Wave Nature of light

Minati Barman
Associate Professor
Department of Physics
JN College, Boko

Nature of light:

- Newton's **corpuscular theory of light:**

In 1672, Newton's gave the **corpuscular theory of light** which states that **light** is made up of small discrete particles called "corpuscles" (little particles) which travel in a straight line with a finite velocity.

This theory was unable to explain the interference , diffraction , polarization phenomena which leads to the wave theory of light.

- Huygens wave theory of light:

In 1678, Christian Huygens gave the wave theory of light. Huygens stated that an expanding sphere of light behaves as if each point on the wave front were a new source of radiation of the same frequency and phase.

Thomas Young and Augustine Jean Fresnel disproved Newton's corpuscular theory.

Electro magnetic theory of light:

In the early 1860, Maxwell pioneered the electromagnetic theory of radiation and established four famous equations theoretically and calculated the velocity of the E M wave.

Electromagnetic wave travels through space at a constant speed of 3.0×10^8 m/s (186,000 mi/s).

Visible light is a small part of the electromagnetic radiation.

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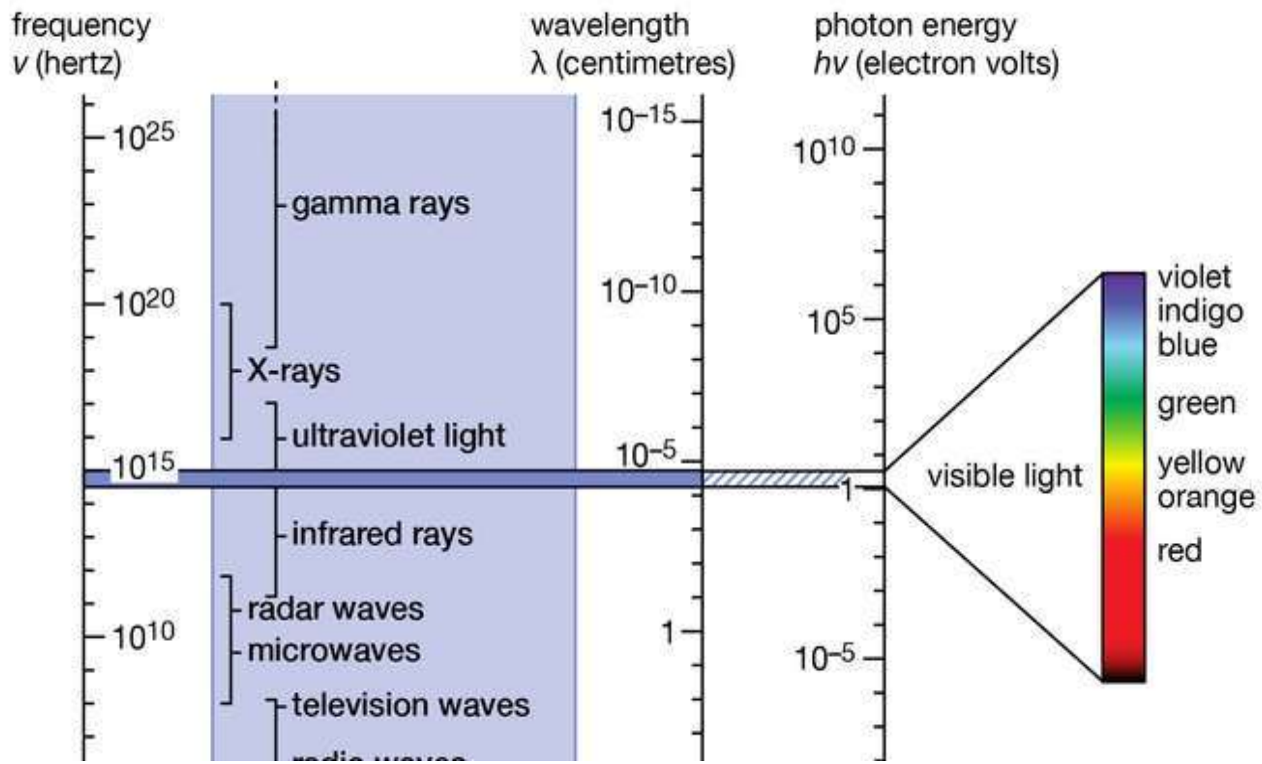
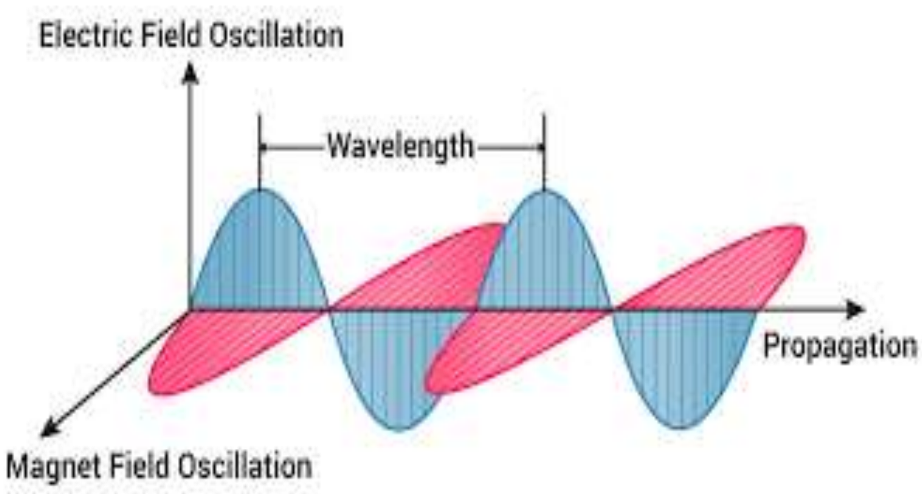


