Covered in Course

- Diode Lasers
- Faraday Isolators
- Fabry Perot Cavities
- Gaussian Beam Propagation
- Optical Coatings
- Acousto-Optic and Electro-Optic Devices
- Vacuum Systems
- Optical Detectors

Applications of Lasers

- Masks for Lithography – IC's
- Optical Communication – Fiber, Free Space
- Read/Write CD's and Scanners – Information Storage, Retrieval
- Frequency Standards – Clocks and Masers
- Industrial Machining, Surgery – Interaction
- Inertial Sensing – Gravity, Rotation
- Precision Measurements – Validation of Theories, LIGO, Determining Fundamental Constants, Standard Model

4061 – Lecture One

Outline of Lecture

Properties and Requirements of Lasers

- Coherence
- Gain Medium – Atoms, Semiconductors
- Amplifier/Cavity

Properties of Gain Medium

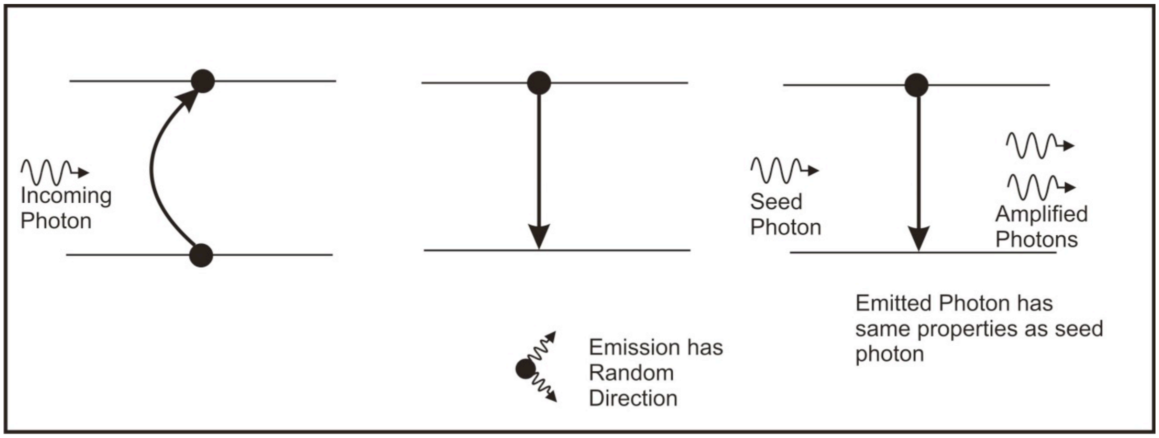
- Absorption
- Spontaneous Emission
- Stimulated Emission

Characteristics of Lasers

1. Longitudinal (Temporal) Coherence
2. Transverse (Spatial) Coherence
3. Brightness

Properties of a Gain Medium

Stimulated Absorption **Spontaneous Emission** **Stimulated Emission**



Coherence

- Correlation in E(r,t) within sample
- Photons in “lock step”
- Plane wave is perfectly coherent

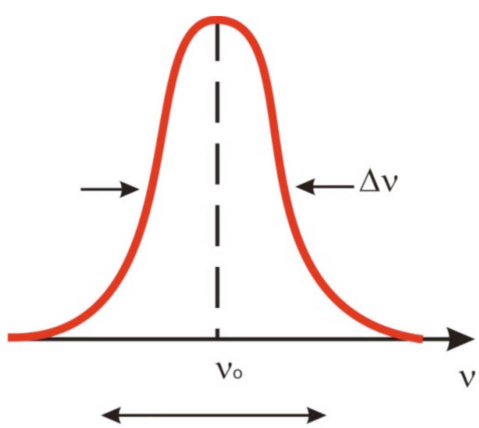
Stimulated Emission

- Coherent and monochromatic

Characteristics of Lasers

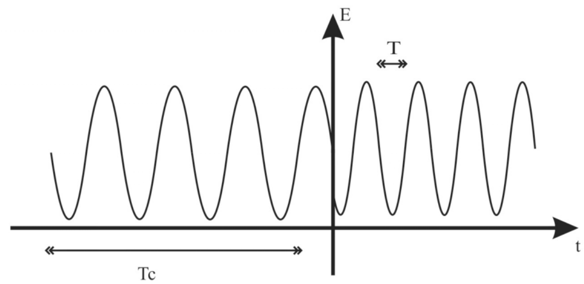
1. Longitudinal or Temporal Coherence – Along **k**
    - Associated with narrow spectral linewidth

$$\Delta\nu = (c/\lambda^2)\, \Delta\lambda$$



- $\Delta\nu \sim 1$ MHz for a good He Ne Laser or grating stabilized diode laser
- $\Delta\nu \sim 10$ GHz for incandescent light bulbs

