LASER DIFFRACTION- MEASUREMENT OF DIAMETER OF HUMAN HAIR, THRED AND WIRE

PROJECT REPORT

Submitted by

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Register No: AB20PHY012

Under the guidance of

Dr. SUSAN MATHEW

In partial fulfillment of the requirement for the award of

BACHELOR DEGREE OF SCIENCE IN PHYSICS

ST.TERESA'S COLLEGE (AUOMOUSTON)

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Year of work: 2022-2023

This is to certify that this project work entitled **"LASER DIFFRACTION-MEASUREMENT OF DIAMETER OF HUMAN HAIR, THREAD AND WIRE"** was done by ANUSHREE ANILKUMAR PILLAI

Staff member in charge | **Head of Department**

DR. SUSAN MATHEW | **DR. PRIYA PARVATHI AMEEENA JOSE**

Submitted for the university examination held in St. Teresa's college, Ernakulam

Examiner: 1.

2.

Date: 25/04/2023

DECLARATION

We, **ANUSHREE ANILKUMAR PILLAI**, Register No**: AB20PHY012** and **GAURY KRISHNA KJ**, Register No: **AB20PHY031**, hereby declare that this project entitled **"LASER DIFFRACTION-MEASUREMENT OF DIAMETER OF HUMAN HAIR, THREAD, AND WIRE"** is an original work done by us under the supervision and guidance of **Dr. SUSAN MATHEW,** faculty, Department of Physics, St. Teresa's Collage, in partial fulfillment for the award of degree of Bachelor of Physics under Mahatma Gandhi University. We 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 are true to the best of our knowledge

1.ANUSHREE ANILKUMAR PILLAI

2.GAURY KRISHNA KJ

PLACE: ERNAKULAM

DATE:

AKNOWLEDGEMENT

I wish to express my deep sense of gratitude to the Management and principle of St. Teresa's Collage, Ernakulam for providing me the necessary infrastructure and resources for completing this project.

I owe an immense depth of gratitude and my thanks to Dr. Susan Mathew; faculty, Department of physics, St. Theresa's Collage, for her guidance and complete assistant throughout the course of work. Her sincere help has enabled me to complete this work successfully.

My sincere thanks to all teaching and non-teaching staff of our department for their support and help rendered.

Finally, I owe sincere gratitude to God Almighty who accompanies me in all my activities.

Laser diffraction - Measurement of diameter of human hair, thread, wire and hole.

ABSTRACT

In this project, the diameter of very thin objects such as hair and wire uses laser diffraction. Small threads and holes were detected, and diffraction patterns were observed as a result of the influence of various objects. The values obtained for wires and threads are checked by measuring their diameter with a micrometer. The results show that the diameter of very thin samples can be accurately determined by the diffraction method.

