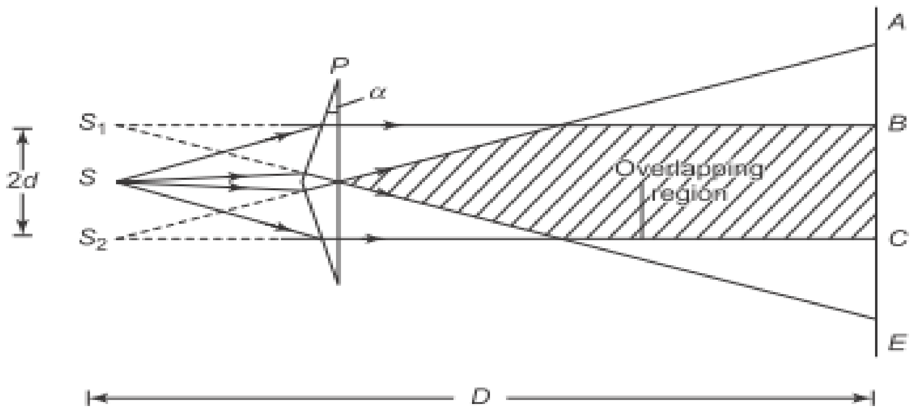
Interference

UNIT III
Optics
Lecture-2



Content of Lecture

- CONDITIONS FOR INTERFERENCE
- COHERENT SOURCES
- PRODUCTION OF COHERENT SOURCES
- FRESNEL’S BIPRISM
- DISPLACEMENT OF FRINGES
- INTERFERENCE DUE TO THIN FILMS (DIVISION OF AMPLITUDE)

Conditions for interference of light

Conditions for sustained interference

(i) The two interfering waves should be coherent, i.e., the phase difference between them must remain constant with time.

(ii) The two waves should have same frequency.

(iii) If the interfering waves are polarised, they must be in the same state of polarisation.

Conditions for interference of light Contd…

Conditions for observation

(i) The separation between the light sources (2d) should be as small as possible.

(ii) The distance D of the screen from the two sources should be quite large.

Conditions for good contrast

(i) The amplitudes of the interfering rays should be equal or at least nearly equal.

(ii) The two sources must be narrow.

COHERENT SOURCES

- Two sources are coherent if the waves they emit maintain a constant phase relation.
- Effectively, this means that the waves do not shift relative to one another as time passes.
- Lasers are coherent sources of light, while incandescent light bulbs and fluorescent lamps are incoherent sources

- **No Interference by Independent Sources**

Production of Coherent Sources of Light

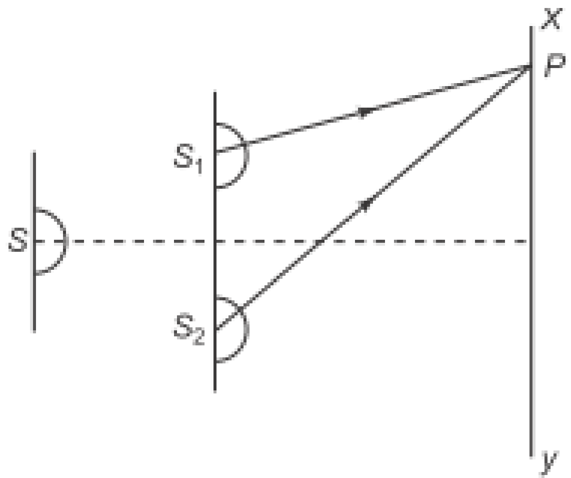
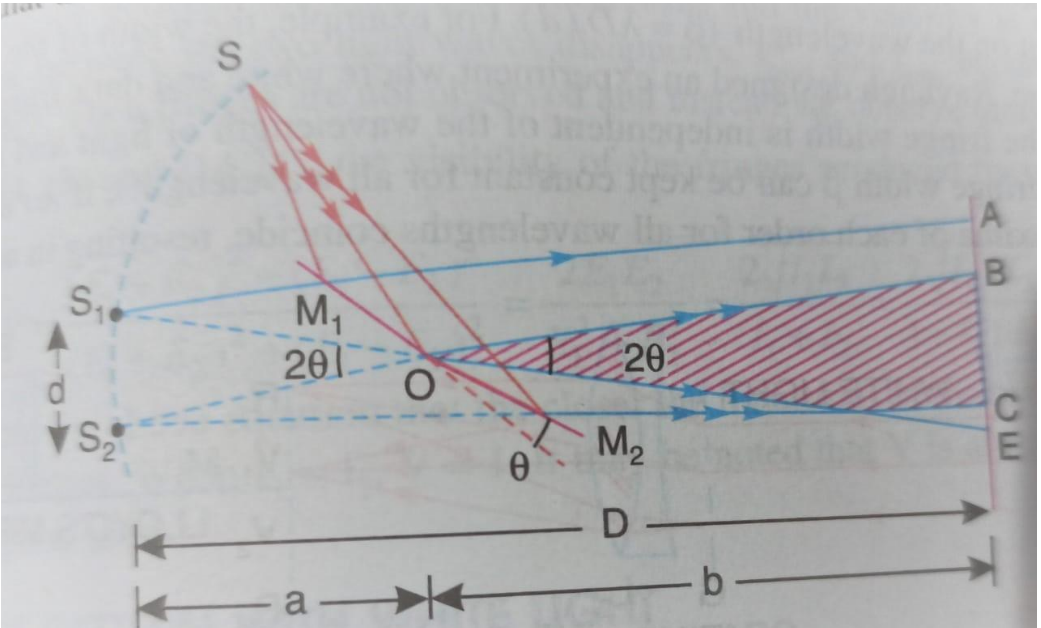


