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Unit 4: LASER

Laser:

LASER stands for Light Amplification by Stimulated Emission by Radiation.

Laser is a device that can produce a very intense monochromatic and coherent beam of light.

Laser light emerges out as a narrow beam which can travel over long distances without much loss in its intensity.

*) Characteristics:

i) It is monochromatic because all the photons have the same energy $E = E_2 - E_1 = h\nu$ and hence same frequency.

ii) it is coherent in the sense that all the photons or waves are in the same phase.

iii) it is very intense because of the same phase photons.

iv) a laser beam diverges hardly at all.

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Emission of Radiation:

The three kinds of transition involving electromagnetic radiations are possible between two energy levels E_1 and E_2 in an atom. They are as follows:

a) Induced absorption b) Spontaneous emission c) Stimulated emission

a) Induced absorption:

An atom or molecule can only have discrete values. These are refered to as the energy levels of the atom.

Quantum transition is the transition of an atom form one energy level to another occuring in jump.

The quantum transition from a lower energy level to the higher one causes absorption of photons while that of form higher energy level to the lower corresponds to an emission of photons.

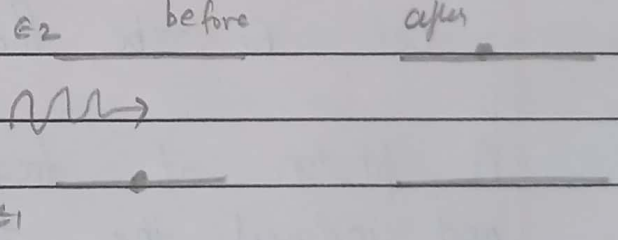

Fig: induced absorption.

Consider two levels of an atom with energies E_1 and E_2.

Suppose E_1 is lower state. If a photon of energy $E_{12} = h\nu = E_2 - E_1$ travels nearby the atom, it may absorb this incident photon making transition to higher energy level E_2.

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b) Spontaneous Emission

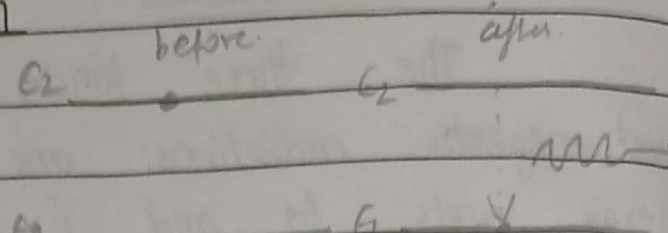

Fig: Spontaneous Emission

The atom in excited level E_2 has a tendency to lower level E_1 without any external inducing agent.

This emission of photons is referred to as spontaneous emission because it is not caused by any external agent.

The emitted photons will have the energy $E_{21} = h\nu = E_2 - E_1$ but its other characteristics such as direction of momentum, polarization and phase may be arbitrary. This is uncontrollable process.

c) Stimulated Emission

The way to cause a non-random transition is stimulated emission of photon.

Let E_2 be the excited state.

A photon of frequency may become stimulate and induced the transition from E_2 to E_1 resulting with another photon of same frequency ν.

Both induced and inducing photons have

i) same energy

ii) identical direction of their momenta, polarization and phase.

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ie, secondary photon finds itself in the state as primary photon.

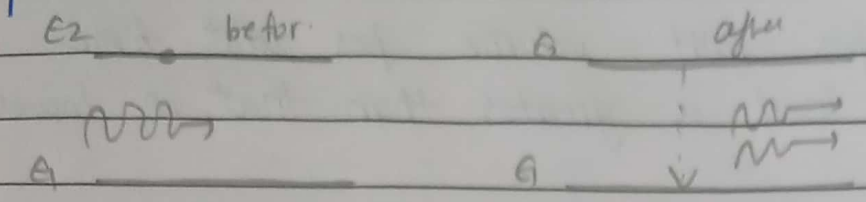

Fig: stimulated emission

The physical behaviour of inducing photon plays the same roles as the catalyst. The two photons again cause similar emission and the process continues.

Since the incident photon stimulates or cause the emission of another photon of exactly same nature, type of emission of radiation is called stimulated emission.

This emission is not random and it is controllable process.

Population Inversion and Pumping

Under ordinary conditions of thermal equilibrium, the number of atoms in the higher energy state is smaller than that in lower energy state ~~($N_2 > N_1$)~~ ($N_2 < N_1$).

Hence, there is very stimulated emission compared with absorption.

Let by some means, $N_2 > N_1$.

This is called population inversion.

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X) Population Inversion:

Population inversion means that the number of active centers per unit volume per unit time in upper lasing level is greater than that in lower lasing level.

They are: optical and electrical pumping.

a) Optical Pumping:

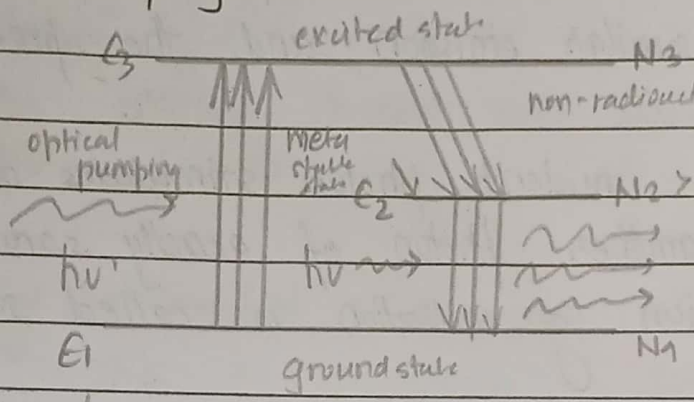

Fig: optical pumping.

The pumping done by photons is called optical pumping.

Consider a material whose atoms can be reside in ~~their~~ three different states as shown in figure.

Atoms in ground state are pumped to state E_3 by photons of energy $h\nu' = E_3 - E_1$.

The excited atoms remains nearly 10^{-8} sec and then undergo non-radioactive transitions to level E_2.

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They remain in meta-stable state for 10^{-3} sec.

Thus, there will be more atoms in E_2 than in E_1, we have population inversion.

Atoms in meta state E_2 are now bombarded by photons $h\nu = E_2 - E_1$ resulting in stimulated emission. giving intense coherent beam in direction of the incident photons.

b) Electrical Pumping:

Electrical pumping is accomplished by means of a sufficiently intense electrical discharge in the medium and is particularly suitable for gas media at low pressure.

The discharge converts gas into plasma where free electron collide with active centers inelastically and causes the predominant population in upper lasing level ie, due to continuous discharge at low pressure, the active centers get excited to the higher pumping levels.

Applications of Laser

i) communication in absence of medium
ii) piercing holes in material, cutting and welding of metals
iii) detecting objects at great distance.
iv) measuring of atmospheric pollution
v) medical and engineering use.