USER'S MANUAL

BI-PRISM EXPERIMENT

A Product of:

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Aim of the experiment: To estimate the wavelength of Sodium light by Fresnel's bi-prism experiment.

Apparatus used: Optical bench with uprights, sodium lamp, bi-prism, convex lens, slit and micrometer eye piece are already fitted on the optical bench.

Formula used: The wavelength λ of the sodium light is given by the formula in case of bi-prism experiment.

$\lambda = \beta \, 2d / L$

Where β = fringe width,

2d = distance between the two virtual sources,

L = distance between the slit and screen.

Again $2d = \sqrt{(d_1 d_2)}$, where d_1 = distance between the two virtual images of the slit formed by the convex lens posited closer to the slit and d_2 = distance between the same two images when the convex lens is moved closer to the eye-piece.

Description of the Apparatus:

Two coherent sources, from a single source, to produce interference pattern are obtained with the help of a Bi-prism. A bi-prism may be regarded as made up of two prisms of very small refracting angles placed base to base. In actual practice a single glass plate is suitably grinded and polished to give a single prism of obtuse angle about 170° leaving remaining two acute angles of 30° each. The optical bench used in the experiment consists of a heavy cast iron base supported on four leveling screws. There is a graduated scale along its one arm. The bench is provided with four uprights which can be clamped anywhere and the position can be read by means of vernier attached to it. Each of the uprights is subjected to the following motions:

i) Motion along bench

ii) Transverse motion

iii) Rotation about the axis of the upright.

iv) With the help of the tangent screw, the slit and bi-prism can be rotated in their own vertical planes.

The bench arrangement is shown in the Fig. 11.1.

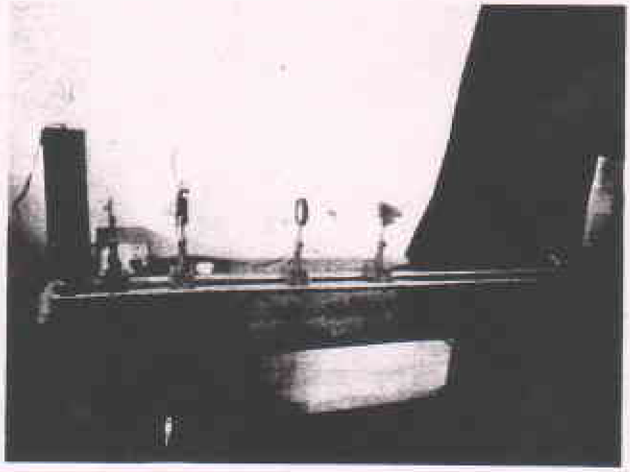

Fig. 11.1: Experimental setup for Fresnel's bi-prism

Action of bi-prism:

The action of the bi-prism is shown in the Fig. 11.2. Monochromatic light from source S falls on two points of the prism and is bent towards the base. Due to the division of wavefront, the refracted light appears to come from S_1 and S_2 as shown Fig.11.2. The waves from two sources unite and give interference pattern.

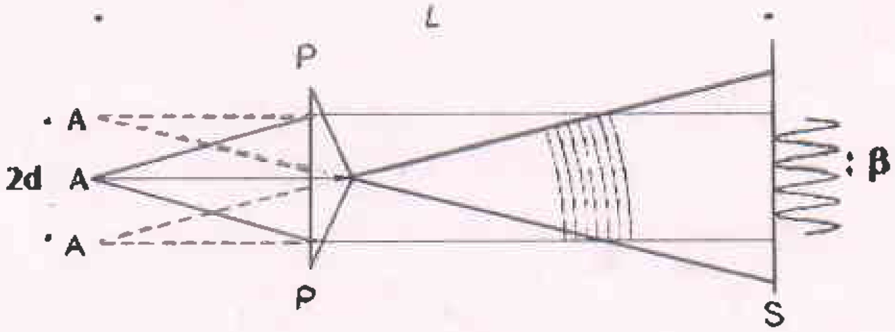

Fig. 11.2: Mechanism of formation of interference fringes by Fresnel's bi-prism

The fringed are hyperbolic. However, due to high eccentricity they appear to be straight lines in the focal plane of eyepiece as shown in Fig. 11.3.

