Michelson’s Interferometer

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Construction

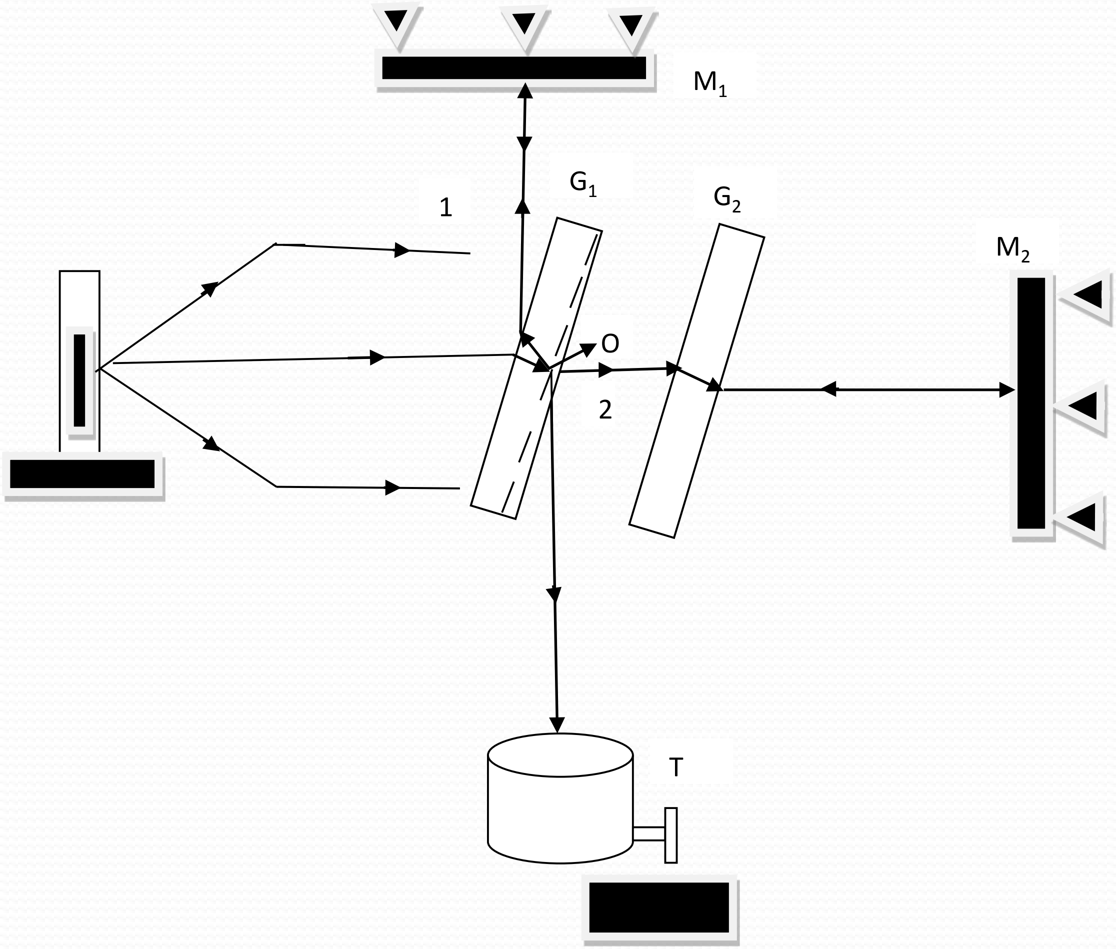
- Michelson's Interferometer consists of two highly plane polished mirror M_1 and M_2 which are right angle to each other. There are two glass plates G_1 and G_2 of the same thickness and of the same material placed parallel to each other. The face of glass G_1 towards the glass plate G_2 is made semi silvered. The mirror M_1 and M_2 provides three leveling screw with the help of these leveling screw mirror M_1 and M_2 are tilted horizontal and vertical axis so that mirror M_1 and M_2 can made exactly perpendicular to each other. T be the telescope which receive reflected light

Working

- **S** is the source of monochromatic light. Light from the source **S** is allowed to fall on convex lens. It render’s a parallel beam of light. When this beam of light is allowed to fall on semi-silvered surface of glass plate **G_1** then the semi-silvered surface glass plate **G_1** divide the incident beam of light into two parts one being reflected and comes out in the form of ray **No 1** Which moves towards mirror **M_1** and other being transmitted and comes out in the form of **ray No 2** Which moves towards mirror **M_2.** Both the ray No 1 and ray **No 2** incident normally on the mirror **M_1** and **M_2** and reflected and return back along the same path and again meet at the semi-silvered surface **O,** and entering in the field of view of telescope.

