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Study Material - Physics / Sem. 2 / Interference / Dr. T. Kar / Class 2

Thin film / Transmitted Light

$\alpha \to$ wedge angle, $\mu \to$ r.i of the film

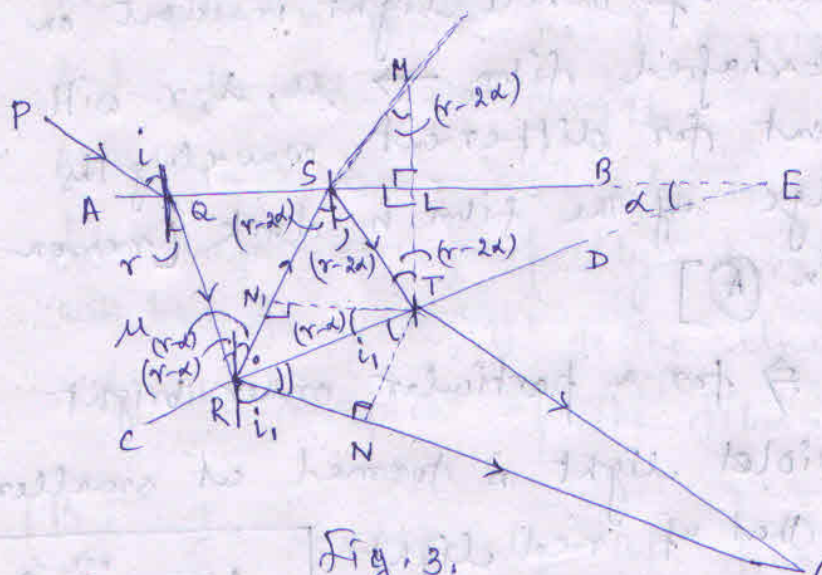


Fig. 3.

All the reflections are backed by rarer medium $\Rightarrow$ no additional path diff.

From fig. 3.,
$ST = SM$
& $ML = LT = d$ = Thickness of the film at 'L'

$\therefore$ The path diff. between two emergent rays

$$= l = \mu(RN_1 + N_1S + ST) - RN$$
$$= \mu(RN_1 + N_1S + SM) - RN$$
$$= \mu(RN_1) + \mu(N_1M) - RN$$
$$= \mu(N_1M)$$

$$\boxed{l = 2\mu d\cos(r - 2\alpha)}$$

Again,
$$\mu = \frac{\sin i_1}{\sin(r-\alpha)} = \frac{RN/RT}{RN_1/RT}$$
$\therefore RN = \mu RN_1$

from ΔN_1TM,
$$\frac{N_1M}{MT} = \cos(r-2\alpha)$$
or, $N_1M = MT\cos(r-2\alpha) = 2d\cos(r-2\alpha)$

For maxima,

$$2\mu d\cos(r-2\alpha) = 2n\left(\frac{\lambda}{2}\right) \to (1)$$

For minima: $2\mu\cos(r-2\alpha) = (2n+1)\frac{\lambda}{2} \to (2)$

If The wedge angle is very small or if The film is parallel (i.e, $\alpha = 0$), Then →

Condition of maxima I in reflected pattern

$$2\mu d\cos r = (2n+1)\frac{\lambda}{2} \rightarrow (3)$$

Condition of minima in reflected pattern

$$2\mu d\cos r = 2n\frac{\lambda}{2} \rightarrow (4)$$

Condition of maxima in transmitted pattern

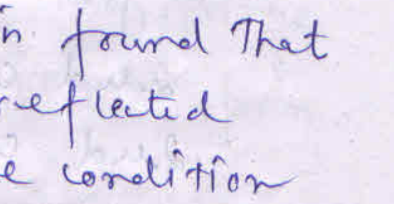
$$2\mu d\cos r = 2n\frac{\lambda}{2} \rightarrow (5)$$

Condition of minima in transmitted pattern

$$2\mu d\cos r = (2n+1)\frac{\lambda}{2} \rightarrow (6)$$

From The above equation it is found That The condition of maxima in reflected pattern is corresponds to The condition of minima in transmitted pattern or vice-versa. Therefore, we can conclude That The fringes observed with The reflected and transmitted lights are complementary to each other.