- Coherence Time
  - $T_c = 1/\Delta\nu$ (Coherence time is the average time between phase interruptions)
  - $T = 1/\nu_0$ (Period of wave)



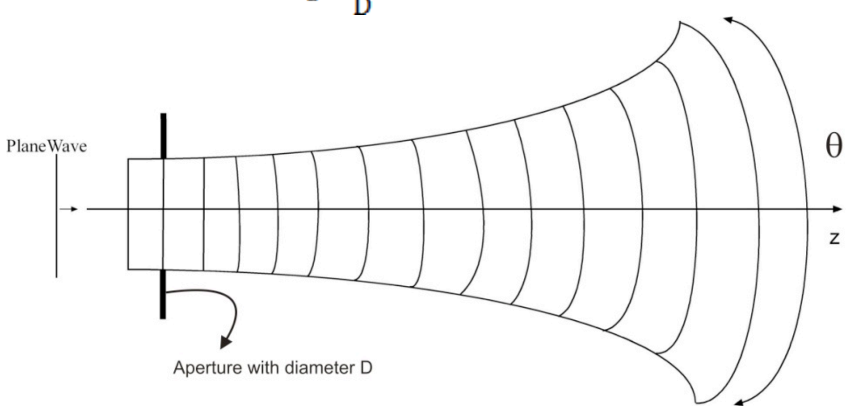
  - Interruptions lead to spectral broadening

- Coherence Length
  - Average distance over which laser remains coherent
  - $L_c \sim 300$m for a diode laser with $\Delta\nu \sim 1$ MHz

$$L_c = cT_c$$

2. Spatial or Transverse Coherence – Perpendicular to **k**
   - Correlation between 2 points on wave front

$$\theta_d \sim \frac{\lambda}{D}$$



- θ_d is the divergence angle of a perfectly coherent beam
- D is the diameter of an aperture, or the coherence length of a diffraction limited beam

$$\theta_c = \frac{\lambda}{D_c}$$

- θ_c is the divergence angle for partially coherent beam
- D_c is the transverse coherence length, the maximum separation for phase correlation

- The above figure represents a Gaussian laser beam for which

$$\theta_{1/2} = \lambda / \pi w_o$$

- w_o is the initial beam radius
- Gaussian beam is a plane wave at focus

Incoherent

- Small D_c, therefore rapid spread
- $D_c < D$

Coherent

- Diffraction Limited Beam
- $D_c = D$

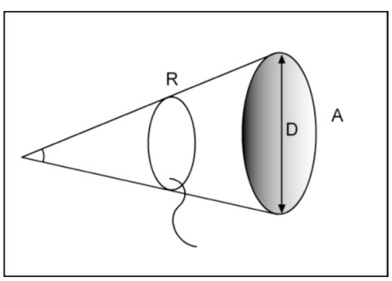
Define

$$M^2 = \frac{\text{Divergence of partially coherent beam}}{\text{divergence of fully coherent beam}}$$

$$M^2 = \frac{\theta_c}{\theta_d} = \frac{\frac{\lambda}{D_c}}{\frac{\lambda}{D}} = \frac{D}{D_c}$$

$M^2 = 1$ for $D_c = D$ (Coherent)
$M^2 >> 1$ for $D_c << D$ (Incoherent)

3. Brightness
   - Intensity in the focal plane



$$B = \frac{P}{\Omega A} = \frac{I}{\Omega}$$

$$I = \frac{P}{A}$$

$$\Omega = \frac{A}{R^2} = \frac{\pi(R\theta)^2}{R^2} = \pi\theta^2$$

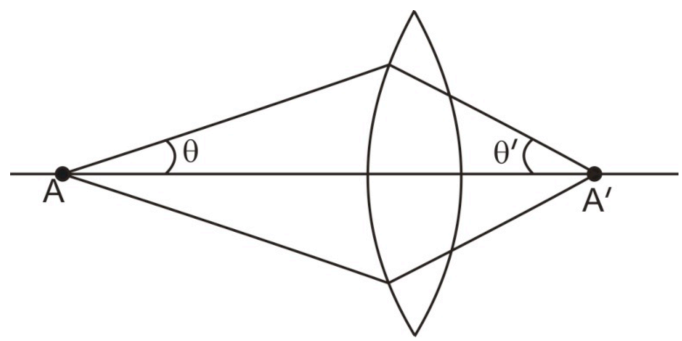
- This holds for small angles only

- The brightness should be independent of the diameter since $A \alpha D^2$ and $\theta^2 \alpha \lambda^2/D^2$

$$B = P / \pi\lambda^2$$

- B is unchanged by a change of lossless optical elements

$$B = P/\Omega A = P/\Omega' A'$$



- Intensity at focus:

$$I' = B\,\Omega'$$

- The intensity is changed by focusing, not the brightness
- Larger brightness → Larger intensity in the focal plane