Electro magnetic wave spectrum

Electromagnetic Wave:

An electromagnetic wave is a combination of electric and magnetic fields vibrating perpendicularly to each other travelling through space .



Quantum theory of light:

Quantum theory tells us that Light is composed of tiny particles called photon which have wavelike properties associated with them.

It is called as Wave-Particle Duality of Light.

Photons are nothing but discrete packet of energy $E=hf$, where h is Planck's constant and f is the frequency of light radiation.

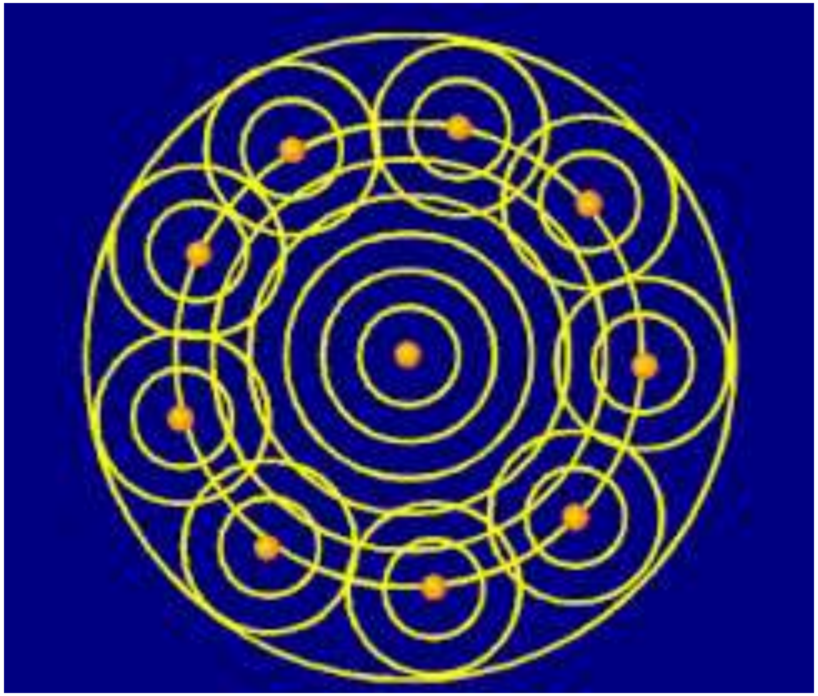
Huygens's wave theory:

Huygens proposed that every point source creates disturbances in ether medium and produce spherical wave which travels with same speed in all direction in a homogenous , isotropic medium.

