Expt-3
Fresnel's Bi-prism

Objective: To obtain the wavelength of Sodium light using Fresnel's bi-prism.

Apparatus: Optical rail with uprights, sodium lamp, bi-prism, convex lens, slit and micrometer eyepiece.

Theory:

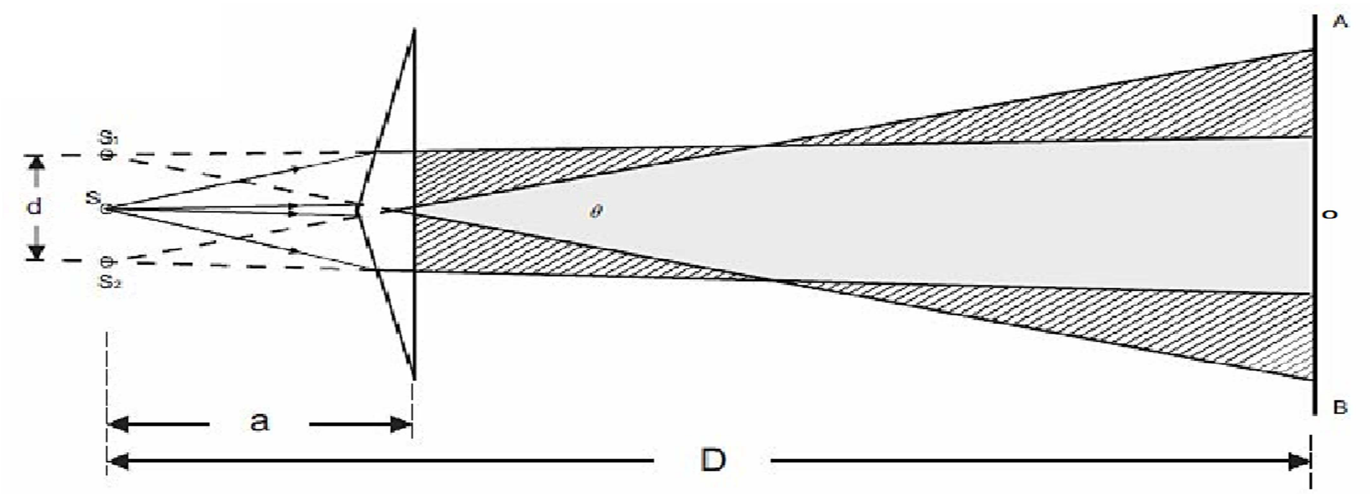

Fig. 1: Formation of two coherent virtual sources from a single slit

1) The Fresnel biprism, a prism which has one of its angles slightly less than two right angles and two equal small base angles acts like two very thin prisms placed base to base.
2) When rays from a slit S illuminated by a monochromatic light, such as sodium light are incident on the biprism, the emergent rays from the two halves appear to diverge from two coherent virtual sources, S_1 and S_2 (see Fig. 1).
3) If a screen (AB) is placed with its plane perpendicular to that containing the slit and the common base of the biprism, the emergent beams of light overlap on the screen producing alternate dark and bright fringes.
4) If d is the difference between the two virtual sources S_1 and S_2, D is the distance between slit and the screen, and λ is the wavelength of

monochromatic radiation, then fringe width x i.e., the distance between two consecutive dark or bright fringes is given by,

$$x = \lambda \frac{D}{d} \qquad (1)$$

Then Wavelength is given by,

$$\lambda = \frac{xd}{D} \qquad (2)$$

5) To determine d, a convex lens having such a focal length that the distance between the slit and the focal plane of the eye-piece exceeds four times the focal length is interposed between the biprism and the eye-piece.
6) The lens is adjusted so that for two of its positions the real images of the two virtual sources S_1 and S_2 are focused on the focal plane of the eye-piece. If d_1 and d_2 are the distances between the real images of S_1 and S_2 respectively for two positions of the lens, then

