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ENGINEERING PHYSICS

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Unit IV : Application of Quantum Mechanics to Optical Waves: LASERS

- Class #36
- Properties of lasers

1. Monochromaticty
2. Coherence
3. Unidirectionality
4. High Intensity

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Unit IV : Review of concepts leading to Quantum Mechanics: LASERS

➢ *Suggested Reading*

1. Lasers: Fudamentals and Applications

K Thyagarajan, A Ghatak

2. Course material developed by the department

➢ *Reference Videos*

https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/

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Properties of a laser

High Mono-chromaticity

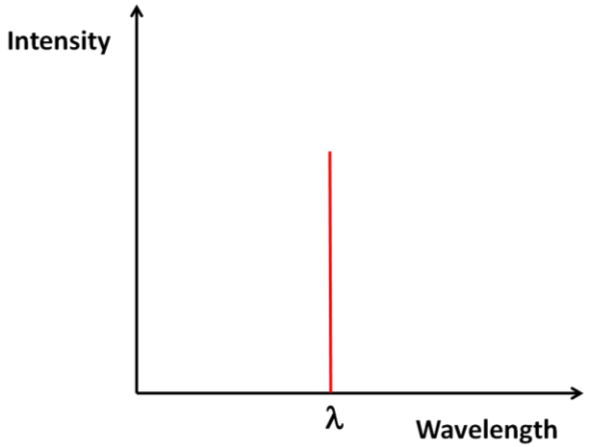


Fig. 1

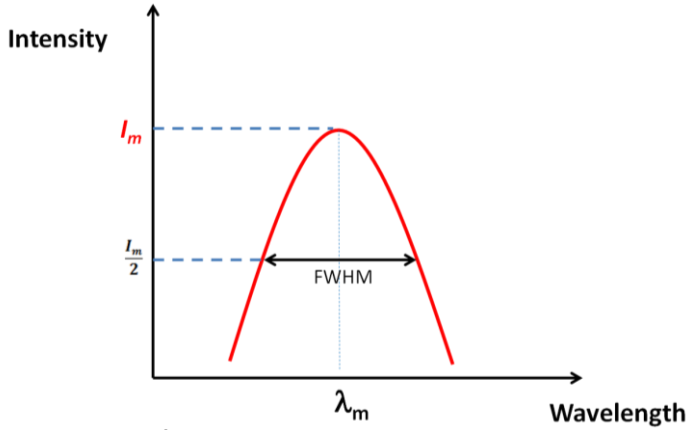


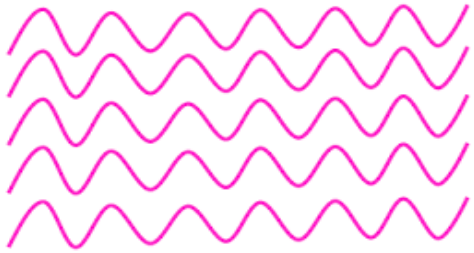
Fig. 2

The line width $\Delta\lambda$ = FWHM (Full Width at Half Maximum)

In terms of frequency, the line width

$$\Delta\upsilon = \frac{c\,\Delta\lambda}{\lambda_m^2}$$

Properties of a laser



Coherence.

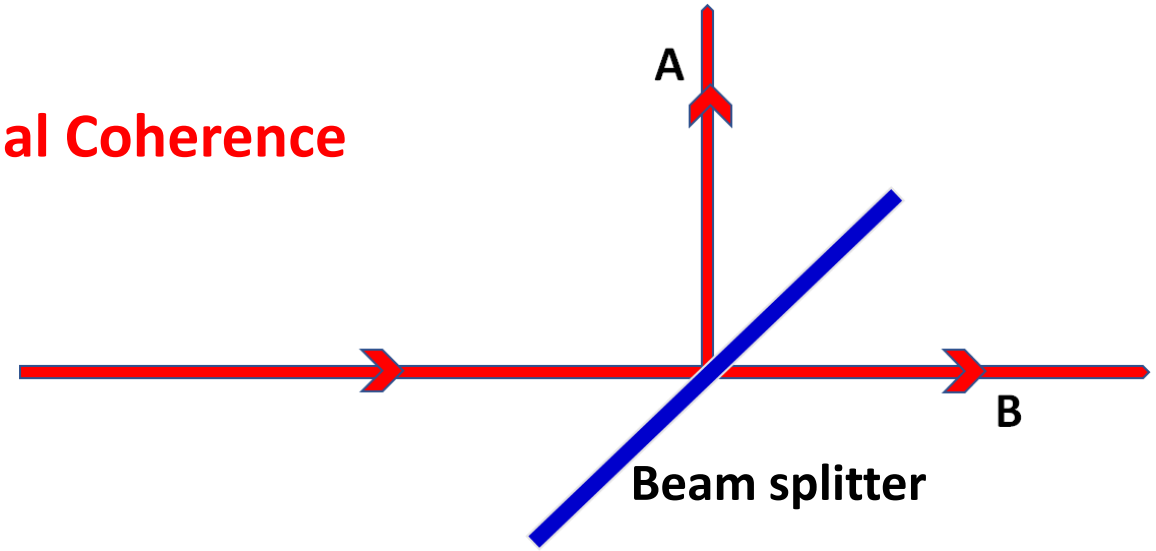
Refers to inter relationship of phases of the electromagnetic waves of a laser beam

Spatial Coherence

When electromagnetic fields at different spatial regions have a phase correlation (either zero or a constant phase difference), the beam is said to be spatially coherent.