Content

CHAPTER I

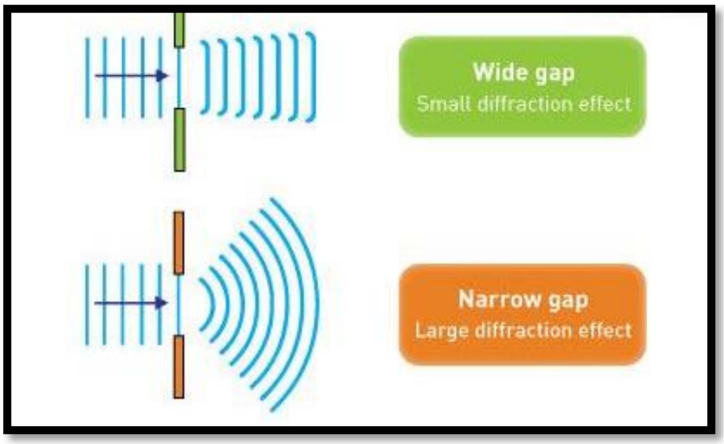
INTRODUCTION

Diffraction is an optical phenomenon which occurs when waves bend around small obstacles, or spread out after they pass through small openings. Diffraction occurs with all waves, including sound waves, water waves, and electromagnetic waves such as light that the eye can see. The effects of diffraction of light were first carefully observed and characterized by Francesco Maria Grimaldi, who also coined the term diffraction, from the Latin **diffraction** , 'to break into pieces', referring to light breaking up into different directions. The results of Grimaldi's observations were published posthumously in 1665. Isaac Newton studied these effects and attributed them to inflexion of light rays. James Gregory (1638–1675) observed the diffraction patterns caused by a bird feather, which was effectively the first diffraction grating to be discovered. Thomas Young performed a celebrated experiment in 1803 demonstrating interference from two closely spaced slits. Explaining public in 1816 and 1818, and thereby gave great support to the wave theory of light that had been advanced and reinvigorated by Young, against Newton's particle theory his results by interference of the waves emanating from the two different slits, he deduced that light must propagate as waves. Augustin-Jean Fresnel did more definitive studies by Christian Huygens and calculations of diffraction, made.

Diffraction is caused by one wave of light being shifted by a diffracting object. This shift will cause the wave to have interference with itself. Interference can be either constructive or destructive. When interference is constructive, the intensity of the wave will increase. When interference is destructive, the intensity will decrease, sometimes to a point where it is completely destroyed. These patterns of interference rely on the size of the diffracting object and the size of the wave. The strongest examples of diffraction occur in waves where the wavelength is similar to the size of the object causing diffraction.

In Fresnel diffraction the source of light and the screen are effectively at finite distances from the obstacle. The incident wave front is not planar. Whereas, in Fraunhoffer diffraction the source and the screen are effectively at infinite distance from the obstacle and the incident wave front is plane. The Fraunhoffer diffraction pattern produced by waves when they bend can be used to determine the structure of very tiny objects, such as the diameter of a human hair, thin wires, holes, particles etc. for this we use a highly monochromatic and coherent light source, a laser.

Laser diffraction measures particle size distributions by measuring the angular variation in intensity of light scattered as a laser beam passes through a dispersed particulate sample. Large particles scatter light at small angles relative to the laser beam and small particles scatter light at large angles. The angular scattering intensity data is then analyzed to calculate the size of the particles responsible for creating the scattering pattern, using the Mie theory of light scattering. The particle size is reported as a volume equivalent sphere diameter.



Laser diffraction is a widely used particle sizing technique for materials ranging from hundreds of nanometers up to several millimeters in size. The main reasons for its success are:

- Wide dynamic range - from submicron to the millimeter size range.
- Rapid measurements - results generated in less than a minute.
- Repeatability - large numbers of particles are sampled in each measurement.
- Instant feedback - monitor and control the particle dispersion process.
- High sample throughput - hundreds of measurements per day.
- Calibration not necessary - easily verified using standard reference materials.

For these reasons, laser diffraction is becoming the standard particle sizing technique across many industry sectors, being faster, simpler and having better resolution than more traditional sizing techniques such as sieve analysis.

