18PYB101J MODULE-5

LECTURE 2

- CHARACTERISTICS OF LASER
- AMPLIFICATION OF LIGHT BY POPULATION INVERSION

CHARACTERISTICS OF LASER

Characteristics of laser

Laser is basically a light source. Laser light has the following important characteristics

(i) **High directionality**

(ii) **High intensity**

(iii) **Highly monochromatic**

(iv) **Highly coherent**

(i) High directionality

An ordinary light source emits the light in all directions. But, a laser source emits light in only one direction. The divergence of laser beam is very small (fig. 7.12). So, laser light has high directionality.

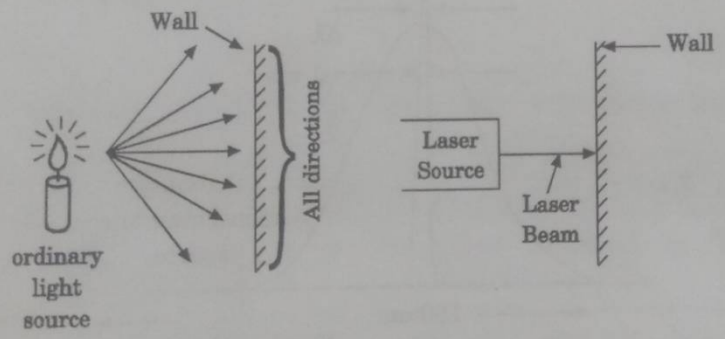


Fig. 7.12. High directionality

CHARACTERISTICS OF LASER

(ii) High Intensity

Laser source emits light as a narrow beam and its energy is concentrated in a small region (spot). This concentration of energy gives a high intensity to the laser light.(fig. 7.13).

(iii) Highly monochromatic

Ordinary light spreads over a wavelength range of the order of 100 nm.

CHARACTERISTICS OF LASER

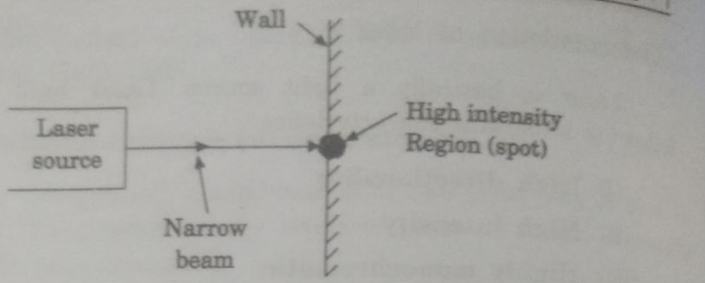


Fig. 7.13. High intensity

But a laser beam has very little spreading of the order of 1 nm. (fig. 7.14). Thus, laser beam is highly monochromatic. ie., it emits only one colour of light.

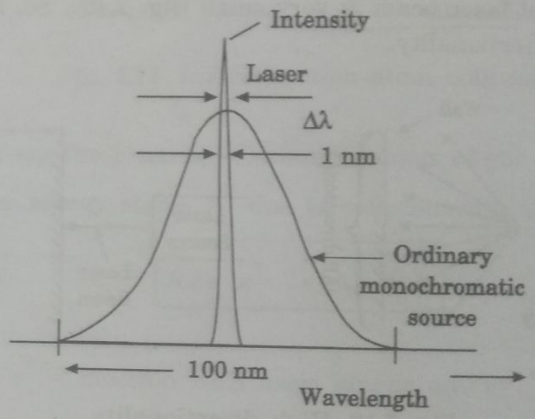


Fig. 7.14 Spectral width of laser

CHARACTERISTICS OF LASER

(iv) Highly Coherent

The light emitted from a laser source consists of wave trains. These wave trains have same frquency, phase and direction. So, they are coherent (fig. 7.15).

Laser light has a high degree of coherence. The coherence of laser emission results in extremely high intensity and hence more power.