Coherence

Spatial Coherence



- The E-fields at point A and B have a phase difference of 90° which remains constant over time.
- So we say the beams are spatially coherent.
- If the beams are made to interfere the resulting amplitude or intensity would remain unchanged in time

Coherence

Temporal Coherence

- If the electric fields of a laser are sampled at different times and if the samples exhibit a well defined phase correlation, then the laser is said to be temporally coherent.

- A perfectly monochromatic emission for example has perfect temporal coherence.

- The interference of a wave with a time delayed copy of itself will reveal the nature of temporal coherence.

Properties of a laser

Coherence time (τ_c)

- The time duration up to which a laser emission maintains its temporal coherence.

$$\tau_c = \frac{1}{\Delta\nu}$$

Where $\Delta\upsilon$ is the line width of the laser

Coherence length (l_c)

- The distance up to which a beam exhibits temporal coherence.

$$l_c = c\tau_c$$

- For example a pure sine wave has a coherence length of infinity.

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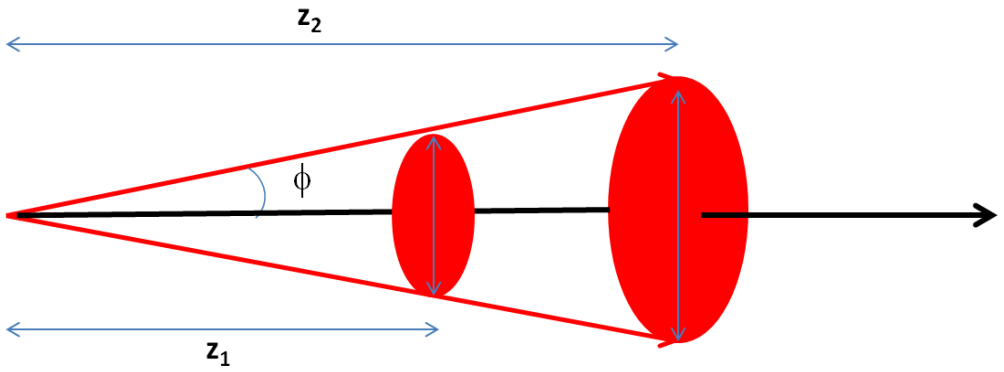
Properties of a laser

BEAM DIVERGENCE

- For a circular cross section



$$\phi_d = \frac{d_2 - d_1}{z_2 - z_1}$$

Here d_1 and d_2 are the diameters of the beam at distances z_1 and z_2 respectively.

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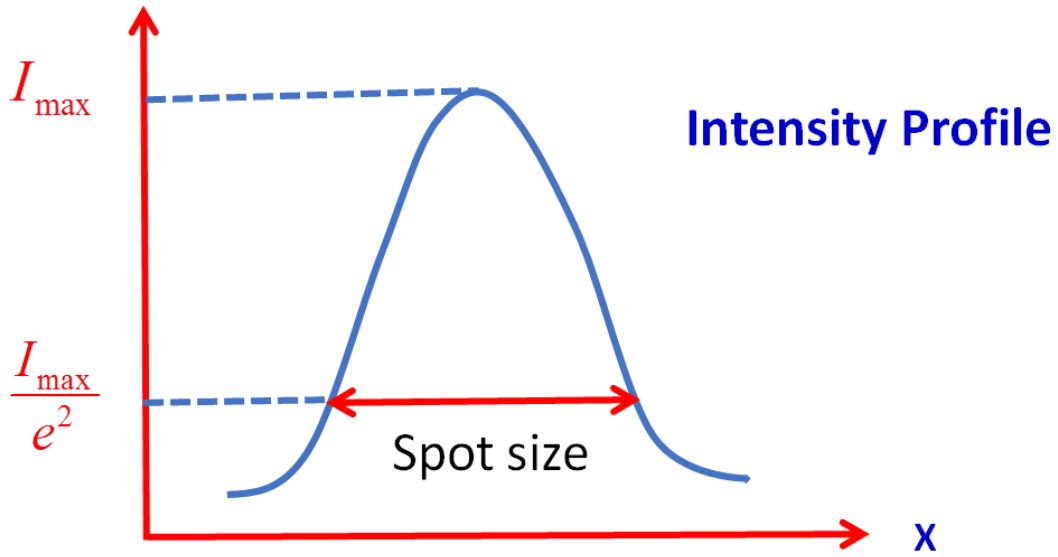
LASERS, BEAM DIVERGENCE



For a Gaussian beam profile, the beam divergence is given by

$$\phi_d = \frac{\lambda}{\pi\omega}$$

Where λ is the wavelength and ω is the radius of the beam at the beam waist

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Properties of Lasers

High Intensity

- A lot of energy is concentrated in a small cross sectional area
- Negligible scattering
- Can be focused to a tight spot
- High power IR lasers are used to cut metals
- Lasers of today cover a large spectrum
- Applications in non linear optics: femto and atto second lasers, revolutionizing electronics and Ccomputer science

Check Your Understanding (Yes/No)

1. A beam defined by a pure sinusoidal wave is temporally coherent

2. The line width of a laser beam is in mm

3. Laser beam divergence is in the range of radian

4. Coherence time is inversely related to the line width

THANK YOU

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