Study Material / Sem. 2 / Interference / Dr. T. Ker

Class - 1

Phase Change on reflection : Stoke's Treatment

Let,

$a \rightarrow$ incident amplitude

$r \rightarrow$ fraction of incident amplitude reflected in medium (1) i.e, rarer medium $\Rightarrow$ reflection coeff.

$t \rightarrow$ fraction of incident amplitude transmitted from medium (1) $\Rightarrow$ i.e transmission coeff.

r' and t' are the reflection and transmission coeff. of med. (2) i.e, denser medium.

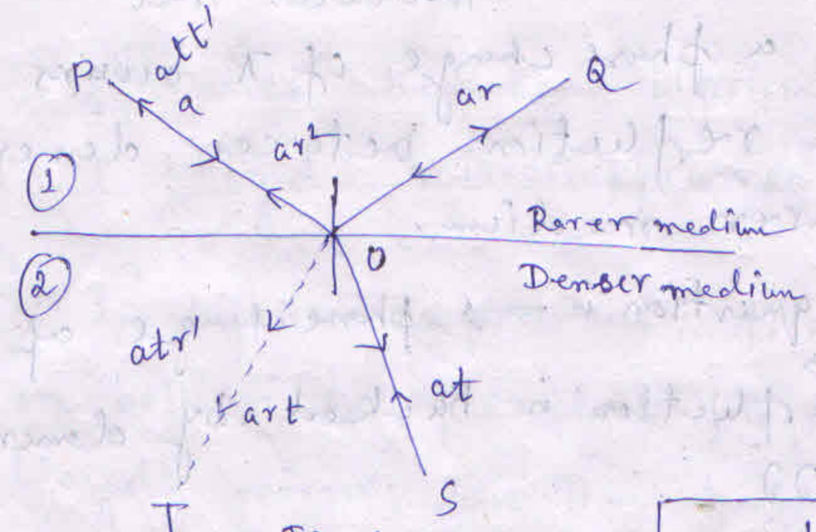


Fig. 1

If there is no absorption of light, then wave motion is completely an reversible phenomenon. So, if the reflected wave along OQ (having amplitude ar) be reversed, we get one reflected ray having amplitude ar^2 and one transmitted ray having amplitude art. Similarly by reversing the transmitted ray OS, we get one reflected ray having amplitude atr' and one transmitted ray having amplitude att'.

From, fig. ①, we get,

$a = ar^2 + att' \Rightarrow 1 - r^2 = tt'$

$0 = art + atr' \Rightarrow \boxed{r = -r'}$

$\Downarrow$ indicates That

a phase change of π occurs during reflection between denser and rarer medium.

Now The question is → phase change of π occurs →

i) when reflection is backed by denser medium ??

OR

ii) when reflection is backed by rarer medium ??

We get the answer from Lloyd's mirror experiment. In This experiment, The central fringe is dark. The central ~~frig~~ fringe froms at a point which is equidistant from both The coherent sources → so path difference is zero → the central fringe is bright. But in Lloyd's mirror expt, There is a phase change of π due to reflection backed by denser medium which makes the central fringe dark.

So, we can conclude that an phase change of π occurs due to reflection backed by denser medium.

Difference between biprism fringes and Lloyd's mirror fringes

i) In biprism experiment, fringes are formed on both sides of central fringe, whereas in Lloyd's mirror, less than half of the fringes are obtained on one side of central fringe.

ii) In biprism, the central fringe is bright but in Lloyd's mirror it is dark.

iii) In briprism, two coherent sources are virtual (formed by refraction) whereas in Lloyd's mirror one soure is read and another one is virtual (formed by reflection).

iv) In biprism the separation between every pair of corresponding points of the coherent sources is same and the fringe width is same for all parts of the source. But in Lloyd's mirror, due to

④ lateral inversion, The separation between the pair of corresponding points in coherent sources is not same, so fringe width is not same for all parts of the source.

Interference by Division of Amplitude:
Thin film / reflected light:

