# Interference part-2

## 4.11 FRESNEL'S BIPRISM

Fresnel biprism consists of two acute angle prisms with their bases in contact. Generally the angles are $179^0$, 30' and 30' as shown in figure 4.9. The light coming from a source is allowed to fall symmetrically on a biprism as shown in figure 4.9. As we know, when a light beam is incident on a prism, the light is deviated from its original path through an angle called angle of deviations. Similarly in case of biprism, the light beam coming from source S, is appeared to be coming from $S_1$ and $S_2$ as shown in figure 4.10. Thus we can say for prism $S_1$ and $S_2$ behave as virtual sources for the biprism.


**Fig. 4.9**

In case of biprism, it can be considered that two cones of lights $AS_1Q$ and $BS_2P$ are coming from $S_1$ and $S_2$ and superimposed on each other and produce interference fringes in the region of superposition (between AB). The formation of interference fringes due to Fresnel's biprism is the same as due to Young's double slit experiment.

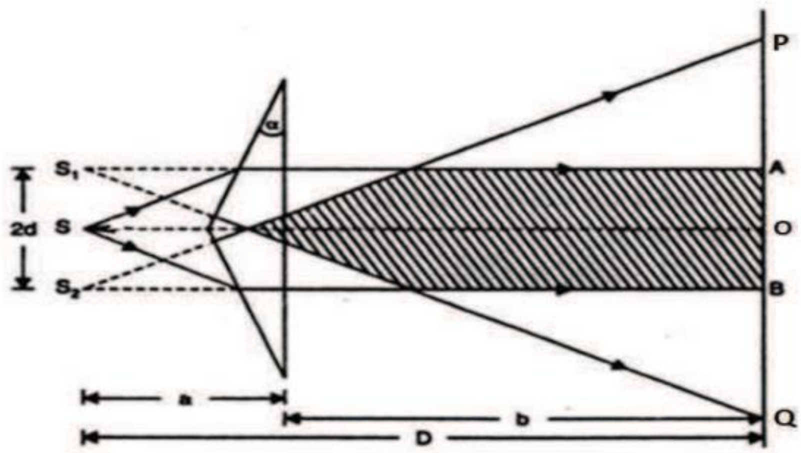


**Fig. 4.10**

In this experiment point O is equidistance from both slits $S_1$ and $S_2$. If we consider distance between source and screen is D and separation between two slits $S_1$ and $S_2$ is 2d the fringe width can be given as

$$\omega = \frac{D\lambda}{2d}$$

The position of $n^{th}$ bright fringe is given by $y_n = n \frac{D\lambda}{2d}$

Similarly the position of $n^{th}$ dark fringe is given by $y_n = \frac{2n-1}{2} . \frac{D\lambda}{2d}$

The wave length of the light source used in biprism experiment can be obtained by using above relation as

$$\lambda = \omega \frac{2d}{D} \qquad \text{....... (4.21)}$$

## 4.11.1 Experimental Arrangement of Biprism Apparatus

The experiment is performed on an optical bench as shown in figure 4.11. In this experiment we have an optical bench, which is an arrangement of two parallel metallic rods which are horizontal at same label. The rods or optical bench carry upright on which optical instruments are mounted. These upright are movable on the rods. In the first uprights, we have a slit illuminated by a monochromatic light source S. The slit provides a linear monochromatic light to the biprism which is mounted on the second upright. The biprism is placed in such a way that its refracting edges parallel to the slit so that light falls symmetrically on the biprism. In third upright there is a concave lens for conversing the light coming from biprism. Finally on forth upright a micrometer eyepiece is mounted in which interference fringes are observed.

For obtaining fringes, following adjustments are to be made.

(i) The optical bench is leveled with the help of spirit level.
(ii) Axis of slit is made parallel to edge of biprism.
(iii) The heights of all four uprights should be same so that line joining slit, biprism and micrometer should be parallel to optical bench.