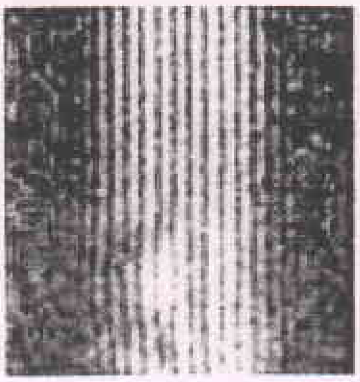

Fig. 11.3: Interference pattern formed by Fresnel's bi-prism.

Background theory:

If a rectangular aperture, illuminated by a monochromatic light source with wavelength λ, is placed in front of the apex of a bi-prism, two virtual images (A_1 and A_2) of the slit are formed on the side opposite to the flat edge of the bi-prism, as depicted in Fig. 11.2. Let the separation in between the two images be 2d. Light rays coming from A_1 and A_2 being coherent, can interfere with each other to form sustained interference patterns on a screen S, a distance L away from the virtual sources.

The optical path difference in between the two rays reaching the point S from A_1 and A_2 is given by:

$\delta = 2d\sin\theta$ (1),

where θ is the angle of deviation with respected to the horizontal line. It is well known from the basics of interference that if

$\delta = n\lambda \ (n \in I)$ (2)

the rays coming from A_1 and A_2 interfere constructively and the corresponding order of interference is n. Let the position of this maxima from the central maxima be Y_n.

If 2d<<L, θ will be a small quantity and the following approximations will be valid.

$\sin\theta \simeq \theta \simeq \tan\theta = Y_n/L$ (3)

Combining (1)-(3) we get,

$n\lambda = 2dY_n/L$ (4)

Similarly, for $(n\pm1)^{th}$ order maxima, we can write

$(n\pm1)\lambda = 2dY_{(n\pm1)}/L$ (5)

Subtracting (4) from (5) are rearranging finally we get,

$Y_{(n\pm1)} - Y_n$=distance between two consecutive maxima=fringe width=$\beta = \lambda L/2d$ or

$\lambda = 2d\beta/L$ (6).

Equation (6) is the experimental formula using which we can estimate the value of λ. In the experiment, therefore, we have to measure three unknown quantities: (i) β, (ii) 2d and (iii) L. In the following sections we will discuss how to measure these quantities.

Procedure:

i) With the help of spirit level and leveling screws make the optical bench perfectly horizontal.

ii) The slit, bi-prism and eye-piece are to be maintained at the same height. Make the slit and the cross wire of eye piece perpendicular to the optical bench.

iii) The eye piece is to be focused on the cross wire.

iv) The light from the sodium lamp is allowed to fall on the slit and the bench is adjusted in such a way that light comes straight along its length. Precautions are to be taken to avoid the loss of light intensity for the interference pattern.

v) Place the bi-prism upright near the slit and move the eye piece sideways. See the two images of the slit through bi-prism. In case they are not distinctly seen, move the upright of bi-prism right angle to the bench till they are obtained. Make the two images parallel by rotating bi-prism parallel to its plane face.

vi) Bring the eye piece near to the bi-prism and rotate it at 90° to the bench to obtain a patch of light containing the interference fringes provided that the edge of the prism is parallel to the slit.

vii) Rotate the bi-prism with the help of tangent screw attached to it till the edge of the bi-prism parallel to the slit and a clear interference pattern is obtained.

viii) The line joining the centre of the slit and the upper surface of the bi-prism should be parallel to the bed of the bench. Otherwise, there will be a lateral shift and its removal is very important for the accurate measurement of the wavelength.

(a) For setting the apparatus for no lateral shift, the eyepiece is first slowly moved away from bi-prism. The fringes will thus move either to right or left. By turning the base screw provided with bi-prism, the bi-prism can be moved at right angle to the bench in such a direction so that the fringes are always back to their original position.

