Semester- 2
PHYCC204: Waves and Optics
Unit- 3

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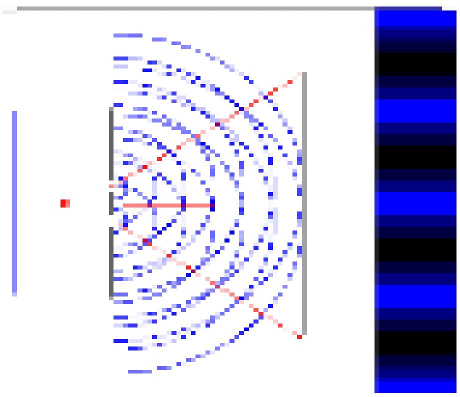
INTERFERENCE

Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude.

Interference means the net effect of the combination of two or more wave trains moving on intersecting or coincident paths. The effect is that of the addition of the amplitudes of the individual waves at each point affected by more than one wave. If two of the components are of the same frequency and phase (*i.e.,* they vibrate at the same rate and are maximum at the same time), the wave amplitudes are reinforced, producing constructive interference; but, if the two waves are out of phase by $^1/_2$ period (*i.e.,* one is minimum when the other is maximum), the result is destructive interference, producing complete annulment if they are of equal amplitude.

Interference fringe:

Interference fringe, a bright or dark band caused by beams of light that are in phase or out of phase with one another. Light waves and similar wave propagation, when superimposed, will add their crests if they meet in the same phase (the waves are both increasing or both decreasing); or the troughs will cancel the crests if they are out of phase; these phenomena are called constructive and destructive interference, respectively. If a beam of monochromatic light (all waves having the same wavelength) is passed through two narrow slits (an experiment first performed in 1801 by Thomas Young, an English scientist, who inferred from the phenomenon the wavelike nature of light), the two resulting light beams can be directed to a flat screen on which, instead of forming two patches of overlapping light, they will form interference fringes, a pattern of evenly spaced alternating bright and dark bands. All optical interferometers function by virtue of the interference fringes that they produce.



Condition for interference:

The two waves must be along the same direction.

The waves must be inclined at an angle to each other.

The two waves must have same amplitude or nearly same amplitude and frequency.

The two waves must be coherent.

Phase difference is independent of time.

The path difference for darkness is given by

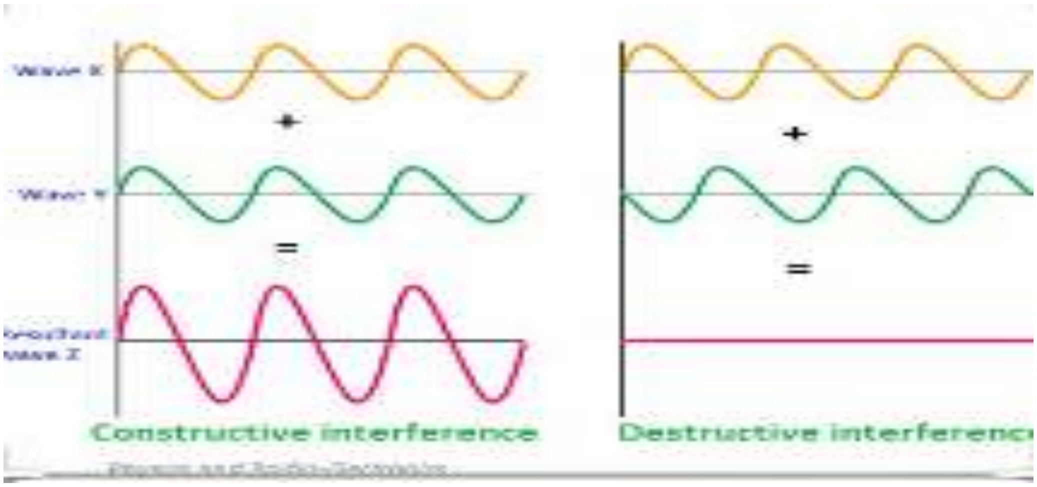
$$[(2s+1)\lambda/2] \quad \text{where } S=0,1,2,3,\ldots\ldots\ldots$$

Path difference for brightness is given by $S\lambda$.

Types of Interference:

Constructive interference

Destructive interference

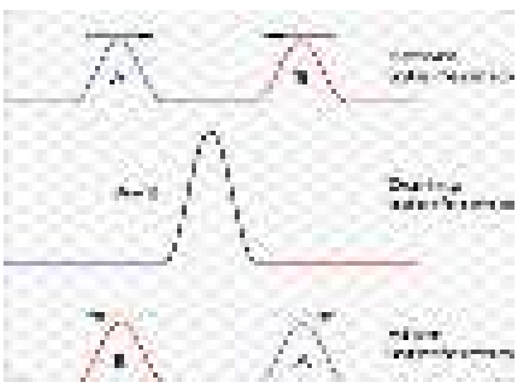


Constructive Interference:

It is a type of interference where the two interfering wave have a displacement in the same direction.