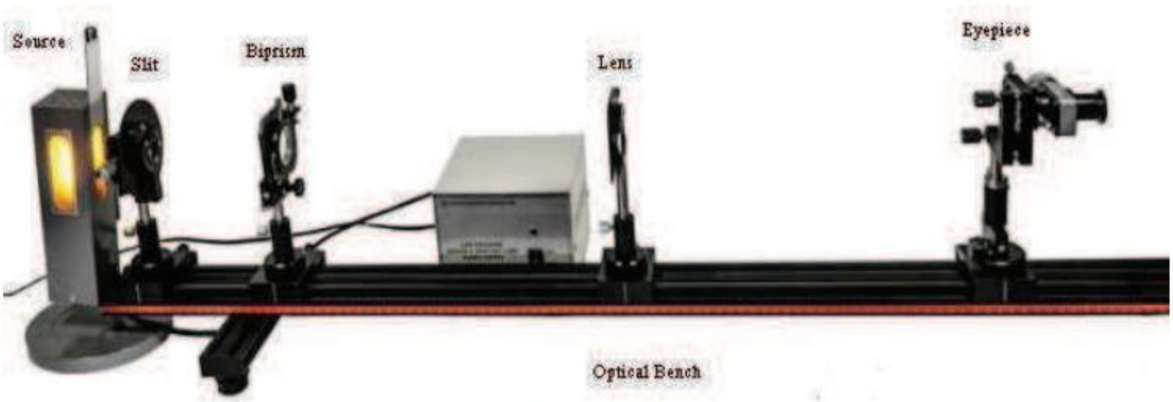


**Figure 4.11**

## 4.11.2 Lateral Shift

If the eyepiece of micrometer is moved away from the biprism, and fringes shift either left or right of bench then it is called lateral shift. Simply, we can say the shift of fringes across the bench is called lateral shift. It indicates that the line joining the slit biprism and eyepiece is not parallel to the optical bench.

To remove the lateral shift we put the eyepiece near the birprism and fix the vertical crosswire on any fringe. Now micrometer eyepiece is moved some distance away from biprism and direction of fringe shift is observed. Now biprism is moved in the direction opposite to the fringe shift so that vertical crosswise again reached on same fringe. We repeat this process again and again so that lateral shift removes compatibly.

### 4.11.3 Measurement of Wavelength of Light (λ) by Fresnel Biprism

By using the Fresnel biprism we can determine the wavelength of given source of light. For this purpose we use the given light source in experimental arrangement. We adjust the apparatus for fringes are to be observed on the eyepiece. We measure the fringe width on apparatus and apply the formula for fringe width as

$$\omega = \frac{D\lambda}{2d} \qquad \text{or} \qquad \lambda = \omega . \frac{2d}{D}$$

Fringe width $\omega$ can be measured with the help of micrometer on eyepiece. D is the distance between eyepiece and slit, and can be measured with the help of optical bend. The 2d is the distance between two virtual sources ($S_1$ and $S_2$) and cannot be measured directly with the help of any scale. We apply two methods for the measurement of distance 2d.

### Magnification Method

To determine the distance 2d, we placed a convex lens of short focal length between biprism and screen. We find out a position $L_1$, of lens very near to biprism so that two sharp real images are obtained in the field of view of eyepiece. In figure 4.12 the position of Lens $L_1$ is denoted by bold lines. In this position, we measure distance between two images $d_1$, with the help of micrometer of eyepiece.

For this position the magnification is given by

$$\frac{v}{u} = \frac{d_1}{2d}$$

Now we move the lens some distance away from the biprism and obtain another position $L_2$ so that two sharp images are seen again in the field of view. We again measure the distance between two images, say $d_2$ with the help of micrometer of eyepiece.

In this case of position $L_2$ the magnification is given as

$$\frac{u}{v} = \frac{d_2}{2d}$$

By using above two equations (10) and (11) we get:

$$1 = \frac{d_1}{2d} . \frac{d_2}{2d}$$

or

$$2d = \sqrt{d_1 d_2} \qquad \text{....... (4.22)}$$

By putting the value of $d_1$ and $d_2$ we can determine the value of 2d.