(b) Followed by this, move the eye piece towards or away from the bi-prism. The fringe system will once again move laterally. However, this time, they are brought to their original position by turning the screw of attached to the eye piece.

Measurements:

(A) Estimation of the fringe width (β):

i) Find out the least count of the micrometer screw.

ii) Place the micrometer screw at such a distance from bi-prism, where fringes are distinct, bright and widely spaced, say 100 cm.

iii) The cross wire is moved on one side of the fringes to avoid backlash error. Now the cross wire is fixed at the centre of a bright fringe.

iv) The crosswire is now moved and fixed at the centre of every second fringe. The micrometer readings are noted. From these observations β can be calculated.

**** There is a very common mistake that is often encountered while taking the micrometer readings. The main scale of the micrometer is graduated in mm from -10 mm to + 10mm having 0 at the center. The readings on the positive side are similar to those recorded by an ordinary screw gauge. However, on the negative side the M.S.R. and the C.S.R. are to be recorded using the following relations.*

Actual M.S.R.= M.S.R. observed-1 (take care of the sign)

Actual C.S.R.= (C.S.D. observed-100)×L.C. (take care of the sign)

(B) Measurement of L:

The distance between the slit and eyepiece is L, the value of which is corrected taking into account the bench error.

(C) Measurement of 2d:

For measuring 2d, we use a simple principle of ray optics of imaging of an object with the help of a bi-convex lens, as schematically depicted in Fig. 11.4(b). The distance 2d between the two virtual sources can be measured with the help of Fig.11.4.

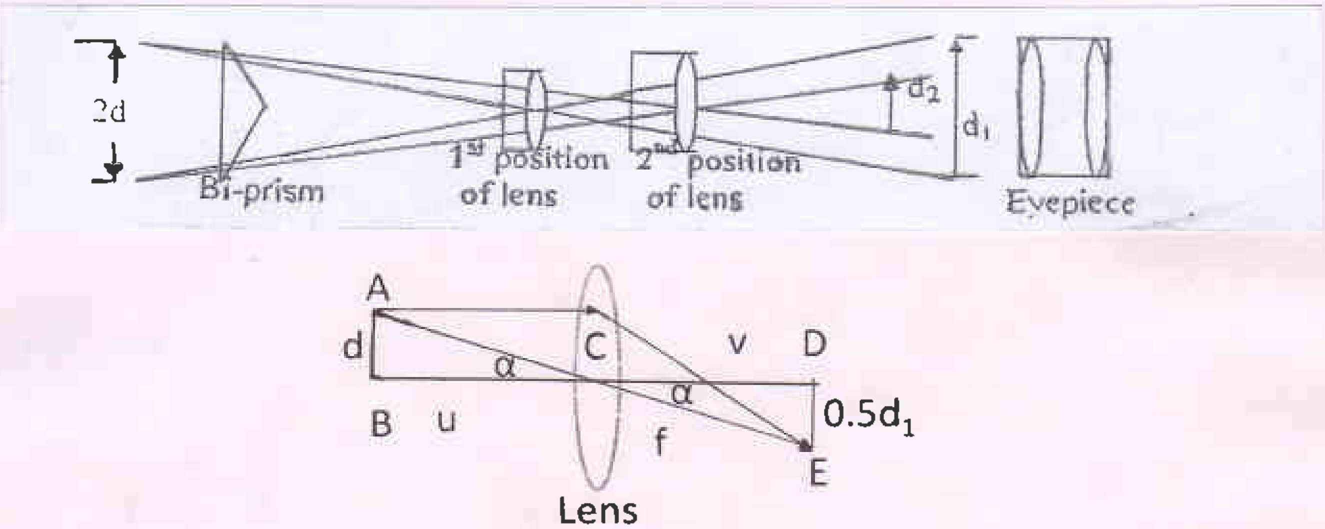

Fig. 11.4: (a) Distance between two virtual sources as a function of the position of the convex lens. (b) Principle of image magnification by a bi-convex lens.

