Optics

(Lec-3)

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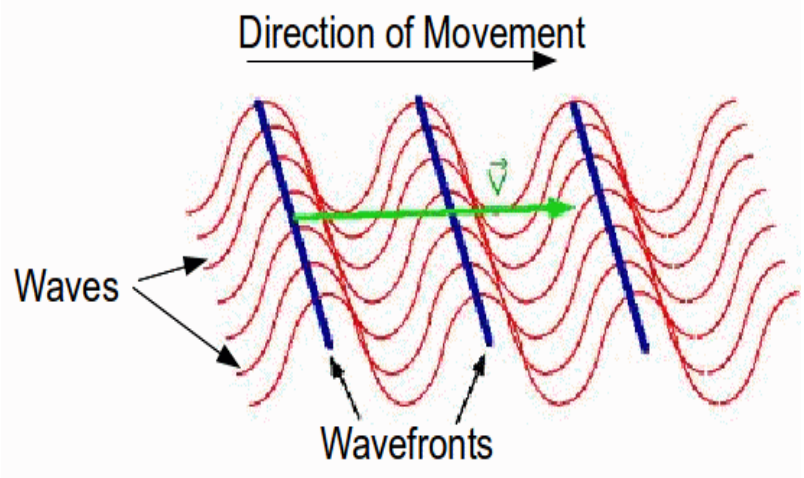
OUTLINES

- Wavefront
- Huygens's principle
- Superposition principle

Wavefront

A wavefront is a surface over which an optical wave has a constant phase. For example, a wavefront could be the surface over which the wave has a maximum (the crest of a water wave, for example) or a minimum (the trough of the same wave) value.

The shape of a wavefront is usually determined by the geometry of the source. A point source has wavefronts that are spheres whose centers are at the point source. A fluorescent tube would have wavefronts that are cylinders concentric with the tube itself. A very large sheet of material that is uniformly illuminated would generate wavefronts that are plane waves parallel to the sheet.



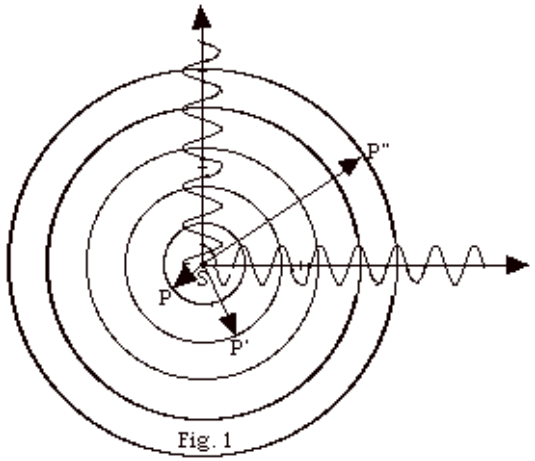


Fig. 1

Huygens's Principle

Sir Isaac Newton proposed that light was made of tiny particles known as the photons while Christian Huygens believed that light was made of waves propagating perpendicular to the direction of its movement.

In 1678, Huygens proposed that *"Every point on a wave-front may be considered a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets". This theory of light is known as the 'Huygens' Principle'.*

Using the above-stated principle, Huygens was successful in deriving the laws of reflection and refraction of light. He was also successful in explaining the linear and spherical propagation of light using this theory. However, he wasn't able to explain the diffraction effects of light. Later, in 1803, the experiment conducted by Thomas Young on the interference of light proved the Huygens wave theory of light to be correct. Later in 1815, Fresnel provided mathematical equations for Young's experiment.

