Experiment No. 2

Object : *To determine the wavelength of monochromatic light by diffraction at a straight edge.*

Apparatus Required : An optical bench provided with three vertical stands, a sharp razor blade (*i.e.*, straight edge), micrometer eyepiece, sodium lamp, reading lamp and reading lens.

Description of the Apparatus : Fig. 5 shows the experimental arrangement. It consists of an optical bench of nearly 1·5 m long heavy base provided with four adjusting screws below it. A metre scale is graduated on the base. The bench is provided with three vertical stands which can be clamped at any position on the

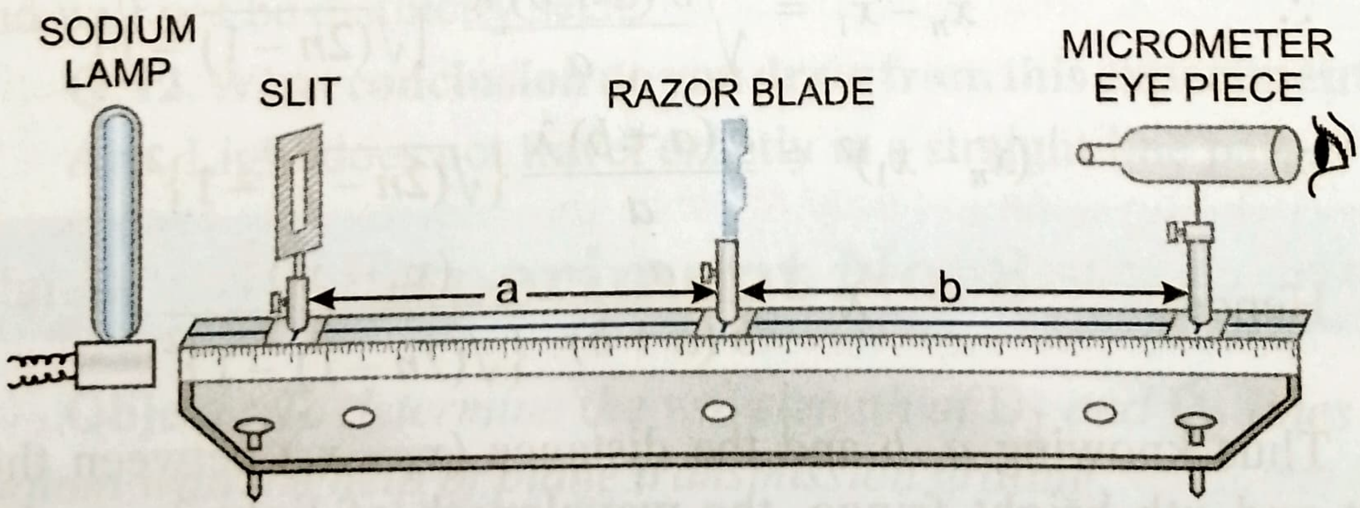

Fig. 5. Arrangement for Straight edge diffraction

bench. Each vertical stand can be moved along the length of the optical bench, can be moved perpendicular to its length and can be rotated about the vertical axis of the stand. On one vertical stand, slit is mounted; on the other the razor blade is mounted and on the third stand, the micrometer eyepiece is mounted. The slit is kept narrow and vertical. The razor blade is kept parallel to the length of the slit. The slit is illuminated with the monochromatic light (sodium lamp).

Theory : In Fig. 6, light from a narrow slit S illuminated with a monochromatic light source, is incident on a straight edge (such as edge of blade) E. The screen P (or the micrometer eyepiece) is kept at some distance from the razor blade, on which we study the distribution of intensity of light. The straight edge is parallel to the slit. The slit, straight edge and the screen are perpendicular to the plane of paper. The line joining the slit S and the straight edge E meets the screen at a point P_0. According to the rectilinear propagation of light, there must be perfect illumination on the screen above the point P_0 and complete darkness in the geometrical shadow region, below the point P_0. But experimentally we find that :

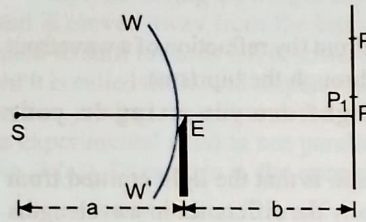

Fig. 6. Diffraction at a straight edge

(i) At the point P_0 on the screen (which is the point of projection of the straight edge E on the screen), the intensity of light is not maximum, but the intensity of light is maximum at a point P_1 slightly above the point P_0.

(ii) Above the point P_0 on the screen, there are alternate bright and dark fringes. As we move above the point P_0, the intensity of light on the bright fringes decreases and the intensity of light on the dark fringes increases. In addition to it, the separation between the fringes also decreases.