Constructive interference is observed at any location where the two interfering waves are displaced upward.

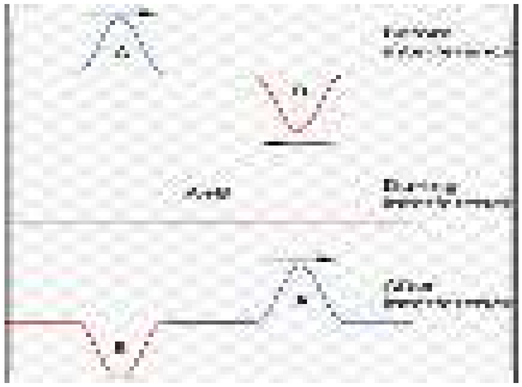
It is also observed when both interfering waves are displaced downward.



Destructive Interference:

It is a type of interference where the two interfering waves have a displacement in the opposite direction.

Destructive interference occurs when the difference is an odd multiple of Π.



Principle of interference:

If two rays of same wavelength meet at some point, mutual interference occurs and natural interference depends on Phase of two waves at their meeting point.

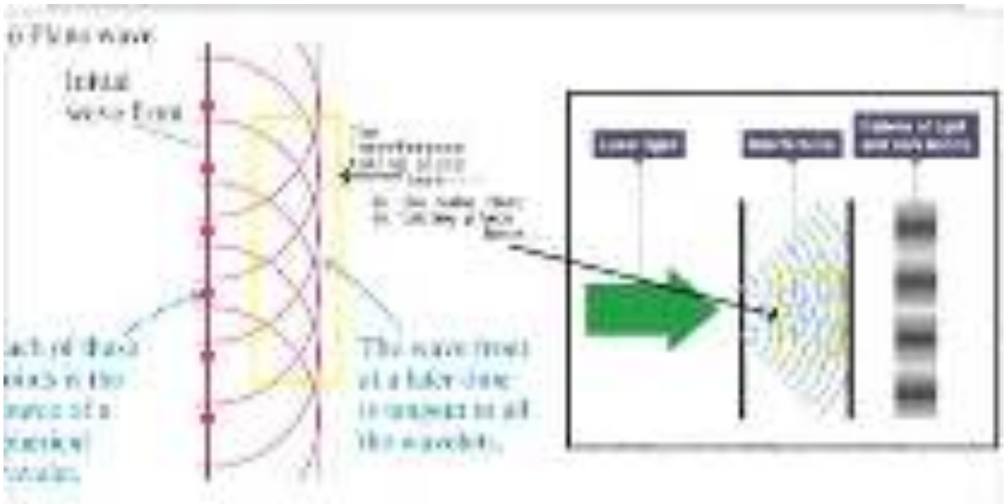
If two rays are in same phase, then resulting intensity will be the sum of two intensities.

If two rays are out of phase, then resulting intensity will be the difference of two intensities.

If two rays having same amplitude are in same phase, then resultant will be twice & result will be

Bright spot.

If two rays having same amplitude are out of phase, then resultant will be zero & result will be dark spot.



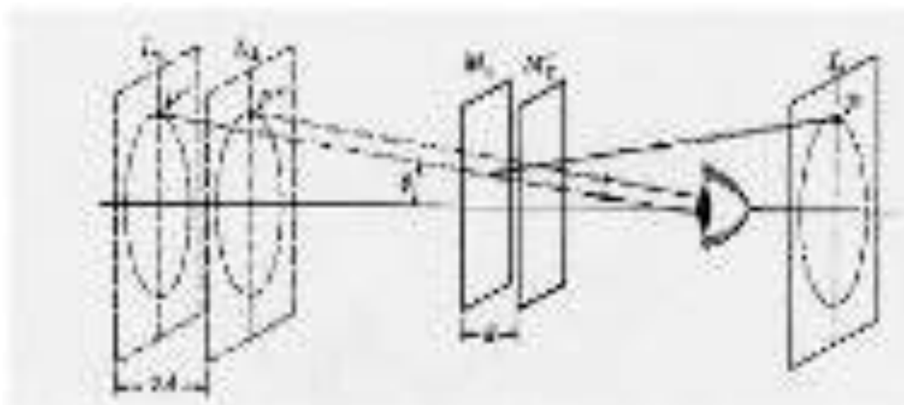
Types of fringes:

Circular fringes

Circular fringes are produced with monochromatic light when the mirrors are in exact adjustment as shown in Figure 2. The real mirror, M2, has been replaced by its virtual image, M2', formed by reflection in G1. Mirror M2' is then parallel to M1. These virtual sources are coherent because the phases of corresponding points in the two sources are exactly the same at all instants. If d is the separation M1M2', the virtual sources will be separated by 2d. When d is exactly an integral number of half wavelengths, all light reflected normally to the mirrors will be in phase. The path difference between the two rays coming to the eye from corresponding points P' and P" is $2d\cos\theta = n\lambda$. Hence, when the eye is focused to receive parallel rays, the rays will reinforce each other to produce maxima for those angles θ which satisfy the equation,

$$2d\cos\theta = n\lambda$$

Since, for a given n, λ and d the angle θ is constant, the maxima will lie in the form of circles centred on the perpendicular from the eye to the mirrors. Fringes of this type are called fringes of equal inclination.