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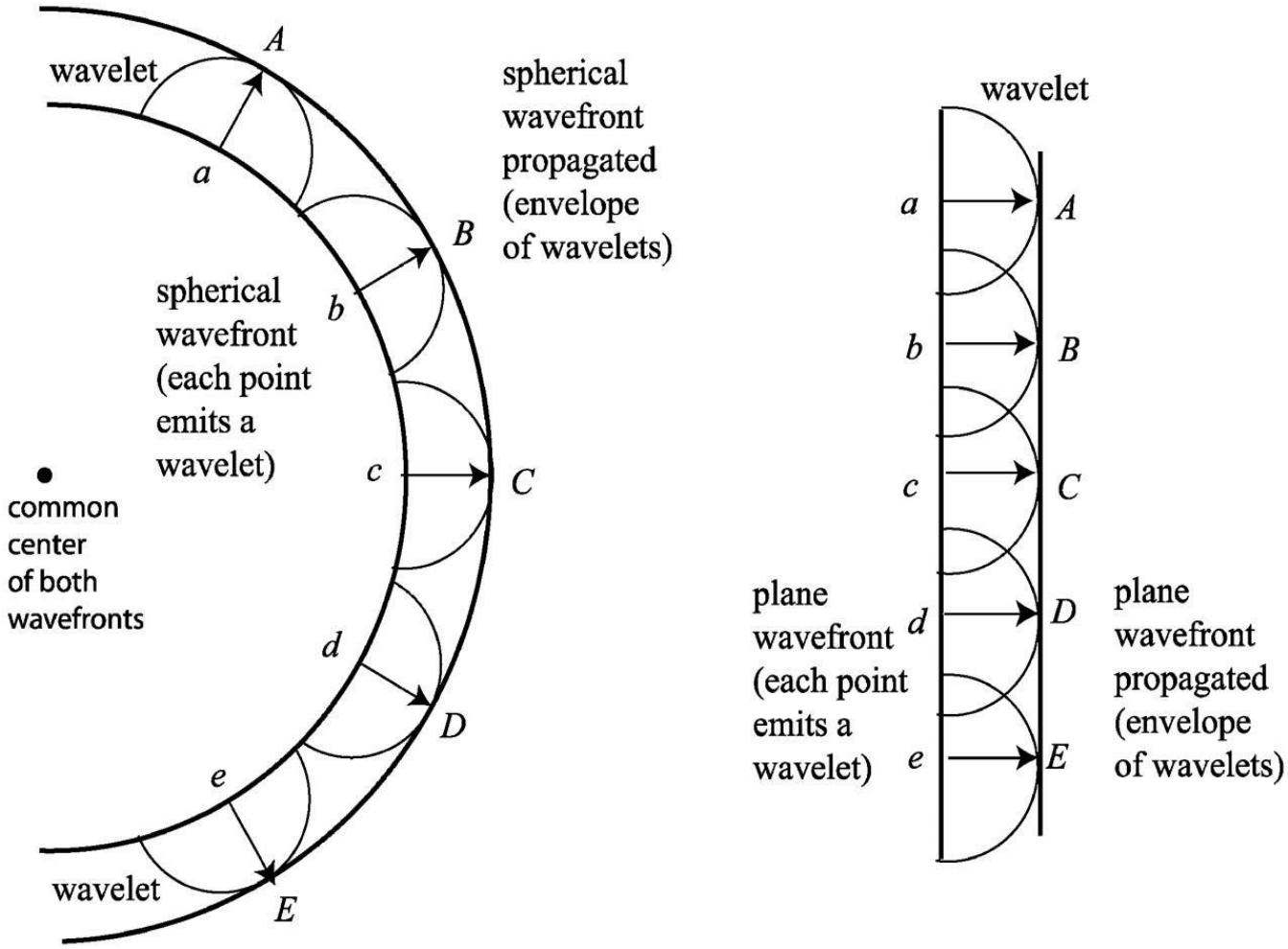

wavelet
A
a
B
b
C
c
d
D
e
E
wavelet
spherical wavefront propagated (envelope of wavelets)
spherical wavefront (each point emits a wavelet)
common center of both wavefronts
wavelet
a
A
b
B
c
C
d
D
e
E
plane wavefront (each point emits a wavelet)
plane wavefront propagated (envelope of wavelets)

Fig. 1

Superposition of waves

When a medium is disturbed simultaneously by any number of waves, the instantaneous resultant displacement of the media at every point at any instant is the algebraic sum of the displacements of the medium due to individual waves. In Young's own words, "When two undulations from different origin coincide either perfectly or very nearly, in direction, their joint effect is a combination of the motions belonging to each." Let us consider two waves crossed a particle in a medium and the different displacements of particle by the two waves are y_1 and y_2. If the waves are in same phase, then the resultant displacement of the particle is y $= y_1 + y_2$. And if they are in opposite phase, then the resultant displacement of the particle is y = $y_1 - y_2$.