Every point in the spherical wave acts as a source of secondary waves which travel with same speed.

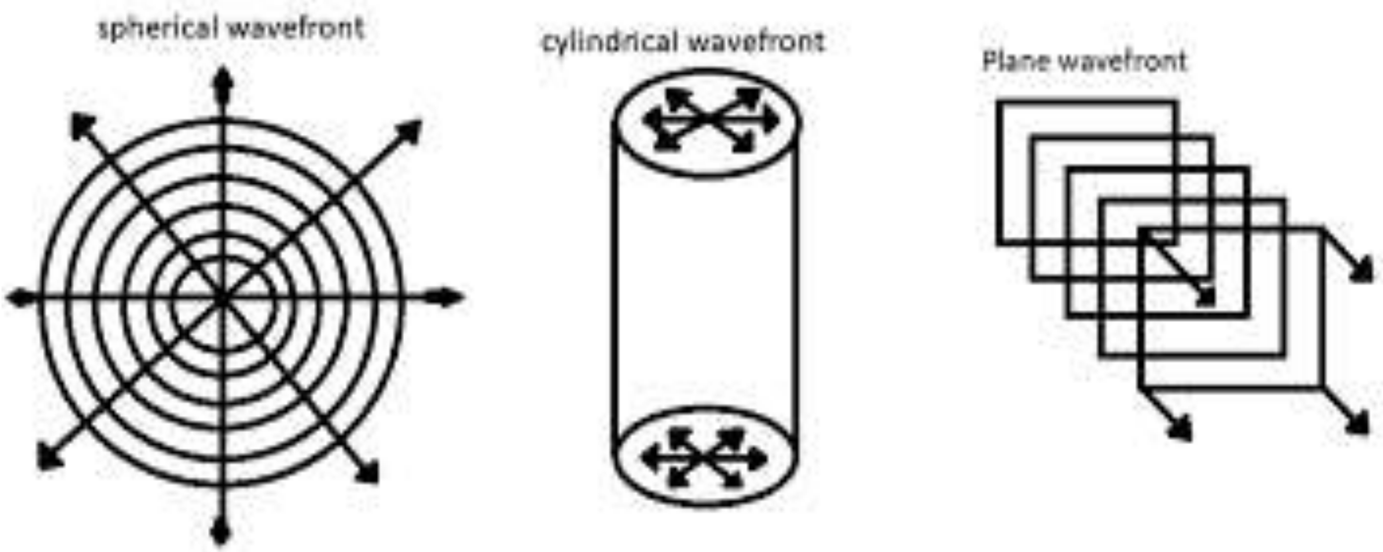
The surface upon which the phase of disturbance is the same at an instant of time is called as an wavefront. A wave always travels in a direction normal to the wavefront.

Wave front, the envelope of particles vibrating with same phase



Types of wavefront:

- Plane wavefront
- Spherical wavefront
- Cylindrical wavefront



- When the source is a point source then the wavefront is spherical.