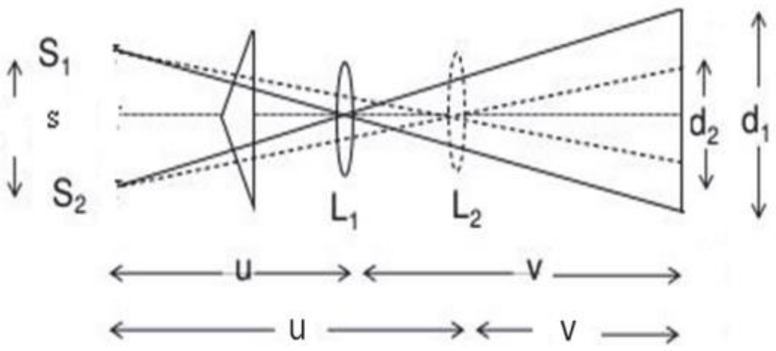


**Figure 4.12**

## Refractive Index Method

In this method, we use the formula of angle of deviation for a prism. As shown in figure 4.13 the angle of deviation can be given as

$$\delta = (\mu - 1)\,\alpha \qquad \text{....... (4.23)}$$

Where μ is refractive index and α is angle of prism as shown in figure 4.13. Again the angle of deviation can be given as.

$$\delta = \frac{d}{a} \text{ or } d = a\,\delta \qquad \text{....... (4.24)}$$

Using equations (4.23) and (4.24), we obtain, 2d = 2a $\delta$

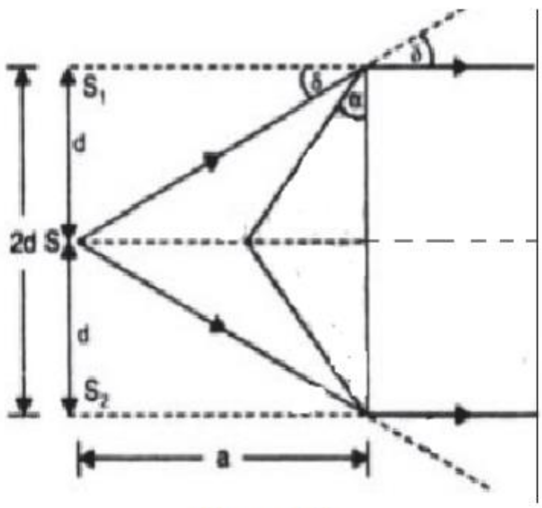


**Figure 4.13**

or $$2d=2a\,(\mu-1)\,\alpha \qquad \text{....... (4.25)}$$

By using any of the above mentioned methods, we can determine the value of 2d and then putting this value is equation 4.21, we can determine the wavelength of given light source.

## *4.12 INTERFERENCE WITH WHITE LIGHT*

Now let us discuss what happen when the monochromatic light source in a Young's double slit experiment is replaced by a white light. Since the white light consists innumerable wavelengths from red to violet, when white light is used, all wavelengths have their own fringe pattern and finally superimposed on each other. Since the path different for all colours at center point is same then the waves of all colours reach at mid point without any path difference and we observed a white fringe at Center point. This central fringe is called zero order fringes. After central fringe, we observed few coloured fringes with poor contrast. These fringes are due to superposition of different fringes of different colours. Thus the interference pattern is not clear but the superposition of many colours.

### Self Assessment Questions

1. What is difference between coherence and non coherence light?
2. Why non-coherent sources do not produce interference pattern?
3. What are the conditions for sustainable interference?
4. Young's double slit experiment, why the central fringe is bright?
5. How can we arrange coherence sources in practical?
6. What is meant by interference of light?
7. Explain the principle of superposition of light wave?
8. How is the shape of fringes formed by biprism?

## *4.13 SOLVED EXAMPLES*

**Example 4.2:** A monochromatic light of wave length 5100 Å from a slit is incident on a double slit. If the overall separation of 30 fringes on a screen 200 cm always is 3cm, find the distance between slits.