Suppose half of the distance between the two virtual (i.e. AB=d) sources is above the line BD passing through the center of the lens C. If u is the object distance of the lens for which we obtain an image DE at a distance v from the lens, we see that ΔABC and ΔCDE are similar.

$\therefore \tan\alpha = AB/BC = DE/CD$

$\Rightarrow d/u = d_1/2v$

$\Rightarrow v/u = d_1/2d$ (6)

Now, following the principle of reversal of track of light, if the lens is moved to a distance v from the source, a second image of the source will form at a distance u from the lens. So, following the same procedure as above, we get

$d/v = d_2/2u$

$\Rightarrow v/u = 2d/d_2$ (7)

Combing equations (6) and (7) we finally obtain

$d_1/2d = 2d/d_2$

$\therefore 2d = \sqrt{(d_1 d_2)}$ (8)

i) To obtain the value of 2d, the positions of slit and bi-prism uprights are kept unaltered.

ii) A convex lens is introduced between the bi-prism and the eye-piece and moved in between to obtain the second position where again two sharp and focused images are obtained. The distance between two images is noted. In the first position the distance is d_1.

iii) The lens is again moved towards the eye-piece to obtain the second position where again two sharp and focused images are obtained. The distance in this case is denoted by d_2. Knowing d_1 and d_2, 2d can be calculated by using the formula:

$$2d = \sqrt{(d_1 d_2)}$$

Result: Wavelength of sodium light λ = ...Å

Standard value of λ = ...Å

% Error = ...%

Observations:

Pitch of the screw = ...mm

No. of divisions on the micrometer screw = ...mm

L.C. of micrometer screw = ...mm

Table 11.1: Determination of fringe-width β

Fringe No.	Micrometer reading (a)			Fringe No.	Micrometer reading (b)			Diff. of 20 fringes (b-a)	Mean of 20 fringes (<20β>) (mm)	Fringe Width β= <20β>/20 (mm)
	M.S.R. (mm)	C.S.R (mm)	T.R (mm)		M.S.R. (mm)	C.S.R (mm)	T.R (mm)			
1				21						
3				23						
5				25						
7				27						
9				29						
11				31						
13				33						
15				35						
17				37						

(2) Measurement of L:

Position of upright carrying slit = ...mm

Position of upright carrying the eyepiece = ...mm

Observed value of L = ...mm

Value of L for bench error = ...mm

Measurement of 2d:

Table 11.2(a): Measurement of d_1

Image No.	Micrometer reading				d_1 ($<x_2>-<x_1>$) (mm)
	1st position of the lens				
I	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_1) (mm)	Average value of x_1 $<x_1>$/mm	
II	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_2) (mm)	Average value of x_2 $<x_2>$/mm	

Table 11.2(b): Measurement of d_2

Image No.	Micrometer reading				d_2 ($<x_2>-<x_1>$) (mm)
	2nd position of the lens				
I	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_1) (mm)	Average value of x_1 $<x_1>$ (mm)	

II	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_2) (mm)	Average value of x_2 $\langle x_2 \rangle$ (mm)	

Hence $2d=\sqrt{d_1 d_2}$=..................................mm

Calculations:

$\lambda = \beta.2d/L$ = ...Å

Precautions and Sources of Error:

i) The setting of uprights at the same level is essential.

ii) The slit should be vertical and narrow.

iii) Fringe shift should be removed.

iv) Bench error should be taken into account.

v) Crosswire should be fixed in the center of the fringe while taking observations for fringe width.

vi) The micrometer screw should be rotated only in one direction to avoid backlash error.

vii) The fringe width should be measured at a fairly large distance.

viii) Convex lens of shorter focal length should be used (f = 25 cm approx)

ix) Motion of eyepiece should be perpendicular to the lengths of the bench.

Questionnaire:

1. What do you mean by interference of light?
2. Is there any loss of energy in the interference phenomenon?
3. What are the different types of interference?
4. What are interference fringes?
5. What is a Bi-prism?
6. Why are the refracting angles of the two prisms made so small?