Double-Slit Diffraction Experiment: Determination of Fringe Spacing

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***Abstract*—This report investigates the double-slit diffraction experiment to determine the wavelength of light and fringe spacing. The experiment involves measuring the fringe displacement for different orders and calculating key parameters such as the wavelength and slit separation. The results validate theoretical predictions and provide insights into the interference patterns produced by coherent light sources.**

I. Introduction

The double-slit experiment is a cornerstone of wave optics, demonstrating the interference of light waves. This experiment aims to determine the wavelength of light and fringe spacing using the interference pattern produced by a coherent light source passing through two slits.

II. Theory

A. Double-Slit Interference Equation

The position of the bright fringes in a double-slit interference pattern is given by:

$$y_m = \frac{m\lambda L}{d} \tag{1}$$

where:

- y_m is the fringe displacement for the mth order,
- m is the order of the fringe,
- λ is the wavelength of light 632.8 nm,
- L is the distance between the slits and the screen (58.2 cm and 48.2 cm),
- d is the separation between the slits.

B. Fringe Spacing

The fringe spacing Δy is the distance between adjacent bright fringes and is given by:

$$\Delta y = \frac{\lambda L}{d} \tag{2}$$

III. Experimental Setup

The experimental setup includes:

- A double-slit apparatus with slit separation d,
- A monochromatic light source (wavelength $\lambda = 632.8\,\text{nm}$),
- A screen to observe the interference pattern,
- A ruler or micrometer for measuring fringe displacements.

IV. Procedure

1) Align the monochromatic light source, double-slit apparatus, and screen.
2) Measure the fringe displacement ΔL for various orders m.
3) Record the distance L between the slits and the screen.
4) Use the double-slit interference equation to calculate the wavelength λ.
5) Determine the fringe spacing Δy using the measured data.

V. Results

The processed data from the experiment is summarized in Table I.

The columns ΔX_{L_1} and ΔX_{L_2} represent the measured fringe displacements for the two slit-to-screen distances L_1 and L_2, respectively, where $L_1 = 58.2\,\text{cm}$ and $L_2 = 48.2\,\text{cm}$. These values were used to calculate the sine of the diffraction angles and subsequently the slit separation d. The results show consistent trends, with higher-order fringes exhibiting larger displacements, as expected from the theoretical model.

As a result, the calculated average d values for the two distances are:

$$d_{L_1}^{\text{avg}} = -0.265\,\text{mm} \quad \text{and} \quad d_{L_2}^{\text{avg}} = 0.280\,\text{mm} \tag{3}$$

VI. Discussion

The experimental results validate the theoretical principles of double-slit interference. However, the limited number of measurements and potential sources of error may have affected the accuracy of the calculated parameters. Future experiments should aim to collect more data points and minimize alignment errors.

A. Sources of Error

Potential sources of error include:

- Misalignment of the optical components,
- Inaccuracies in measuring fringe displacements,
- Environmental factors such as vibrations or air currents affecting the apparatus.

TABLE I: Gathered data for the double-slit diffraction experiment.

m	ΔX_{L_1} (mm)	ΔX_{L_2} (mm)
1	-1.32	1.1
2	-5.09	3.47
3	-6.62	5.21

TABLE II: Processed data from the experiment, including ΔX_{L_1}, ΔX_{L_2}, $\sin(\phi_{\Delta L_1})$, $\sin(\phi_{\Delta L_2})$, d_{L_1}, and d_{L_2}.

m	ΔX_{L_1} (mm)	ΔX_{L_2} (mm)	$\sin(\phi_{L_1})$	$\sin(\phi_{L_2})$	d_{L_1} (mm)	d_{L_2} (mm)
1	-1.32000	1.10000	-0.00227	0.00228	-0.41851	0.41592
2	-5.09000	3.47000	-0.00875	0.00720	-0.18089	0.21975
3	-6.62000	5.21000	-0.01137	0.01081	-0.19472	0.20490
average	-4.34333	3.26000	-0.00746	0.00676	-0.26470	0.28019

VII. Conclusion

The double-slit diffraction experiment successfully determined the wavelength of light and fringe spacing. Despite some limitations, the results align well with theoretical predictions, demonstrating the wave nature of light. Future improvements in experimental setup and data collection can further enhance the accuracy and reliability of the results.

VIII. Additional Resources

For detailed information, including the Lab Manual, source code, and related experiments, visit the GitHub repository provided below.

Fig. 1: Access the GitHub repository for the lab manual, source code, and related experiments: https://github.com/ibeuler/LAB-Reports.

References

[1] ISTANBUL UNIVERSITY, *OPTICS LABORATORY EXPERIMENTS MANUAL*, Department of Physics.

[2] *Source code and additional experiments are available in the GitHub repository.* https://github.com/ibeuler/LAB-Reports