



Lebanese University
Faculty of Science II

SCIENTIFIC REPORT

Optics Lab P3303

Experiment VI: Fresnel Double Mirror

By

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I. Abstract

This experiment helps determine the wavelength of light and the distances between the 2 virtual sources S_1 and S_2 with the help of the observed interference pattern. The procedure involved sending a monochromatic light to reflect off of 2 inclined mirrors M_1 and M_2 , creating a 2 virtual sources to create interference fringes on the screen. Measurements were taken in order to distances a_j between the virtual sources which are 1.488 mm and 1.736 mm and eventually find the wavelength of the light to be 708.57 nm. Finally, to be more precise, the uncertainty on the wavelength was computed to be 280 nm.

key words: *Fresnel double mirror, interference, fringes, wavelength*

II. Introduction

Before the discovery of the wave-particle duality of light, two opposing theories dominated the scientific community: Newton's corpuscular theory of light and the wave nature theory of light. Notable scientific figures who worked on the wave theory were Thomas Young (1773-1829) and Augustin Fresnel (1788-1827) and their contribution to the interference phenomena. Young's work includes his double slit experiment and Fresnel's which includes his **Double Mirror** experiment [1]. The aim of this experiment is to measure the distances between two virtual sources and deduce the wavelengths along with their precisions for a red filter.

Experiment Description:

The Fresnel Double Mirror Experiment demonstrates the interference of light using two mirrors. Light emerges from a source S , and the mirrors, M_1 and M_2 , create two coherent virtual sources, S_1 and S_2 , producing interference fringes on a screen.

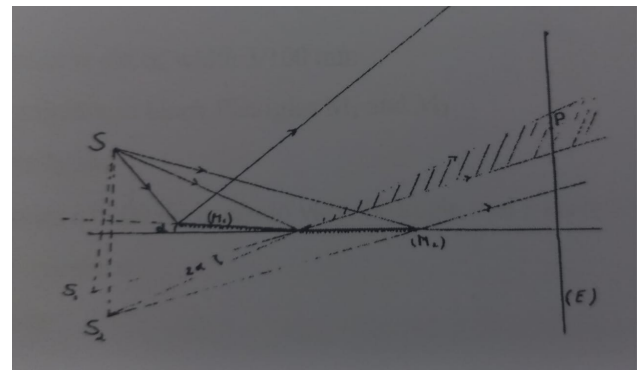


Figure I: Double Mirror light paths

III. Procedure

1. Measure the distance l between the source slit S and the plexiglass mirrors, M_1 and M_2 , and the distance D between the virtual sources and the screen. Note that both these distances are **fixed** throughout the whole experiment.
2. Insert the red filter into the filter holder of the device and then switch on the luminous source so that the light passes through slit S .
3. Using the vernier scale, vary angle α_j between the mirrors twice.
4. By looking through the micrometric eyepiece, determine the number of fringes N_j on the interference pattern obtained on the screen for each angle.

5. Find the distance a_j between the virtual sources and then deduce the number of wavelength λ all by using the following equations:

$$a_j = 2\alpha_j l \quad (1)$$

$$a_j = \frac{\lambda D}{i_j} \quad (2)$$

Where:

- l is the constant distance between S and the mirrors.
- α_j is the angle between the mirrors.
- i_j is the interfringe.
- D is the distance between the virtual sources and the screen.
- λ is the wavelength of the light.
- a_j is the distance between the virtual sources for a measured angle

Table 1 contains small description of the Fresnel Double Mirror device(Figure II).

Table 1: Materials Used in Experiment

Part / Device	Material Details
Fresnel Double Mirror	-6V luminous source -Slit of width $\frac{3}{100}$ mm -Plexiglass mirrors M_1 and M_2 -Filter holder -100 division vernier to vary angle α
Micrometric Eyepiece	Used for precise measurement of fringe separation and position.
Optical Bench	Holds the Fresnel mirrors, light source, slit, and measurement instruments.

