. It is the relatively narrow frequency band of electromagnetic waves. The primary properties of light are intensity, propagation direction, frequency or wavelength spectrum and polarization. Its speed in a vacuum, 299 792 458 metres a second (m/s), is one of the fundamental constants of nature [1].

1.22 ELECTROMAGNETIC SPECTRUM

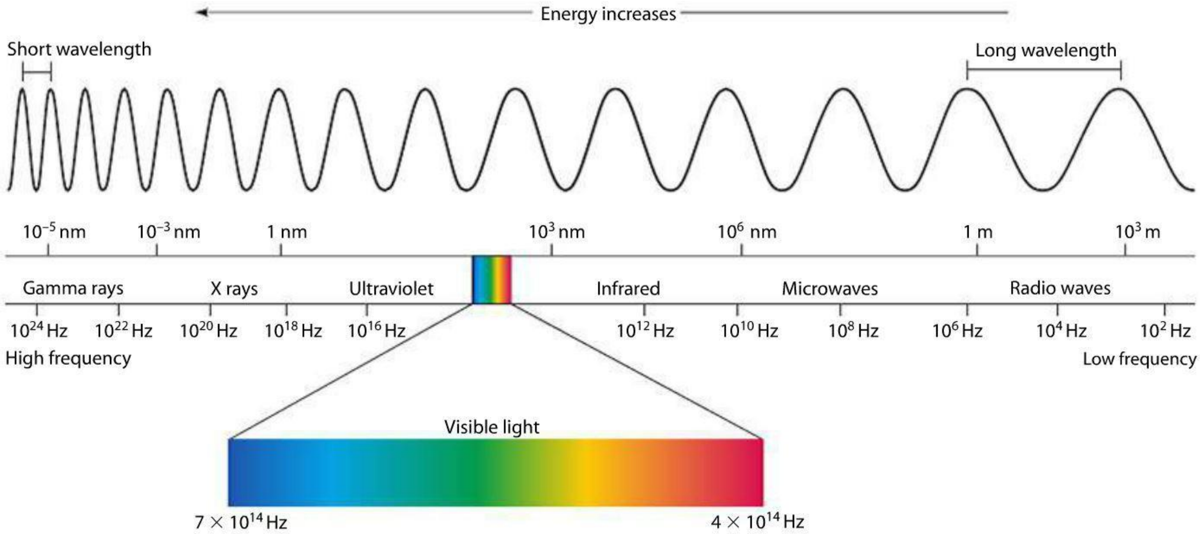

Fig1.1: Electromagnetic spectrum

The electromagnetic spectrum can be considered in terms of seven types of electromagnetic radiation, all corresponding to different wavelengths and frequencies: radio, microwave, infrared, visible light, ultraviolet, x-rays, and gamma rays. In electromagnetic waves, radio wave has highest wavelength and gamma rays has the lowest wavelength [2]. The visible light spectrum is the segment of the electromagnetic spectrum that the human eye can view [3].

1.23 APPLICATIONS OF LIGHT

Light is a key element; visible light is extremely important as it makes the vision. Visible light is concentrated to make "LASERS" to use in everything from surgery to CD players to laser pointers. It is used to disinfect and clean surfaces on medical products, food, and packages etc [4]. This technology is finding its way into a vast array of applications since it is dry processing that is eco-friendly causing no dust or damage. This also gives a higher processing speed, quality, and production yield [5]. Each form has a specific application in the society. In general, electromagnetic waves are used in cell phones, radio broadcasting Wi-Fi, cooking, vision, medical imaging, and cancer treatment [18].

1.3 DIFFRACTION

The bending of light beams at the edges and corners of a barrier is known as diffraction [6]. It occurs when light waves extend into geometrical shadows of an object whose edges are not crisp and well defined. For diffraction to take place the size of the obstacle must be comparable with the wavelength of light. Both light and sound waves exhibit diffraction [7].

1.31 FEATURES OF DIFFRACTION

- Diffraction effects are produced with a slit, pinhole, a wire or edges of a razor blade.
- Diffraction is produced by the superposition of secondary wavelets originating from the same wavefront.
- Widths of the fringes in the diffraction pattern are never equal.
- The distances between the bright and dark band gradually decreases.
- Diffracted light can produce fringes of light, dark or colored bands [8-9].