**Solution:** The fringe width $\omega = \frac{D\lambda}{2D}$

Where $\omega$ = fringe width, D = distance between slit and screen, 2d= distance between slits.

It is given that D =200 cm, $\omega = \frac{3}{30} = 0.1cm$

Therefore, $2d = D\lambda/\omega = \frac{5100 \times 10^{-8} \times 200}{0.1} = 0.025$ cm

**Example 4.3**: In Young's double slit experiment the two slits are 0.05 mm apart and screen is located 2m away from the slit. The third bright fringe from the slit is displaced 8.3 cm apart from the central fringe. Determine the wavelength of incident light.

**Solution:** For the third bright fringe n= 3

$x_n = \frac{nD\lambda}{2d}$ or $\lambda = \frac{x_n.2d}{nD} = \frac{8.3 \times 10^{-2} \times 0.05 \times 10^{-3}}{3 \times 2} = 6.91 \times 10^{-7}$ m = 6910 Å

**Example 4.4:** In Fresnel's biprism experiment, a light of wavelength 6000 Å falls on biprism. The distance between source and screen is 1m and distance between source and birprism is 10 cm. The angle of biprism is $1^0$. If the fringe width is 0.03cm, find out the refractive index of the material of biprism.

**Solution:** The fringe width $\omega = \frac{D\lambda}{2d}$

If the refractive index of material is μ and angle of prism is $\alpha$ then

2d = 2a (μ-1) $\alpha$. Then $\omega = \frac{D\lambda}{2a\,\omega(\mu-1)\,\alpha}$

Here, D = 1m = a+b and a= 10 cm, b= 90cm, $\lambda$= 6000× $10^{-8}$ cm, $\alpha = 1^0 = \frac{\pi}{180}$ radian and $\omega$ = 0.03 cm

Thus, $\mu\text{-}1 = \frac{D\lambda}{2a\,\omega\alpha} = \frac{100\times6000\times10^{-8}}{2\times10\times0.03\times\frac{\pi}{180}} = 0.57$

∴ $\mu = 1+0.57 = 1.57$

**Example 4.5:** A light of wavelength 6900 Å is incident on a biprism of refracting angle $1^0$ and refractive index 1.5. Interference fringes are observed on a screen 80 cm away from the biprism. If the distance between source and the biprism is 20 cm, calculated the fringe width.

**Solution :** The fringe width is given by $\omega = \frac{D\lambda}{2d}$ and 2d =2( μ-1)a$\alpha$

Here λ=6900 Å =6900 ×$10^{-8}$ cm, $\alpha = 1^0 = \frac{\pi}{180}$ redius, μ = 1.5, D = a+b = (20+80) cm =100cm

$$\omega = \frac{D\lambda}{2a(\mu-1)\alpha} = \frac{100\times6900\times10^{-8}}{2\times20\times(1.5-1)\times\frac{\pi}{180}} = 0.02 \text{ cm.}$$

**Example 4.6:** A thin sheet of a transparent material of refractive index μ =1.60 is placed in the path of one of the interfering beam in a biprism experiment. The wave length of the light used is 5890Å. After placing the sheet, the central fringe shifted to a position originally occupied by 12th bright fringe. Calculate the thickness of the sheet.

**Solution:** On introducing a thin transparent sheet in the path of one interfering say, the interfering system is shifted by a distance x and

$$x = \frac{D}{2d}(\mu-1)t$$

In this case the fringe shifted by 12th bright fringe.

$$x = y_{12} = 12\,\frac{D}{2d} \qquad [\because y_n = n\,\frac{D\lambda}{2d}]$$

Therefore, $12\,\frac{D\lambda}{2d} = \frac{D}{2d}(\mu-1)t$ or $t = \frac{12\lambda}{(\mu-1)} = \frac{12\times5890\times10^{-8}}{(1.6-1)} = 1.18\times10^{-3}$ cm