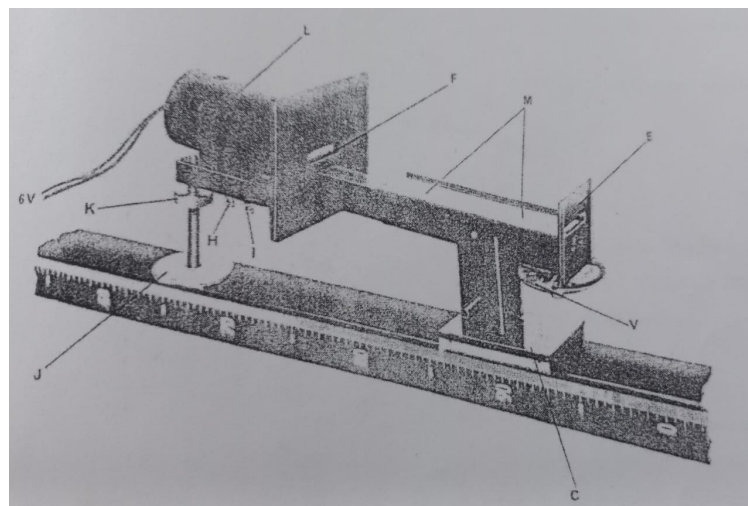


Figure II: Double Mirror device

IV. Results and Analysis

In this section, the distances a_i and the wavelength will be calculated along with its uncertainty from the previously found measurements. In addition, several sources of errors will be

mentioned as well as some suggestions to minimize them. Any tedious calculations will be placed in the appendix.

IV.1 Measurements

Table 2 contains all the measurements found during the experiment. Note that the number of fringes were found between 45 and 55mm on the screen. The uncertainty on the angle D are :

$$\Delta\alpha = 0.5 \times (\text{smallest division}) = 0.5 \times 10^{-4} = 5 \times 10^{-5} \text{rad}$$

$$\Delta D = 0.5 \times (\text{smallest division}) = 0.5 \times 1 = 0.5 \text{mm}$$

Table 2: Data for two configurations

j	$\alpha_j \pm \Delta\alpha$ (rad)	$D_j \pm \Delta D$ (mm)	l_j (mm)	N_j (fringes)
1	$10^{-3} \pm 5 \times 10^{-5}$	350 ± 0.5	124	7
2	$2 \times 10^{-3} \pm 5 \times 10^{-5}$	350 ± 0.5	124	8

IV.2 Calculations

To start with, the relation to calculate the interfringe is given by the number of divisions m covered by N_j fringes:

$$i_j = \frac{\eta}{N_j - 1} \quad \text{with } \eta = \frac{n}{10} \text{mm} \quad (3)$$

η is just the number of divisions n multiplied by the smallest division of $\frac{1}{10} \text{mm}$. The number of divisions was divided by 10 since the number of fringes were counted in a range between 45 and 55mm (10mm difference). Note that:

$$\Delta i = \Delta \eta \quad \text{where } \Delta i = 0.5 \times (\text{smallest division}) = 0.05 \text{mm}$$

From **Equation 3**:

$$i_1 = \frac{1}{6} \pm 0.05 \text{mm} \quad \text{and} \quad i_2 = \frac{1}{7} \pm 0.05 \text{mm}$$

By subtracting a_1 by a_2 using **Equation 1**:

$$a_1 - a_2 = 2(\alpha_1 - \alpha_2)l = -0.248 \text{mm} \quad (4)$$

By dividing a_1 and a_2 of **Equation 2**

$$\frac{a_1}{a_2} = \frac{i_2}{i_1} \implies a_1 = \frac{a_2 i_2}{i_1} \quad (5)$$

Replacing **Equation 5** in **Equation 4**:

$$a_2 \left(\frac{i_2}{i_1} - 1 \right) = -0.248$$

With $i_1 = \frac{1}{6}$, $i_2 = \frac{1}{7}$:

$$a_2 \left(\frac{6}{7} - 1 \right) = -0.248 \quad \Rightarrow \quad a_2 = 1.736 \text{ mm}$$

Then from **Equation 5**:

$$a_1 = 1.736 \times \frac{6}{7} = 1.488 \text{ mm}$$

Using **Equation 2**:

$$\lambda_1 = \frac{a_1 i_1}{D} = \frac{1.488 \times \frac{1}{6}}{350} = 7.0857 \times 10^{-4} \text{ mm} = 708.57 \text{ nm}$$

$$\lambda_2 = \frac{a_2 i_2}{D} = \frac{1.736 \times \frac{1}{7}}{350} = 7.0857 \times 10^{-4} \text{ mm} = 708.57 \text{ nm}$$