Fig. 12.6 Young's double slit

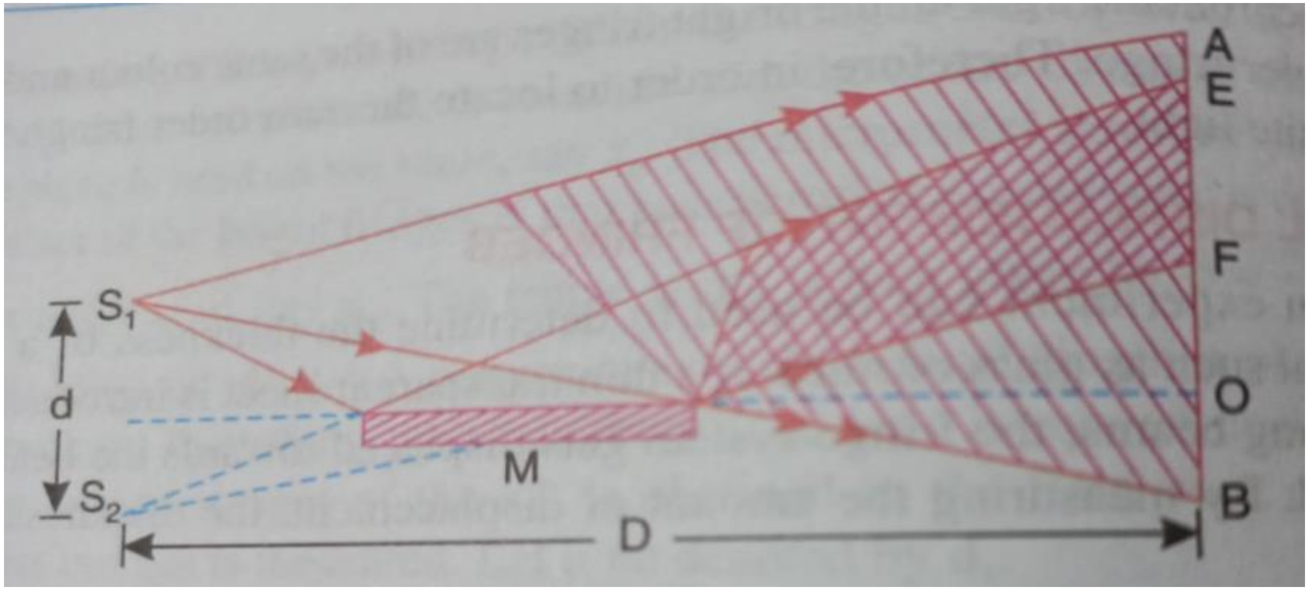


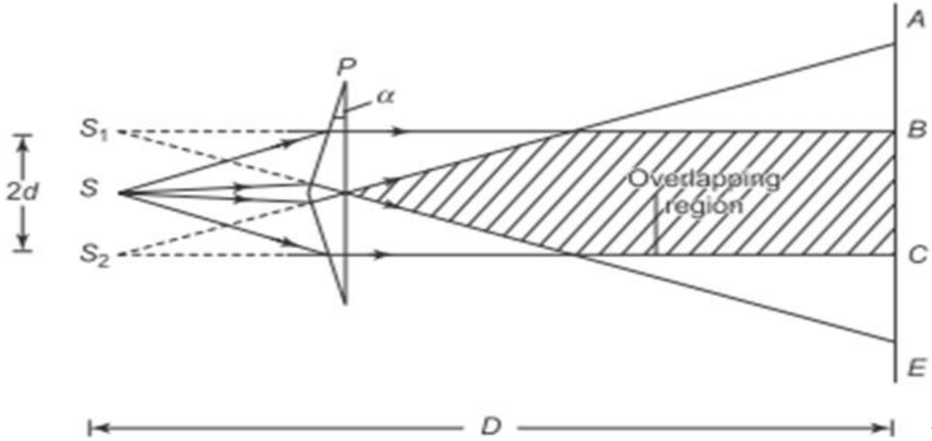
Fresnel's mirrors.

Fresnel's double mirror:

Production of Coherent Sources of Light

Llyod's single mirror:



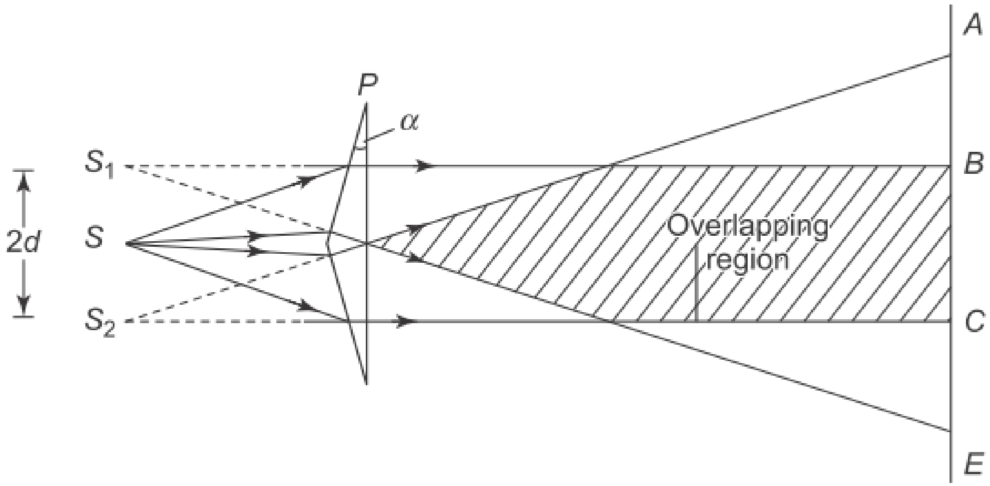


Fresnel's Biprism

FRESNEL'S BIPRISM

- It is a device which can produce two coherent sources for getting sustained interference.
- It is made from a single plate by grinding and polishing, so that it is a single prism with one of its angles about 179° and the other two obviously 30' each.

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



Experimental Method for Determination of Wavelength

- To obtain sharp fringes, following adjustments are made:

- (i) The optical bench is properly levelled with the help of sources provided with the optical bench.
- (ii) The eyepiece is focused on the cross-wires.
- (iii) All the uprights are adjusted to same vertical height.
- (iv) The axis of the slit is made vertical so that light can be incident normally on the biprism.
- (v) The edge of the biprism and the centre of the slit are made parallel.

Measurements

Fringe width (β): $$\beta = \frac{\text{Difference of micrometer readings}}{\text{Number of fringes counted}}$$

Measurement of D: The distance between slit and eyepiece on the optical bench will give the value of D.

Measurement of 2d: Displacement method is used to calculate the distance between sources. As shown in Fig., at position L_1 we have