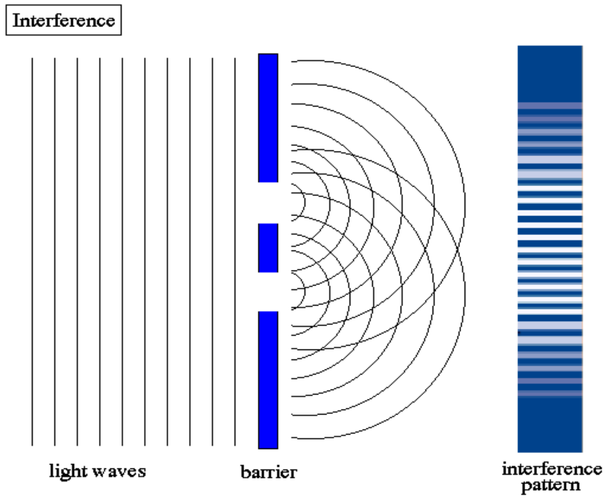
- When the source is linear, the wavefront is cylindrical.

- When the loci of points of constant phase lie on a plane, the wave front is plane wavefront.

At a sufficient distance from the source a small portion of wavefront may be considered as plane wavefront.

What are coherent sources?

Two sources are said to be coherent when the waves emitted from them have the same frequency, amplitude and constant phase difference. Interference from such waves constantly produce bright and dark fringes at every point of a screen.



Coherence is a essential condition for interference of light waves.

There are two types of coherence:

i. Temporal coherence
ii. Spatial coherence.

TEMPORAL COHERENCE

The correlation of the wave fields at different instant of time at one location is Temporal coherence.

If at any fixed point, the amplitude of the wave remains constant and phase varies linearly with time, then the wave field is said to be temporally coherent.

The longest time period for which the same wave pulse continue to pass through a space point is called coherence time.

Let coherence time, $\Delta t = \tau c$

Therefore the coherence length

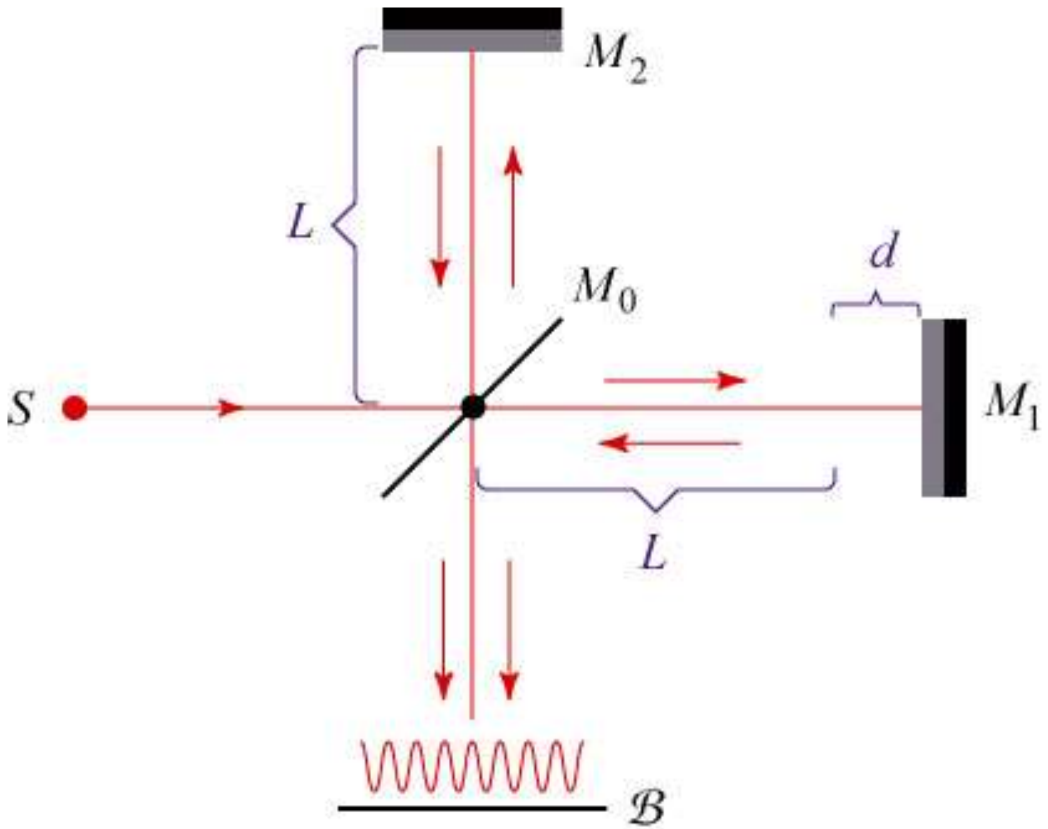
$$Lc = \text{speed of the wave} \times \tau c$$

In interference phenomenon,

if the path difference >coherence length Lc

then no interference pattern is observed.