$$d = \sqrt{d_1 d_2} \qquad (3)$$

Fresnel's Bi-prism

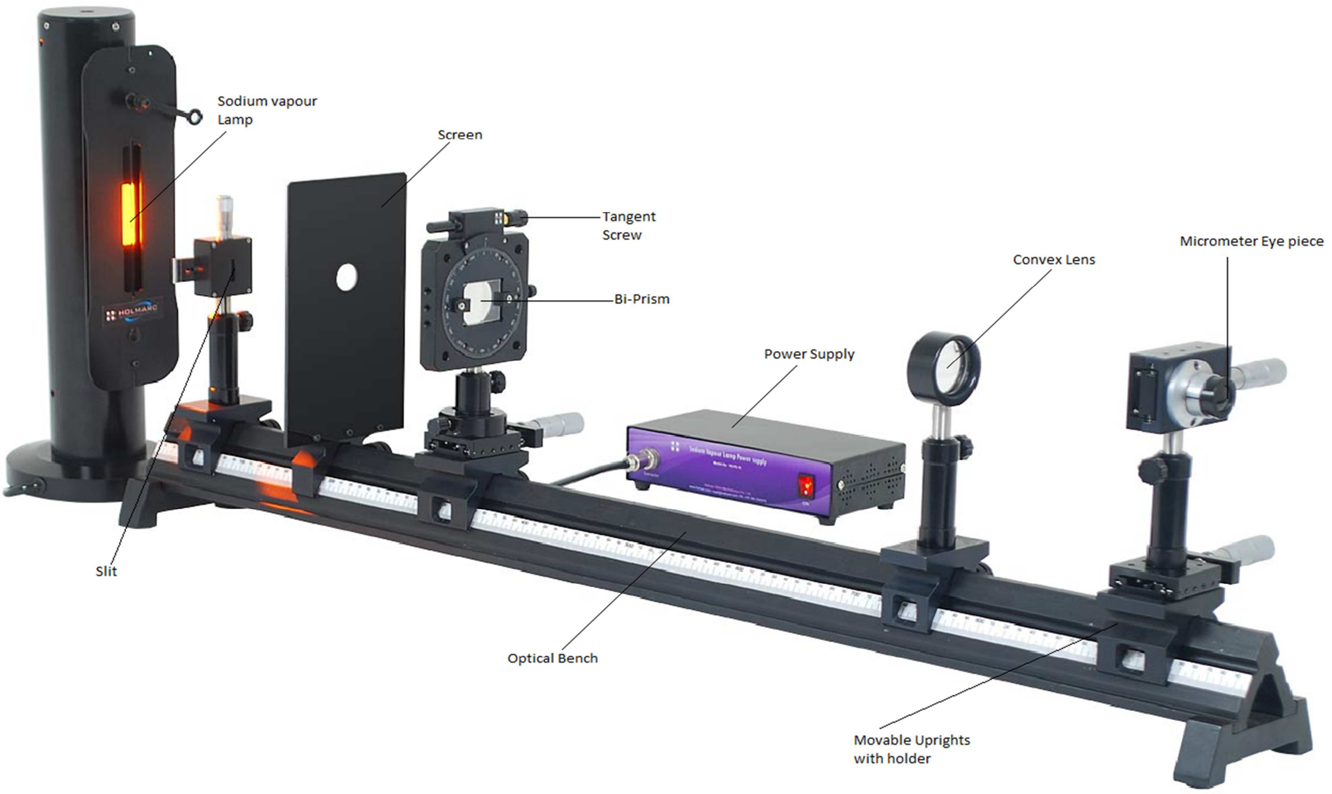

Fig. 2: Experimental setup

Experimental procedure:

1) Place the Sodium vapour lamp in front of the optical rail and switch it on.

2) Place the slit on the rail. Adjust its height in order to make it aligned with the lamp opening. There is a micrometer screw to adjust the width of the slit. Slightly, open the slit.

