BS 192: Undergraduate Science Laboratory (Physics)

A
Laboratory Report
on

Fresnel's Biprism

by

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Index

Experiment No. 4

Fresnel's Biprism

I. Aim:

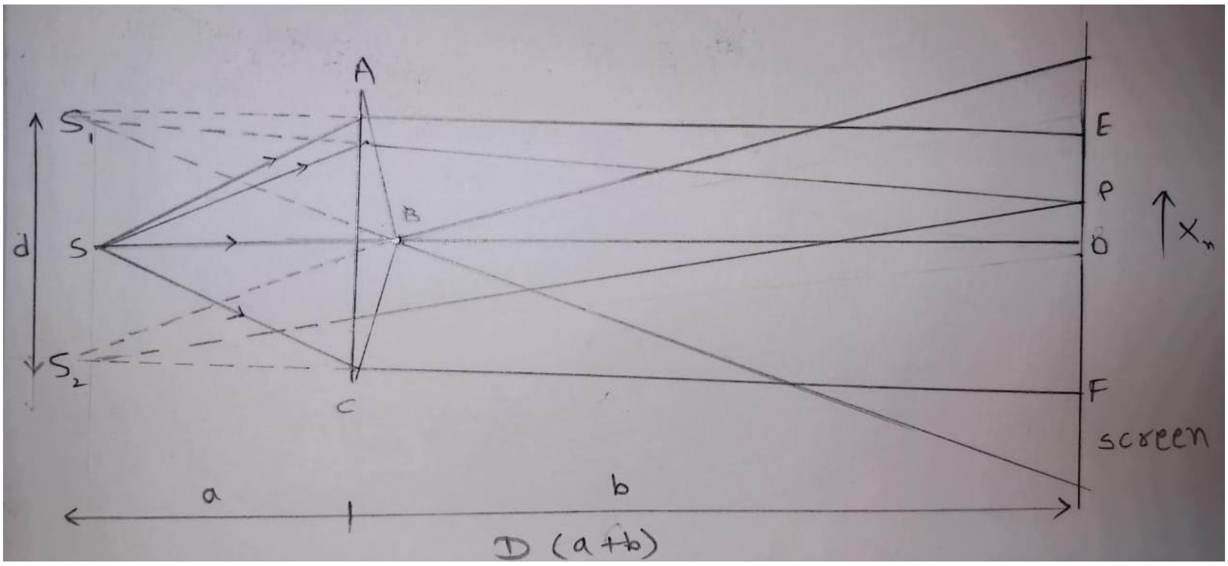
To determine the wavelength of sodium light using Fresnel's biprism method.

II. Apparatus:

Optical bench, Sodium vapour lamp, slit, uprights, biprism, convex lens, micrometre eyepiece.

III. Theory:

The Fresnel Biprism is a modified version of Young's double slit experiment. It helps us study the phenomenon of interference of light. The biprism consists of two prisms, both having a very small refracting angle around 0.5 to 1 degree, placed together base to base. Monochromatic light of wavelength λ, passing through a narrow-slit S, parallel to the base B is allowed to fall symmetrically on the biprism. The single falling wavefront divides into two parts. The left wavefront bends towards right and right wavefront bends towards left. Since both the wavefronts originate from the same source, both are coherent. Back tracing the wavefront, we see, that they seem to originate from two virtual sources S_1 and S_2. To find an expression for position of fringes, we consider interference of light at any point P.



The path difference between the rays coming from the virtual sources is,

$$\Delta x = S_1P - S_2P$$

Let $S_1S_2 = d$, $SO = D$ and, $OP = X_n$,

$$S_1P = D\left[1 + \frac{1}{2}\left(\frac{\frac{d}{2}+X_n}{D}\right)^2\right], \text{ and } S_2P = D\left[1 + \frac{1}{2}\left(\frac{\frac{d}{2}-X_n}{D}\right)^2\right]$$

Assuming $\frac{d}{2} \pm X_n \ll D$,

$$\Delta x = \frac{d}{D} X_n$$

If X_n happens to be the position of n^{th} bright fringe, then,

$$\Delta x = n\lambda$$

$$\frac{d}{D} X_n = n\lambda$$

Fringe width, which is defined as the difference between two bright (or dark) fringes,

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

Now if we know β, D and d, we can get the value of λ.