(iii) At a point far above the point P_0 on the screen, fringes disappear and there is perfect illumination.

(iv) Below the point P_0 on the screen, in the geometrical shadow region, there is no complete darkness, but as we go below and below the point P_0, the intensity of light rapidly decreases, ultimately there is complete darkness.

The position of nth bright fringe P on the screen is given as

$$x_n = \sqrt{\frac{b\,(a+b)\,\lambda}{a}}\;\sqrt{(2n-1)}$$

where a is the distance of straight edge from the slit and b is the distance of screen from the straight edge.

Hence for the first bright fringe $x_1 = \sqrt{\frac{b\,(a+b)\,\lambda}{a}}$

$$\therefore \quad x_n - x_1 = \sqrt{\frac{b\,(a+b)\,\lambda}{a}}\;[\sqrt{(2n-1)} - 1]$$

or $$(x_n - x_1)^2 = \frac{b\,(a+b)\,\lambda}{a}\,\{\sqrt{(2n-1)} - 1\}^2$$

Hence $$\lambda = \frac{a}{b\,(a+b)}\;\frac{(x_n - x_1)^2}{\{\sqrt{(2n-1)} - 1\}^2}$$

Thus knowing a, b and the distance $(x_n - x_1)$ between the first and nth bright fringe, the wavelength of light λ can be calculated.

Formula Used : Wavelength of light used

$$\lambda = \frac{a}{b\,(a+b)}\;\frac{(x_n - x_1)^2}{\{\sqrt{(2n-1)} - 1\}^2}$$

where a = distance of straight edge from the slit, b = distance of micrometer eyepiece from the straight edge, $(x_n - x_1)$ = distance of nth bright fringe from the first bright fringe.

Procedure : The experiment is performed in the following two steps :

(1) Adjustment to obtain fringes : (i) First the optical bench is made horizontal with the help of spirit level and levelling screws provided below the base. All the three vertical stands are adjusted at the same vertical height.

(ii) The eyepiece is moved to and fro within the eyepiece tube so that the cross-wires are distinctly seen. One cross-wire is made vertical.

(iii) Now the slit is illuminated with light from the sodium lamp and the slit is made as narrow as possible. Then the slit is made vertical by rotating the slit in its plane with the help of tangential screw.

(iv) The razor blade is mounted on the vertical stand such that its sharp edge is vertical. This stand is kept close to the slit.

(v) Then the eyepiece is moved perpendicular to the optical bench to see the diffraction fringes in the field of view. If the fringes are not distinct, the razor blade is rotated in its own plane with the help of tangential screw to make the fringes distinct.

(vi) Then the eyepiece is moved away from the razor blade. If there is lateral displacement in the fringes, the lateral displacement is removed by the method described in bi-prism experiment no. 1.

(2) Measurement of Position of Fringes : (i) First note the least count of the micrometer screw of the eyepiece.

(ii) Now the eyepiece is placed at a distance from the razor blade such that distinct diffraction fringes are seen in the field of view. Then with the help of micrometer screw, the vertical cross-wire is made to coincide with the first bright fringe and the reading of micrometer screw is noted.

(iii) Then moving the micrometer screw, the vertical cross-wire is made to coincide the consecutive bright fringes of different orders and each time the reading of micrometer screw is noted.

(iv) The positions of slit stand, razor blade stand and the eyepiece stand on the optical bench, are noted.

Observations : Pitch of the micrometer screw = ... cm.

Total number of divisions on the circular scale = ... cm

Least count

$$= \frac{\text{Pitch}}{\text{Total number of divisions on the circular scale}}$$

= .... cm.

No. of fringe	Reading of micrometer screw			Distance between the first and nth bright fringes	
	M.S. reading (in cm)	C.S. reading (in cm)	Total reading x (in cm)	$x_n - x_1$ (in cm)	n
1.	.....	.....	x_1 = ...		
2.	.....	.....	x_2 = ...	$x_2 - x_1$ = ...	2
3.	.....	.....	x_3 = ...	$x_3 - x_1$ = ...	3
4.	.....	.....	x_4 = ...	$x_4 - x_1$ = ...	4
5.	.....	.....	x_5 = ...	$x_5 - x_1$ = ...	5
6.	.....	.....	x_6 = ...	$x_6 - x_1$ = ...	6

Position of slit on the optical bench p = ... cm
Position of razor blade on the optical bench q = ... cm
Position of eyepiece on the optical bench r = ... cm
∴ Distance of razor blade from the slit $a = p \sim q$ = ... cm
Distance of eyepiece from the razor blade $b = q \sim r$ =..... cm

Calculations : Substituting the values of a, b, $(x_n - x_1)$ and n in the formula $\lambda = \dfrac{a\,(x_n - x_1)^2}{b\,(a+b)\,\{\sqrt{(2n-1)} - 1\}^2}$, the value of λ can be calculated for each observation and then the mean value of λ is obtained. Since a, b and $(x_n - x_1)$ are in cm, the value of λ so obtained is in cm.

