Fresnel's Biprism

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Aim:

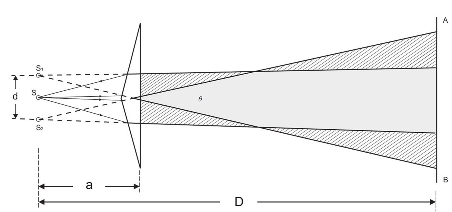
We aim to observe two-beam interference fringes and the measurement of the wavelength of monochromatic light.

Experiment:

Apparatus:

- Optical bench
- Biprism and holder
- Micrometer eyepiece
- Meter scale
- Sodium lamp
- Retort stand and clamps
- Set of aperture lens (7 D)

Experimental Setup:



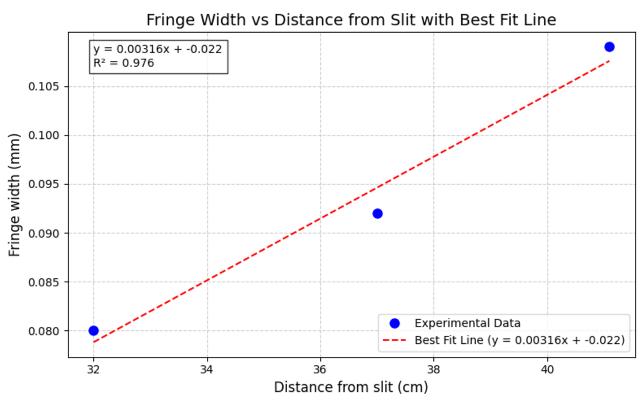
Observations:

Table 1: Fringe measurements

Fringe, f_1 (mm)	Fringe, f_2 (mm)	Distance from slit, a (cm)	Fringe width, $x = \frac{f_1 - f_2}{5}$ (mm)
-3.34	-3.74	32	0.080
-3.96	-3.5	37	0.092
-4.82	-4.275	41.1	0.109

Table 2: Line measurements

First line, l_1 (mm)	Second line, l_2 (mm)	$l_2 - l_1$ (mm)
-6.665	-4.265	2.4
-5.685	-4.455	1.23



Calculations:

The linear relationship is given by:

$$y = mx + n$$

Where:

- Slope, $m = 0.000\,316$
- Intercept, $n = -0.022\,25\,\mathrm{mm}$

The fringe width is related to the experimental parameters by:

$$x = \frac{ac}{\lambda}$$

Where $c = \sqrt{c_1 c_2} = \sqrt{2.4 \times 1.23} \times 10^{-3}\,\mathrm{m} = 1.7181\,\mathrm{mm}$
From the slope of the graph:

$$\frac{x}{a} = \text{slope} = 0.000\,316$$

Calculating the wavelength:

$$\lambda = c \times \text{slope} = 1.7181 \times 10^{-3}\,\mathrm{m} \times 0.000\,316 = 5.429 \times 10^{-7}\,\mathrm{m}$$

$$\lambda = 542.9\,\mathrm{nm}$$

Error Analysis:

The relative error in wavelength is given by:

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta a}{a} + \frac{\Delta c_1}{c_1} + \frac{\Delta c_2}{c_2} + \frac{\Delta x}{x}$$

Substituting the values:

$$\frac{\Delta\lambda}{\lambda} = \frac{1}{320} + \frac{1}{240} + \frac{1}{123} + \frac{1}{80}$$

$$\frac{\Delta\lambda}{\lambda} = 0.0279$$

$$\frac{\Delta\lambda}{\lambda} = 2.79\%$$

Result:

The wavelength of the monochromatic source of light was measured to be:

$$\lambda = 542.9 \pm 15.1 nm$$

Sources of Error:

Improper alignment of the biprism, light source, or microscope can lead to distortions in the observed interference fringes. The main sources of error include:

- **Biprism Imperfections**: Surface irregularities, scratches, or incorrect angles in the biprism can modify the interference pattern.
- **Optical Distortions**: Lenses used to focus the light may introduce aberrations, reducing fringe clarity.
- **Observer Positioning Errors**:

  - Incorrect eye placement during measurements can lead to reading errors.
  - Slight eye movements significantly impact fringe counting due to the challenge of maintaining a consistent reference.
  - This introduces a substantial human error component that is difficult to quantify in error analysis.
  - Using an eyepiece with two adjustable cursors (one as a reference) can mitigate this issue.

- **Environmental Factors**: Vibrations, air currents, or external light sources may degrade fringe visibility.
- **Backlash Error**: Mechanical play during fringe counting can introduce inaccuracies.

Discussion:

Effect of Wavelength on Fringe Width

The fringe width (β) is directly proportional to the wavelength (λ) of light:

$$\beta \propto \lambda \tag{1}$$

Thus, longer wavelengths produce wider fringes.

Effect of Refractive Index

The refractive index (μ) of the biprism influences the experiment in two ways:

- It determines the separation between the virtual sources.
- Higher refractive indices cause greater light deviation, altering the interference pattern.