3) A black screen with a circular aperture can now be placed 3-5 cm away from the slit.

4) Place the bi-prism in front of the screen in such a way that the edge formed by the intersection of the inclined planes of the bi-prism faces the slit. The holder has a circular aperture and it can rotate the bi-prism in its own plane. A finer rotation can be carried out using a tangent screw. Another micrometer screw is attached to the base for the lateral movement of the bi-prism.

5) Keep the bi-prism stand at a distance of about 10-12 cm from the slit.

6) Mount the eyepiece on the rail. The eyepiece is attached with a crosswire. A micrometer screw provides the lateral movement of the crosswire in the field of

view. Another micrometer screw is attached to the base to move the eyepiece laterally.

7) Make sure that all components are aligned at the same height.

8) Bring the eyepiece close to the bi-prism. Looking through the eyepiece a bright vertical patch of light should be seen. Slowly rotate the bi-prism using the tangent screw. At some stage, the light patch will appear to break up into vertical equidistant fringes. Use the tangent screw to make them sharp. Note that the fringes are obtained when the edge formed by the intersection of the inclined planes of the bi-prism becomes exactly parallel to the vertical slit.

9) Adjust the slit width to get the best compromise between the intensity and sharpness of the fringe pattern.

Removal of lateral shift:

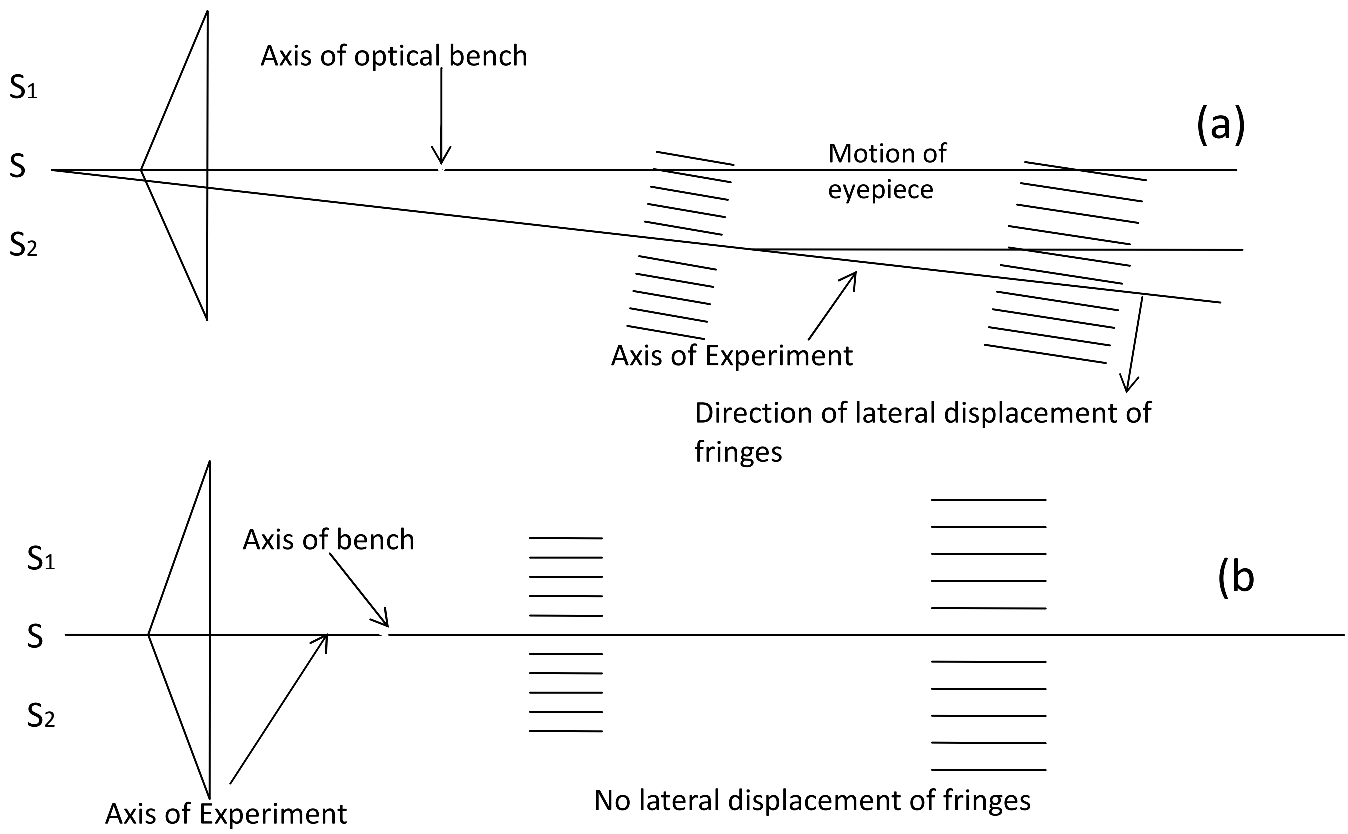

Fig.3: Removal of lateral shift

Fresnel's Bi-prism

1) First bring the eyepiece close to the biprism. Move the eyepiece laterally using base knob to bring the fringes to the centre of its field of view. Let the vertical crosswire coincide with the centre bright fringe.
2) Now, move the eyepiece backwards and during this motion observe the fringe pattern. If the fringe pattern appears to shift left w.r.t the vertical cross wire, then move the biprism laterally to the right, by slightly turning the base knob. Alternatively, if the fringe pattern shifts to the right w.r.t. the cross wire, then biprism is to be moved laterally to the left.