To calculate the uncertainty on the wavelength, first determine Δa from **Equation 4**:

$$\frac{\Delta a}{a} = \frac{\Delta(\alpha_1 - \alpha_2)}{\alpha_1 - \alpha_2} + \frac{\Delta l}{l} = \frac{\Delta\alpha_1 + \Delta\alpha_2}{\alpha_1 - \alpha_2} = \frac{(5 + 5) \times 10^{-5}}{(1 - 2) \times 10^{-3}} = +0.1 \text{ (abs)} \quad (6)$$

Where Δl is 0 since l is given as 124 mm and not determined. From **Equation 2**:

$$\frac{\Delta \lambda}{\lambda} = \frac{\Delta a}{a} + \frac{\Delta i}{i} + \frac{\Delta D}{D} \quad (7)$$

Knowing $i = i_1 = 0.17 \text{ mm}$, $\lambda = 708.57 \times 10^{-6} \text{ mm}$, $\frac{\Delta a}{a} = 0.1$ and $\frac{\Delta D}{D} = 1.42 \times 10^{-3}$:

$$\Delta \lambda = 280 \text{ nm}$$

$$\Rightarrow \lambda \pm \Delta \lambda = 708.57 \pm 280 \text{ nm}$$

Table 3 contains all the important values found throughout the experiment (refer to appendix for uncertainties).

Table 3: Final Values

Parameter	Value	Uncertainty
Virtual source distance a_1	1.488 mm	$\pm 0.149 \text{ mm}$
Virtual source distance a_2	1.736 mm	$\pm 0.087 \text{ mm}$
Wavelength λ	708.57 nm	$\pm 280 \text{ nm}$
Fringe spacing i_1	0.167 mm	$\pm 0.050 \text{ mm}$
Fringe spacing i_2	0.143 mm	$\pm 0.050 \text{ mm}$

IV.3 Sources of Errors

Physically, errors are described by sources that affect the numerical values of the errors. These sources include:

1. **Random Errors:** Fluctuation of temperature, contaminants in the air and other effects of an uncontrolled environment.
2. **Instrumental Errors:** Uncalibrated vernier for angle measurements, incorrect value of the given l and slit width(manufacturing error), inclined mirrors, damaged filters. ...
3. **Human/Reading Errors:** Incorrect measurements of the angles and distances, eyes failing a person when reading the number of fringes, performing the experiment only once....

V. Conclusion

To sum up, the experiment was performed successfully and the distances between the virtual sources were found to be 1.736 mm and 1.488 mm at 2 different angles as well as the wavelength which was 708.57 nm for both angles. It is logical to get the same wavelength since the luminous source is monochromatic and the wavelength is constant for the same source. The uncertainty on the wavelength was found to be 280 nm. So in order to minimize the uncertainties, one must perform the experiment in a controlled environment, make sure to calibrate the measurement devices and set up the entire Fresnel double mirror device properly, repeat the experiment multiple times and check each and every measurement.

VI. Appendix

1. In order to derive **Equation 7**:

$$\text{From } \lambda = \frac{ai}{D}:$$

$$\ln \lambda = \ln a + \ln i - \ln D$$

Differentiating and taking absolute values:

$$\frac{\Delta \lambda}{\lambda} = \frac{\Delta a}{a} + \frac{\Delta i}{i} + \frac{\Delta D}{D}$$

2. Uncertainty on a_j :

$$\frac{\Delta a_j}{a_j} = \frac{2\Delta \alpha_j}{\alpha_j} + \frac{\Delta l}{l} \implies \Delta a_j = \frac{2a_j \Delta \alpha_j}{\alpha_j}$$

VII. References

[1]Y. Kulandina, Young and Fresnel: A Case-Study Investigating the Progress of the Wave Theory in the Beginning of the Nineteenth Century in the Light of its Implications to the History and Methodology of Science, M.S. thesis, Dept. of Philosophy, Middle East Technical Univ., Ankara, Turkey, 2013.

[2] P3303 Physics Laboratory Manual, Department of Physics and Electronics, Lebanese University, 2025.