Fringe Width (β)



* very small wedge angle
* parallel beam of monochromatic light incident normally on The film → Then

$$2\mu d = (2n+1)\frac{\lambda}{2}$$

Now, $\tan\alpha = \alpha = \frac{d}{x_n}$

$$\Rightarrow 2\mu\alpha x_n = (2n+1)\frac{\lambda}{2}$$

(3)

or, $x_n = \frac{(2n+1)\lambda}{4\mu\alpha}$

Similarly, $x_{n+1} = \frac{(2n+3)\lambda}{4\mu\alpha}$

$\therefore \beta = x_{n+1} - x_n$

$= \frac{(2n+3-2n-1)\lambda}{4\mu\alpha} = \frac{\lambda}{2\mu\alpha} \Rightarrow \beta \propto \frac{1}{\text{wedge angle}}$

Fringes of Equal Width or Thickness

For fringes formed with reflected light $\longrightarrow$

$2\mu d \cos(r-\alpha) = (2n+1)\frac{\lambda}{2} \rightarrow$ max.

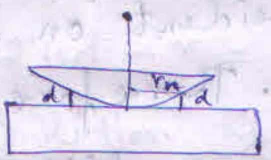
$2\mu d \cos(r-\alpha) = 2n\frac{\lambda}{2} \rightarrow$ min.

For a parallel beam of monochromatic light $\rightarrow$ μ, r, α are constants.

$\Rightarrow$ order no. (n) of the fringes are controlled by the thickness of the film (d).

Hence the fringe of a particular order no. will lie on the locus of all points having a constant thickness. These fringes are called fringes of equal width or thickness. If the film surfaces are perfectly plane we get straight fringes which are parallel to The line of intersection of The film surfaces where The central dark fringe is situated.

The Newton's rings are The example of fringes of equal width type. Here equal Thickness of air film exists over The circumference of a circle, having The point of contact of plano-convex lens and glass plate as centre and hence The fringes assume circular form.



$d \rightarrow$ air film Thickness
$r_n \rightarrow$ radius of ring

The fringes of equal Thickness are employed to test The optical planeness of a surface. For this purpose, an air film is formed between The working surface and a standard optically flat surface. The fringes of equal Thickness formed by air film are repeatedly observed with monochromatic light and The polishing of The working surface is continued until The fringes are perfectly straight and parallel to The line of intersection of The surfaces of The air film.

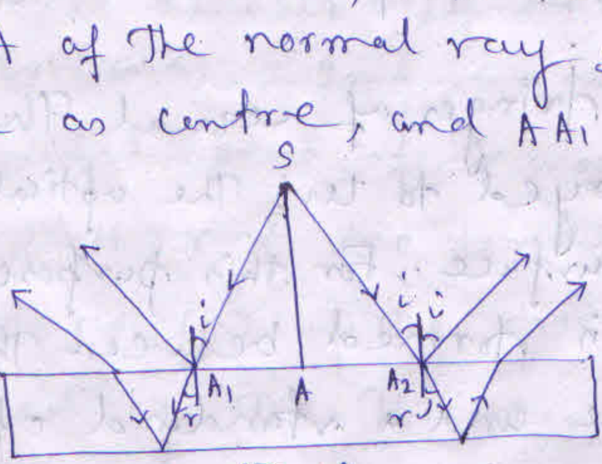
Fringes of Equal Inclination

For fringes formed with reflected light ⟶

$$2\mu d \cos(r-\alpha) = (2n+1)\frac{\lambda}{2} \rightarrow \text{max.}$$

$$2\mu d \cos(r-\alpha) = 2n\frac{\lambda}{2} \rightarrow \text{min.}$$

When monochromatic divergent rays from an extended source are incident on a film of uniform thickness. Therefore, $\mu, \lambda, d \rightarrow$ constant, & $\alpha = 0$. Hence different order no. 'n' of the fringes will be controlled by the different values of r. If we draw a circle, with the cutting point A of the normal ray SA with the surface as centre, and AA_1 as radius,



(Fig. 4)

then all rays incident on the circumference of this circle will have same angle of incidence 'i'. Thus the fringes of a particular order will be a circle with 'A' as centre. Fringe system will consist of concentric bright and dark rings. Fringe of a particular order

is characterised by a particular angle of incidence. Therefore, these fringes are called fringes of equal inclination.
As the angle of incidence(i) increases, ~~corresponding~~ ~~values~~ angle of refraction (r) also increases, hence value of $\cos r$ decreases. As $\cos r$ decreases, the order no. (n) also decreases. Thus fringes of bigger radii have smaller order no.
Haidinger's fringes are the example of fringes of equal inclination. These fringes are employed to ~~produce~~ test the flatness of a plate to a high degree of accuracy. For accurately plane-parallel surfaces Haidinger's fringes are perfectly circular. But any deviation from it will be indicated by the distortion in the rings.