Experimental Arrangement

- Michelson Interferometer



Function of Glass Plate G_2 (second glass plate)

- Now looking towards the ray **No 1** which passes glass plate G_1 twice where ray **No 2** only once. So in the absence of glass plate G_1 the two paths are not equal. So in order to equalize the two paths take another glass plate G_2 of the same thickness and of same material placed in the path of ray No 2. Due to this nature glass plate G_2 are called compensatory glass plate.

Type of Fringe’s

- Now looking in the direction of mirror M_1 through the telescope. We observe the mirror M_1 and the virtual image of M_1 and M_2 that is formed at thus Michelson’s Interferometer is equivalent to air film enclosed between M_1 and . Thus the interference pattern may straight, circular or curved fringe’s depends upon path difference between the reflected rays. Thus path difference between the reflected ray will be:- $2\mu t \cos(r+\alpha) + \frac{\lambda}{2}$
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Circular Fringe

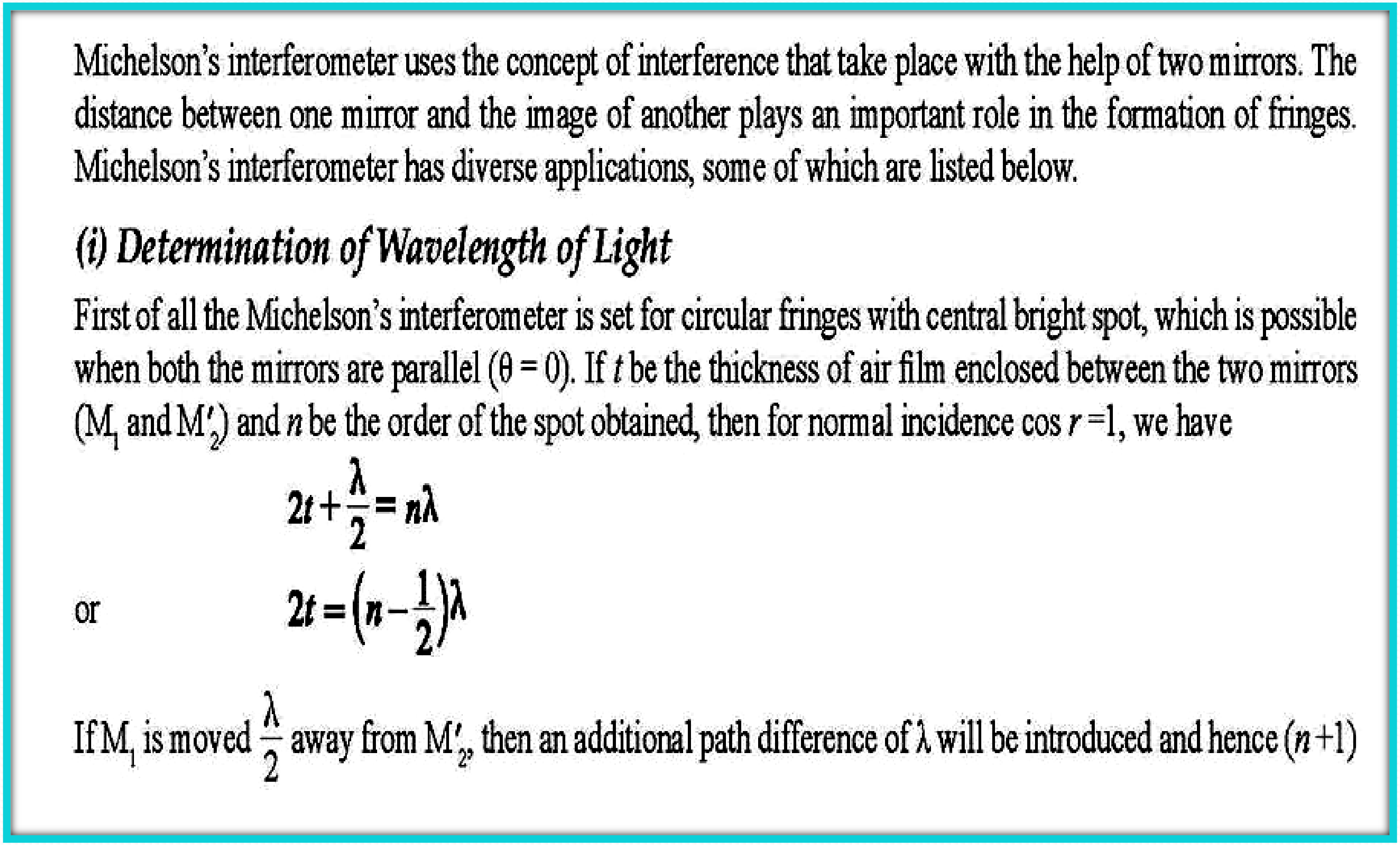
- When mirror M_1 and M_2 are exactly perpendicular to each other then mirror M_1 and are exactly parallel to each other. Then air film of constant thickness is formed between M_1 and .So that at a particular constant thickness radii or foci are constant so that at a particular constant thickness the interference pattern is take place in the form of circular ring. Now the ring will appear dark or bright depends upon path difference between the two reflected rays that is $2\mu t \cos(r+\alpha) + \frac{\lambda}{2}$
- Now in such a case $\alpha = 0$
- For normal incidence $r = 0$
- For air film $\mu = 1$
- Then path difference between the two reflected ray will be:- $2t + \frac{\lambda}{2}$

