23.14 FRESNEL'S DOUBLE MIRROR METHOD

Fresnel used two plane mirror OM_1 and OM_2 silvered in the front, placed close together, so that their planes make a very small angle θ with each other, to produce two coherent sources. Light from a narrow slit S placed parallel to the mirror and illuminated by monochromatic light is made to fall on the mirrors. The mirrors OM_1 and OM_2 give rise to two virtual images S_1 and S_2 respectively. If a screen XY is placed, as shown in Fig. 23.15 interference fringes are obtained in the region CD where the two reflected beams reaching A and B, and C and D appear to come respectively from the virtual sources S_1 and S_2, overlap. These fringes are equally spaced and can be observed in the field of view of a micrometer eye-piece.

If d is the distance between the two virtual images of the sources S_1 and S_2 and x the distance of O from the centre of the line joining S_1 and S_2 and y the distance OO' from the screen, then

Fringe width
$$\beta = \frac{\lambda D}{d} = \frac{\lambda(x+y)}{d} \quad \text{... (i)}$$

Where λ is the wavelength of monochromatic light

The angle subtended by $S_1 S_2$ at O is 2 θ.

∴
$$d = x\, 2\theta = 2\, x\, \theta$$

Substituting the value of d in (i), we have

$$\beta = \frac{(x+y)\lambda}{2x\theta} \quad \text{...(23.20)}$$

As θ is small and y is large, the fringes are seen as separate

∴
$$\lambda = \frac{2x\theta}{x+y}\beta \quad \text{... (23.21)}$$

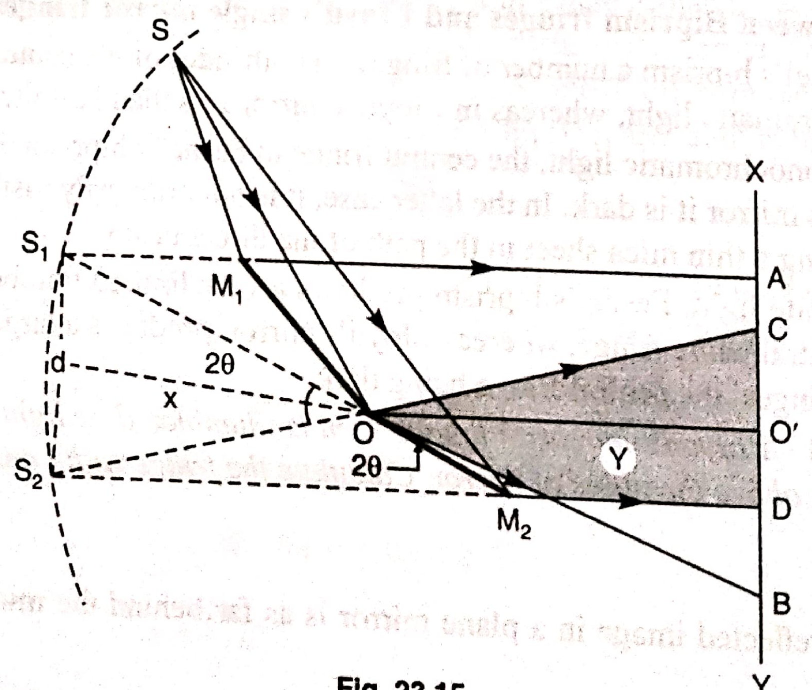

Fig. 23.15

Example 23.19 *A pair of Fresnel's double mirrors, making an angle of 2°, are held at a distance of 10 cm from a slit source emitting light of wavelength 600 Å. Find the fringe-width on a screen distant one metre from the intersection of the mirrors.*

Solution. Here
$$\theta = 2° = \pi/90 \text{ radian}, \lambda = 6000 \text{ Å} = 6 \times 10^{-7} \text{ m}$$
$$x = 10 \text{ cm} = 0.1 \text{ m}, y = 1\text{m}$$

Now
$$\beta = \frac{(x+y)\lambda}{2x\theta} = \frac{1.1 \times 6 \times 10^{-7} \times 90}{2 \times 0.1 \times \pi}$$
$$= 0.945 \times 10^{-4} \text{ m}$$

***Example 23.20** In interference with white light fringe width of red coloured fringes is double than that of violet coloured. Why?* **(P.U. 2000)**

Solution. The wave length of violet light is about 4000 Å and that of red light is about 8000 Å i.e. the wave length of red light is about twice that of violet light. The fringe width is given by $\beta = \lambda \frac{D}{d}$ i.e. β is proportional to λ.