CHAPTER 2

THEORY OF LASER DIFFRACTION

2.1 THE PHYSICS BEHIND LASER DIFFRACTION (LD)

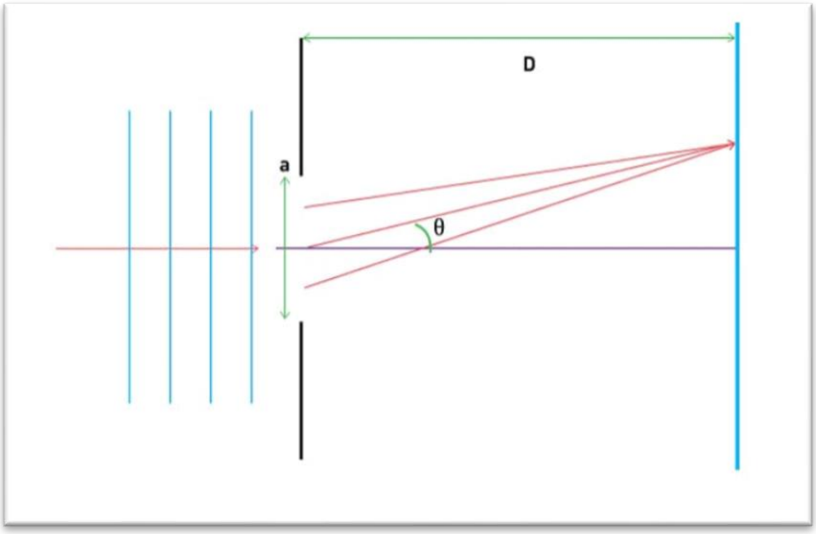
When laser light (monochromatic, coherent, polarized) hits an object, diffraction phenomena occur. For example, diffraction can be observed from apertures, slits, gratings, and particles. From the edges of a particle, the light propagates in the form of spherical wave fronts, whose interference then leads to the diffraction.

The diffraction angle is determined by the wavelength of the light and the size of the particle, with angles becoming smaller with increasing particle size. For intermediately sized particles, Mie theory can be applied to the scattering patterns to determine the size. Particles in this range and larger have size dependent scattering patterns. Larger particles have higher scattering in the forward direction than smaller ones

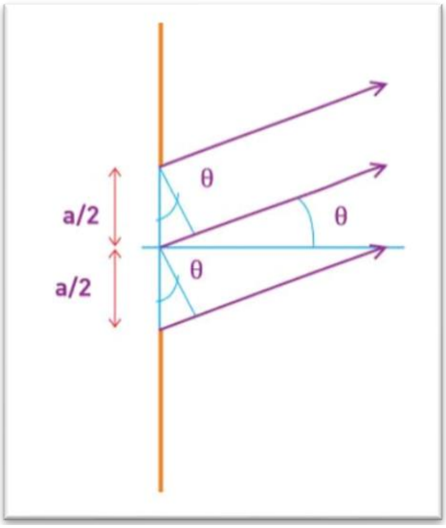
For very small particles, the interaction of light with these particles can be described by Rayleigh scattering. In the Rayleigh regime, scattered light is weaker and almost isotropic in all spatial directions.

2.2 SINGLE SLIT DIFFRACTION

In diffraction experiments, the slit width (a) is very much less than the separation between slit and source. The schematic diagram is given below



The angular position of any point on the screen can be identified by θ measured from the slit centre which divides the slit by a/2 lengths. To describe the pattern, we shall first see the condition for dark fringes. Also, let us divide the slit into zones of equal widths a/2. Let us consider a pair of rays that emanate from distances a/2 from each other as shown below.



The path difference between the top two rays is obtained from the geometry.

$$\Delta L = \frac{a}{2}\sin\theta$$

We can consider any number of ray pairings that start from a distance a/2 from one another such as the bottom two rays in the diagram. Any arbitrary pair of rays at a distance of a/2 can be considered. For a dark fringe, the path difference must cause destructive interference; the path difference must be odd multiple of λ/2 where λ is the wavelength of light used

For the first fringe,

$$\Delta L = \frac{\lambda}{2} = \frac{a}{2}\sin\theta \text{ or}$$
$$\lambda = a\sin\theta$$

For a ray emanating from any point in the slit, there exists another ray at a distance of a/2 that can cause destructive interference. Thus, at $\boldsymbol{\theta = \sin^{-1}\lambda a}$, there is destructive interference as any ray emanating from a point has a counterpart that causes destructive interference. Hence, a dark fringe is obtained.