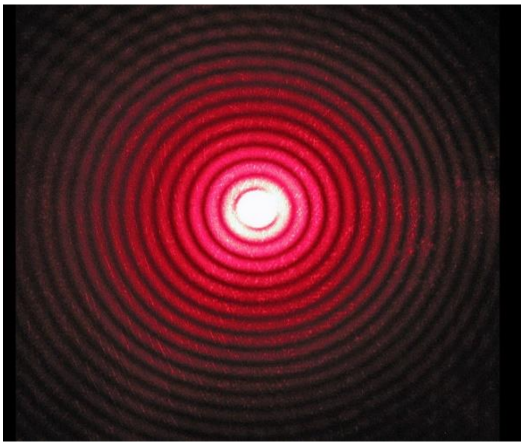

Fig 1.2: Diffraction pattern

1.32 TYPES OF DIFFRACTION

Two types of diffraction are:

- Fresnel Diffraction
- Fraunhofer Diffraction

FRESNEL DIFFRACTION

In this group either the source or the screen or both are at finite distance from the obstacle or aperture causing diffraction. No lenses are used to make the rays parallel or divergent or convergent. The incident wavefront is either spherical or cylindrical. Here the distance is important.

The diffraction is a projection of diffracting element but modified by certain diffraction effects and the geometry of the source. Theoretical treatments are only approximate [20].

FRAUNHOFER DIFFRACTION

The source or the screen or both are effectively at infinite distances form the obstacle of aperture causing diffraction. Lenses are used to make the incident rays parallel and to focus diffracted beam on the screen. The incident wavefront is plane. Here the angular inclinations are important instead of distances. The effects of a number of diffracting element may be combined properly and theoretical treatment is only approximate [10]. The different cases in Fraunhofer diffraction are

1. Diffraction due to single slit

2. Diffraction due to double slit

3. Diffraction due to grating

1.4 THEORY OF DIFFRACTION

1.41 SINGLE SLIT

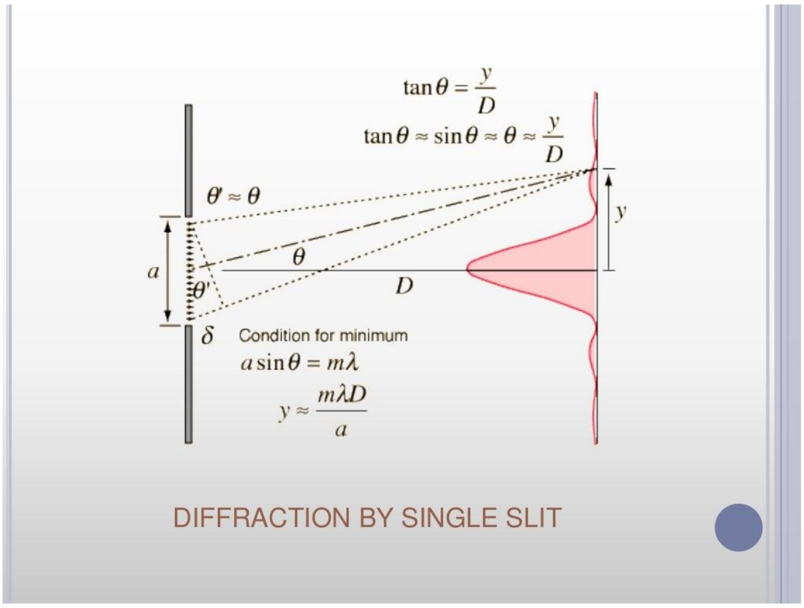

Fig 1.3: Diffraction due to single slit

When a wavelength of monochromatic light strikes a slit, the light diverges, resulting in a pattern of alternating bright and dark pictures on the screen. This pattern is known as Fraunhofer's diffraction, and it is the most basic type of diffraction. Because light is an electromagnetic wave, the diffraction process may be explained. Different parts of the slit behave as if they are separate light sources.

The criterion for producing minima in a single slit experiment is a sin θ= nʎ, where a is the slit width, n is the order of the fringe, and ʎ is the wavelength of the source. The maxima lie between the minima and the width of the central maximum is simply the distance between the 1st order minima from the centre of the screen on both sides of the centre. Further, condition for obtaining maxima

a sin θ =$\frac{(2n+1)ʎ}{2}$ [11],[19]. The intensity variation of the distance from the central maximum in Fraunhofer diffraction due to single slit is shown in the figure below.