IV. Procedure:

1. Clean all the optics glasses with the isopropyl alcohol provided. And turn on the Sodium vapor lamp so that it will reach its maximum intensity.
2. Now, adjust the heights of the uprights in such a way that the centres of the slit, the biprism and lens holders, and the eyepiece are all at the same height. Also, adjust their planes so they are nearly perpendicular to the axis of the bench.
3. Start by placing the biprism on the holder with its flat face toward the slit. Align the refracting edge of the biprism to the center of the circular aperture. Use the side knob to move the upright laterally until the biprism's edge is nearly in line with the slit. Rotate the biprism holder to ensure the edge is almost vertical, then lock it in place.
4. Set the upright, now holding the biprism, at approximately 10 cm from the slit. This ensures the optimal configuration for the experiment. Fine-tune the lateral position with the side knob for precision.
5. Finally, adjust the slit width to the open condition. This step is important for obtaining accurate results in the experiment. Make necessary adjustments until the slit is at the desired width.
6. Move the eyepiece upright to about 1000mm from the biprism. And look into the biprism, and we should be able to see two virtual images of the slit. And if not, slightly move the biprism laterally using the base knob on the upright.
7. Now, gently place the eyepiece back into its designated position. Upon doing so, you should immediately observe alternating dark and bright fringes on the screen. If not, use the side knob to move the biprism upright laterally until the fringes become visible.
8. Try to achieve optimal clarity and contrast of the fringes by making slight lateral adjustments to the biprism upright using the tangent screw so that we can easily measure the slit width between them.
9. Move the eyepiece towards the biprism. Observing the lateral movement of the fringes concerning the vertical cross wire indicates that the biprism's refracting edge is not aligned with the bench axis. In this case, the horizontal line connecting the slit and the biprism's edge does not coincide with the bench axis.
10. When the fringes shift laterally with respect to the vertical crosswire, it suggests that the fringes are formed on a plane not normal to the bench axis since the eyepiece is restricted to move along the bench axis, moving it backward or forward results in the appearance of the vertical crosswire traversing the fringe pattern.

11. We should remove the lateral shift by moving the eyepiece close to the prism and adjusting it to see no lateral displacement along the bench axis.
12. To find the distance between the virtual sources, introduce a convex lens in between and move it along the bench axis to get two sharp images of the virtual slits.
13. At each of the two positions of the lens, move the vertical crosshair in the eyepiece, measure the distance between the two virtual sources, and note it down.

V. Observations and Graphs:

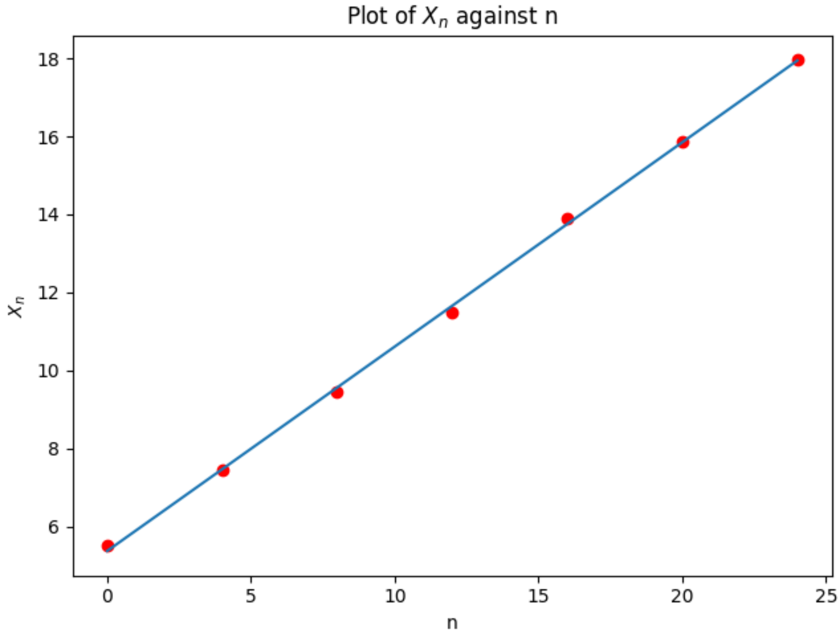
Fringe No.	MSR	CSR	Xn (mm)
0	5.5	0	5.50
4	7.0	44	7.44
8	9.0	46	9.46
12	11.0	48	11.48
16	13.5	39	13.89
20	15.5	37	15.87
24	17.5	46	17.96