For the next fringe, we can divide the slit into 4 equal parts of a/4 and apply the same logic. Thus, for the second minima:

$$\frac{\lambda}{2} = \frac{a}{4}\sin\theta$$

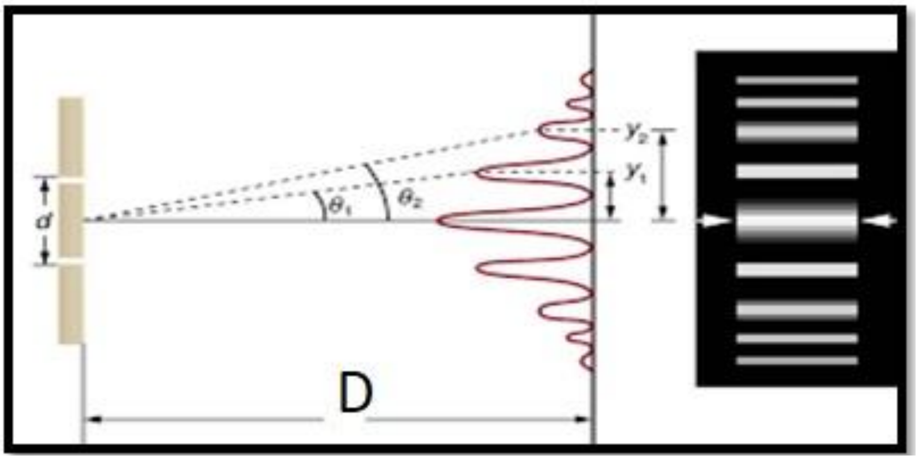
$$2\lambda = a\sin\theta$$

Similarly, for the n^{th} fringe, we can divide the slit into 2n parts and condition is

$$n\lambda = a\sin\theta$$

2.3 DETERMINATION OF THICKNESS OF THE MATERIAL USING LASER DIFFRACTION

To determine the thickness of the material using laser diffraction we place the object of thickness d in the place and laser beam is incident on it. The laser beam diffracts through the edges of the object and forms a diffraction pattern on the screen kept at a distance D from the object.



The length of the object is perpendicular to the plane of the paper.

The minima of the intensity pattern is observed at angle **θ** given by,

$$n\lambda = d\sin\theta \quad \text{………………….} \; A$$

Let y is the average distance of nth dark ring from the centre of the screen, then the above picture

$$\sin\theta = \frac{y}{D} \text{……………………….} B$$

The thickness of the object d is given by

$$d = \frac{n\lambda D}{y} \text{…………………………..} C$$

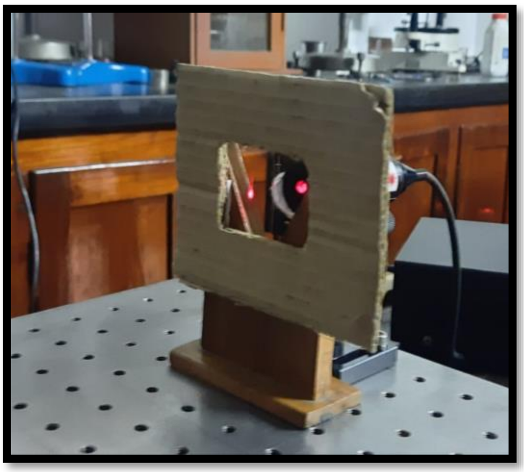
This equation can be used to find the thickness of the object by laser diffraction.

CHAPTER 3

EXPERIMENTAL TECHNIQUE AND OBSERVATION

3.1 EXPERIMENT

The experimental set up for the measurement of thickness of narrow particle using laser in our lab is shown below. The experimental procedure is described by in the following steps.



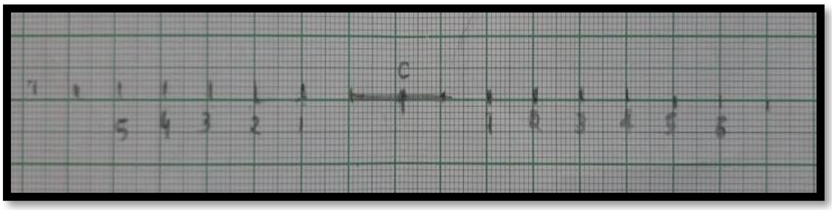
1. Mounting bracket is obtained by making a hole at the center of the cardboard piece mounted on a stand.
2. The object whose diameter is to be measured (for example: hair, thread or wire) is mounted on the mounting bracket.
3. The position of laser device is adjusted so that beam strikes the hair in the mounting bracket thereby getting diffraction pattern on the screen placed at a distance 1m from the object .
4. Record the diffraction pattern on the data sheet. Knowing the wavelength of laser and measuring the parameters a, n and D we can calculate the thickness of the object by using the formula $d = \frac{n\lambda D}{y}$

