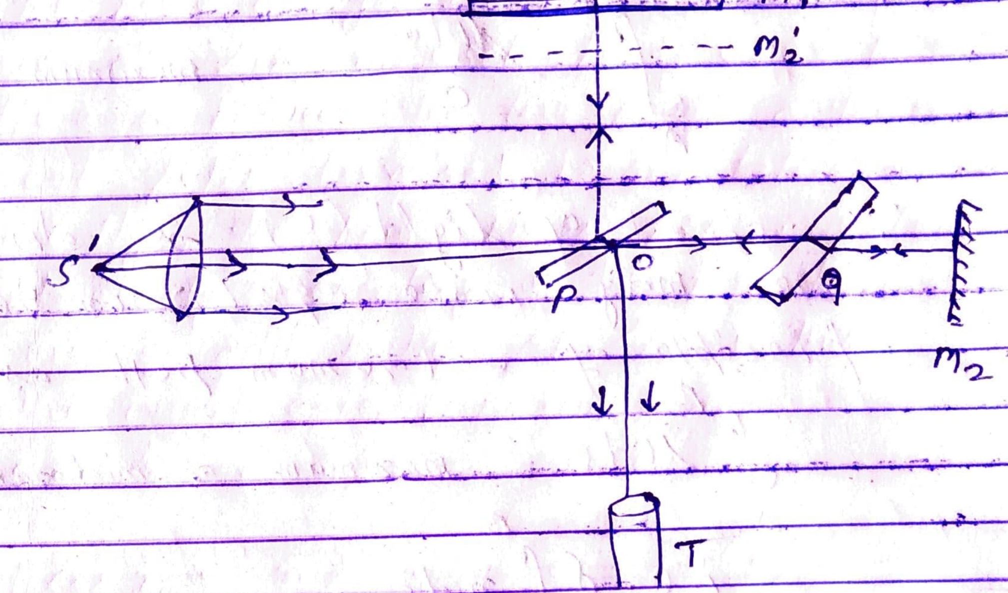
Optics

Interference of light :

Michelson's Interferometer :→



Apparatus :→ It essentially consists of (i) a glass plate P half silvered on its back surface included at an angle 45° to the beam of light (ii) another glass plate Q such that P and Q are equal of thickness and of the same material mounted parallel to each other (iii) Two plane mirrors M_1 and M_2 silvered on their front surfaces and mounted vertically on two arms at right angles to each other. The planes of the mirrors can be slightly titled with the fine screws at their backs. The mirror M_1 is fixed on a carriage and can be moved parallel to itself with the help of a fine screw of uniform pitch.

Working → Light from an extended monochromatic sources S, rendered parallel by a lens L, falls on the plate P. The plate P due to being semi silvered, divides the beam into two parts of nearly equal intensities, namely reflected and transmitted beams; The reflected beam moves towards mirror M_1 and falls normally on it and hence it is reflected back to P enters the telescope T. The transmitted beam moves towards mirror M_2 and falls on it normally after passing through the plate Q, therefore it is reflected by the mirror M_2 and retraces its path. At P it is reflected to enter the telescope T. Since the beams entering the telescope have been derived from the same incident beam, they are coherent and hence are capable of giving rise to the phenomenon of interference, thereby producing interference fringes.

Function of the plate Q : The beam reflected at P crosses the plate P twice, while other beam in the absence of Q lies wholly in air. Du to this the beam reflected at P has to travel an extra optical path $2(\mu-1)t$ where μ is the r.i. of plate P and 't' is its thickness. This extra optical path is compensated by plate Q in the path of transmitted beam. Thus the function of the plate Q is only to equalise the optical paths traversed by both the beams. The plate Q is called the compensating plate.

Types of fringes :→ The types of the fringes in Michelson interferometer depends upon the inclination of M_1 and M_2'. Let M_2' be the image of M_2 formed by reflection at the half - silvered surface of the plate P so that $OM_2 = OM_2'$. The interference pattern may be regarded to be due to the light reflected from the surfaces M_1 (real) & M_2' (virtual) respectively. Thus the arrangement is equivalent to an air film enclosed between the reflecting surfaces M_1 and M_2'.

The phase changes on reflection at M_1 and M_2 are similar and Edser has shown that for thin coating of silver on plate P the phase changes due to reflection from it in air and glass are also similar, each being equal to π. The optical path difference between the two beams is therefore simply due to different paths traversed in air before reaching the observer. Consequently, the two waves will interfere constructively or destructively, according as the path difference Δ between them is even or odd multiple of $\lambda/2$; Thus condition of constructive interference (maxima) is

$$\Delta = 2n \cdot \frac{\lambda}{2} = n\lambda$$

$$\text{i.e.} \quad 2t\cos r = n\lambda \quad \text{---} \quad (1)$$

and the condition of destructive interference (minima) is

$$\Delta = (2n-1)\frac{\lambda}{2}$$

$$\text{i.e.} \quad 2t\cos r = (2n-1)\frac{\lambda}{2} \quad \text{---} \quad (2)$$

It is obvious that the path difference between the two beams produced by the reflecting surfaces M_1 and M_2' is equal to twice the thickness of the film $M_1 M_2'$. This path difference can be varied by moving M_1 backward or forward parallel to itself. If we use monochromatic light, the system of bright and dark fringes will be produced. The shape of the fringes will depends upon the inclination of M_1 and M_2. If M_1 and M_2 are exactly at right angles to each other, the reflecting surfaces M_1 and M_2' are parallel and hence air film between M_1 and M_2' is of constant thickness so that we get circular fringes of equal inclination or Haidinger's fringes in the field of view of telescope.

The circular fringes of equal inclination are formed because a number of pencils of rays fall at different angles on the glass plate P. When the distances between the mirrors M_1 and M_2 or between M_1 and M_2' is decreased, the circular fringes shrink and vanish at the centre. A ring disappears each time when $2t$ decreases by λ. This is so because the condition is maxima is $2t \cos r = n\lambda$

When t is further decreased, a limit comes when M_1 and M_2' coincide and the path difference between the two rays becomes zero. Now the field of view is perfectly bright. When M_1 is further moved, the fringes appear again.

If M_1 and M_2 are not perfectly perpendicular, a wedge shaped film is formed between M_1 and M_2 and then we get straight line fringes of equal thickness in the field of view of telescope.

→ White light fringes: We use white light only when the path difference is small. With white light the central fringes will be bright and around it there will be a few coloured fringes.

If mirrors M_1 and M_2 are slightly tilted, the wedge shaped air film will be formed between M_1 and M_2'. If we use white light in this case there will be a distinct bright (white) straight fringe and on either side of it there will be a few coloured fringes.

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