Xn (mm)	B = 4*b (mm)	|B - Bo| (mm)
5.50	1.94	0.14
7.44	2.02	0.06
9.46	2.02	0.06
11.48	2.41	0.33
13.89	1.98	0.10
15.87	2.09	0.01
17.96		
Bo = Mean B (mm)	2.08	
Mean |B-Bo| (mm)	0.12	
For 1 Fringe		
b = B/4 (mm)	0.52	
Δb (mm)	0.03	

	MSR	CSR	Value (mm)
P1 (mm)	8.5	33	8.83
P1' (mm)	10.5	24	10.74
P2 (mm)	10.5	24	10.74
P2' (mm)	11.0	38	11.38
d1 = |P1-P1'| (mm)	1.91		
d2 = |P2-P2'| (mm)	0.64		

(Images of these readings are in Section IX)

Plotting X_n against n, we get the following graph,



VI. Calculations:

Slope of the plot above will give us the fringe width, which comes out to be,

$$\beta = 0.52\, mm$$

The fractional error in β will be,

$$\frac{\Delta\beta}{\beta} = \frac{|\beta_{min} - \beta_{max}|}{2\beta}$$

$$\beta_{min} = 0.48, \beta_{max} = 0.60$$

Or,

$$\Delta\beta = 0.06\, mm$$

The value of $\Delta\beta$ we got from taking the absolute error was, 0.03

Taking the higher value of $\Delta\beta$,

$$\beta = 0.52 \pm 0.06\, mm$$

The value of slit width d,

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

Or,

$$d = 1.11\, mm$$

$$\frac{\Delta d}{d} = \frac{1}{2}\left(\frac{\Delta d_1}{d_1} + \frac{\Delta d_2}{d_2}\right)$$

$$\Delta d_1 = \Delta d_2 = 0.01mm(LeastCountofmicrometre)$$

$$\Delta d = 0.02\,mm$$

Or,

$$d = 1.11 \pm 0.02\,mm$$

To calculate the value of D, which is the distance between the slit and the eyepiece,

$$D = D_{eyepiece} - D_{slit}$$

$$D = 1070\,mm - 70\,mm = 1000\,mm$$

The value of λ, from the formula $\lambda = \frac{\beta \times d}{D}$,

$$\lambda = \frac{0.52 \times 1.11}{1000} mm$$

$$\lambda = 0.0005772\,mm$$

$$\lambda = 577.20 \times 10^{-9}\,m$$

VII. Result, Discussion and Error Analysis:

To get the error in the value of wavelength,

$$\lambda = \frac{\beta \times d}{D}$$

$$ln(\lambda) = ln\left(\frac{\beta \times d}{D}\right)$$

$$ln(\lambda) = ln(\beta) + ln(d) - ln(D)$$

Differentiating each term on both the sides, and adding their magnitude,

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

Substituting the values for each term and taking $\Delta D = 1\,mm$, which is the least count of the optical bench.

