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Fresnel's Biprism

Determining wavelength of sodium vapour lamp

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***Abstract*—This Fresnel Biprism Experiment uses a specially designed biprism to study the optical phenomenon of interference. By splitting a light beam, the Fresnel biprism produces interference patterns. The wavelength of light used is then determined by analyzing the resulting fringes. It covers the phenomenon of interference, the importance of fringe patterns, and how Fresnel's biprism is used to understand wave optics. Overall, the experiment provides a useful, practical investigation of wave behaviour in optics and sheds light on interference problems.**

***Index Terms*—Biprism, conjugate foci method to measure distance between two virtual sources, fringe width,sodium vapor lamp.**

I. Objective

The experiment aims to determine the wavelength of a monochromatic light source using Fresnel's biprism method.

II. Materials and Methods

A. Materials

Biprism, Optical bench, sodium lamp, micrometre eyepiece, uprights, slit, a convex lens.

B. Methods

The given experiment explains the interference of light. When two coherent sources of the same amplitude interfere, alternately bright and dark fringes are obtained. This is Constructive and destructive interference.// Fresnel biprism experiment is a variation of Young's double slit experiment. In the case of Young's double-slit experiment, a single source is split into two different coherent sources, which are used for interference. Whereas, Fresnel's biprism experiment consists of two thin prisms, each of very small refracting angle α (0.5 to 1 degree) joined together to make an isosceles triangle. Light from the source is allowed to fall on this biprism symmetrically. The left portion of the wavefront is refracted right, while the right segment is refracted left. In the superposition region, interference occurs as two virtual sources ($S_1 and S_2$)exist here. Since both of these sources are derived from the same source S, thus they are coherent. As a result, an interference pattern is observed in the overlapping region.

In order to find the path difference we assume two rays of light from both the sources incident on any point on the screen, say P.

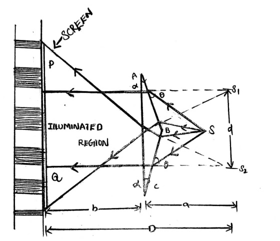


Fig. 1. Division of Wavefront by Fresnel's Biprism

The path difference is now given by:

$$\Delta x = S_1P - S_2P \tag{1}$$

Let $S_1S_2 = d$, $SO = D$ and $OP = X_n$, It can be seen that

$$S_1P = D[1 + \frac{1}{2}(\frac{\frac{d}{2} + X_n}{D})^2] \tag{2}$$

$$S_2P = D[1 + \frac{1}{2}(\frac{\frac{d}{2} - X_n}{D})^2] \tag{3}$$

Assuming $\frac{d}{2} \pm X_n \leq D$

$$\Delta x = \frac{dX_n}{D} \tag{4}$$

Here X_n is the position of n^{th} bright fringe then:

$$\Delta x = n\lambda \tag{5}$$

$$\frac{dX_n}{D} = n\lambda \tag{6}$$

Fringe width β is the distance between two bright (or dark) fringes is given by:

$$\beta = X_n - X_{n-1} = \frac{\lambda D}{d} \tag{7}$$

Now if β,d and D are known we can find the wavelength λ by using formula:

$$\lambda = \frac{d\beta}{D} \tag{8}$$

III. Procedure

1) Clean all the optics with Isopropyl alcohol and switch on the sodium vapour lamp so that it reaches its maximum intensity.
2) Now, level the optical bench using levelling screws and ensure that the slits, the biprism, the lens holders and the eyepiece are at the same level. Also, ensure that their planes are perpendicular to the horizontal.
3) Write down the least counts of optical bench and micrometre.

4) Mount the slit on the first rider of the bench and mount the micrometre eyepiece on the rider. Adjust the light source and slit in order to get the maximum light intensity on the slit, and all of them should lie on the same axis.
5) Mount the biprism on the biprism holder with its plane facing towards the slit and place the biprism holder on the upright next to the slit. Position it such that the refracting edge of the biprism is at the centre of the circular aperture. Also, ensure that the edge of the biprism is vertical.
6) Adjust the width of the slit so that it becomes as narrow as it can be.
7) Move the eyepiece away from the biprism. Two sources should be visible when looking at the prism directly with the naked eye. If the sources are not visible, then slowly move the biprism laterally using the base knob on the upright.
8) Now, focus the micrometre eyepiece
9) Try to obtain maximum clarity and contrast by slightly rotating the biprism in its plane using the tangent screw. So that measuring the distance between the fringes is easy.
10) Now, move the eyepiece towards the biprism and then if the fringe pattern shifts laterally left w.r.t the crosswire, then move the biprism laterally right by slightly turning the side knob and vice versa. This step basically removes any lateral shift that may be present.
11) Now find the fringe width by the given formula:

$$\beta = \frac{\text{Total distance moved}}{\text{Number of fringes moved across the cross wire}} \tag{9}$$

