Optical Sources
LASER Diodes

L A S E R

AMPLIFIER

OR

OSCILLATOR

LASER

(Light Amplification by the Stimulated Emission of Radiation)

- Laser is an optical oscillator.
- It comprises a resonant optical amplifier whose output is fed back into its input with matching phase.
- Any oscillator contains:
  - ➢ An amplifier with a gain-saturated mechanism
  - ➢ A feedback system
  - ➢ A frequency selection mechanism
  - ➢ An output coupling scheme

LASER

(Light Amplification by the Stimulated Emission of Radiation)

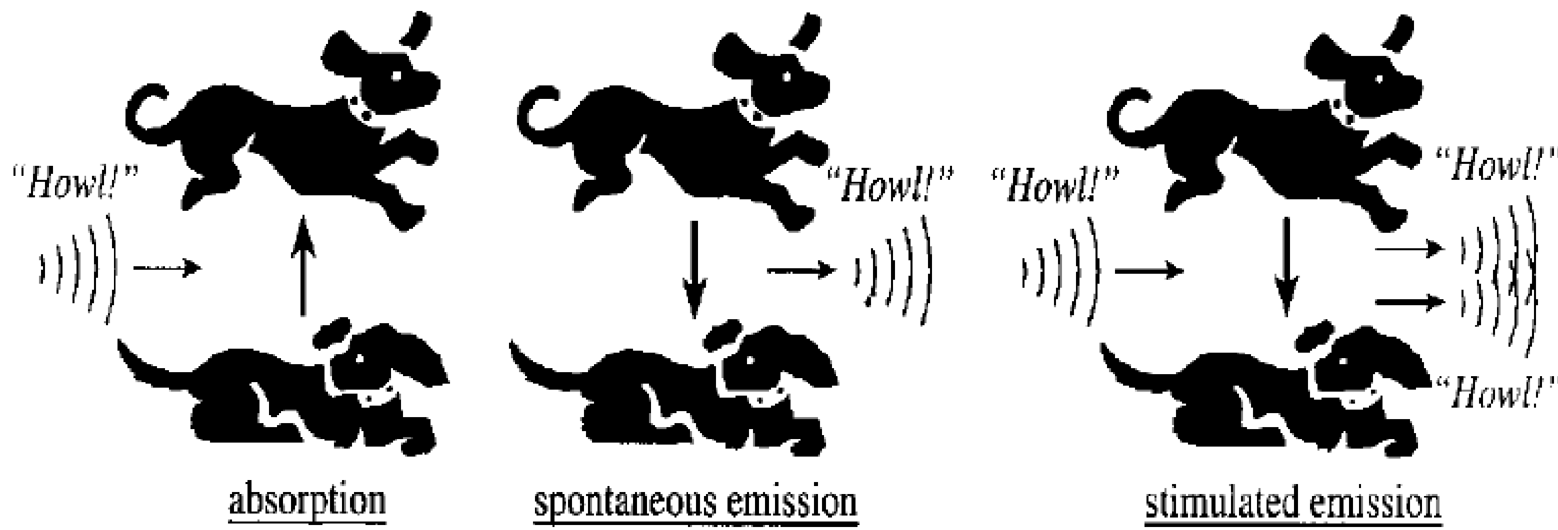
- In laser the **amplifier is the pumped active medium**, such as biased semiconductor region, **feedback can be obtained by placing active medium in an optical resonator**, such as Fabry-Perot structure, two mirrors separated by a prescribed distance.
- **Frequency selection is achieved by resonant amplifier and by the resonators**, which admits certain modes.
- Output coupling is accomplished by making one of the resonator mirrors partially transmitting.

Howling Dog Analogy

1. absorption: a dog in the ground state might hear the howl from another dog and become excited, thus making a transition to the excited state.

2. spontaneous emission: a dog in the excited state might randomly let out a howl, which, through release of tension, enables him to relax to the ground state.

3. stimulated emission: a dog in the excited state might be stimulated to let out a howl when he hears the howl from another dog. The single howl becomes two howls voiced simultaneously, thus sounding like one howl with twice the intensity!