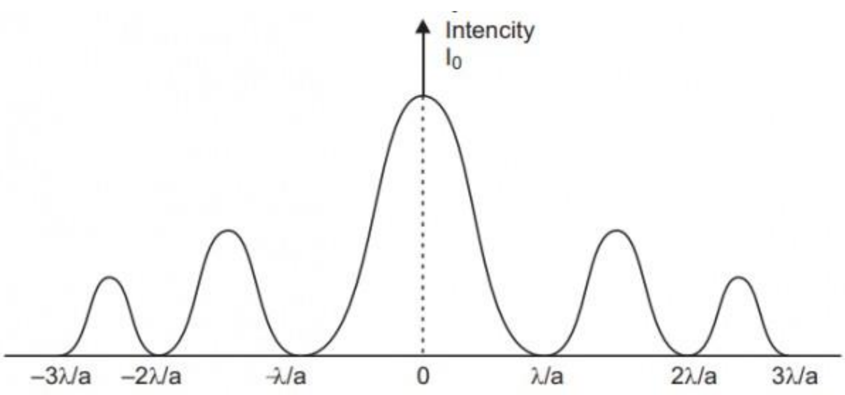

Fig 1.4: Single slit intensity pattern

1.42 DOUBLE SLIT

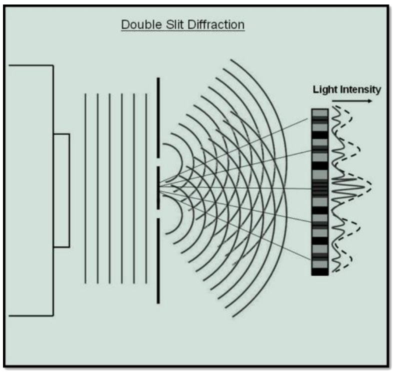

Fig 1.5: Diffraction due to double slit

Both slits operate as sources of coherent light in a double slit experiment, and they interfere at the observation screen. The conditions are comparable to a single slit experiment, and the distance between two may be calculated using the equation d=$\frac{n\lambda}{sin\theta m}$. where θ_m is the angle subtended between central maxima and nth order maxima, d is the distance between the source and the screen. A coherent light source, such as a laser beam, illuminates a plate with two parallel slits, with the light travelling through the slits visible on a screen behind the plate. Because of the wave nature of light, it splits the light wave travelling through it, resulting in bright and dark fringes on the surface. The diffraction pattern in this situation is made up of two parts: (i) Interference pattern caused by secondary waves from the corresponding two slits and (ii) the diffraction pattern due to the secondary waves generated by the two slits separately. This experiment demonstrates that light and matter can display characteristics of both classically defined waves and particles. The resulting double slit diffraction intensity pattern is illustrated below [12].

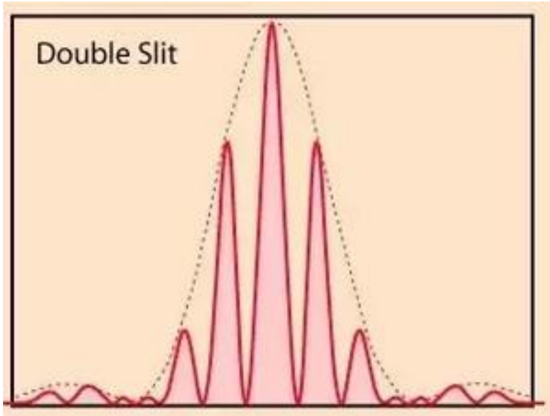

Fig 1.6 Double slit intensity pattern

1.43 GRATING

An arrangement consisting of a large number of equidistant narrow parallel rectangular slits of equal width separated by equal opaque portion is called diffraction grating. This was first constructed by Fraunhofer. It is made by ruling equidistant and parallel lines with diamond point on an optically plane glass plate. The ruled width is opaque to the light while the space between any two successive line is transparent and act as parallel slits. This is called transmission grating. From the original grating replica grating is made and are used for practical purposes.

If the rulings are made in a silver surface it is called reflection grating. In a concave reflection grating equidistant parallel lines are ruled on a concave spherical metal surface. In this case this space in between the rulings reflect light. Number of rulings per centimetre of grating used in the visible region from 5000-12000 lines per cm. Compact disc CD is an example of grating.

The plane transmission grating and the screen are placed perpendicular the plane of the paper. The slit width is ' a ' and the width of each opaque object is b. The sum a+b is called grating element. The points which is separated by the distance (a+b) are called corresponding points [13].

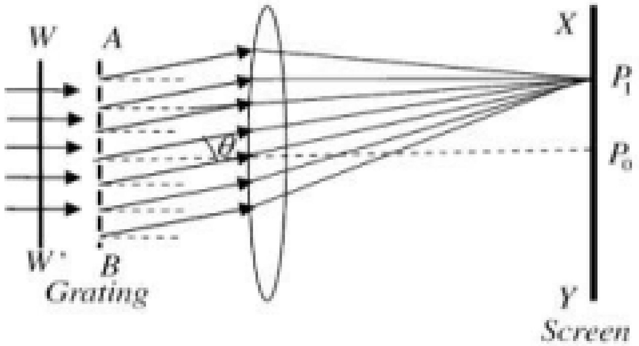

Fig.1.7: Diffraction due to grating

1.5 APPLICATION OF DIFFRACTION

- Sun appears red during sunset: Sun appears red because light gets diffracted due to a dust particle in the atmosphere.
- From the shadow of an object: Light through a shadow of an object is also a real-life example of diffraction. Light from behind gets diffracted because an object is acting as an obstacle in the path of light waves.
- Spectrometer: In spectroscopy, diffraction of light helps to measure the accurate wavelength of light. By measuring the wavelength of light from the stars with the help of diffraction grating, astronomers can tell the elements a star is composed of.
- X-ray diffraction: X-ray diffraction is used to identify the structure of crystalline materials. This method is based on the principle of dual way/particle nature of X-ray. The main primary objective of X-ray diffraction is to find identification and characteristic of a compound on the basis of their diffraction pattern.
- To separate white light: The diffracting gradient separates white lights into different colours when light passes through many fine slits of the grating. This is how the separation of white light is done with the help of diffraction [14].