12) We took the reading for fringe width twice for improved accuracy.
13) To measure the distance between two virtual sources, mount the short focal length convex lens on an upright and put it between the eyepiece and biprism. Adjust the height of the lens.
14) Keeping the position of the slit, biprism, and the eyepiece upright fixed. Move the lens from the eyepiece to the biprism so that a diminished image of the source is obtained
15) Take the reading. This is the distance d_1
16) Now move the convex lens further towards the prism and obtain the distance at which a magnified image of the sources is obtained.
17) Take the reading. This is the distance d_2
18) Using d1 and d2, you can find the distance between two virtual sources(d) by the following formula:

$$d = \sqrt{d_1 \times d_2} \tag{10}$$

IV. Observation and Graphs

A. Observation Table for Calculating fringe width

In order to improve accuracy, we calculated the fringe width twice and then took the average to enter the final fringe width.

1) Attempt I

Fringe Number	M.S.R(in mm)	C.S.R	Xn (in mm)	Fringe Width
1	10.0	0	10.00	
5	11.5	29	11.79	0.36

TABLE I
CALCULATING FRINGE WIDTH (ATTEMPT 1)

2) Attempt II

Fringe Number	M.S.R(in mm)	C.S.R	Xn (in mm)	Fringe Width
1	8.0	13	8.13	
5	9.5	45	9.95	0.36

TABLE II
CALCULATING FRINGE WIDTH (ATTEMPT 2)

Thus, Average fringe width $(\beta) = \frac{0.36+0.36}{2} = 0.36mm$

B. Observation Table for Calculating Distance between the virtual sources (d)

In order to improve accuracy, we calculated d_1 and d_2 twice and then took the average to find the final distance between the virtual sources i.e (d)

1) Attempt I

Diminished Image			
Sr.no.(n)	**M.S.R**	**C.S.R**	**X_n(in mm)**
1	10.0	10	10.10
2	10.5	12	10.62
Width$\|X_1 - X_2\|$ (d_1) (in mm) = 0.52			
Magnified Image			
1	10.0	27	10.27
2	5.5	22	5.72
Width$\|X_1 - X_2\|$ (d_2) (in mm) = 4.55			

TABLE III
CALCULATING d_1 AND d_2 (ATTEMPT 1)

2) Attempt II

Diminished Image			
Sr.no.(n)	**M.S.R**	**C.S.R**	**X_n(in mm)**
1	8.5	38	8.88
2	9.5	10	9.60
Width$\|X_1 - X_2\|$ (d_1) (in mm) = 0.72			
Magnified Image			
1	9.5	22	9.72
2	5.5	18	5.68
Width$\|X_1 - X_2\|$ (d_2) (in mm) = 4.04			

TABLE IV
CALCULATING d_1 AND d_2 (ATTEMPT 2)

Thus, the Average value of the distance between the sources in diminished image$(d_1) = \frac{0.52+0.72}{2} = 0.62\ mm$

Thus, the Average value of the distance between the sources in magnified image$(d_2) = \frac{4.55+4.04}{2} = 4.30\ mm$

Thus, the value of the distance between the sources $(d) = \sqrt{0.62 \times 4.30} = 1.63\ mm$

V. Calculations and Discussion

A. Calculations

$$\text{Fringe Width} = \beta = 0.36mm$$

$$\text{Distance between sources} = d = \sqrt{d_1 \times d_2} = 1.63mm$$

Distance between source and eyepiece = D = 1000 mm

The value of λ is given by the equation

$$\lambda = \frac{\beta \times \sqrt{d_1 d_2}}{D} \tag{11}$$

$$\lambda = \frac{0.36 \times 1.63}{1000} = 5.868 \times 10^{-4}\ mm = 586.8nm$$

B. Discussions

In this experiment, we create two coherent virtual sources with the help of a Fresnel bi-prism. A single source of light is split into two virtual sources using two prisms, each having a very small refracting angle. Since it is the same light source, the light is coherent. The fringes observed are light and dark vertical bands. The biprism is adjusted laterally to ensure the bands align with the crosswires. We conducted the experiment in a dark room to better observe the fringes.

