Interference of light

Lecture-2

Minati Barman
Associate professor
Department of Physics
JN College, Boko

Contents:

Interference of light:

Interference is the phenomenon in which two monochromatic waves superpose to form the resultant wave . The amplitude of the resultant wave may be lower, higher or same as that of the incident wave.

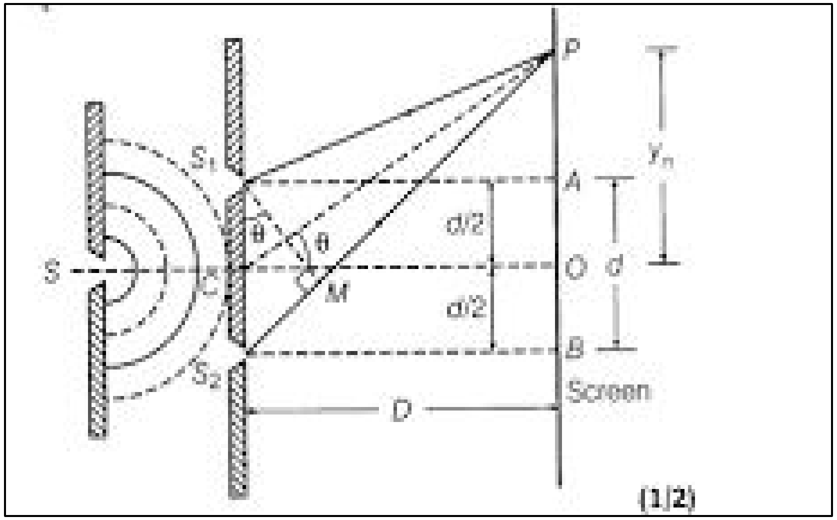
Types of Interference:

1. Division of wave front

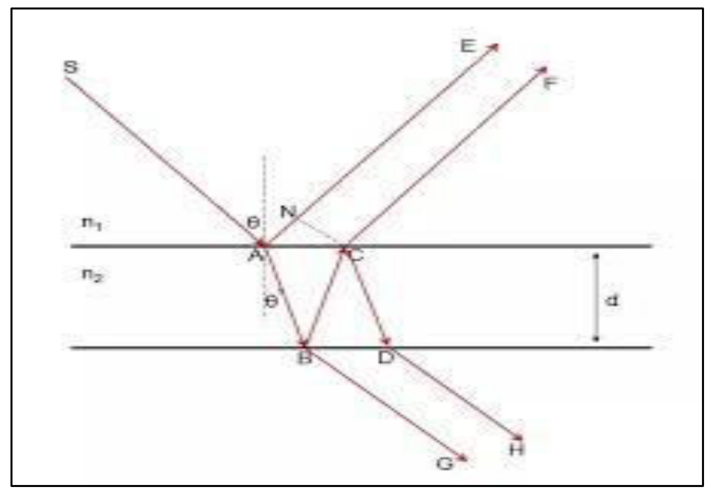
   Ex: Young's double slit experiment.

1. Division of amplitude

   E: interference on a thin film, Newton's rings experiment, Michelson interferometer



Young’s double slit experiment
Division of wavefront



Interference in thin film
Division of amplitude

Theory of interference:

Let us consider two monochromatic waves coming from two coherent sources incident on a screen with a phase difference $\emptyset$ at a point.

Let y_1 and $\mathbf{y_2}$ are displacement of the two waves respectively such that

$$y_1 = a_1 \sin\varpi t \text{..........................(i)}$$

$$y_2 = a_2 \sin(\varpi t+\emptyset) \text{.....................(ii)}$$

Then the resultant displacement at that point is

$$\begin{aligned} y &= y_1+y_2 \\ &= a_1 \sin\varpi t + a_2 \sin(\varpi t+\emptyset) \\ &= a_1 \sin\varpi t + a_2 \sin\varpi t \cos\emptyset + a_2 \cos\varpi t \sin\emptyset \\ &= \sin\varpi t\,(a_1 + a_2 \cos\emptyset) + \cos\varpi t\,(a_2 \sin\emptyset) \end{aligned}$$

$$a_1 + a_2 \cos\phi = R \cos\Theta \quad \text{.................................(iii)}$$

$$a_2 \sin\phi = R \sin\Theta \quad \text{.................................(iv)}$$