1.6 LASER

A laser produces a very narrow beam of light that is useful in many technologies and instruments. The letters in the word laser stand for Light Amplification by Stimulated Emission of Radiation. In stimulated emission the transmission is initiated by incoming radiation and the emitted light is in phase with the incident light. Spontaneous and stimulated emission are competing process [15].

(a) Why laser used in diffraction experiment?

Laser is used in diffraction experiments as it is a convenient source of narrow beam of light. It has added advantage over white light, as white light would produce light of a similar effect but the diffraction pattern would not be as wide, as different wavelength would interfere at different points. When a collimated beam of laser passes through an aperture, or if it encounters an obstacle, it spreads out and the resulting pattern contains bright and dark regions. Basic construction of laser involves two mirrors, one being flat and one being curved. Due to this curvature, a light beam with a suitable beam radius can circulate around the resonators without getting wider and wider each time thus favouring the diffraction [16].

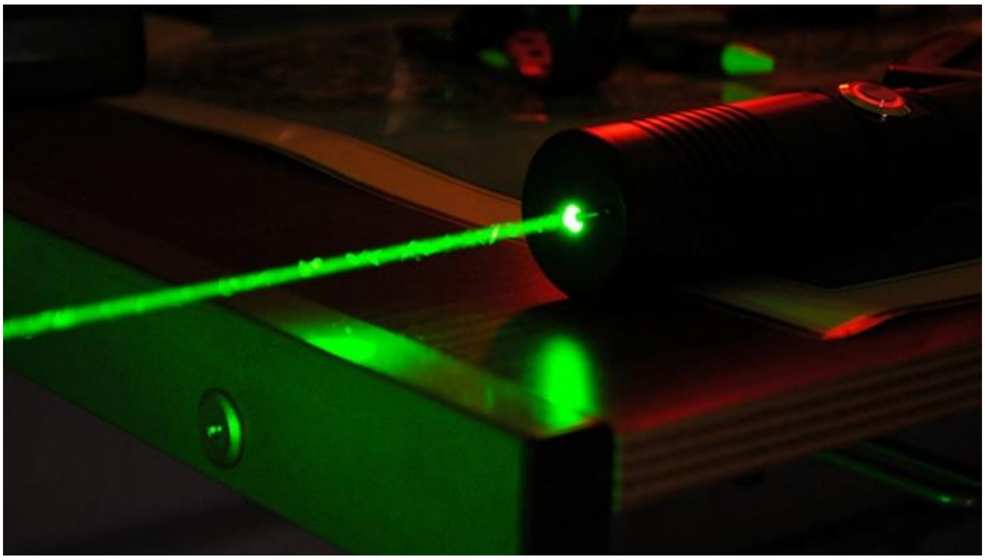

Fig 1.8: Laser in diffraction

(b) Properties of laser

- Coherence: Coherence is the property of having a phase difference between two or more waves that is either zero or constant.
- Directionality: Laser light has a high degree of parallelism and directionality
- High Intensity: A large number of laser light beams collide in a compact area. As a result, the light intensity is high and the brightness is high.
- Monochromaticity: The property of a light emitting a single wavelength is known as monochromaticity. The light will be very monochromatic if the line width of the wave length spread is very narrow [17].

CHAPTER -2

METHODOLOGY

Components used in the present work are listed below

- Single Slit
- Double Slit
- Grating
- Laser Source
- Screen
- Lens adjusting stand
- Slit adjusting stand
- Convex lens
- Meter scale
- Optical Bread Board
- Diffraction cells
- Cell mount
- Glass slide
- Kinematic laser mount
- Diode laser with power supply