$$\Delta\lambda = 0.13 \times \lambda$$

$$\Delta\lambda = 75.04\,nm$$

The value of wavelength of sodium vapour lamp is,

$$\lambda = 577.20 \pm 75.04\,nm$$

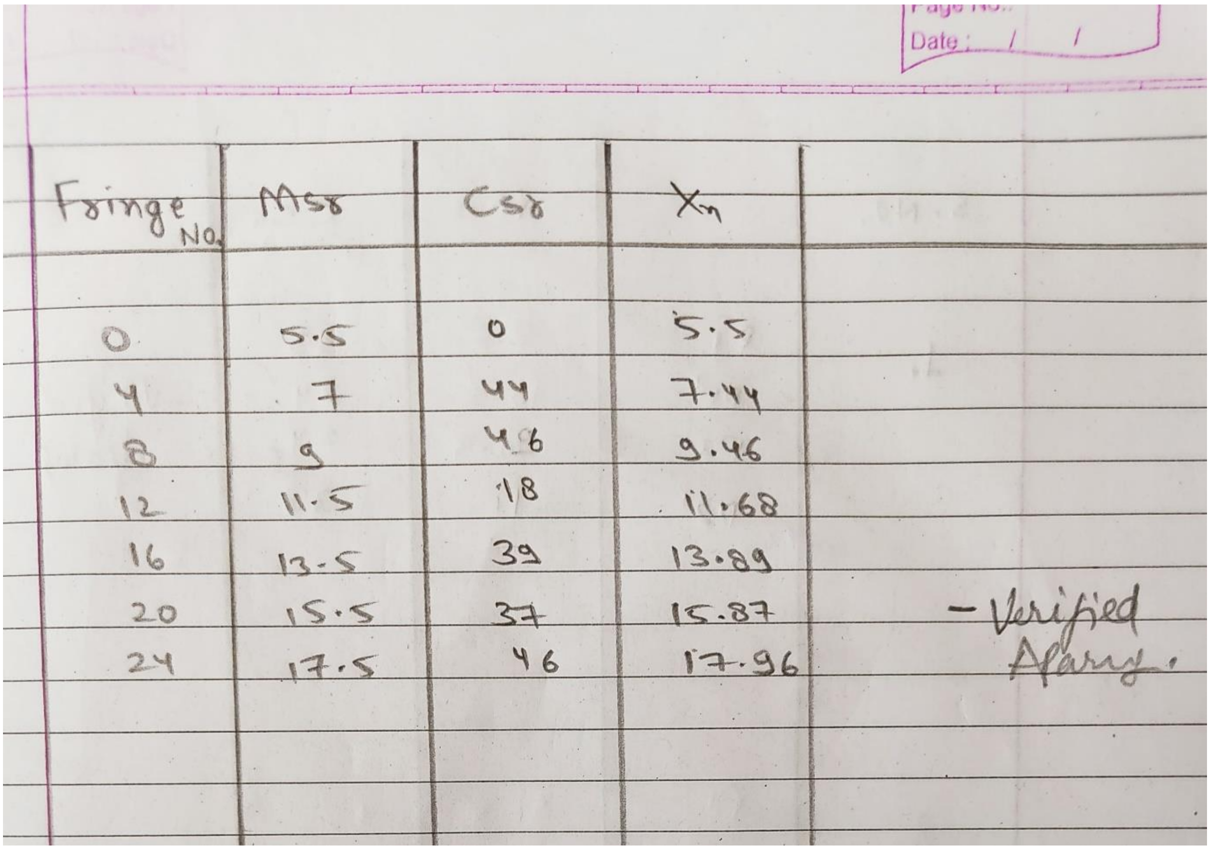
- Possible sources of errors:
    1. While moving the eyepiece back one might observe the fringe pattern shifts laterally. This is called lateral shift. It occurs when the plane of eyepiece is not parallel to the plane of the biprism. This might introduce error while measuring the fringe width of the fringes.
    2. The screw should be turned only in one direction, to avoid the possible backlash error.

3. Other errors are human errors, as it is difficult to accurately determine the distance between fringes, since the intensity diminished, as the eyepiece was far away. Placing the convex lens to find the sharpest point is also subject to human error.

VIII. Conclusion:

We conducted this experiment to determine the wavelength of sodium light using Fresnel's biprism method, which comes out to be $\lambda = 577.20 \pm 75.04$ nm. We observed the interference of light from two coherent virtual sources show a straight alternating fringe pattern. This experiment also enables us to study the wave nature of light, and the phenomenon of interference. In future, we can use different coloured lights to observe the interference pattern. We can also dip the setup in a fluid and see how its refractive index affects the fringes. Another scope of interest could be placing an object of known refractive index and thickness in path of one of the rays and observing the fringe pattern.

