WAVE NATURE OF LIGHT

Light wave is basically an electromagnetic wave. Electromagnetic wave consists of electric and magnetic field vectors. The directions of electric and magnetic vectors are perpendicular to direction of propagation as shown in the figure 4.1. The electric and magnetic vectors are denoted by E and H and vary with time.

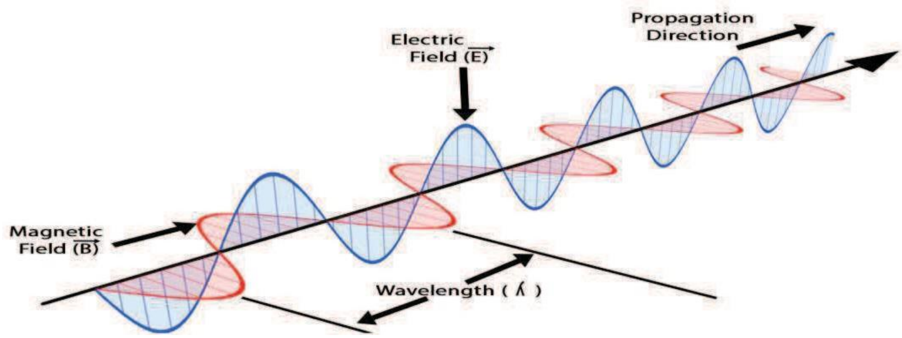

Figure 4.1

In light, electric vectors (or magnetic vectors) vary in sinusoidal manner as shown in figure 4.1. Therefore, the electric vectors can be given as

$$E = E_0 \sin(kz - \omega t)$$

Where E = Electric field vector, E_0 = maximum amplitude of field vector, k = wave number (= $2\pi/\lambda$), z = displacement along the direction of propagation (say z axis), ω = angular velocity and t = time.

Before understanding the interference we should understand some terms and properties of light which are related to interference.

4.1.1 Monochromatic Light

The visible light is a continuous spectrum which consist a large number of wavelengths (approximately 3500Å to 7800Å). Every single wavelength (or frequency) of this continuous spectrum is called monochromatic light. However, the individual wavelengths are sufficiently close and indistinguishable. Some time we consider very narrow band of wave lengths as monochromatic light.

Ordinary light or white light, coming from sun, electric bulb, CFL, LED etc. consists a large number of wave lengths and hence non-monochromatic. But some specific sources like sodium lamp and helium neon laser emit monochromatic lights with wave lengths 589.3 nm and 632.8 nm respectively. It should be noted that sodium lamp, actually emits two spectral lines of wavelengths 589.0 nm and 589.6 nm which are very close together, and source is to be consider monochromatic.

4.1.2 Plane Wave

A plane wave is a wave whose wave front remains in a plane during the propagation of wave. In light wave, the maximum amplitude of electric vector E_0 remains constant and confined in a plane perpendicular to direction of propagation. Such type of wave called plane wave.

4.1.3 Polarized and Unpolarized Light

Light coming from many sources like sun, flame, incandescent lamp produce unpolarized light in which electric vector are oriented in all possible directions perpendicular to direction of propagation. But in polarized light electric vector are confined to only a single direction. The detail about polarized light will be discussed in the next block.

4.1.4 Phase Difference and Coherence

Wave is basically transportation of energy by mean of propagation of disturbance or vibrations. In wave motion through a medium, the particles of medium vibrate but in case of electromagnetic wave the electric or magnetic vectors vibrate form its equilibrium position.

The term phase describes the position and motion of vibration at any time. For example if y= a sin (ωt +θ) represents a wave, then the term (ωt +θ) represents the phase of wave. The unit of phase is degree or radium. After completion of 360^0 or 2π, the cycle of wave or phase repeats.

Phase difference

If there are two waves have some frequency then the phase difference is the angle (or time) after which the one wave achieves the same position and phase as of first wave. In the figure 4.2, two waves with phase different θ are shown.

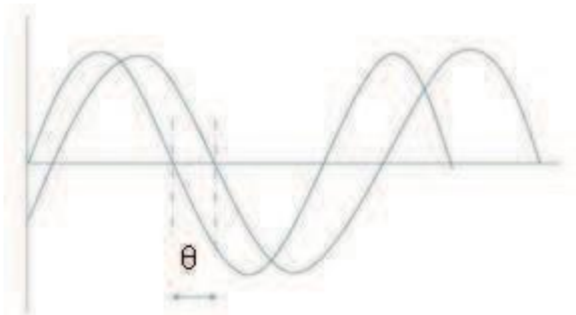

Figure 4.2

Coherence

If two or more waves of same frequencies are in same phase or have constant phase difference, those waves are called coherent wave. Figure 4.3 shows coherent wave with same phase (zero phase difference) and with constant phase difference.

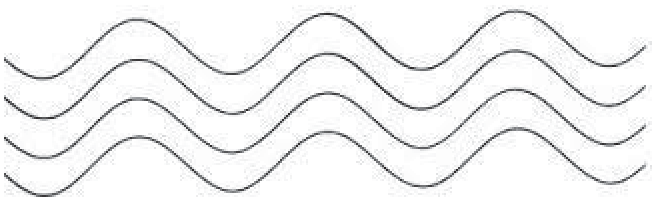

Figure 4.3

4.1.5 Optical path and Geometric Path

Optical path length (OPL) denoted by Δ is the equivalents path length in the vacuum corresponding to a path length in a medium. Path length in a medium can be considered as geometric path length (*L*). Suppose a light wave travels a path length *L* in a medium of refractive index μ and velocity of light is *v* in this medium, then for a time period *t* the geometric path length *L* is given by

$$L = vt$$

In the same time interval *t*, the light wave travel a distance *Δ* in vacuum which is optical path length corresponding to length *L*. Then

$$\Delta = ct = c\frac{L}{v}$$

Where, c is the velocity of light in

vacuum. or Δ

$= \mu L$

or The Optical path length = μ × (Geometrical path length in a medium).

In case of interference we always calculate optical path for simplification of understanding and mathematical calculations.

4.2 PRINCIPLE OF SUPERPOSITION

According to Young's principle of superposition, if two or more waves are travelling and overlap on each other at any point then the resultant displacement of wave is the sum of the displacement of individual waves (figure 4.4). If two waves are represented by $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin (\omega t+\delta)$. Then according to principle of superposition, the resultant wave is represented by $y = y1 + y2$

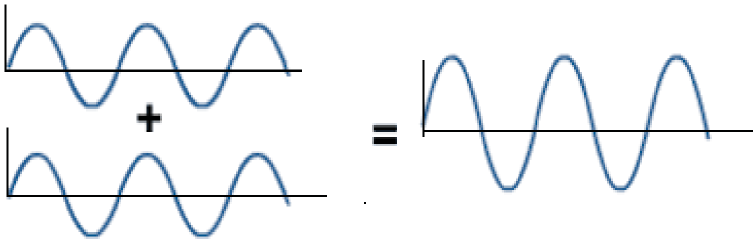

Figure 4.4