- At a particular constant thickness ring will appear bright only when path diff. = nλ, or $2t + \frac{\lambda}{2} = n\lambda$
- or $2t = (n - \frac{1}{2})\lambda$ n = 1, 2
- Thus ring will appear bright only when $2t = (n - \frac{1}{2})\lambda$
- And ring will appear dark only when
- $2t + \frac{\lambda}{2} = \frac{(2n+1)\lambda}{2} = n\lambda + \frac{\lambda}{2}$ or $2t = n\lambda$

Curved Fringe

When the mirror M_1 and M_2 are not perpendicular to each other then air film of increasing thickness is formed between M_1 and M_2. Thus the shape of Fringe's depends upon path difference between the two reflected rays. When the two mirror are inclined then air film of increasing thickness is formed (wedge shape film is formed). Thus in such a curve fringe are formed.

Application



Michelson's interferometer uses the concept of interference that take place with the help of two mirrors. The distance between one mirror and the image of another plays an important role in the formation of fringes. Michelson's interferometer has diverse applications, some of which are listed below.

(i) Determination of Wavelength of Light

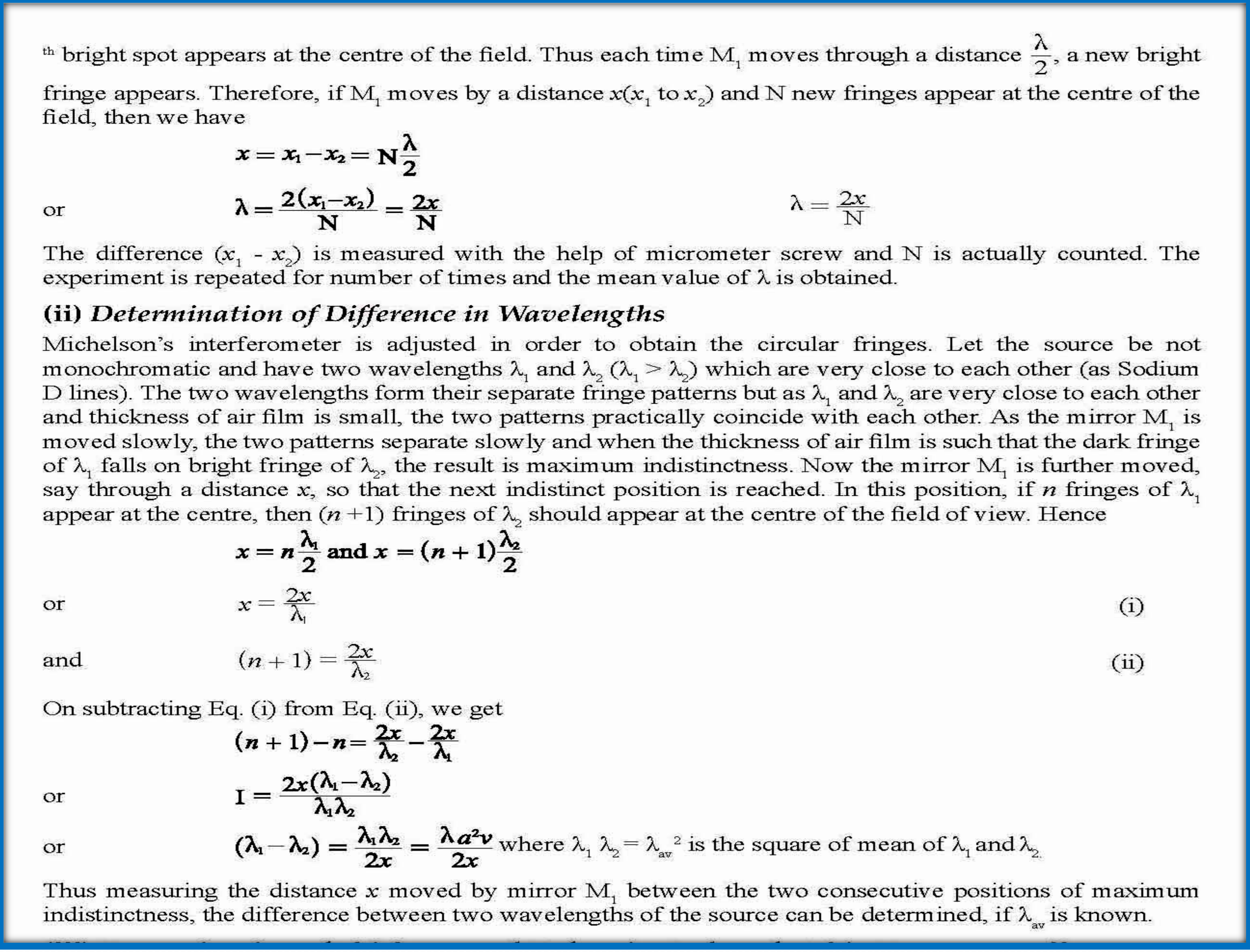
First of all the Michelson's interferometer is set for circular fringes with central bright spot, which is possible when both the mirrors are parallel ($\theta = 0$). If t be the thickness of air film enclosed between the two mirrors (M_1 and M'_2) and n be the order of the spot obtained, then for normal incidence $\cos r = 1$, we have

