LASERS

BY
PROF. SD

What is LASER????

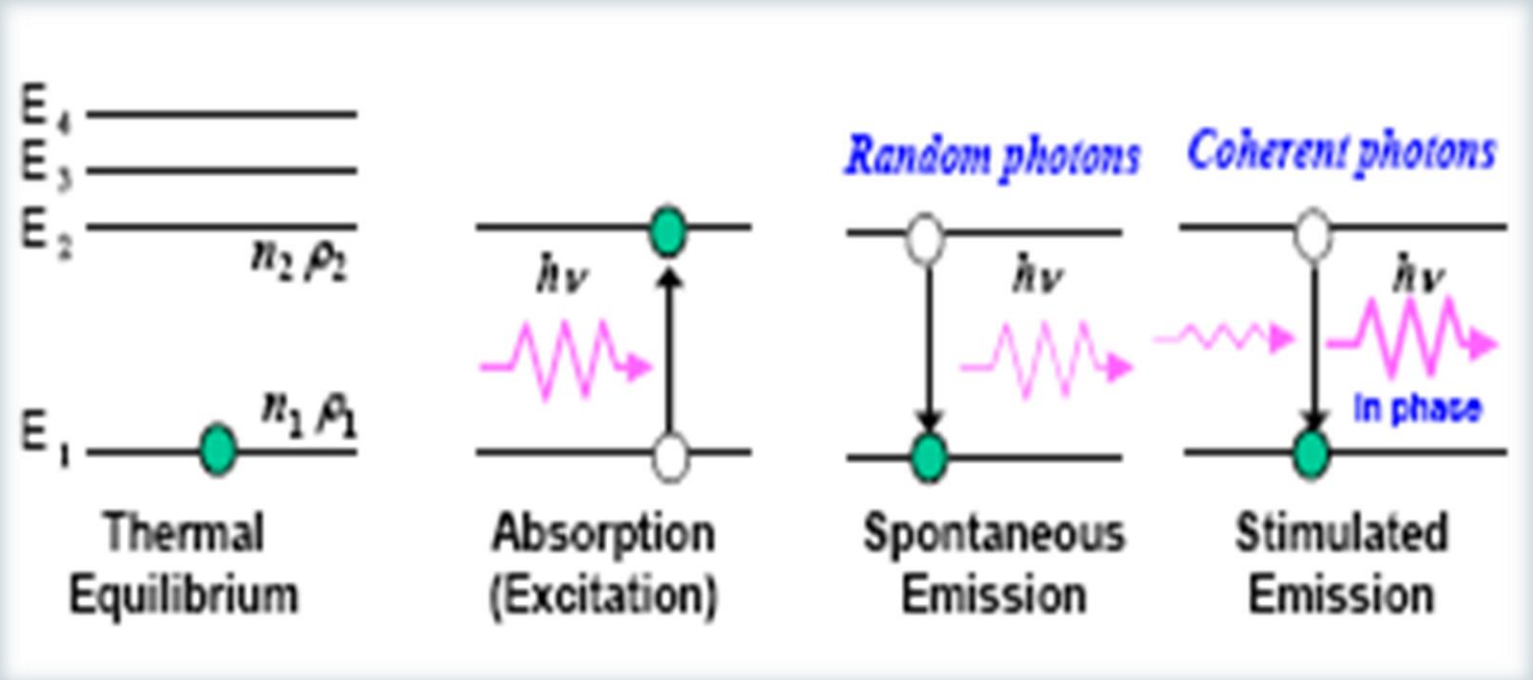
Light Amplification by Stimulated Emission of Radiation

- A device that produces a coherent beam of optical radiation by stimulating electronic, ionic, or molecular transitions to higher energy levels.
- When they return to lower energy levels by stimulated emission, they emit energy.