Difference between spontaneous emission and stimulated emission

Property	Spontaneous emission (ordinary light)	Stimulated emission (laser light)
Stimuli	Not required	Required
Monochromaticity	Less	High
Directionality	Less	High
Intensity	Less	High
Coherence	Less	High

Population inversion-Negative temperature condition

- Boltzmann distribution law specifies what fraction of atoms are found in any particular energy state for any given equilibrium temperature

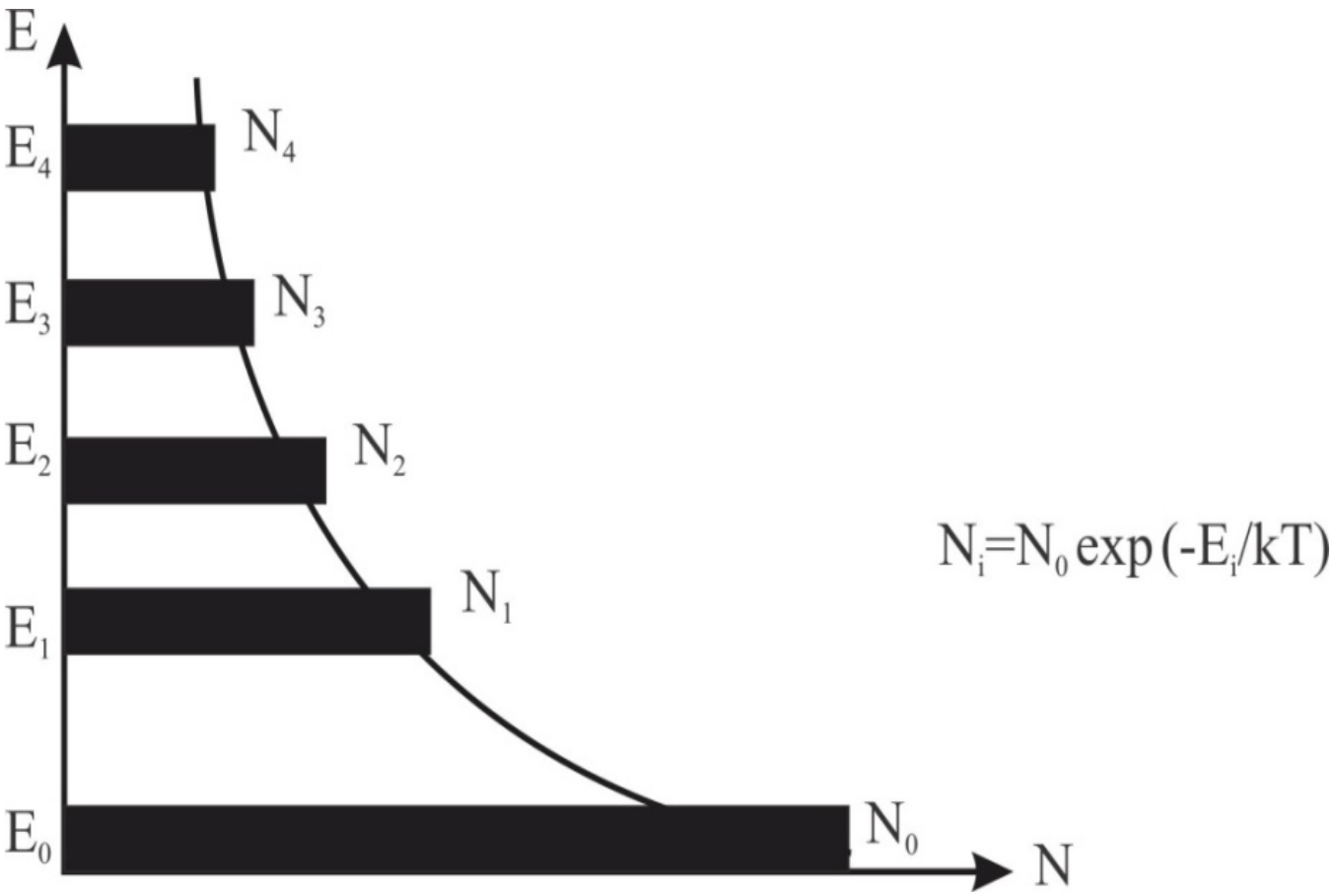
- If N_0 is the number of atoms in the ground state, N_1 is the number of atoms in the excited state of energy E_2 measured relative to the ground state, then (ignoring degeneracy)

$$\frac{N_i}{N_o} = \exp\left(\frac{-E_i}{kT}\right)$$

where T is the absolute temperature in degree kelvin, and
$k = 1.38 \times 10^{-23}$ K (Boltzmann constant)

Boltzmann distribution is graphically represented in fig

- For laser action, $N_1 > N_0$ (i.e., absorption <stimulated emission)
- The establishment of $N_1 > N_0$ is known as population inversion.