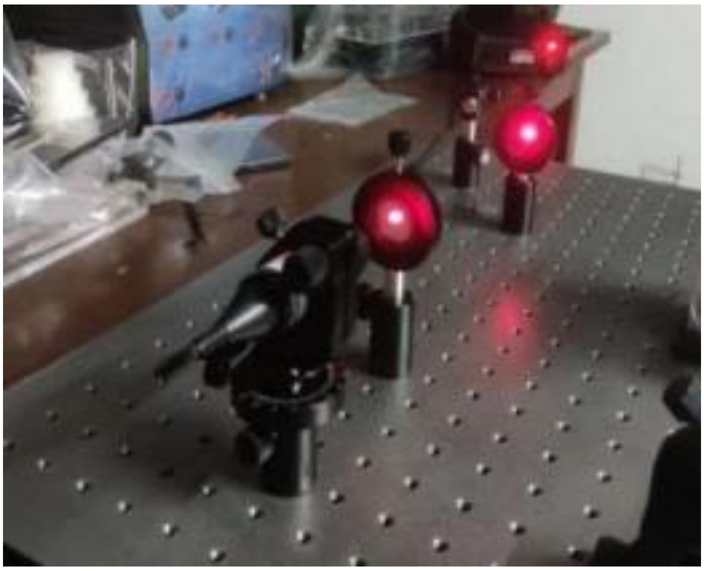

Fig 2.1: Experimental arrangement for diffraction

Experimental set up

The laser module was put into the laser mount, which was fixed above the optical bread board. The diffraction cell was carefully put on the cell mount, which was positioned above the bread board. After that, ‘single slit’ was inserted into the mount. The laser power supply was turned on, and the screen was held at a certain distance in front of the slit. The distance between the diffraction element and the screen must be sufficient to get a clear diffraction pattern and an accurate result.

Single slit

The aim is to find the slit width from the study of Fraunhofer diffraction pattern.

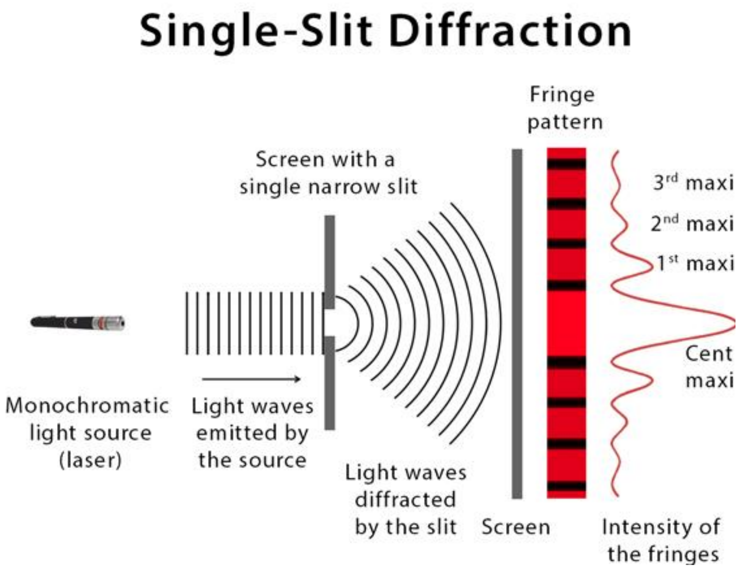

Fig.2.2: Diffraction at single slit

For a single slit, the theory of diffraction at normal incidence is given by

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

where, m is the order of diffraction

d is the slit width

λ is the wavelength of light used

θ is the angle of diffraction

$$\sin\theta = \frac{x}{\sqrt{x^2+D^2}}$$

where,

x is the distance from the central maxima to the spot of the m^{th} order

D is the distance from the central slit. Then the slit width is $d=\frac{1}{N}$, $N=\frac{\sin\theta}{m\lambda}$

Procedure

An adjustable single slit is mounted on a stand. The laser beam is allowed to incident normally on the slit so as to form a diffraction pattern on the screen fixed vertically at a distance of few meter (D) from the slit. The distance of diffraction spot from the principal maxima for which each slit width can be calculated by the formula d =1/N

Double slit

The aim is to find the slit width from the study of Fraunhofer diffraction pattern.

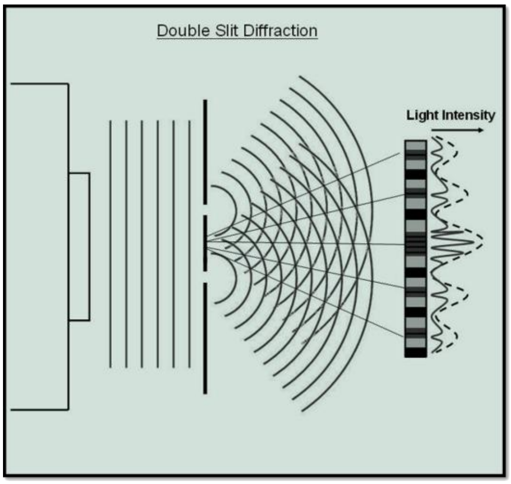

Fig 2.3: Diffraction at a double slit

By diffraction theory, slit width is given by

$$d= \frac{D\lambda(m-m')}{x_m - x_{m'}}$$

Where,

D is the distance between slit and screen. The quantity $\frac{(m-m')}{x_m - x_{m'}}$ is obtained by drawing a graph.

Procedure

The laser beam is expanded and collimated. The diffraction pattern is observed at screen which is fixed vertically at a distance of few meter (D) from the slit. The distance of diffraction spot from the principal maxima for which each order of diffraction is tabulated. The slit width is calculated by the formula given above.

