Interference of light

Lecture-3

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Intensity distribution curve:

Intensity at any point of the screen is expressed as

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

If $a_1=a_2$, then $I= 4a^2$ for bright fringe and for dark fringe $I=0$. In fact as Øincrease gradually from 0 to л cosØ gradually 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.

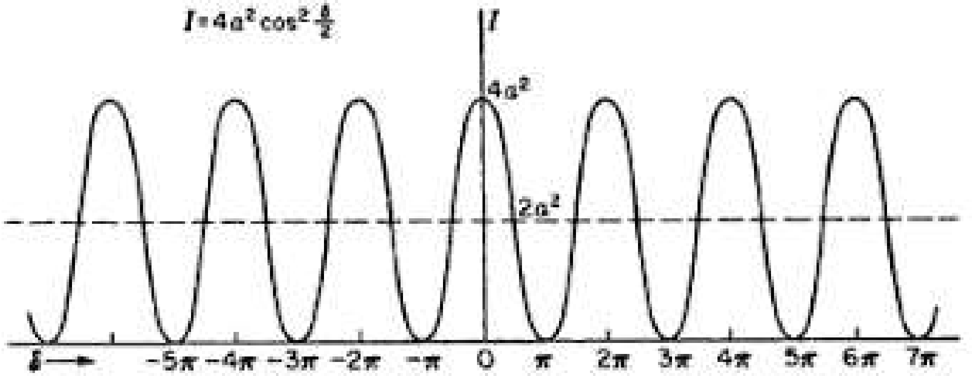

Figure: Intensity distribution of curve

There is no destruction of light energy in the interference phenomenon. But redistribution of light 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 $\emptyset=0$ to $\emptyset=2\pi$ 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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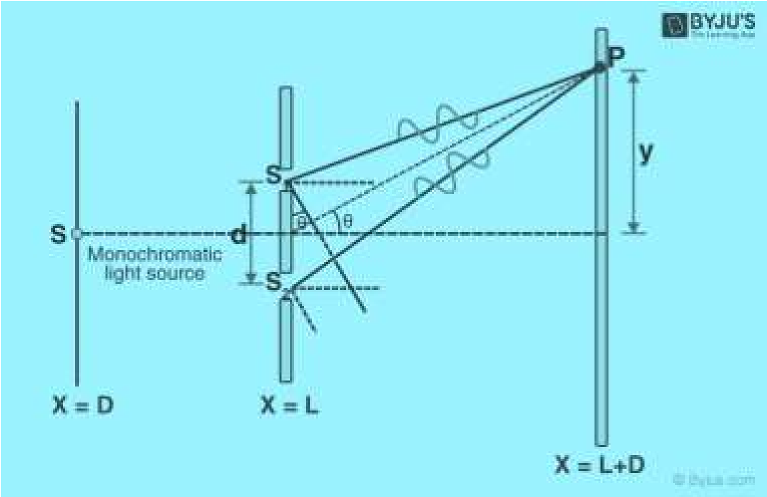
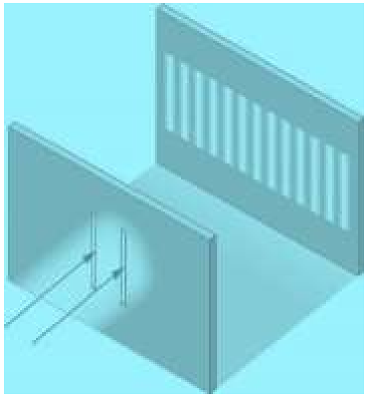
Young's double slit experiment:

Let us consider two coherent sources S_1 and S_2 separated by a distance d sending monochromatic waves of wavelengthλ. C is central point on the screen and it is equidistant from S_1 and S_2. The perpendicular distance from the source to the screen is D. Let mth bright fringe be formed at point P which is at a distance y from the central point.