IX. Readings Images:



Date : / /

Fringe No.	Msr	Csr	X_n	
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12	11.5	18	11.68	
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20	15.5	37	15.87	– Verified Aparna.
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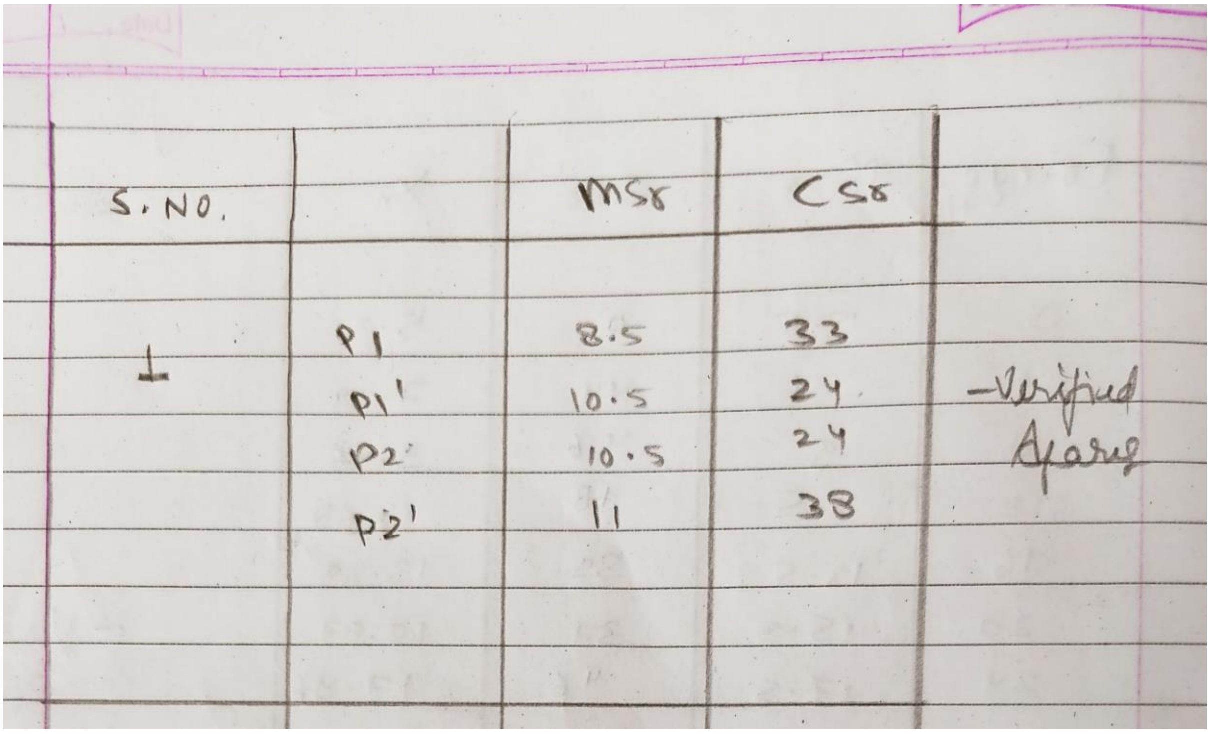

S. NO.		Msr	Csr	
1	P1	8.5	33	
	P1'	10.5	24	– Verified Aparna
	P2	10.5	24	
	P2'	11	38	

X. Author Contribution:

Name	Roll Number	Contribution	Signature
Jaskirat Singh Maskeen	23110146	Reading screw gauge, Theory, Error analysis, Finding possible sources of error and conclusion, plotting graph using Matplotlib.	
Nischay Bhutoria	23110222	Will submit lab report individually	
Kavya Lavti	23110164	Index, Aim, Document structure, Taking readings in lab, Procedure	
Kanhaiyalal	23110155	Index, Aim, Noting readings, Apparatus Diagrams.	