LASER

Laser is an acronym for light amplification by stimulated emission of radiation.

Any light beam is composed of photons, two photons are said to be coherent if they have same energy, phase and direction. Laser beam is composed of such coherent photos where as ordinary light contain incoherent photons. So the property of coherence adds special characteristics to LASER beam such as high directionality, high intensity, monochromacity and penetration.

Laser source is an electromagnetic radiation with absolute purity and high intensity which were never found in any other electromagnetic radiation.

Characteristics of laser radiation:

The four characteristics of a laser radiation over conventional light sources are

(1) Laser is highly monochromatic

(2) Laser is highly directional

(3) Laser is highly coherent

(4) The intensity of laser is very high

HIGHLY MONOCHROMATIC:

The band width of ordinary light is about $1000A^0$. The band width of laser light is about $10A^0$. The narrow band width of a laser light is called on high monochromacity.

BAND WIDTH:- The spread of the wavelength (frequency) about the wavelength of maximum intensity is band width.

Laser light is more monochromatic than that of a conventional light source. Because of this

monochromaticity large energy can be concentrated in to an extremely. Small band width.

For good laser dv=50Hz v=5×1014 Hz. The degree of non-monochromaticity for a conventional sodium light.

HIGH DIREATIONALITY:

The conventional light sources like lamp, torch light, sodium lamp emits light in all directions. This is called divergence. on the other hand , Laser emits light only in one direction.This is called directionality of laser light

- Light from ordinary light spreads in about few kilometers**.**
- Light from laser spreads to a diameter less than 1 cm for many kilometers.

The directionality of laser beam is expressed in term of divergence.

$$\text{Divergence } \Delta\theta = \frac{(r2 - r1)}{d2 - d1}$$

Where r_2, r_1 are the radius of laser beam spots d_2 ,d_1 are distances respectively from the laser source. Hence for getting a high directionality then should be low divergence.

HIGHLY COHERENT:

When two light rays are having the phase difference independent of time then they are said to be coherent. It is expressed in terms of ordering of light field

Laser has high degree of ordering than other common sources.

Due to its coherence only it is possible to create high power(10^{12} watts) in space with laser beam of 1μm diameter.

There are two independent concepts of coherence.

1) Spatial coherence (2) Temporal coherence

SPATIAL COHERENCE: The two light fields at different point in space maintain a constant phase difference over any time (t) they are said to be spatial coherence.

In He- Ne gas laser the coherence length(Lc) is about 600km.It means over the distancethe phase difference is maintained over any time .

For sodium light it is about 3cm.

The coherence & monochoremacity is related by

$$\xi = (\Delta\upsilon / \upsilon) \ \alpha \ 1/ Lc$$

$\therefore$ For the higher coherence length ξ is small hence it has high monochromacity

TEMPORAL COHERENCE: The correlation of phase between the light fields at a point over a period of time.

For He- Ne laser it is a about 10^{-3} second , for sodium it is about 10^{-10} second only.

$$\therefore \xi = (\Delta\upsilon / \upsilon) \ \alpha \ 1/ tc$$

Higher is the tc higher is the monochromacity.

HIGH INTENSITY:

Intensity of a wave is the energy per unit time flowing through a unit area.

The light from an ordinary source spreads out uniformly in all directions and from spherical wave fronts around it.

Ex:- If you look a 100W bulb from a distance of 30cm the power entering the eye is About 1 / 1000 of watt.
But in case of a laser light, energy is in small region of space and in a small wavelength and hence is said to be of great intensity.

The power range of laser about 10-3W for gas laser and 109W for solid state laser

BasicTerms :

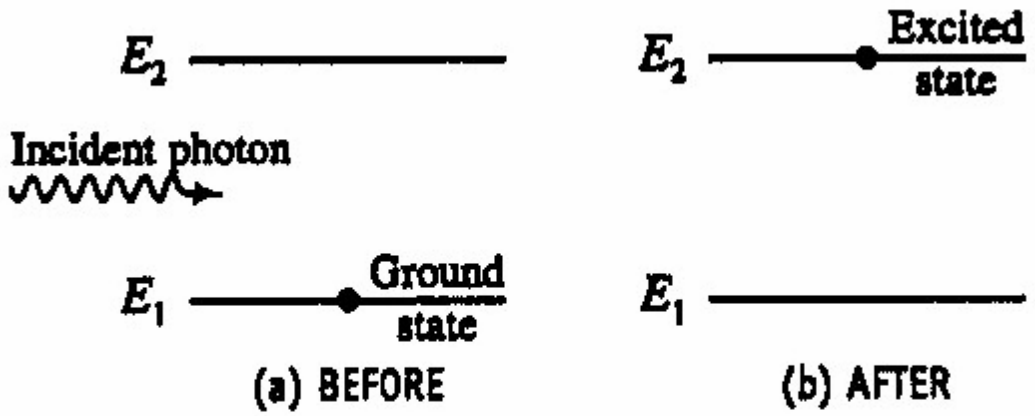
Absorption:

When at atom absorbs an amount of energy „hv" in the form of photon from the external agency and excited into the higher energy levels from ground state, then this process is known as absorption

$$atom + hv \rightarrow atom^*$$

SPONTANEOUS AND STIMULATED (INDUCED) EMISSION:

Light is emitted or absorbed by particles during their transitions from one energy state to another .the process of transferring a particle from ground state to higher energy state is called excitation. Then the particle is said to be excited.