Now from figure we have

$$S_2P^2 = D^2 + (y + d/2)^2$$

$$S_2P = D[1 + (\frac{y + d/2}{D})^2]^{½}$$

$$= D[1 + \frac{1}{2}(\frac{y + d/2)^2}{D})]$$

Since D>>d, higher powers are neglected

$$S_1P^2 = D^2 + (y - d/2)^2$$

$$S_1P = D[1 + (\frac{(y - d/2)}{D})^2]^{½}$$

$$= D[1 + \frac{1}{2}(\frac{y - d/2)^2}{D})]$$

$$S_2P - S_1P \text{ (path difference)} = \frac{1}{2}\frac{(y + d/2)^2}{D} - \frac{1}{2}\frac{(y - d/2)^2}{D}$$

$$\text{path difference } x = \frac{1}{2}\frac{2yd}{D} = \frac{yd}{D}$$

For mth order bright fringe $Y=Y_m$

$$S_2P - S_1P = m\lambda$$

$$Y_m.d/D = m\lambda$$

$$Y_m = m\lambda D/d \quad ....(1)$$

Similarly for(m+1) th order bright fringe

$$Y_{(m+1)} = (m+1)\lambda D/d \quad ....(2)$$

Thus the distance between two consecutive bright fringe is

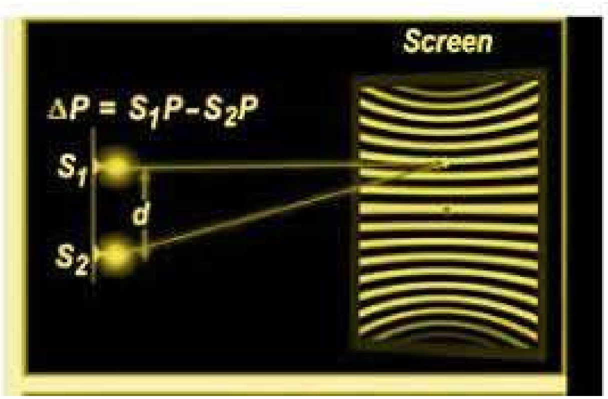
$$\beta = Y_{(m+1)} - Y_m = \lambda D/d \quad ....(3)$$

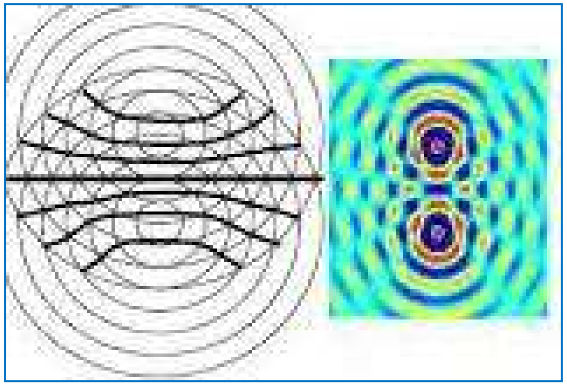
Similarly we can show that for dark fringe also

$$\beta = Y_{(m+1)} - Y_m = \lambda D/d \quad ....(4)$$

So fringe width β for dark and bright fringes are equal β is called as fringe width between two consecutive bright or dark fringes. Measuring β,D and d , λ can be measured.

Shape of interference fringes: If the two sources are pinholes instead of slits then the interference pattern would be hyperbolic as shown in the figure below.





If the screen is placed perpendicular to the line joining the two sources we get a number of alternately bright and dark concentric circles. These are non localized fringes because they can be obtained on a screen wherever it is placed. If path difference $x \sim 10^{-8}$ cm and slits separation $d \sim 10^{-2}$ cm then the fringes are straight lines.

Interference with white light:

In white light there are different wavelengths for different colours. For the central fringe the path difference as well as phase difference is equal to zero for all colours. So we get a white fringe there at the central point.

We know that $Y_m = m\lambda D/d$ which shows that when $m > 0$, Y_m increases for greater values of λ. Since wavelength for red colour is greater than the wavelength of violet so value of Y_m for red is greater the Y_m value for violet. As a result of this we get a few coloured band in place of the bright fringe on either side of the central fringe and beyond it there we get general illumination.

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