Grating

Aim is to determine the number of lines per meter of grating by diffraction using laser beam

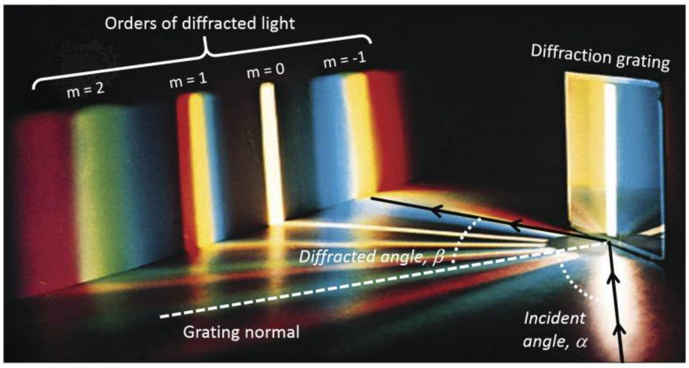

Fig 2.4: Diffraction at a plane transmission grating

By diffraction theory, condition for getting nth order diffraction pattern is

$$\text{Sin } \theta = nN\lambda,$$

where,

N is the no of lines per meter of grating,

n is the order of diffraction,

λ is wavelength of laser beam and θ is angle of diffraction for spectral line.

Procedure

The grating is mounted on a stand at a small distance from the screen. The laser beam allowed to fall on a grating undergoes diffraction and diffraction pattern is observed on the screen. Position of principle maxima and diffraction orders are located on either side of it. The distance between two principal maxima and first order is obtained on both sides are measured as x. Distance between screen and grating D is also measured using the equation sin θ = $\frac{x}{\sqrt{x^2+D^2}}$, θ is measured.

Similarly, distance between second, third order and principal maxima are measured and corresponding value of sin θ are calculated. If the wave length of laser source used is known, we can calculate the no of lens per meter of the grating using the equation

$$N = \frac{sin\theta}{n\lambda}$$

CHAPTER-3

RESULTS AND DISCUSSIONS

SINGLE SLIT

Observation for single slit

λ = 655nm, D = 2m

Table 3.1: Observation for single slit

Order	x_1 (cm)	x_2 (cm)	x(mean) (cm)	Sinθ = $\frac{x}{\sqrt{x^2+D^2}}$	d =$\frac{m\lambda}{sin\theta}$ (m)
1	1.054	0.492	0.773	3.867$\times 10^{-3}$	1.693$\times 10^{-4}$
2	1.809	1.194	1.502	7.509$\times 10^{-3}$	1.74457$\times 10^{-4}$
3	2.445	1.896	2.171	0.0108	1.819$\times 10^{-4}$
4	3.302	2.704	3.003	0.01501	1.745$\times 10^{-4}$