Hence thickness of red fringe $\beta_r = \lambda_r \frac{D}{d}$

and thickness of violet fringe $\beta_v = \lambda_v \frac{D}{d}$

$$\therefore \quad \frac{\text{Thickness of red fringe}}{\text{Thickness of violet fringe}} = \frac{\beta_r}{\beta_v} = \frac{\lambda_r}{\lambda_v} = \frac{8000\,Å}{4000\,Å} = 2$$

Hence fringe width of red coloured fringes is double than that of violet coloured.

23.15 RAYLEIGH REFRACTOMETER

Rayleigh devised the arrangement to measure refractive Index of a gas. The principle is explained by Fig. 23.16.

The slits S, S_1 and S_2 make Young's double-slit device, and the two coherent beams pass through separate tubes A and B, in one of which the gas pressure may be varied. Interference fringes are observed in the focal plane of lens L_2. Pressure change in any tube makes fringes shift laterally across the cross-wire of the eyepiece E. If tube length is L, then

$$L.\,\Delta\mu = m\,\lambda$$

where m is the number of fringes passing. The refractive index for any pressure can thus be obtained, since $(\mu - 1)$ is proportional to the pressure. It may be noted that the tubes may have to be about a metre long (unlike the very thin sheet t in Fig. 23.11). Since $(\mu - 1)$ for gas is of the order of 10^{-4}. This is also known as Rayleigh interferometer.

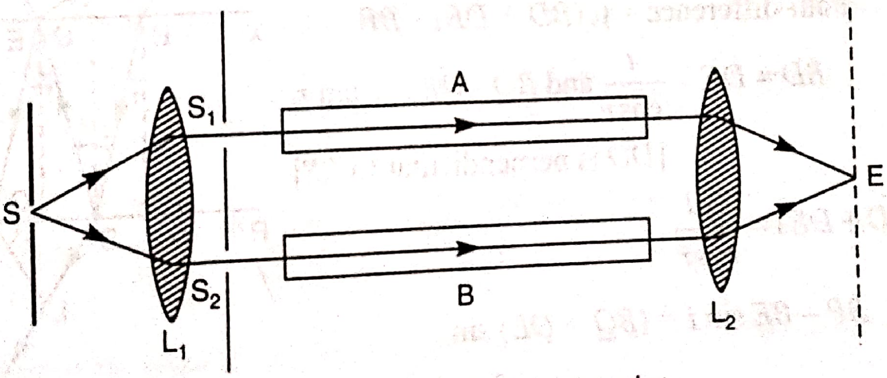

Fig. 23.16. Rayleigh Refractometer

23.16 INTERFERENCE BY DIVISION OF AMPLITUDE

Consider a thin plate $PQRS$ of a transparent material. A ray of light AB is incident on its surface PQ. It is partially reflected along BC and partially refracted along BD. The refracted ray BD is again partially reflected along DB' at the surface RS and partially refracted along DE. The reflected ray DB' is again reflected and refracted partially, and the process continues as shown in Fig. 23.17. Finally we get a number of parallel rays BC, $B'C'$, $B''C''$... etc in the reflected system and DE, $D'E'$, $D''E''$ ... etc in the transmitted system. The process of division of amplitude begins with the first reflection at B and at every further reflection or refraction the amplitude (and hence the intensity) of the light wave goes on decreasing *i.e., the amplitude goes on suffering further and further division.*