For the first observation, $\lambda = \dfrac{a\,(x_2 - x_1)^2}{b\,(a+b)\,\{\sqrt{3} - 1\}^2}$ = ... cm

For the second observation, $\lambda = \dfrac{a\,(x_3 - x_1)^2}{b\,(a+b)\,\{\sqrt{5} - 1\}^2}$ =..... cm

....

....

Mean value of λ = ... cm = ...Å
(where 10^{-8} cm = 1 Å)

Result : Wavelength of monochromatic light source (.....)
λ = ...Å

Standard value : λ = ...Å (From the standard tables)

Percentage error :

Percentage error

$$= \frac{\text{Standard value} \sim \text{Experimental value}}{\text{Standard value}} \times 100\%$$

= .....%

Permissible Percentage error : The permissible percentage error in the value of λ is

$$\left(\frac{\Delta\lambda}{\lambda}\right) \times 100\% = \left\{\frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{2\,\Delta a}{(a+b)} + 2 \times \frac{\Delta x}{(x_n - x_1)}\right\} \times 100\%$$

= .....%

where $\Delta a = \Delta b$ = least count of the scale graduated on the optical bench, and Δx = least count of the micrometer screw.

Precautions : (1) The slit, the straight edge and the eyepiece must be at the same vertical height.

(2) The slit must be as narrow as possible and vertical.

(3) There must not be lateral displacement in the fringes. It should be removed before taking the observations.

(4) To avoid the backlash error, the micrometer screw should always be rotated in one direction.

(5) The razor blade should be sharp.

Viva-Voce

Q. 1. On what phenomenon of light does your experiment depend ?

Ans. On diffraction.

Q. 2. What do you mean by diffraction of light ?

Ans. When light is incident on an opaque obstacle or an aperture, it bends at the corners of obstacle or aperture. This bending of light is called diffraction.

Q. 3. Does diffraction occur only in light, not in sound ?

Ans. Diffraction occurs both in light and sound. Actually, the diffraction is the property of waves.

Q. 4. Give one example of diffraction of sound in our daily life.

Ans. This is due to the diffraction of sound waves that the sound of a person speaking outside the room is easily heard inside the room.

Q. 5. Why is it easier to demonstrate the diffraction of sound waves as compared to that of light waves ?

Ans. The reason is that for diffraction, the size of the obstacle or the aperture must be of the order of wavelength of the wave. The wavelength of sound waves is very long as compared to that of light waves. Hence it is easy to demonstrate the diffraction of sound waves as compared to that of light waves.

Q. 6. What do you use as a straight edge, in your experiment ?

Ans. Razor blade.

Q. 7. Why are the fringes formed in your experiment ?

Ans. A part of the incident wavefront from the light source is obstructed by the razor blade (or the straight edge) and the rest part of it is exposed. From each point of the exposed part of wavefront, secondary wavelets are given out which superpose. As a result, diffraction fringes are formed.

Q. 8. How do these fringes differ from the biprism fringes ?

Ans. These (diffraction) fringes are of successively decreasing intensities, while the interference fringes in the biprism experiment are of uniform intensity. The distance between the two consecutive bright diffraction fringes gradually decreases, while in the biprism experiment the interference fringes are equidistant.

Q. 9. How does the diffraction in your experiment differ from that in grating experiment ?

Ans. In this experiment, the diffraction is of Fresnel's class in which both the light source and the point of observation are at finite distance. But in the grating experiment, the diffraction is of Fraunhofer's class in which the light source and the point of observation both are effectively at infinity.

Q. 10. What light source do you use in your experiment ?

Ans. Monochromatic light source (sodium lamp).

Q. 11. Can you perform your experiment with a white light source ? Give reason.

Ans. No. The reason is that if white light source is used, we shall get only few coloured fringes near the edge in the order from violet to red. The fringes of higher orders will overlap each other and will not be distinctly seen.

Q. 12. What conclusion do you draw from this experiment ?

Ans. Light does not travel exactly in a straight line path.

Experiment No. 3

Object : *To determine the wavelength of* D_1 *and* D_2 *lines of sodium with the help of plane transmission grating.*

Apparatus Required : Plane transmission grating, spectrometer, sodium lamp, prism, reading lamp and reading lens.

Description of the Apparatus : (a) Spectrometer : The spectrometer is shown in Fig. 7. It consists of three parts : (1) the collimator, (2) the prism table, and (3) the telescope.