Where R and Θ are two new constants

$$y = R \sin\omega t \cos\Theta + R \cos\omega t \sin\Theta$$

$$= R \sin(\omega t + \Theta)$$

Now squaring and adding equation (iii) and (iv)we get

$$R^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$$

Here R is resultant amplitude of the amplitude. We know that intensity of light at point P is proportional to square of the amplitude, so

$$I \propto R^2$$

$$= a_1^2 + a_2^2 + 2a_1a_2 \cos\phi \quad \text{..........................(v)}$$

Equation(v) shows that Intensity I depends on the value of phase difference Ø of the two interfering waves .

We know that the relation between the path difference x and phase difference Ø is $x = (\lambda / 2л)$ Ø

i) If we put Ø=2mл in equation (v) then cosØ=1 and then $x = m\lambda$ where m=0,1,2,3..............................and then intensity $I = (a_1 + a_2)^2$ which is maximum. This is the condition of constructive interference or bright fringe.

ii) If Ø =(2m +1)л, then cosØ= -1 and x= (2m+1) λ where m=0,1,2,3............Then intensity $I = (a_1 - a_2)^2$ and I is minimum. This is the condition of destructive interference or dark fringe.

iii) When $a_1 = a_2$, then minimum intensity is zero and maximum intensity is $4a^2$. So we get alternate bright and dark fringes as we go away from the central fringe. At the central point, path difference as well as phase difference is equal to zero and we get maximum intensity there ,which is equal to $4a^2$

Intensity distribution curve:

Intensity at any point of the screen is expressed as

$$I = a_1^2 + a_2^2 + 2a_1a_2 \cos\emptyset$$

If $a_1 = a_2$, then $I = 4a^2$ for bright fringe and for dark fringe $I=0$. In fact as $\emptyset$ increases gradually from 0 to л ,cos$\emptyset$ decreases from +1 to-1 through 0 and intensity decreases gradually from $4a^2$ to 0 . The shape of the intensity distribution curve is as shown in the figure below.

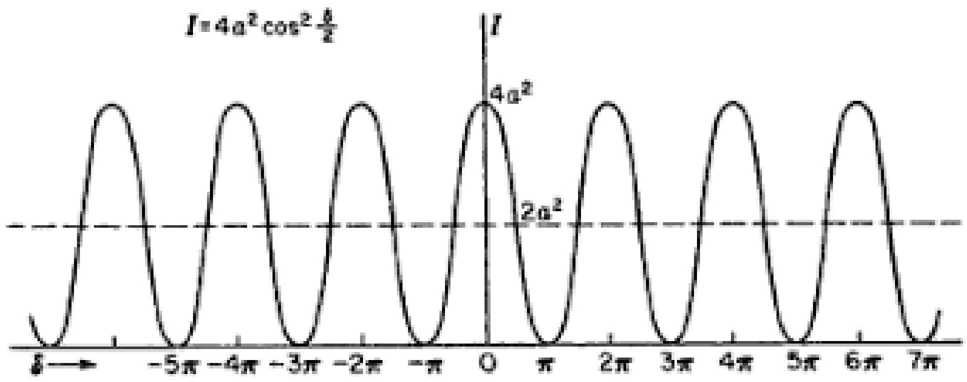


Figure: Intensity distribution of curve

There is no destruction of light energy but redistribution of energy occurs in this phenomenon. Actually the energy disappeared in the dark fringe appears in the bright fringe. The intensity of bright fringe is $4a^2$ and the dark fringe is 0. However, the average value of energy over any numbers of fringes is same i.e. $2a^2$. The average value of the intensity on the screen over the range Ø=0 to Ø=2л is given by

$$I_{average} = \frac{\int_0^{2\pi} I d\theta}{\int_0^{2\pi} d\theta}$$

$$= a_1^2 + a_2^2$$

= sum of intensities of the individual waves.

If $a_1 = a_2 = a$ then average intensity is $2a^2$. So we can say that the principle of conservation of energy is strictly followed in the interference phenomenon.

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