Mean d = 1.7505$\times 10^{-4} m$

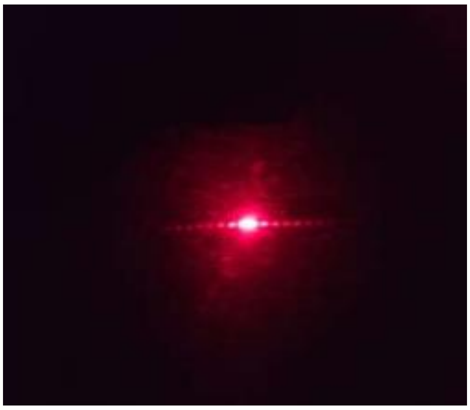

Fig 3.1 Slit obtained by using single slit

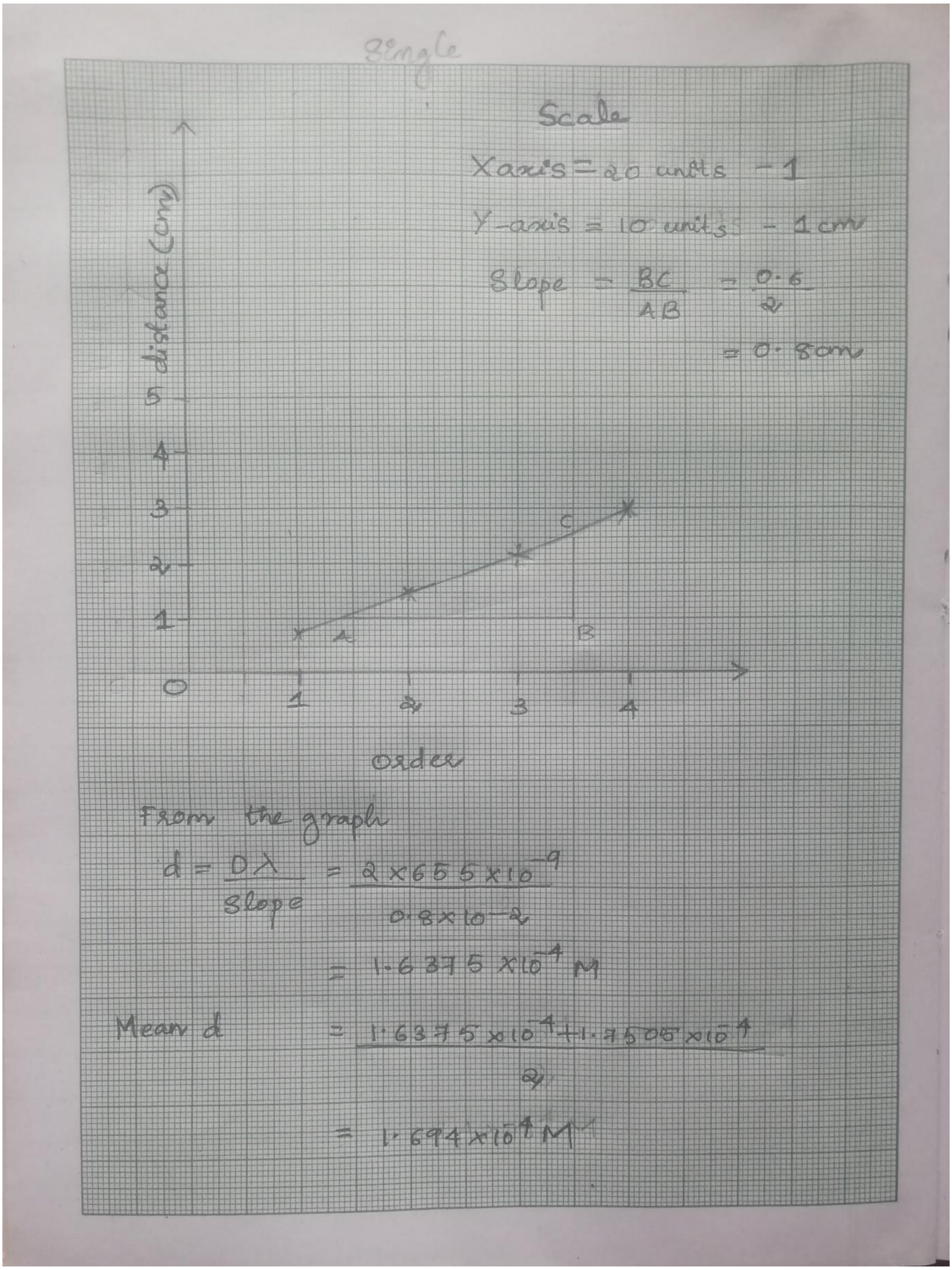

Fig 3.2 Graph of single slit diffraction experiment

Result

The slit width of the given single slit =1.694×10^{-4}m

DOUBLE SLIT

Observations for double slit

ƛ=655nm; D=2m

Order m	x_1 (cm)	x_2 (cm)	x(mean) $(\times 10^{-2})m$
1	0.302	0.355	0.328
2	0.700	0.856	1.154
3	1.099	5.514	1.154

$$d = \frac{D ƛ(m-m')}{x-x'}$$

$$d = \frac{2\times655\times10\text{^}(-9)\times(3-2)}{(1.545-0.778)\times10^{-2}}$$