[*] Haidinger's Fringes

Haidinger's fringes are the fringes of equal inclination type. Fringes of equal inclination can be produced by transmitted light from a thick transparent plate (Fig. 5.). As the

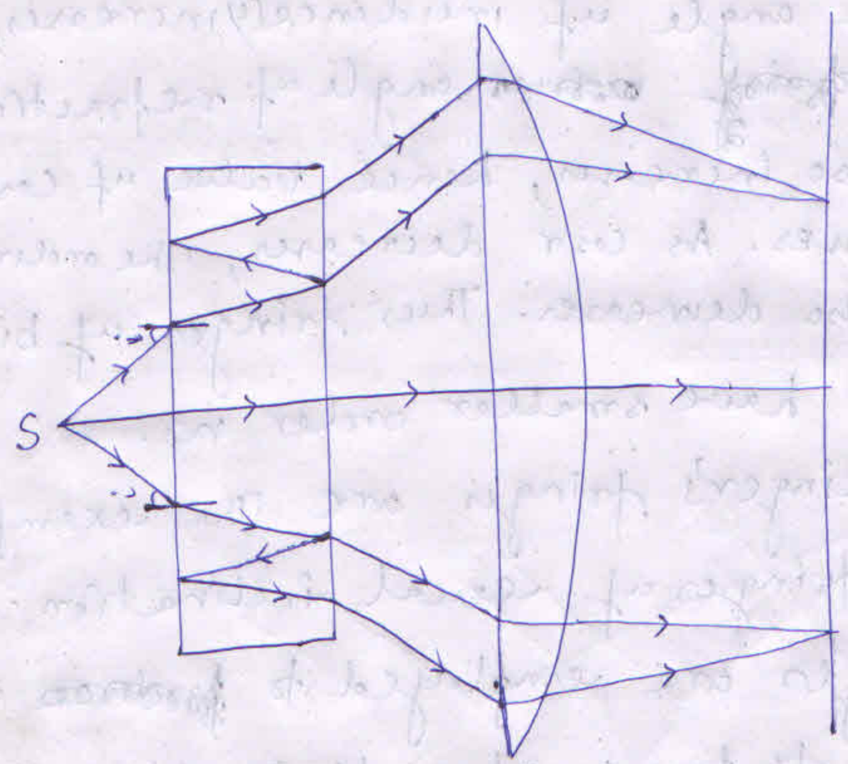


Fig. 5.

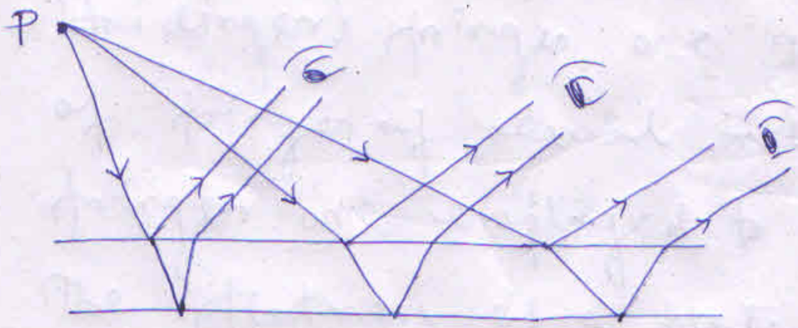
plate is thick, the pair of adjacent transmitted rays will be wide apart. So, a telescope with a bigger diameter objective is employed to collect all the transmitted rays. These collected rays will produce interference phenomena at the focal plane of the objective. The fringe pattern obtained in the focal plane of the telescope consists of concentric bright and dark fringes. These fringes are fringes of equal inclination type and are called Haidinger's fringes.

Necessity of using broad source and thin film

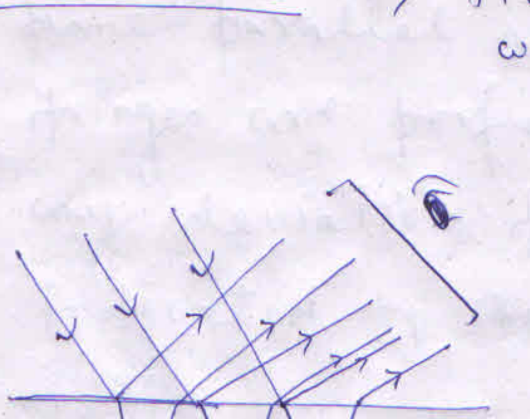
Point source → reflected and transmitted rays are confined to a small range of direction

⇓

Field of view is very small



Broad Source ⇒ Field of view becomes wide and fringes can be seen over the entire film



Thick film

↳ Two adjacent reflected and transmitted rays are wide apart → will not be able to enter eye