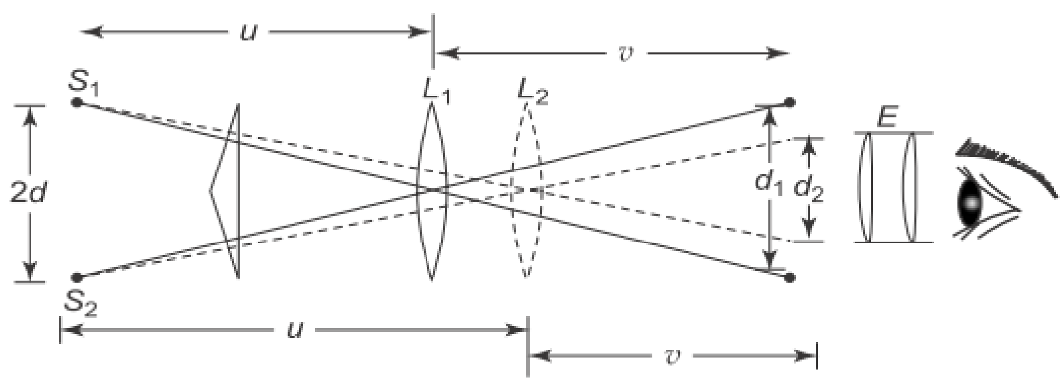
$$\frac{d_1}{2d} = \frac{v}{u}$$

and at position L_2 we have

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

which gives $$\frac{d_1 d_2}{4d^2} = 1$$

or $$2d = \sqrt{d_1 d_2}$$



$$\lambda = \beta\left(\frac{2d}{D}\right)$$

DISPLACEMENT OF FRINGES

- S_1 and S_2 be the two coherent sources emitting light of wavelength λ. Let a thin plate of thickness t and refractive index μ be introduced in the path of light ray from S_1.

- If the velocity of the ray in plate be v, the time taken by the ray from S_1 to P is given as

$$= \frac{S_1P - t}{c} + \frac{t}{v}$$

$$= \frac{S_1P - t}{c} + \frac{\mu t}{c}$$

$$= \frac{S_1P + (\mu - 1)t}{c}$$

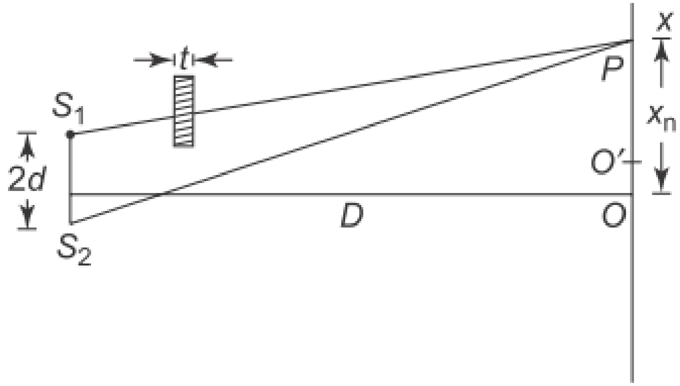
Now at point P, the effective path difference

= S_2P – [S_1P + (μ – 1) t]

$$= S_2P - S_1P - (\mu - 1)\,t$$

However, for the arrangement shown in Fig.

$$S_2P - S_1P = \frac{2d}{D} x_n$$



∴ Effective path difference at $P = \frac{2d}{D} x_n - (\mu - 1)t$

If the point P is the centre of the nth bright fringe, we can write

$$\frac{2d}{D} x_n - (\mu - 1)\, t = n\lambda$$

$$\boldsymbol{x_n} = \frac{\boldsymbol{D}}{\boldsymbol{2d}} n\lambda + \frac{\boldsymbol{D}}{\boldsymbol{2d}} (\mu\text{-}1)t$$

In the absence of plate (t = 0), the distance of nth bright fringe from centre O is $\frac{D}{2d}$ nλ . Therefore, the displacement of nth bright fringe is given by

$$OO' = x_0 = \frac{D}{2d}(\mu - 1)t$$

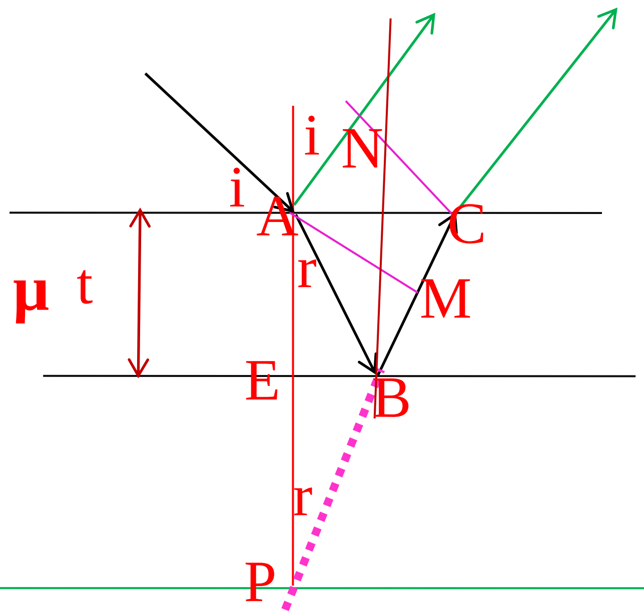
$$x_0 = \frac{\beta}{\lambda}(\mu - 1)t \quad \left(\because \beta = \frac{D\lambda}{2d}\right)$$

Thus, the entire fringe pattern is shifted by a distance

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

INTERFERENCE DUE TO THIN FILMS (DIVISION OF AMPLITUDE)

When a thin film of oil (transparent material) spread over the surface of water is illuminated by light, interference occurs between the light waves reflected from the film and also between the light waves transmitted through the film



Path diffidence between interfering waves can be given as

(AB+BC) μ-AN

=(AB+BC) μ-μMC

=(AB+BM) μ

=(PB+BM) μ

= μPM

=2 μt cos r

Now the actual path diff.