3.2. OBSERVATIONS.

Wavelength of Laser = 650 nm

3.2.1 THICHNESS OF HUMAN HAIR

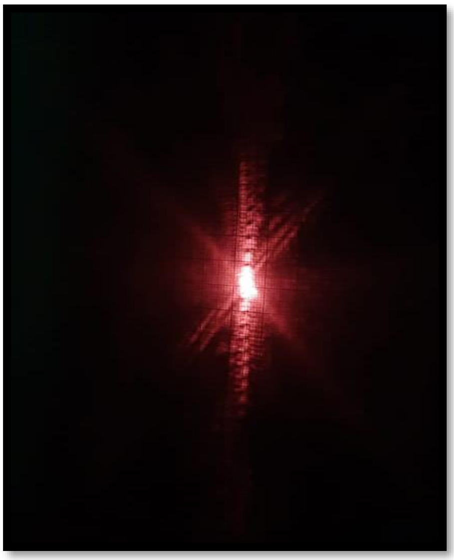
The following pattern was plotted while determining the fringes



Sl No.	Order of maxima	Distance of the Spot from the centre of screen (cm)		Mean y 10^{-2} (m)	Thickness $d = \frac{n\lambda D}{y}$ 10^{-5}(m)
		Left	Right		
1.	1	2.1	1.9	2.0	3.25
2.	2	3.1	2.9	3.0	4.33
3.	3	4.0	3.8	3.9	5.00
4.	4	5.1	4.8	4.95	5.252
5.	5	6.0	5.9	5.95	5.46

Mean Thickness of Hair = 4.658 X 10^{-5}m

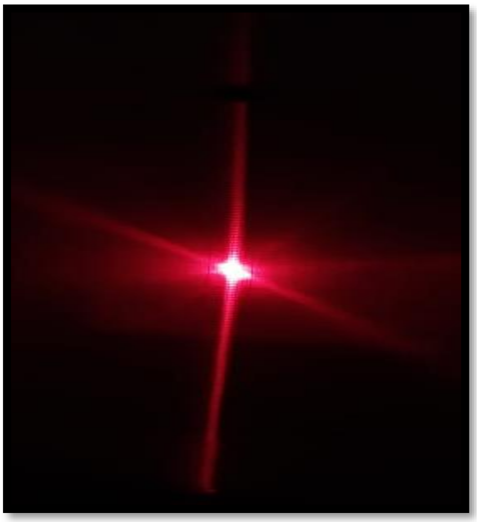
3.2.2 THICHNESS OF THREAD



Sl No.	Order of maxima	Distance of the Spot from the centre of screen y (cm)		Mean y 10^{-2} (m)	Thickness $d = \frac{n\lambda D}{y}$ 10^{-4}(m)
		Left	Right		
1.	3	1.3	1.2	1.25	1.56
2.	4	1.8	1.7	1.75	1.486
3.	5	2.4	2.3	2.35	1.382
4.	6	2.9	2.9	2.9	1.345
5.	7	3.5	3.4	3.45	1.319

Mean Thickness of Thread = 1.418×10^{-4}m

3.2.3 THICHNESS OF WIRE



Sl No.	Order of maxima	Distance of the Spot from the centre of screen y (cm)		Mean y 10^{-2} (m)	Thickness $d = \frac{n\lambda D}{y}$ 10^{-4}(m)
		Left	Right		
1.	2	0.8	0.8	0.8	1.625
2.	3	1	1	1	1.95
3.	4	1.2	1.2	1.2	2.16
4.	5	1.4	1.5	1.45	2.24
5.	6	1.6	1.7	1.65	2.36
6.	7	1.8	1.9	1.85	2.45
7.	8	2	2.1	2.05	2.53
8.	9	2.3	2.3	2.3	2.54×10^{-4}

Mean Thickness of wire = 2. 27 ×10⁻⁴m

To check the accuracy of laser diffraction method, thickness of the wire is also measured by using screw gauge.