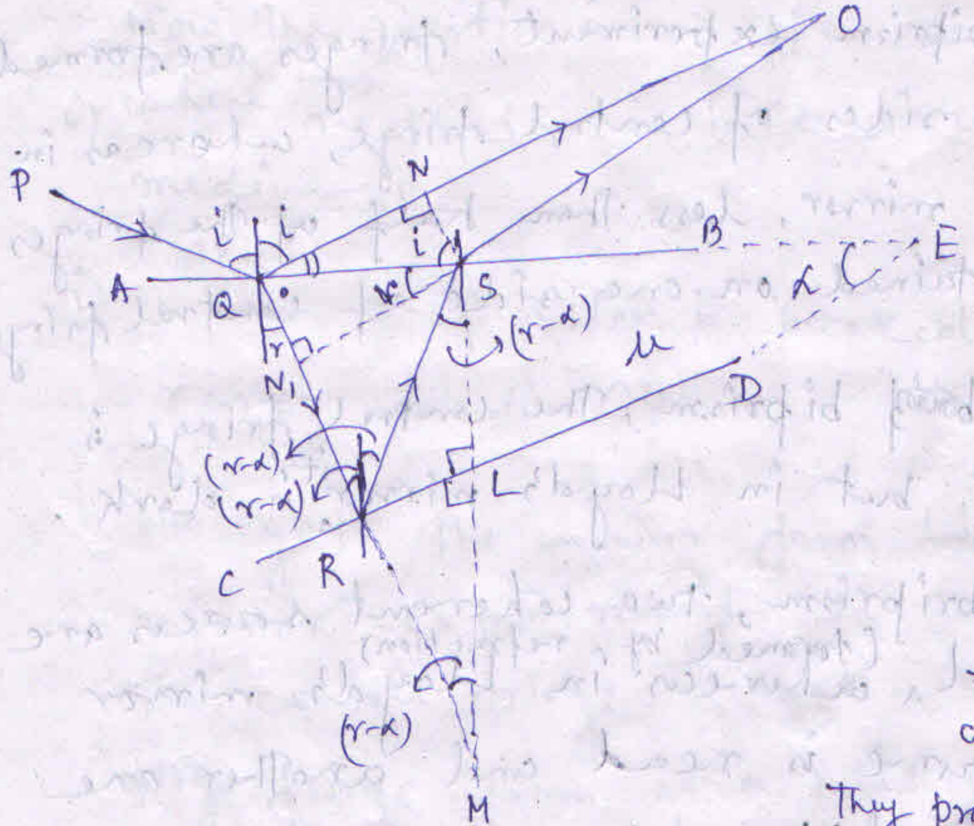


Fig. 2

μ → r.i. of film
α → wedge angle

Reflected rays QO and SO are derived from same incident ray PQ (having wavelength 'λ') → So they are coherent.

They produce interference phenomenon

Path difference between reflected rays is

$$l = \mu(QN_1 + N_1R + RS) - QN \longrightarrow ①$$

Now, $SL = LM = d$ = Thickness of the film at S.

$RS = RM$

$$\mu = \frac{\sin i}{\sin r} = \frac{QN/QS}{QN_1/QS} = \frac{QN}{QN_1} \; ; \; QN = \mu QN_1$$

From ①, $$l = \mu(QN_1 + N_1R + RS) - QN$$
$$= \mu(N_1R + RS)$$
$$= \mu(N_1R + RM)$$
$$= \mu(N_1M)$$
$$= \mu[SM\cos(r-\alpha)]$$
$$l = 2\mu d\cos(r-\alpha) \rightarrow ②$$

There is an extra path difference of $\pm\frac{\lambda}{2}$ (equivalent to phase diff. of π) due to reflection at Q (reflection backed by denser medium). But no such path difference occurs at R because here reflection is backed by rarer medium.
∴ Net path difference is —

$$2\mu d\cos(r-\alpha) \pm \frac{\lambda}{2} \rightarrow ③$$

For maxima

$$2\mu d\cos(r-\alpha) \pm \frac{\lambda}{2} = \text{even multiples of } \frac{\lambda}{2}$$

$$\therefore\ 2\mu d\cos(r-\alpha) = (2n+1)\frac{\lambda}{2},\quad n = 0, 1, 2 \ldots \rightarrow ④$$

For minima

$$2\mu d\cos(r-\alpha) \pm \frac{\lambda}{2} = \text{odd multiples of } \frac{\lambda}{2}$$

$$\therefore\ 2\mu d\cos(r-\alpha) = 2n\left(\frac{\lambda}{2}\right),\quad n = 0, 1, 2 \ldots \rightarrow ⑤$$

Fringes with monochromatic light

Ⓐ Parallel beam of monochromatic

light incident on a film of varying Thickness ⟶

$\mu, \lambda, r, \alpha \Rightarrow$ Constants

∴ order no 'n' depends on 'd' i.e thickness of the film.

$$\left[\begin{aligned} 2\mu d\cos(r-\alpha) &= (2n+1)\frac{\lambda}{2} \Rightarrow \text{Ⓑ} \\ &= 2n\frac{\lambda}{2} \Rightarrow \text{Ⓓ} \end{aligned}\right.$$

At The Thin edge of The film → $d \approx 0$ → only path diff. is $\frac{\lambda}{2}$ ⇒ So, The Thin edge of The film is dark not for a single wavelength but for all wavelengths.

As d increases → n also increases ⇒ If The film surface is perfectly parallel, fringes will be straight, $\parallel^{l}$ to The line of intersection of The surfaces of The film.

Ⓑ. In extremely Thin film (i.e, $d \approx 0$) → only path diff. is $\frac{\lambda}{2}$ → film surface will appear perfectly dark even with white light.

Ⓒ Plane-parallel film ($\alpha = 0$) & parallel beam of monochromatic light is incident on film surface obliquely ⇒ μ, λ, d Constant, only r varies with inclination of incident rays with film surface ⇒ film surface will be uniformly bright or dark as The value of r satisfies The condition of brightness

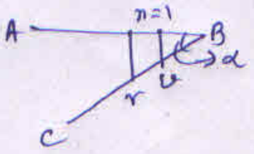
· or darkness.

If the light incidents normally on the film surface ⇒ μ, d, λ constant & $\cos r = 1$. ⇒ Film surface will be uniformly bright or dark as 'd' satisfies the condition of brightness or darkness.

Fringes with white light

Parallel beam of white light incident on thin wedge-shaped film → μ, λ, r will be different for different wavelengths
⇒ Thin edge of the film is dark [reason is stated in Ⓐ]

As $\lambda_r > \lambda_v$ ⇒ for a particular order bright fringe of violet light is formed at smaller thickness and that of red light is formed at greater thickness.
⇒ fringes of equal chromatic order.



But as the thickness of the film increases, there will be overlapping of different coloured fringes ⇒ uniform illumination.