2 μt Cos r ± λ/2

Conditions of maxima and minima in reflected light

The two rays will give maximum when

$$2\mu t\cos r - \frac{\lambda}{2} = n\lambda^{*},\ n = 0, 1, 2,\ldots$$

or $$2\mu t\cos r = (2n+1)\frac{\lambda}{2}$$

In this condition, the film will appear bright in the reflected light.
The two rays will give minimum when

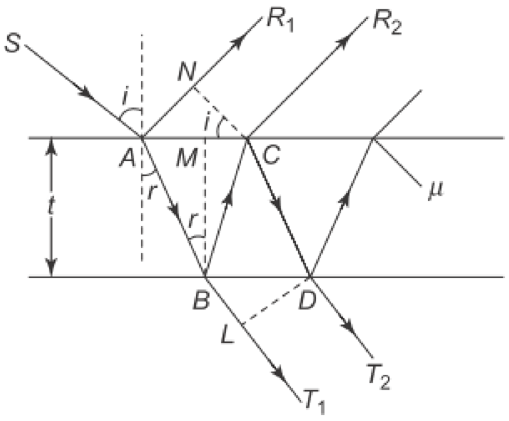
$$2\mu t\cos r - \frac{\lambda}{2} = (2n-1)\frac{\lambda}{2}$$

or $$2\mu t\cos r = n\lambda$$

Interference Due to Transmitted Rays

The path difference between the transmitted rays BT_1 and DT_2 is given by

$$p = \mu(BC + CD) - BL$$
$$= 2\mu t \cos r$$



- In this case, there is no phase change due to reflection at B or C because in either case the light is travelling from denser to rarer medium. Hence, the effective path difference between transmitted rays is also 2μt cos r.

Conditions for Maxima and Minima in Transmitted Light

The two rays will reinforce each other if

$$2\mu t \cos r = n\lambda$$

The film will then appear bright in the transmitted light.

The two rays will interfere destructively if $2\mu t \cos r = (2n+1)\dfrac{\lambda}{2}$

Example-1 In a biprism experiment, the eyepiece was placed at a distance of 120 cm from the source. The distance between the two virtual sources was found to be 0.075 cm. Find the wavelength of light used if the eye-piece has to be moved through a distance of 1.888 cm for 20 fringes.

Solution

Given $\beta = \frac{1.888}{20} = 0.0944 \text{ cm} = 0.000944 \text{ m}$, $D = 120 \text{ cm} = 1.20 \text{ m}$, and $2d = 0.075 \text{ cm} = 0.00075 \text{ m}$.

From the relation $\beta = (D\lambda/2d)$, the wavelength

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

$$= \frac{0.000944 \times 0.00075}{1.20}$$

$$= 5900 \times 10^{-10} \text{ m} = 5900 \text{ Å}$$

Example-2: When a thin sheet of transparent material of thickness 6.3 x 10^{-4} cm is introduced in the path of one of the interfering beams, the central fringe shifts to a position occupied by the sixth bright fringe. If λ = 5460 Å, find the refractive index of the sheet.

Solution

Given $t = 6.3 \times 10^{-4}$ cm $= 6.3 \times 10^{-6}$ m, $\lambda = 5460$ Å $= 5460 \times 10^{-10}$ m, and $n = 6$.

Using the relation $(\mu - 1)\, t = n\lambda$,

$$\mu = \frac{n\lambda}{t} + 1$$

$$= \frac{6 \times 5460 \times 10^{-10}}{6.3 \times 10^{-6}} + 1 = 1.52$$

Assignment Based on this Lecture

- What are the conditions for interference
- Define coherent sources. Discuss the production of coherent sources of light.
- How to find the wavelength of light using Fresnel's biprism
- Obtain the expression for the displacement of fringes if transparent mica sheet is introduced in the path of one interfering wave.
- Obtain the conditions of interference due to thin films (division of amplitude)