General Physics I (PHYS 101)

Lecture 15

Interference (Contd.)

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Outline

1. Young's double slit experiment

2. Interference on thin films due to reflected light

Young's double slit experiment

Consider a source of monochromatic light S. A and B are two narrow slits of width d very close to each other as shown in figure. A screen XY is placed at a distance D form slits as shown in figure.

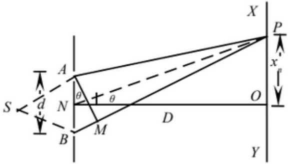

Figure 1

Let P be the position of n^{th} bright or dark fringe and θ be the angle made by NP with NO. A perpendicular AM is drawn to BP. Since A and B are too close to each other, AM meets NP practically at right angles such that $\measuredangle BAM = \theta$. Now, form ΔPNO,

$$\tan\theta = \frac{PO}{NO} = \frac{x_n}{D}$$

And from ΔBAM, $\sin\theta = \frac{BM}{AB} = \frac{BM}{d}$. For small angle, $\sin\theta \approx \tan\theta$. So,

$$\therefore\ \frac{BM}{d} = \frac{x_n}{D}$$

$$\therefore\ BM = \frac{x_n d}{D}$$

Here BM is the path difference between the waves.

Young's double slit experiment (contd.)

Now for bright fringes, path difference $(BM) = n\lambda$

$$\text{or, } \frac{x_n d}{D} = n\lambda$$

$$\therefore\ x_n = \frac{n\lambda D}{d}$$

This relation gives the distance of n^{th} bright fringe from the center of the fringe system.

For $(n-1)^{th}$ bright fringe, we can have

$$x_{n-1} = \frac{(n-1)\lambda D}{d}$$

Young's double slit experiment (contd.)

So, the fringe width β is

$$\beta = x_n - x_{n-1} = \frac{n\lambda D}{d} - \frac{(n-1)\lambda D}{d}$$

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

Again for dark fringes, path difference $(BM) = (2n+1)\frac{\lambda}{2}$

$$\text{or, } \frac{x_n d}{D} = (2n+1)\frac{\lambda}{2}$$

$$\therefore\ x_n = \frac{(2n+1)\lambda D}{2d}$$

This relation gives the distance of nth dark fringe from the center of the fringe system.

Young's double slit experiment (contd.)

For $(n-1)^{th}$ dark fringe, we can have

$$x_{n-1} = \frac{[2(n-1)+1]\lambda D}{2d} = \frac{(2n-1)\lambda D}{2d}$$

So, the fringe width β is

$$\beta = x_n - x_{n-1} = \frac{(2n+1)\lambda D}{2d} - \frac{(2n-1)\lambda D}{2d}$$

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

Thus, the fringe width for dark and bright fringes are equal i.e. fringes in Young's double slit experiment are equally spaced.

Interference on thin films due to reflected light

Let us consider a thin film of thickness t and refractive index μ as shown in figure. A ray of light AB strikes at point B with angle of incident i, get reflected along BE and also refracted along BC with angle of refraction r. At C it again reflected along CD and finally emerges out along DF.

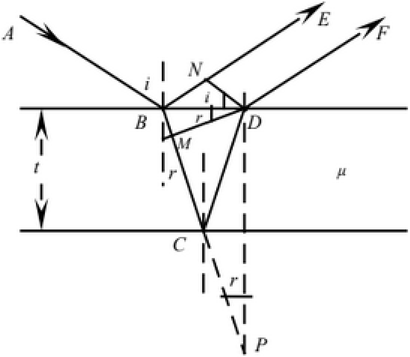

Figure 2

Interference on thin films due to reflected light (contd.)

Draw perpendiculars DN and DM to BE and BC such that $\measuredangle BDN = i$ and $\measuredangle BDM = r$. Produce BC to meet DP at P so that $DP = 2t$ and $\measuredangle MPD = r$. Let x be the path difference between the waves emerging from B and D respectively. Then,

$$x = \mu(BC + CD) - BN \tag{1}$$

From Snell's law,

$$\mu = \frac{\sin i}{\sin r} = \frac{BN/BD}{BM/BD} = \frac{BN}{BM}$$

$$\therefore\ BN = \mu BM$$

And also, CD = CP so equation (1) becomes,

$$x = \mu(BC + CP) - \mu BM$$

$$= \mu\,(BP - BM)$$

$$= \mu\,PM$$

From ΔMPD,

$$\cos r = \frac{PM}{PD} = \frac{PM}{2t} \Rightarrow PM = 2t\cos r$$

Interference on thin films due to reflected light (contd.)

So, path difference is

$$x = 2\mu t \cos r$$

According to electromagnetic theory (Stoke's Law of reflection) :

When a light wave is reflected from the surface of an optically denser medium, it suffers a phase change of π or path difference of $\frac{\lambda}{2}$ but it suffers no change in phase when reflected at the surface of optically rarer medium.So the corrected path difference becomes,

$$x = 2\mu t \cos r + \frac{\lambda}{2}$$

Interference on thin films due to reflected light (contd.)

For bright fringes path difference is integral multiple of λ i.e.

$$x = n\lambda$$

$$\therefore\ 2\mu t\cos r + \frac{\lambda}{2} = n\lambda$$

$$\text{or, } 2\mu t\cos r = n\lambda - \frac{\lambda}{2}$$

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

For dark fringes path difference is half odd integral multiple of λ i.e.

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

Interference on thin films due to reflected light (contd.)

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

$$\therefore\ 2\mu t\cos r = n\lambda \tag{3}$$

Equations (2) and (3) are the required conditions for bright and dark fringes for interference due to reflected light.