3) After moving the biprism laterally in the appropriate direction, bring the eyepiece up again (close to the biprism) and reinspect the lateral shift by moving it backwards. Keep repeating this sequence till no lateral shift is observed when the eye piece is moved over a distance of about 100 cm.

Measurements

A. Measurement of fringe width *x*:

A.1) Obtain the least count of the micrometer screw for the crosswire of the eyepiece.

A.2) Place the eyepiece at a distance of 100 cm from the bi-prism, where the fringes should appear clear, bright and widely spaced. Use the base clamp to lock the eyepiece stand at this position.

A.3) Move the crosswire to one side of the field of view. Bring the crosswire at the centre of a bright (or a dark) fringe.

A.4) Shift the crosswire to successive bright fringes (or dark fringes) and note down the readings. At least 10 readings should be taken for the calculation of the average width of a fringe. Micrometer has a linear and a circular scale. Crosswire position = linear scale reading (M.S.R) + circular scale reading (C.S.R) $\times$ least count (L.C), where L.C = pitch/total number of division on the circular scale = 0.5/50 = 0.01

A.5) Tabulate fringe no. (n) and the fringe position (x_n) (M.S.R, C.S.R and the total separately).

Fresnel's Bi-prism

A.6) Record the distance D between the slit and the eyepiece from the scale attached with the optical bench.

B. Measurement of the distance between the virtual sources d [see Fig.4]**:**

B.1) Place a convex lens in between the bi-prism and the eyepiece. Note that the focal length f of the lens should satisfy $D > 4f$.

B.2) First, place the lens near to the bi-prism. Slowly move it towards the eyepiece until two images of the slit can be seen clearly through the eyepiece. Note down this lens position as L_1. Measure the distance between the two images d_1 using the crosswire micrometer attached with the eyepiece.

B.3) Move the lens to a second position L_2. Measure the distance between the two images d_2.

B.4) Now d can be calculated as $d = \sqrt{d_1 d_2}$. Tabulate (P_1 , P_1' , d_1) , (P_2 , P_2' and d_2) and $d = \sqrt{d_1 d_2}$.