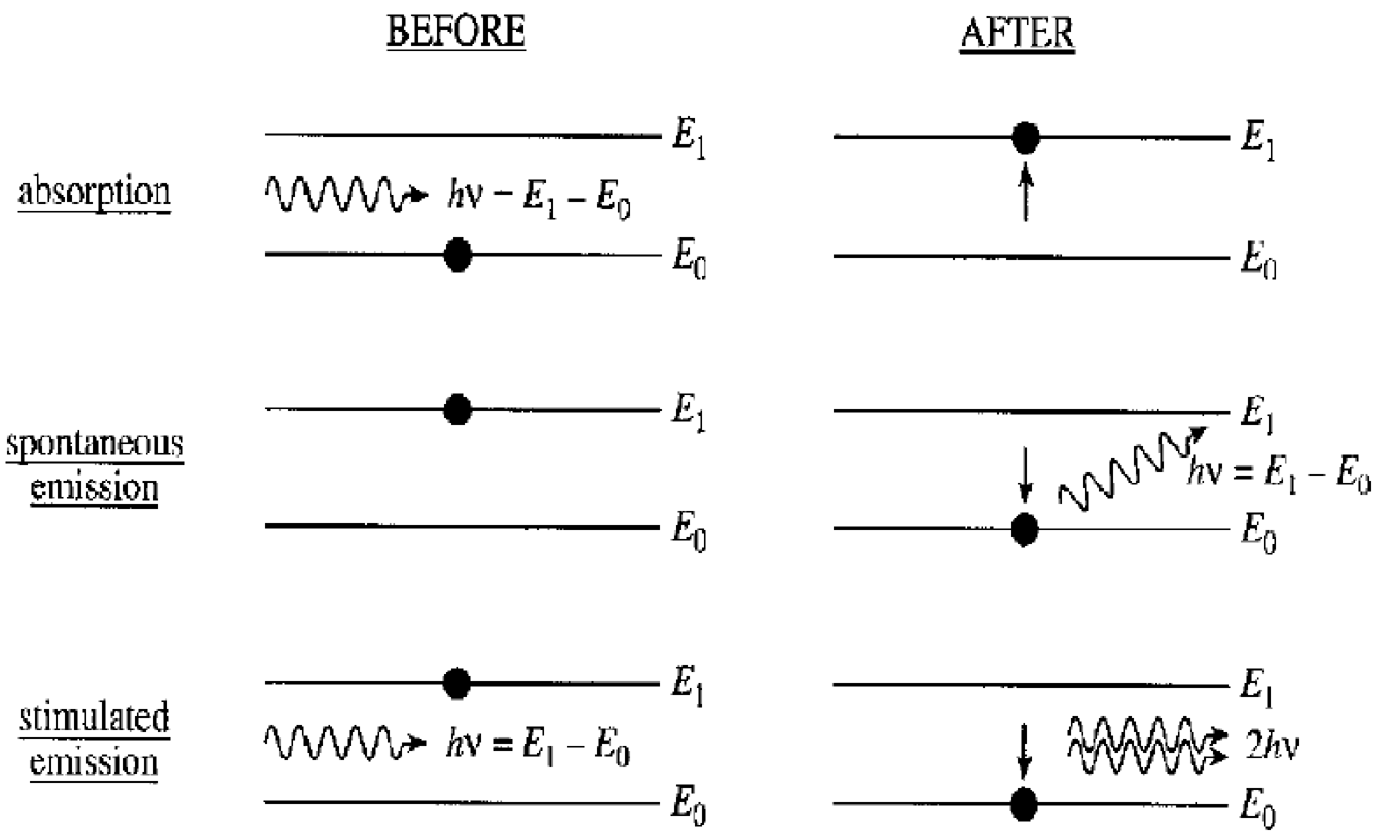
Process for Laser Action

- Three main process:

  1- Photon absorption i.e. energy absorbed from incoming photons

  2- Spontaneous emission

  3- Stimulated emission



- How process starts?

In Stimulated Emission incident and stimulated photons will have

- Identical energy → Identical wavelength → Narrow linewidth
- Identical direction → Narrow beam width
- Identical phase → Coherence and
- Identical polarization