INDUCED ABSORPTION

The particle in the excited state can remain for a short interval of time known as life time. The life time is of the order of 10^{-8} sec, in the excited states in which the life time is much greater than 10^{-8} sec are called meta stable states. The life time of the particle in the Meta stable state is of the order 10^{-3} sec

The probability of transition to the ground state with emission of radiation is made up of two factors one is constant and the other variable.

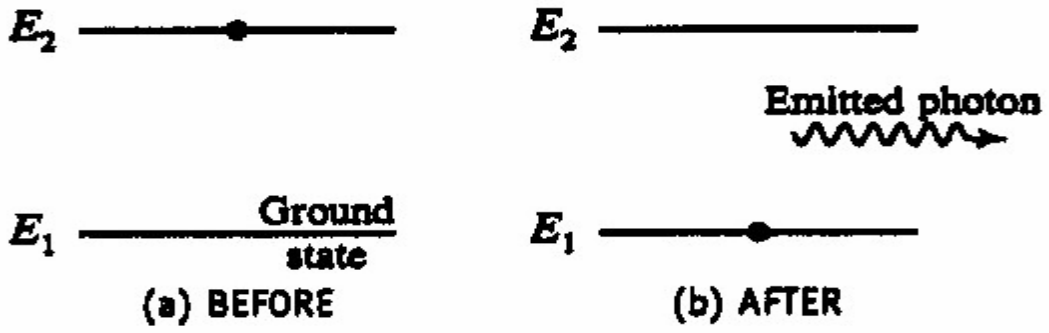
The constant factor of probability is known as spontaneous emission and the variable factor is known as stimulated emission.

SPONTANEOUS EMISSION: When an atom in the excited state emits a photon of energy „hv‟ coming down to ground state by itself without any external agency, such an emission is called spontaneous emission.

$$atom^* \rightarrow atom + hv$$

Photons released in spontaneous emission are not coherent. Hence spontaneous emission is not useful for producing lasers.

The emission of particles from higher energy state to lower energy state spontaneously by emitting a photon of energy hυ is known as "spontaneous emission"



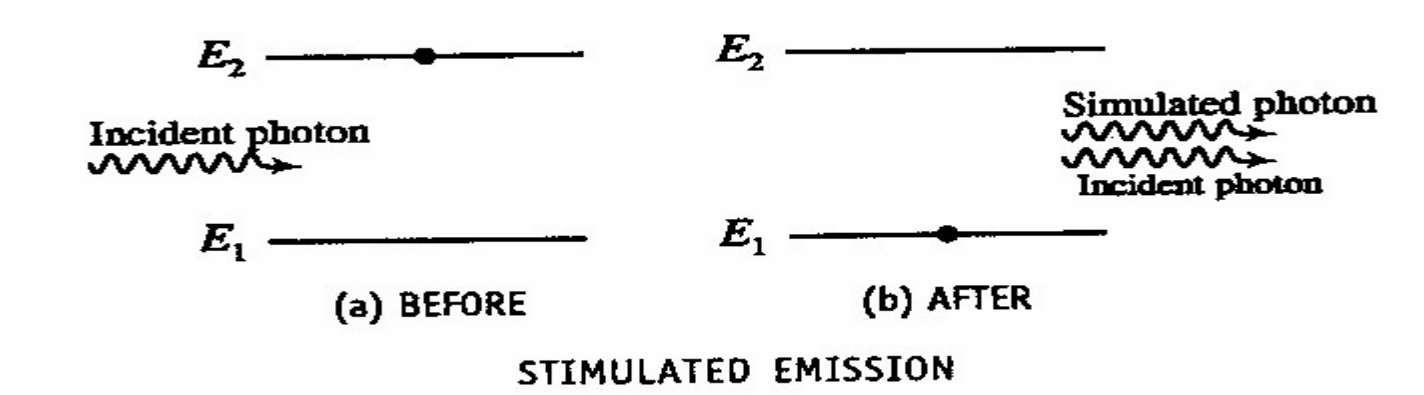
SPONTATNEOUS EMISSION

STIMULATED EMISSION: When an atom in the excited state, emits two photons of same energy hv while coming to down to ground state with the influence of an external agency, such an emission is called stimulated emission.

$$atom^* \rightarrow atom + 2hv$$

In the two photons one photon induces the stimulated emission and the second one is released by the transition of atom from higher energy level to lower energy level. Both the photons are strictly coherent. Hence stimulated emission is responsible for laser production .

The emission of a particle from higher state to lower state by stimulating it with another photon having energy equal to the energy difference between transition energy levels called stimulated emission.



STIMULATED EMISSION

SPONTANEOUS EMISSION	STIMULATED EMISSION
1) Incoherent radiation	1) coherent radiation
2) Less Intensity	2) high intensity
3) Poly chromatic	3) mono chromatic
4) One photon released	4) two photons released
5) Less directionality	5) high directionality
6) More angular spread during propagation	6) less angular spread during Propagation
Ex:-Light from sodium Mercury vapour lamp	ex: - light from a laser source ruby laser, He-He gas laser gas Laser

Principle of Laser Production:

Two coherent photons produced in the stimulated emission, interacts with other two excited atoms, resulting in four coherent photons. Thus, coherent photons are multiplied in a lasing medium. The continuous successive emission of photons results for the production of laser beam.