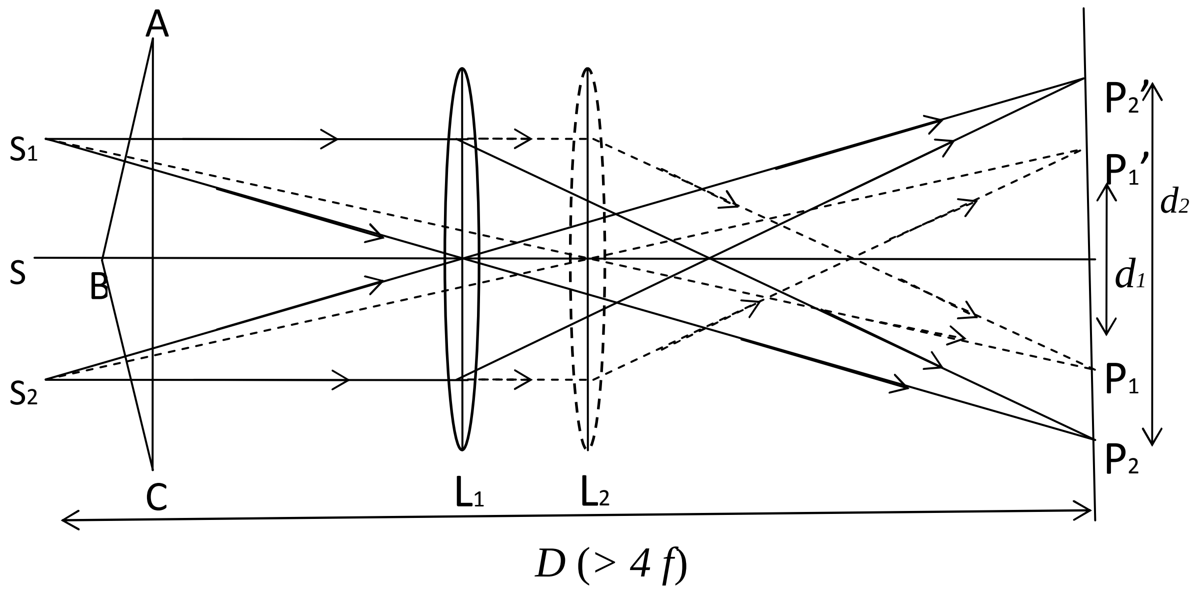

Fig.4: Measurement of d

Fresnel’s Bi-prism

Results and Calculation:

1) Calculate the average value of $d_{avg} = \frac{|d_1 + d_2|}{2}$. Also calculate the error $\Delta d = \frac{|d_1 - d_2|}{2}$. Fractional error in $d = \frac{\Delta d}{d_{avg}}$.

2) Plot x_n vs. n in a graph paper. Calculate the average fringe width x from its slope. Also draw the limiting straight lines, and measure their slopes (x' and x'') to get the limiting values of x. Fractional error in x is $\frac{\Delta x}{x} = \frac{|x' - x''|}{2x}$.

3) Calculate $\lambda = \frac{xd}{D}$ and estimate the error $\Delta\lambda$ using the fractional errors $\Delta d / d$ and $\Delta x / x$ (see Section on Errors). The error in D may be neglected.

Precautions:

1) Distance between the slit and the biprism must be kept constant throughout the experiment. After the initial adjustment to get sharp fringes with good contrast, do not change the slit width or rotate the biprism.

2) Move the eyepiece only backward to observe the lateral shift. For moving lateral shift, there is no other adjustment required except the lateral movement of the biprism. Occasionally, the eyepiece may have to be also moved laterally (using the base screw) only to ensure that the fringe system is in its field of view.

3) During measurement of d_1 and d_2, do not keep the eyepiece at a very large distance (>> $4f$) from the slit, which results in a large difference in d_1 and d_2 leading to enhanced error in their product.

4) While measuring the fringes width, align the cross wire at the centre of a bright fringe.

5) While measuring fringe width, the pointer (crosswire) must be moved only one direction to avoid error due to backlash.