$$2t + \frac{\lambda}{2} = n\lambda$$

or

$$2t = \left(n - \frac{1}{2}\right)\lambda$$

If M_1 is moved $\frac{\lambda}{2}$ away from M'_2, then an additional path difference of λ will be introduced and hence $(n+1)$



th bright spot appears at the centre of the field. Thus each time M_1 moves through a distance $\frac{\lambda}{2}$, a new bright fringe appears. Therefore, if M_1 moves by a distance $x(x_1$ to $x_2)$ and N new fringes appear at the centre of the field, then we have

$$x = x_1 - x_2 = N\frac{\lambda}{2}$$

or $$\lambda = \frac{2(x_1 - x_2)}{N} = \frac{2x}{N} \qquad \lambda = \frac{2x}{N}$$

The difference $(x_1 - x_2)$ is measured with the help of micrometer screw and N is actually counted. The experiment is repeated for number of times and the mean value of λ is obtained.

(ii) *Determination of Difference in Wavelengths*

Michelson's interferometer is adjusted in order to obtain the circular fringes. Let the source be not monochromatic and have two wavelengths λ_1 and λ_2 $(\lambda_1 > \lambda_2)$ which are very close to each other (as Sodium D lines). The two wavelengths form their separate fringe patterns but as λ_1 and λ_2 are very close to each other and thickness of air film is small, the two patterns practically coincide with each other. As the mirror M_1 is moved slowly, the two patterns separate slowly and when the thickness of air film is such that the dark fringe of λ_1 falls on bright fringe of λ_2, the result is maximum indistinctness. Now the mirror M_1 is further moved, say through a distance x, so that the next indistinct position is reached. In this position, if n fringes of λ_1 appear at the centre, then $(n+1)$ fringes of λ_2 should appear at the centre of the field of view. Hence

$$x = n\frac{\lambda_1}{2} \text{ and } x = (n+1)\frac{\lambda_2}{2}$$

or $$x = \frac{2x}{\lambda_1} \qquad \text{(i)}$$

and $$(n+1) = \frac{2x}{\lambda_2} \qquad \text{(ii)}$$

On subtracting Eq. (i) from Eq. (ii), we get

$$(n+1) - n = \frac{2x}{\lambda_2} - \frac{2x}{\lambda_1}$$

or $$I = \frac{2x(\lambda_1 - \lambda_2)}{\lambda_1 \lambda_2}$$

or $$(\lambda_1 - \lambda_2) = \frac{\lambda_1 \lambda_2}{2x} = \frac{\lambda a^2 v}{2x}$$ where $\lambda_1 \lambda_2 = \lambda_{av}{}^2$ is the square of mean of λ_1 and λ_2.

Thus measuring the distance x moved by mirror M_1 between the two consecutive positions of maximum indistinctness, the difference between two wavelengths of the source can be determined, if λ_{av} is known.