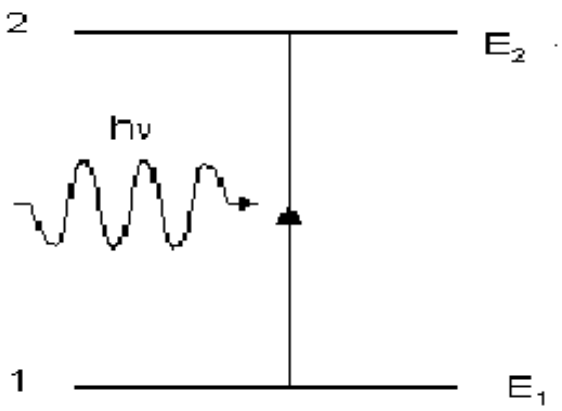
Basic concepts for a laser

- Absorption
- Spontaneous Emission
- Stimulated Emission
- Population inversion

Lasers: Basic Principle
Absorption and Radiation Processes



Absorption

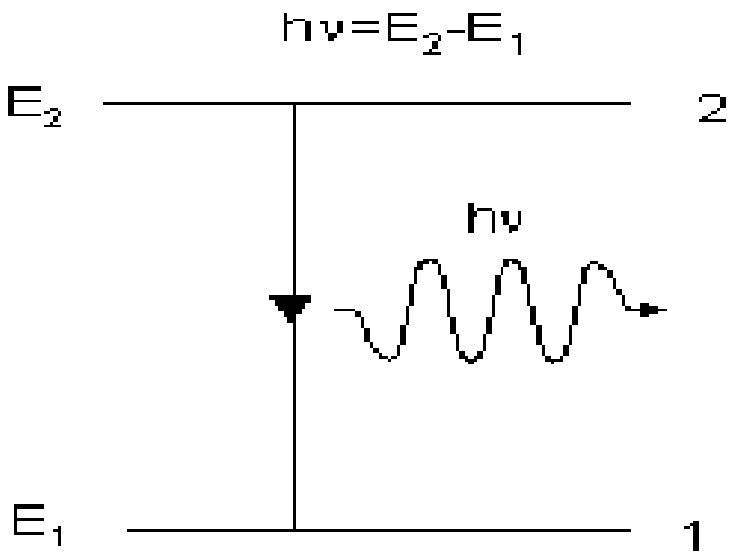


An electron in an atom can be excited from an energy level E_1 to a higher energy level E_2 by absorption:

photon absorption— $h\nu = E_2 - E_1.$

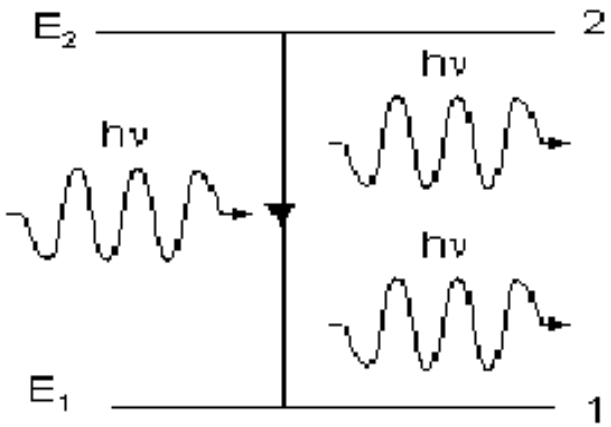
$$\nu = \frac{E_2 - E_1}{h}$$

Spontaneous Emission



The atom decays from level 2 to level 1 through the emission of a photon with the energy *hν*. It is a completely random process.

Stimulated Emission



Atoms in an upper energy level can be triggered or stimulated in phase by an incoming photon of a specific energy.

Stimulated Emission

The stimulated photons have unique properties:

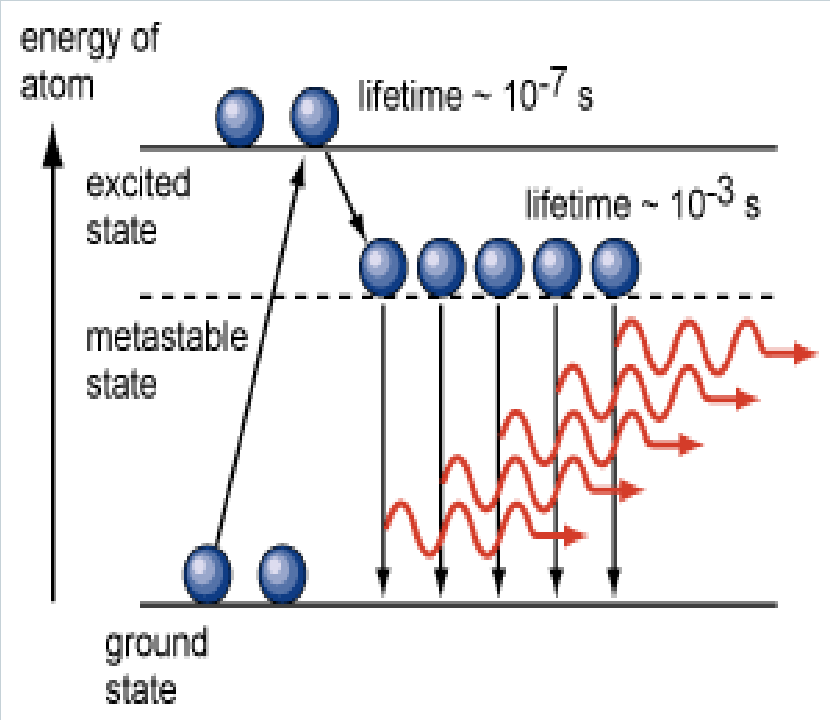
- In phase with the incident photon
- Same wavelength as the incident photon
- Travel in same direction as incident photon

Population Inversion

- A state in which a substance has been energized, or excited to specific energy levels.
- More atoms or molecules are in a higher excited state.
- The process of producing a population inversion is called pumping.
- Examples:

  →by lamps of appropriate intensity

  →by electrical discharge



Metastable states

- An atom or molecule in an excited state remains there for a certain time called the lifetime of that state, before making a transition to a lower state. The lifetime of a state is characteristic of the energy level and varies over a wide range. Most of the states have a short lifetime, of the order of 10^{-8} s. However, some energy states have very long lifetime of the order of 10^{-3} s or higher. Energy states with such long life times are called meta-stable states.

Pumping

- The population inversion can be achieved by exciting the medium with suitable form of energy. This process is called Pumping.
- There are several methods of pumping a laser and producing population inversion necessary for the occurrence of stimulated emission :

  (a) Optical pumping

  (b) Electric Discharge

  (c) Inelastic atom-atom collision

  (d) Direct Conversion

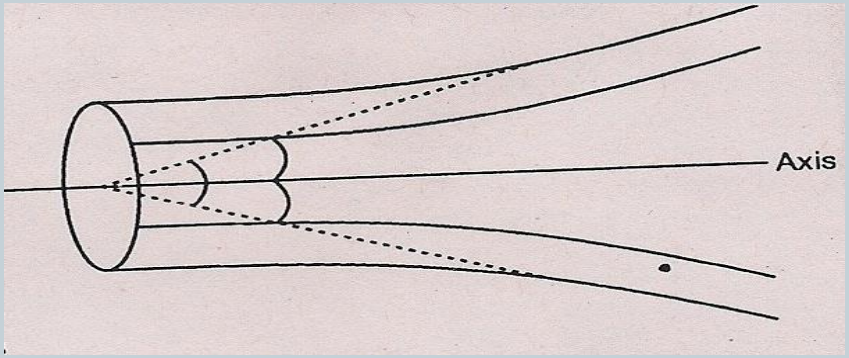
  (e) Chemical reactions

Characteristics of Laser Beam

- High directionality:

Directionality is the characteristic of laser light that causes it to travel in a single direction with a narrow cone of divergence. It is defined in terms of divergence angle.

Divergence angle is twice the angle made by the outer edge with the axis of the beam.



The angular spread of beam on one side of the axis :

$$\theta = \beta \frac{\lambda}{d}$$

High Intensity

The intensity of light is defined as the energy passing per unit area per second through a point normal to the direction of flow. For a spherical source with output power P , intensity at a point distant r from the source is given as:

$$I = \frac{P}{4\pi r^2}$$

Laser beam is highly intense because it emits light as a narrow beam and intensity remains high even at large distance from the source.