Circular fringes of equal inclination

Localized fringes

If on the other hand, the mirrors M1 and M2' are not exactly parallel, fringes will still be seen with monochromatic light for path differences which do not exceed a few millimetres. In this case the space between the mirrors is wedge-shaped. These localised fringes are almost straight because the path difference across the field of view is due primarily to the variation of the thickness of the "air film" between the mirrors.

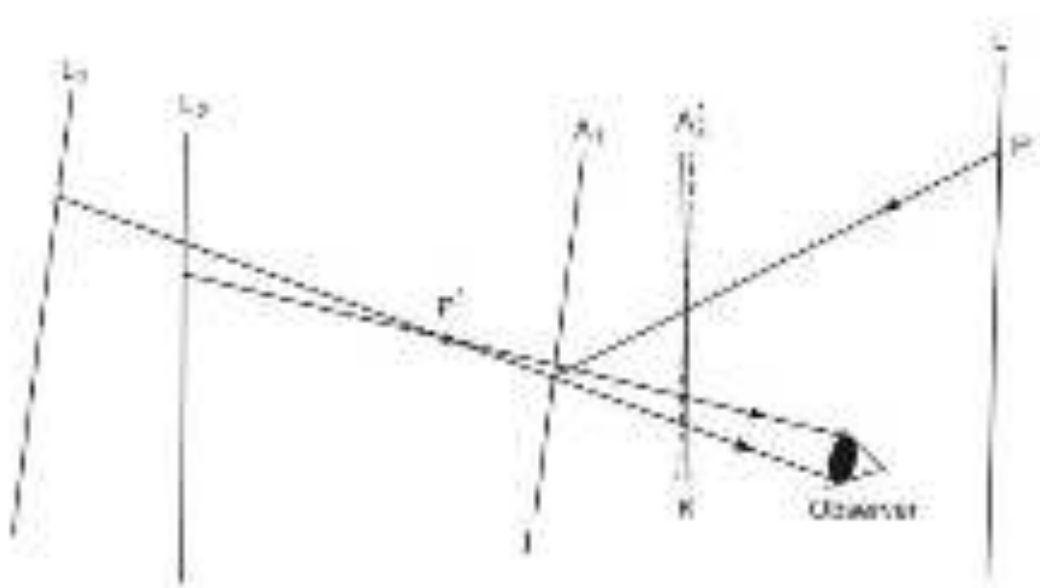
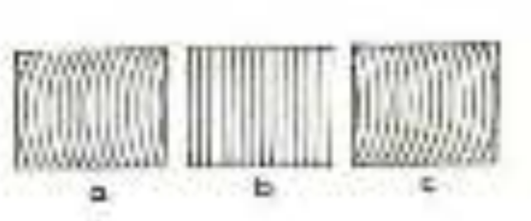


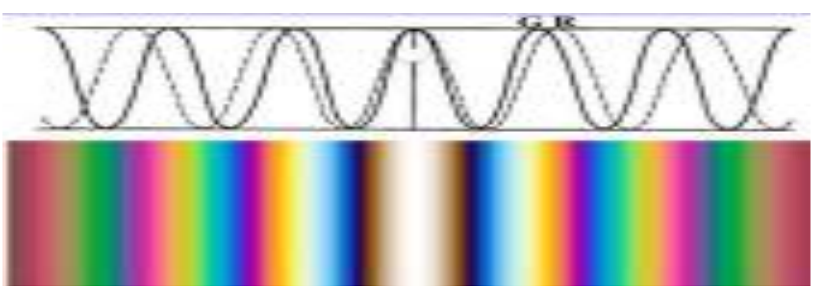
Figure: Formation of localised fringes with non perpendicular mirrors



The localised fringe interference patterns produced by a Michelson interferometer: (a) and (c) are depictions of curved fringes, implying the mirror is far from the region of zero path difference, and (b) shows straight, parallel fringes — this must be at or very near the point of zero path difference.

White light fringes

If a source of white light is used white light fringes are only seen when the path difference d between the two beams is so small that it does not exceed a few wavelengths. A central dark fringe, bordered on either side by 8 or 10 coloured fringes will then be observed. Few fringes are observed with white light which contains all wavelengths between 400 and 700 nm. The fringes in different colours will only coincide for the central uncoloured fringe at d = 0 and will begin to separate on either side of the centre so that after a few fringes, so many colours are present that the resultant is essentially white.



Visibility of Fringes

- Visibility determines the ability to resolve interference fringes. It depends on the coherence degree between the recombined light waves.

- It is defined as:

$$V = I_{max} - I_{min} / I_{max} + I_{min}$$

maximum if $I_{min} = 0$, $V = 1$

When $I_{min} = I_{max}$, $V = 0$

$$[\, 0 \leq V \leq 1 \,].$$