Coherent source

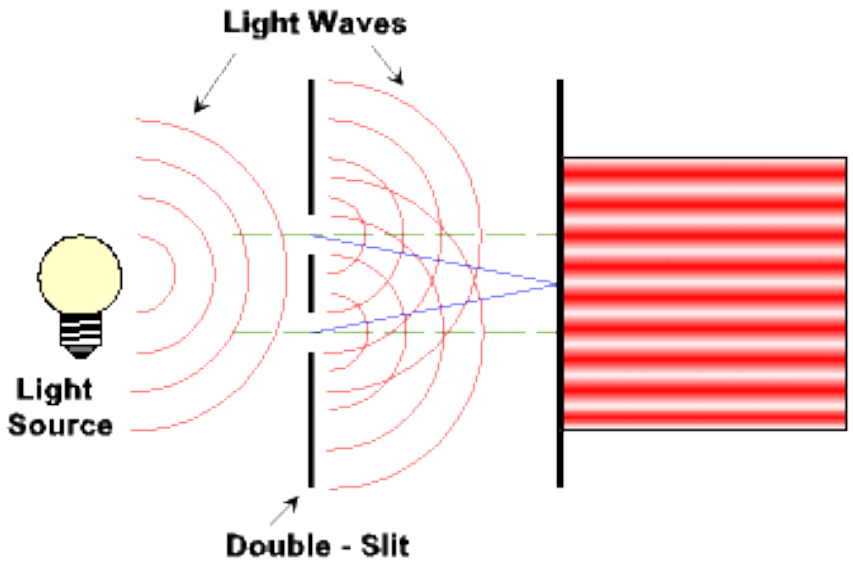
Two sources are said to be coherent if they emit light waves of exactly same frequency, and have zero or constant phase difference. Most of the light sources around us - lamp, sun, candle etc. are combination of multitude of incoherent sources of light. Laser is a coherent source i.e. constituent multiple sources inside the laser are phase-locked.

We need coherent sources of light in order to observe the effects of certain optical phenomena like Interference in lab. Two parallel slits lighted by a laser beam behind can be said to be two coherent point sources.

Slit: A slit is a rectangular aperture of length large compared to its breadth.

❖ Interference of Light

In physics, interference is a phenomenon in which two waves superpose to form a resultant wave of greater or lower amplitude. Interference usually refers to the interaction of waves that are correlated or coherent with each other, either because they come from the same source or because they have the same or nearly the same frequency. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves or matter waves.



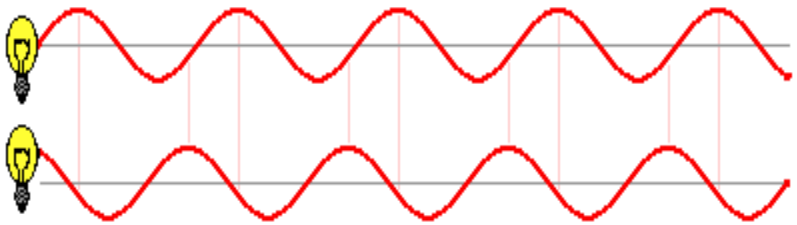
Conditions of Interference

When waves come together, they can interfere constructively or destructively. To set up a stable and clear interference pattern, two conditions must be met:

1. The sources of the waves must be coherent, which means they emit identical waves with a constant phase difference.
2. The waves should be monochromatic - they should be of a single wavelength.

Coherent Sources

Those sources of light which emit light waves continuously of same wavelength, time period, frequency, and amplitude and have zero phase difference or constant phase difference are called coherent sources.

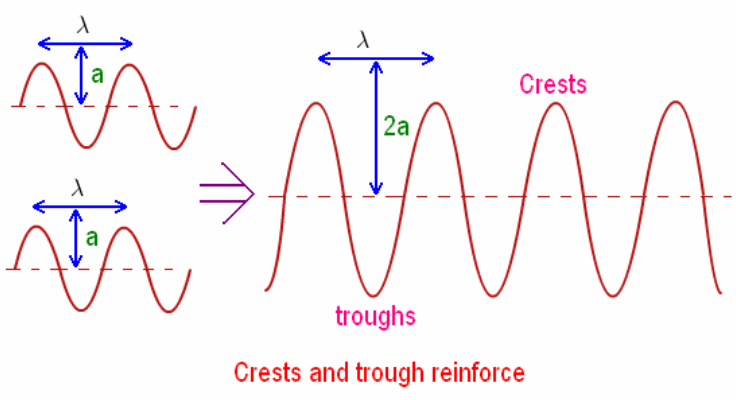


These two waves are coherent - they have a phase difference which is constant over time.

There are two types of interference.
Constructive Interference.
Destructive Interference.

Constructive Interference

When two light waves superpose with each other in such a way that the crest of one wave falls on the crest of the second wave, and trough of one wave falls on the trough of the second wave, then the resultant wave has larger amplitude and it is called constructive interference.



Destructive Interference

When two light waves superpose with each other in such a way that the crest of one wave coincides the trough of the second wave, then the amplitude of resultant wave becomes zero and it is called destructive interference.