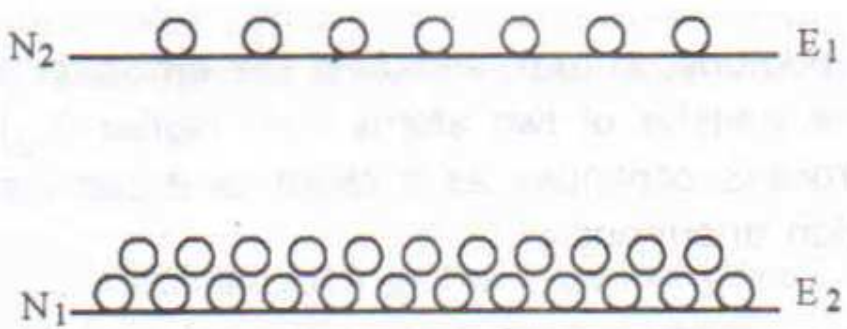


Boltzmann distribution for several energy levels

- The population inversion condition required for light amplification is a non-equilibrium distribution of atoms among the various energy levels of the atomic system.
- i.e., a *negative temperature condition* which establishes $N_1 > N_0$ is known as population inversion.

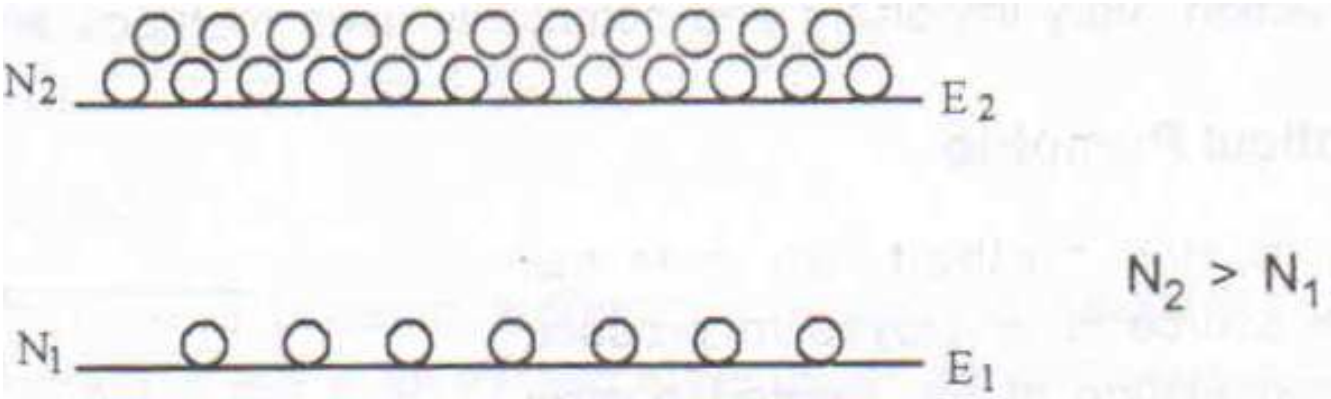
Normal population

- Consider a two level energy system (E_1 and E_2). Suppose a photon of energy same as the energy difference between the two levels is incident on the system, absorption and emission processes are both equally probable.
- Usually the number of atoms or molecules or particles N_2 of higher energy level is less than the population N_1 of lower energy level and it is called 'Normal Population'.



Population Inversion

- Making the number of particles N_2 more in higher energy level than the number of particles N_1 in lower energy level is called Population Inversion or Inverted Population.



Laser Action

- During stimulated emission of radiation, the incident photon and the emitted photons all have same energy, phase, frequency and direction.
- A single photon is incident on the atoms in the state E_2. It releases a photon along with this incident photon. This results in the emission of two photons.

Laser Action

- These two photons, in turn, stimulate the emission of atoms, two more photons due to the transfer of two atoms from higher (E_2) level to the lower (E_1) level.
- This process continues as a chain, and can increase the intensity of coherent radiation enormously.