Interference and interferometer types

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Interference A consequence of **superposition** of waves.

Resultant irradiance that deviates from sum of individual irradiances.

Due to Optical path differences and phase shifts.

Types of interferometers

Wavefront-splitting split primary wavefront into parts to make sources of secondary waves, which interfere. Young's double slit, Fresnel biprism and mirror, Lloyd's mirror.

Amplitude-splitting primary wave divided into segments which travel different paths. Dielectric films, Michelson, Mach-Zender, and Sagnac interferometers.

Interference in terms of irradiances (section 9.1)

$$I = I_1 + I_2 + 2\sqrt{(I_1 I_2)}\cos\delta$$

where δ is the phase difference resulting from initial phase angle differences and **differences in optical path length.**

$$\delta = \vec{\mathbf{k_1}} \cdot \vec{\mathbf{r}} - \vec{\mathbf{k_2}} \cdot \vec{\mathbf{r}} + \varepsilon_1 - \varepsilon_2$$

The **interference term** for irradiances is

$$2\sqrt{(I_1 I_2)}\cos\delta$$

For **total constructive interference:**

$$I_{\text{max}} = I_1 + I_2 + 2\sqrt{I_1 I_2}$$

when

$$\delta = 0,\ \pm 2\pi,\ \pm 4\pi, \ldots$$

Total destructive interference:

$$I_{\text{min}} = I_1 + I_2 - 2\sqrt{I_1 I_2}$$

when

$$\delta = \pm\pi,\ \pm 3\pi,\ \pm 5\pi, \ldots$$

Note that if $I_1 = I_2 = I$, $I_{\text{max}} = 4I$, and $I_{\text{min}} = 0$.

Maxima and minima

Remember that irradiance is what our eyes and detectors register. Irradiance maxima occur when

$$\delta = 2\pi m$$

provided that $m = 0, \pm 1, \pm 2, \ldots$ Minima arise at

$$\delta = \pi(2m + 1).$$

These define hyperbolic surfaces of revolution for two coherent sources.

Coherence For two sources of the same strength

$$\begin{aligned} I &= 4I_0 \cos^2 \frac{\delta}{2} \\ &= 4I_0 \cos^2 \frac{1}{2}[\vec{\mathbf{k_1}} \cdot \vec{\mathbf{r}} - \vec{\mathbf{k_2}} \cdot \vec{\mathbf{r}} + (\varepsilon_1 - \varepsilon_2)]. \end{aligned}$$

For these variations to be observable over space, the phase difference must be fairly stable in *time*. Such a source is **coherent.**

Temporal coherence: is greater the longer a source maintains a steady phase. The **coherence time** is the average time over which the lightwave resembles a sinusoid. **Temporal coherence—spectral purity.**

Spatial coherence: is greater the less the phase deviation is across a wavefront. A measure of "flatness" or "sphericity" of the wavefront.

Longitudinal spatial coherence is just temporal coherence viewed in space along the propagation direction. **Coherence length** for a source is how far it maintains its phase along the propagation direction.

Coherence of various sources.

Thermal sources: low coherence. White light fringes are possible with some interferometers, but tricky.

Quasimonochromatic: filtered gas discharge, etc. More coherent, still require careful arrangement.

Lasers: Excellent. Coherence lengths of many meters/km possible at optical wavelengths.

Masers, Microwave, RF oscillators Coherence near perfect, coherence lengths of greater than planetary scale (GPS, Radio Interferometry).