Value of 1 pitch scale reading=1mm

Distance moved by screw for 6 rotations=6mm

Total number of head scale division=100 div

Least count of screw gauge= $\frac{\text{Value of 1 pitch scale reading}}{\text{Total number of head scale division}}$=$\frac{1mm}{100div}$= 0.01mm

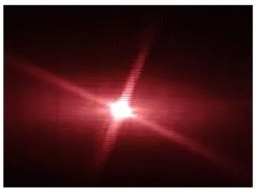
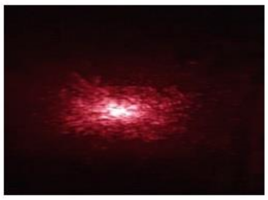
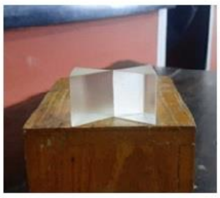
Zero Correction=0

Sl. No	Pitch scale reading (mm)	HSR (div)	Corrected HSR (div)	Thickness of the wire (mm)
1.	0	22	22	0.22
2.	0	25	25	0.25
3.	0	23	23	0.23
4.	0	22	22	0.22
5.	0	22	22	0.22

Mean Thickness of wire = 0.228mm = 2. 27 ×10⁻⁴m

The obtained value is in good agreement with the value that obtained in laser diffraction method.

We tried the diffraction of different objects using the same laser diffraction set up and the patterns obtained are given below.

1)Coconut husk 		4)Tissue 	
2)Magnifying lens 		5) Prisms 	
3)Blade 		6)Comb 	

CHAPTER 4

CONCLUSION AND APPLICATIONS

4.1 CONCLUSION

Laser diffraction technique is used for measuring the thickness of human hair, thread and wire. The accuracy of measurement is checked by measuring the thickness of the wire using screw gauge. The results are given below

Thickness of human hair found out by laser diffraction= 4.658×10^{-5}m

Diameter of thread using laser diffraction =1.418×10^{-4}m

Diameter of wire using Laser diffraction = 2.27×10^{-4}m

Diameter of the wire using screw gauge= 2.28×10^{-4}m

4.1 APPLICATIONS

1. **Soil Studies**

The LS 13320 range of enhanced laser diffraction particle size analyzers are used to measure particle or grain size of soil and sediment samples, a property that can be indicative of how a soil has formed.

2. **Pigment Sizing**

Laser diffraction analysis enabled with polarization intensity differential scattering (PIDS) can measure particles down to the nanometer scale (nm) by sequentially illuminating a sample with wavelengths of alternately polarized light. This method has been used to reliably size pigment particles as small as 10 nm.

3. **Quality Control of Chemical Compounds**

Enhanced laser diffraction analysis is uniquely suited to quality control (QC) applications with a superior resolution and unmatched dynamic range compared to conventional laser diffraction techniques. It provides a rapid assessment of the particle size distributions in powder or liquid samples, with well over 100 light detectors enabling the resolution of subtle differences in particle size.

4. **Research and Development**

Laser diffraction analysis for R&D purposes can be complex as some instruments require prior knowledge of a sample's particle size characteristics, such as whether a single peak of particles is expected or if they may be more than one population of particles such as aggregates. The LS 13320 enhanced laser diffraction analyzer does not. The software carries out complex and comprehensive analysis of the diffraction patterns to provide an accurate particle size distribution without any need for the operator having to guess at the expected result.

Reference

1) ***Laser diffraction – Dr. Henk G***
2) ***Textbook of optics – Dr. N. Subrahmanyam, Brijilal and Dr. M N Avaadhanulu***