Temporal coherence can be explained nicely by Michelson Morley experiment.



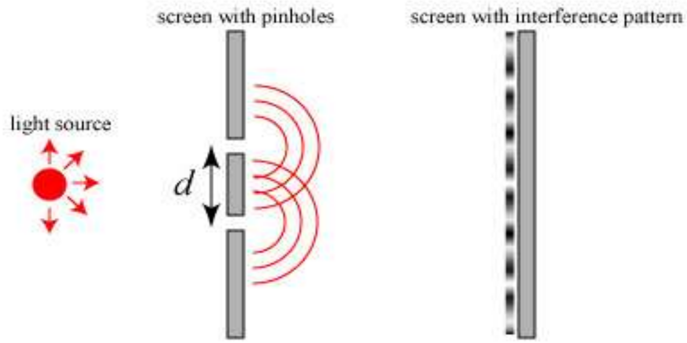
Temporal coherence

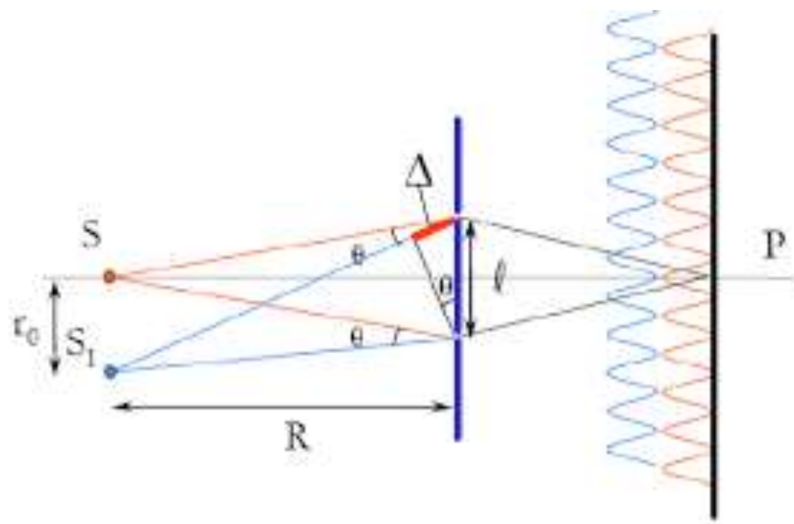
Spatial coherence:

Spatial coherence is the phase relationship between two space points in a particular instant of time. If the wave has only one value of amplitude over an infinite length then the wave is perfectly spatially coherent.

When the shape of a source is gradually increased then lateral dimension of the source over which the radiation remains coherent determines the spatial coherence.

Young's double slit experiment





Spatial coherence

In above figure S and S1 are two sources separated by a distance ro. The two light waves coming from S meets the central point with zero phase difference but light waves from S1 meets central point with a phase difference. If this phase difference is equal to $\lambda/2$, then there will be dark fringe for the source S1, so we get general illumination at point P.

Mathematically it can be shown that ro=λR/2 l. If we have an extended source of linear dimension λR/ l, then no interference pattern will be obtained. Good interference pattern will be obtained onl when

ro<< λR/ l

l << λR/ ro

l << λ/Θ where Θ= R/ ro

If the distance between the holes increases the interference fringes decreases. lw = λ/Θ is the lateral distance over which the beam is spatially coherent and is called as lateral coherence width.

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