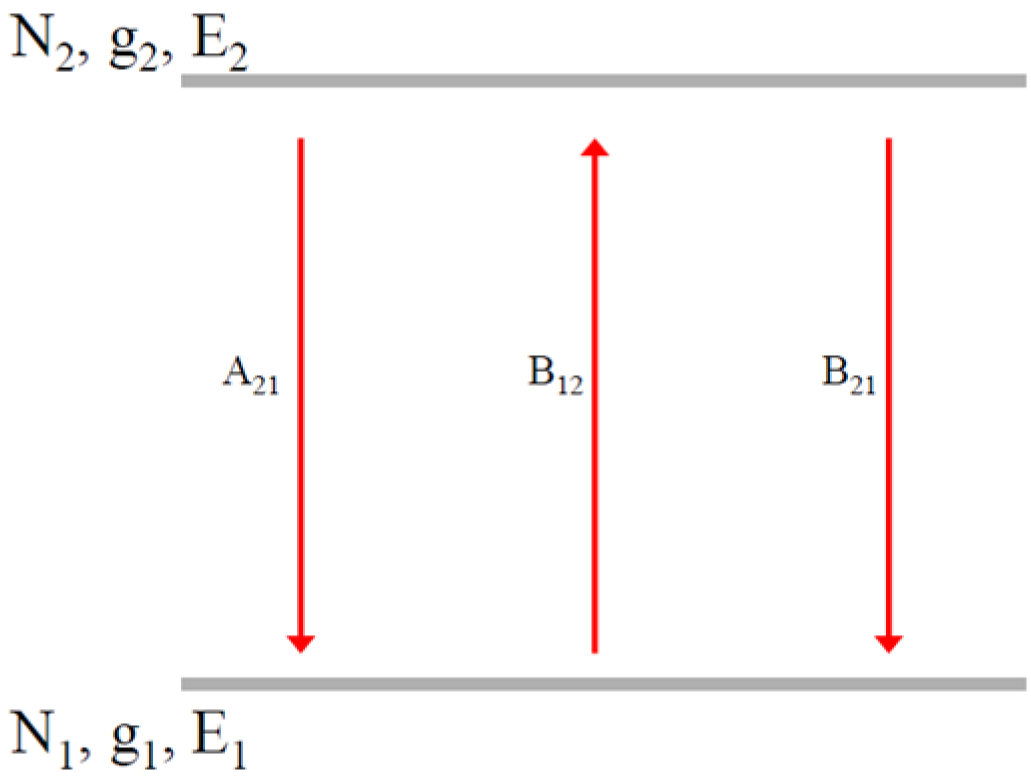
Lasing in a pumped active medium

- In thermal equilibrium the stimulated emission is essentially negligible, since the density of electrons in the excited state is very small, and optical emission is mainly because of the spontaneous emission.
- Stimulated emission will exceed absorption only if the population of the excited states is greater than that of the ground state.
- This condition is known as **Population Inversion**.
- Population inversion is achieved by various **pumping** techniques.
- In a semiconductor laser, population inversion is accomplished by injecting electrons into the material to fill the lower energy states of the conduction band.

Laser Diode Rate Equations

- In order to study all the three phenomena above, certain coefficients have been assigned to these phenomena which are actually defined by the transition probabilities and are called as **Einstein coefficients**.
- The phenomenon that occurs in the absence of external stimulus i.e. **spontaneous emission** is assigned the coefficient, A21.
- The phenomena that occur in presence of external stimuli are denoted by “B”.
- The **absorption** phenomenon is assigned B12.
- The **stimulated emission** is assigned B21.
- Note that the subscripts in the coefficients indicate the direction of transition from the initial level to the final level.
- Using these coefficients, the three processes can now be expressed in mathematically.

Two level system – Einstein's coefficients



assumption: n_1 atoms of energy ε_1 and n_2 atoms of energy ε_2 are in thermal equilibrium at temperature T with the radiation of spectral density $\rho(\nu)$:

Laser Diode Rate Equations

- An optical medium has the **density of atoms N_1** in **lower energy state E_1** and **density of atoms N_2** in **higher energy state E_2**.
- The **upward transition rate** is $$R_{12} = B_{12} N_1 \rho(hv)$$

  where B_{12} is a constant of proportionality, as *Einstein coefficient*.
- The **downward transition rate** is $$R_{21} = A_{21} N_2 + B_{21} N_2 \rho(hv)$$

  where A_{21} is a constant of proportionality. It is known as Einstein coefficient for spontaneous emission. B_{21} is a constant of proportionality as Einstein coefficient for stimulated emission.
- **At thermal equilibrium condition** $$R_{12} = R_{21}$$

  Gives $$\Rightarrow \rho(hv) = \frac{A_{21} / B_{21}}{B_{12} N_1 / B_{21} N_2 - 1}$$

$$\rho(hv) = \frac{A_{21} / B_{21}}{\frac{B_{12}}{B_{21}} \left(\exp\left[-\frac{E_2 - E_1}{kT} \right] \right) - 1}$$

Where, ρ is Radiation Spectral Density