VI. Error analysis

The following are the possible sources of error

1) The stray light may have interfered with the fringes, which in turn affects the reading for the firing width.
2) There could have been parallax and human errors while taking the readings.
3) There is a possibility that the lateral displacement was not eliminated fully as a result there was an error in the readings

VII. Finding Error in d mathematically

The value of d is given by the formula:

$$d = \sqrt{d_1 \times d_2} \tag{12}$$

In order to find an error in d, taking natural log on both sides, we get,

$$ln(d) = \frac{1}{2} \times [ln(d_1) + ln(d_2)] \tag{13}$$

Differentiating all the terms on both sides and adding their magnitudes,

$$\frac{\Delta d}{d} = \frac{1}{2}[\frac{\Delta d_1}{d_1} + \frac{\Delta d_2}{d_2}] \tag{14}$$

$$\frac{\Delta d}{1.63} = \frac{1}{2}[\frac{0.01}{0.62} + \frac{0.01}{4.30}] \tag{15}$$

$$\frac{\Delta d}{1.63} = 0.02 \tag{16}$$

$$\Delta d = 0.04mm \tag{17}$$

VIII. Finding Error in λ mathematically

The value of λ is given by the formula:

$$\lambda = \frac{D\beta}{d} \tag{18}$$

In order to find an error in λ, taking natural log on both sides we get,

$$ln(\lambda) = ln(D) + ln(\beta) - ln(d) \tag{19}$$

Differentiating all the terms on both sides and adding their magnitudes,

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta D}{D} + \frac{\Delta\beta}{\beta} + \frac{\Delta d}{d} \tag{20}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{1}{1000} + \frac{0.01}{0.36} + \frac{0.04}{1.63} \tag{21}$$

$$\frac{\Delta\lambda}{\lambda} = 0.05 \tag{22}$$

$$\Delta\lambda = 0.05 \times 586.8nm \tag{23}$$

$$\Delta\lambda = 31.28mm \tag{24}$$

Thus the value of λ so obtained is $(586.8 \pm 31.28)nm$ The percentage error is $\frac{31.28}{586.8} \times 100$

Which comes out to be 5.33%

IX. Conclusion and Future Prospects

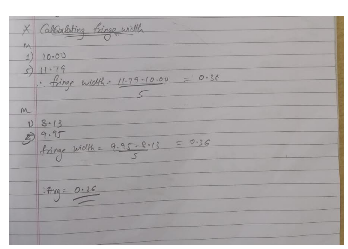
A. Conclusion

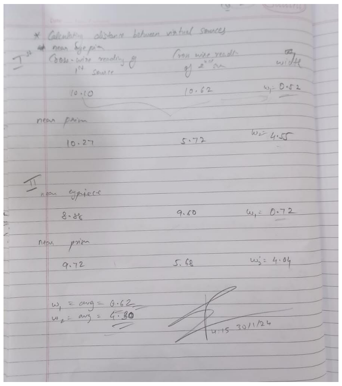
We successfully conducted this experiment and were able to determine the wavelength of the light from the sodium vapour lamp, which came out to be $\lambda = 586.8 \pm 31.28$
with a percentage error of 5.33% We were able to observe the constructive and destructive interference of light, which led to the formation of alternate dark and bright fringes on the screen. This experiment also enables us to understand the wave nature of light.

B. Future prospects

- Application of Fresnel's biprism can lead to new opportunities in interdisciplinary fields of study, including biology and material science.
- In quantum optics, Fresnel's biprism experiments can be expanded to examine the quantum character of light, leading to the development of quantum information processing and communication technologies. This can result in a deeper understanding of wave optics and its application.

X. Reading images





XI. Author Contributions

Name	Roll number	Contribution	Signature
Faayza Vora	23110109	Material and Methods, Procedure, Observations, Error analysis and Taking readings in lab	
Goraksh Bendale	23110118	Lab readings/equipment handling, Discussions, Calculations	
Dishant Tanmay	23110100	Abstract, Objective , Procedure	
Haravath Saroja	23110127	Conclusion and future prospects	

TABLE V
Author's Contribution