$$d = 3.4794\times 10^{-4}m$$

Fig 3.3: Slit obtained by using double slit

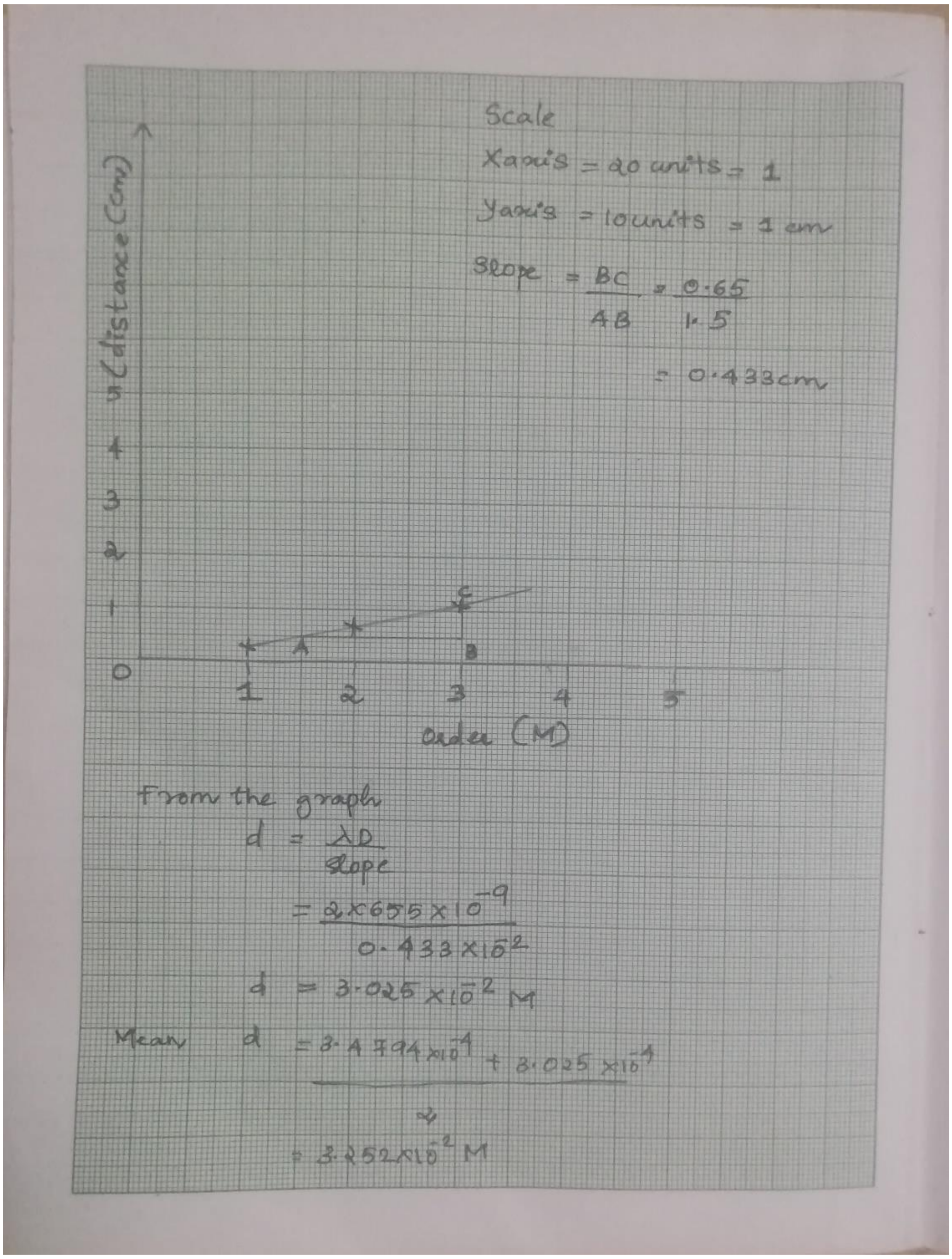

Fig 3.4: Graph obtained using double slit

Result

The slit width of the given double slit =3.252$\times 10^{-4}$m

GRATING

Observations for grating

λ=655nm; D=2m

Order	x_1 (cm)	x_2 (cm)	x(mean) ($\times 10^{-2}$m)	$\sin\theta = \frac{x}{\sqrt{x^2+D^2}}$	N=$\frac{\sin\theta}{m\lambda}$ (Lines/m)
1	0.946	1.016	0.981	0.365	5.577×10^5
2	2.701	3.005	2.853	0.752	5.741×10^5

Mean N =5.659×10^5 lines/metre

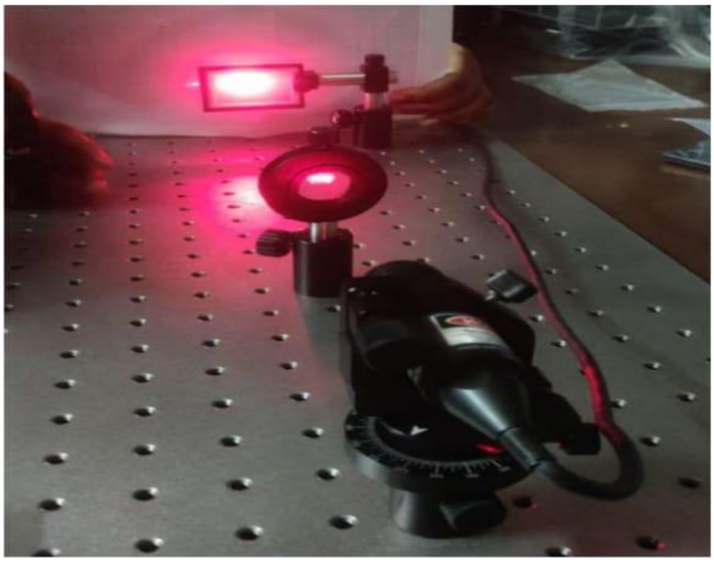

Fig 3.5: Experimental setup of grating

Result

Number of lines per metre of the grating= 5.659×10^5

CHAPTER- 4

SUMMARY AND CONCLUSION

The wave nature of light is demonstrated through diffraction experiment. When the normal passage of light is disrupted by impediments such as slits, diffraction occurs. Diffraction studies with single, double, and multiple slits were successfully carried out in this study, and the experimental data was analysed. Each slit's diffraction pattern was recorded, and graphs were plotted using the data. The single slit and double slit widths were computed. As part of this effort, the number of lines per metre of grating was also calculated using diffraction theory. This study's predictions give information on the influence of diffraction under various conditions and probable outputs, which is valuable for gaining mechanistic insights into the process.

CHAPTER-5

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