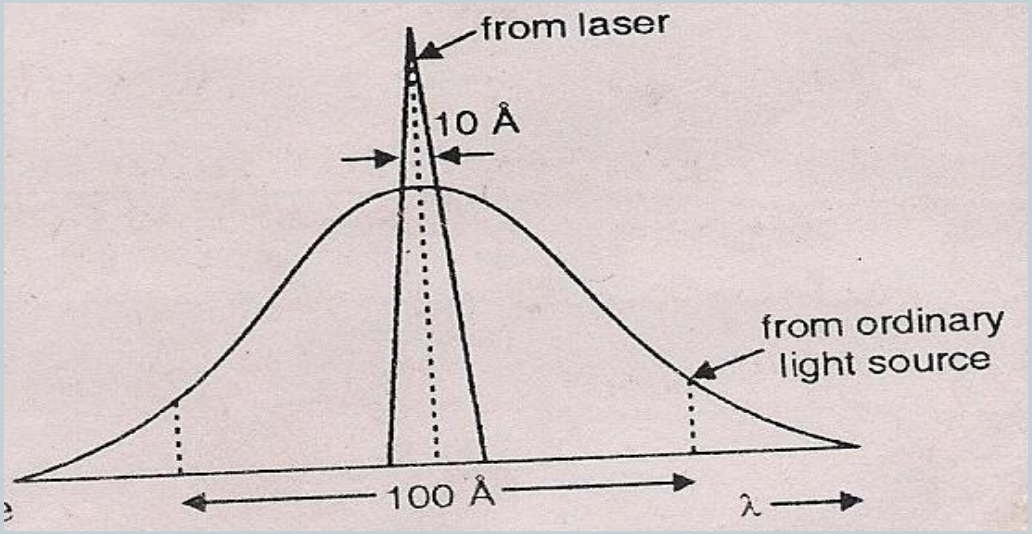
Extraordinary monochromacity

If $\Delta\nu$ is the frequency of a spectral line of frequency ν_o then the degree of monochromacity is defined as:

$$\varepsilon = \Delta\nu / \nu_o$$

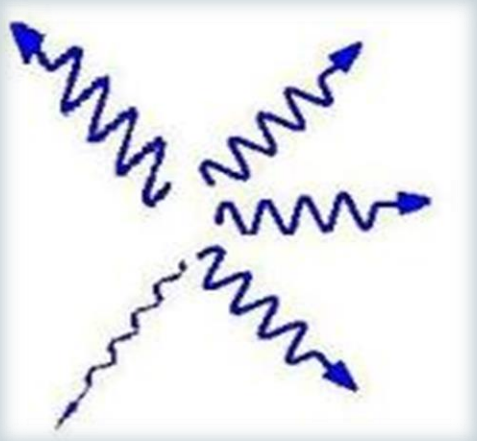
Smaller is the value of ε, higher is the monochromacity of light.

For laser source $\varepsilon = 10^{-12}$ while for ordinary source $\varepsilon \approx 10^{-5}$

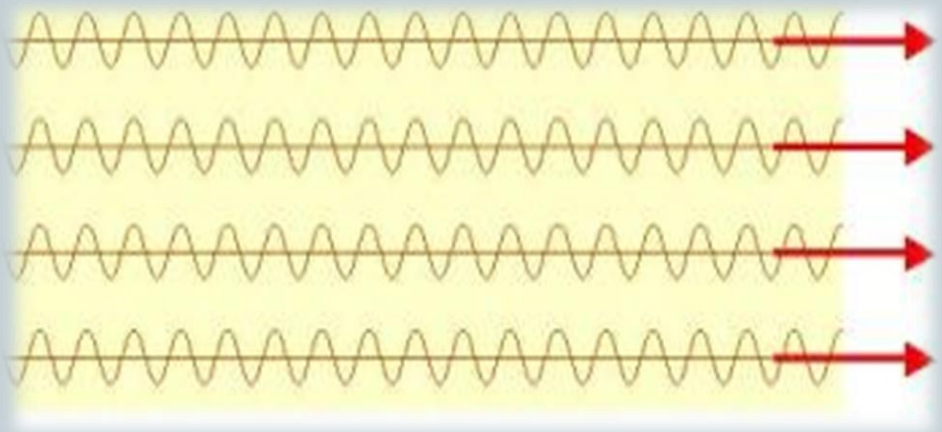


High Coherence

Degree of coherence is the measure of phase correlation in the radiation field at different locations and different time.



Incoherent



Coherent