LASER

&

IT'S APPLICATIONS

(CO-4 Part-I)

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Introduction

- The word *laser* is an acronym that stands for "light amplification by the stimulated emission of radiation".

Lasers are essentially have following *characteristics*-

- highly intense,
- highly monochromatic,
- highly directional &
- highly coherent optical light source.

- Laser based on the principle of *stimulated emission*.
- Stimulated emission was first introduced by Einstein in year 1917.
- In 1960, a solid state Ruby laser is developed by Maiman on this principle.
- In 1961, a gas state He-Ne laser is developed by Ali Javan , W. Bennett and D Herriot.

Principle of Laser

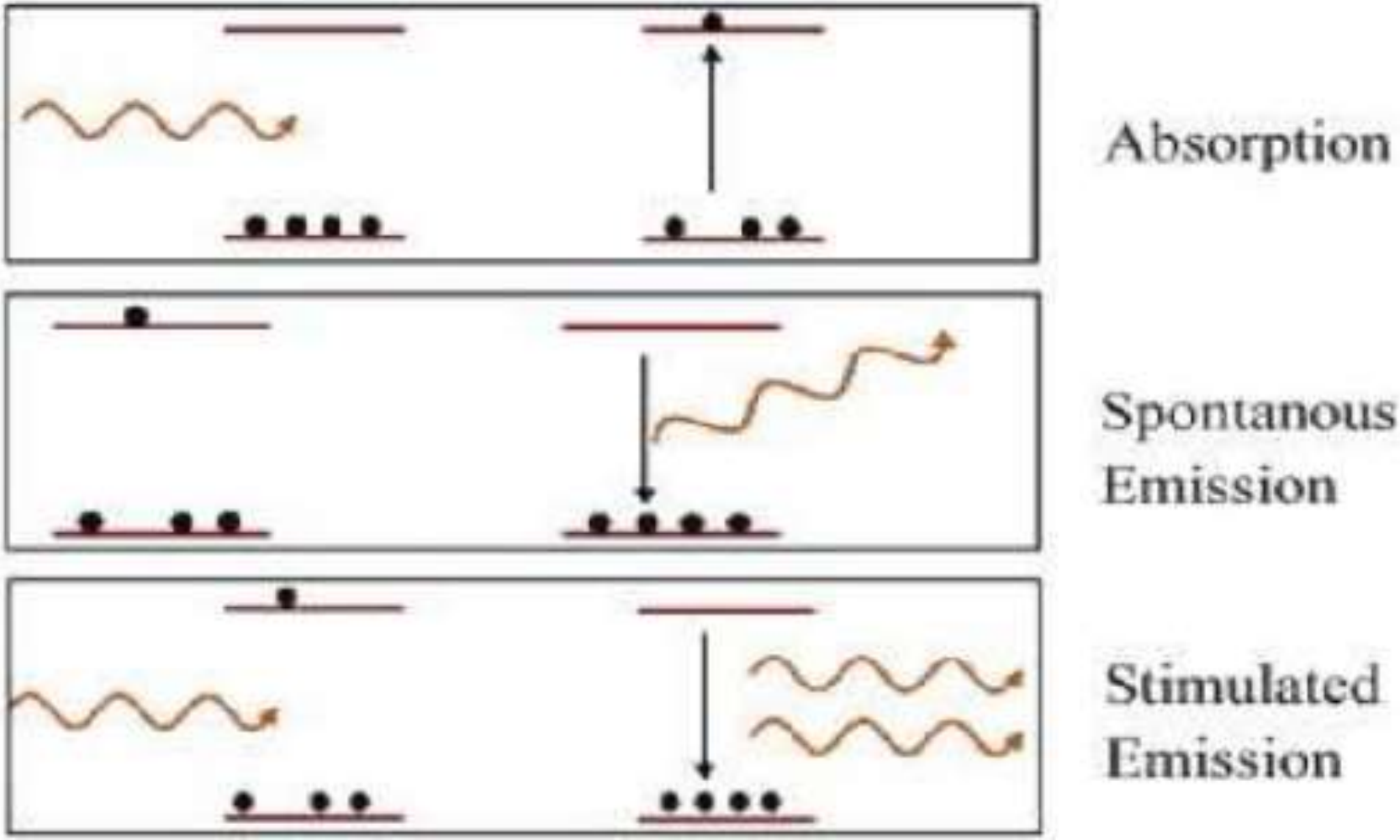

Figure.1*

Absorption of Radiation

The process of exciting the atom from lower to higher energy level by absorbing the incident photon of light is known as *absorption* of radiation.

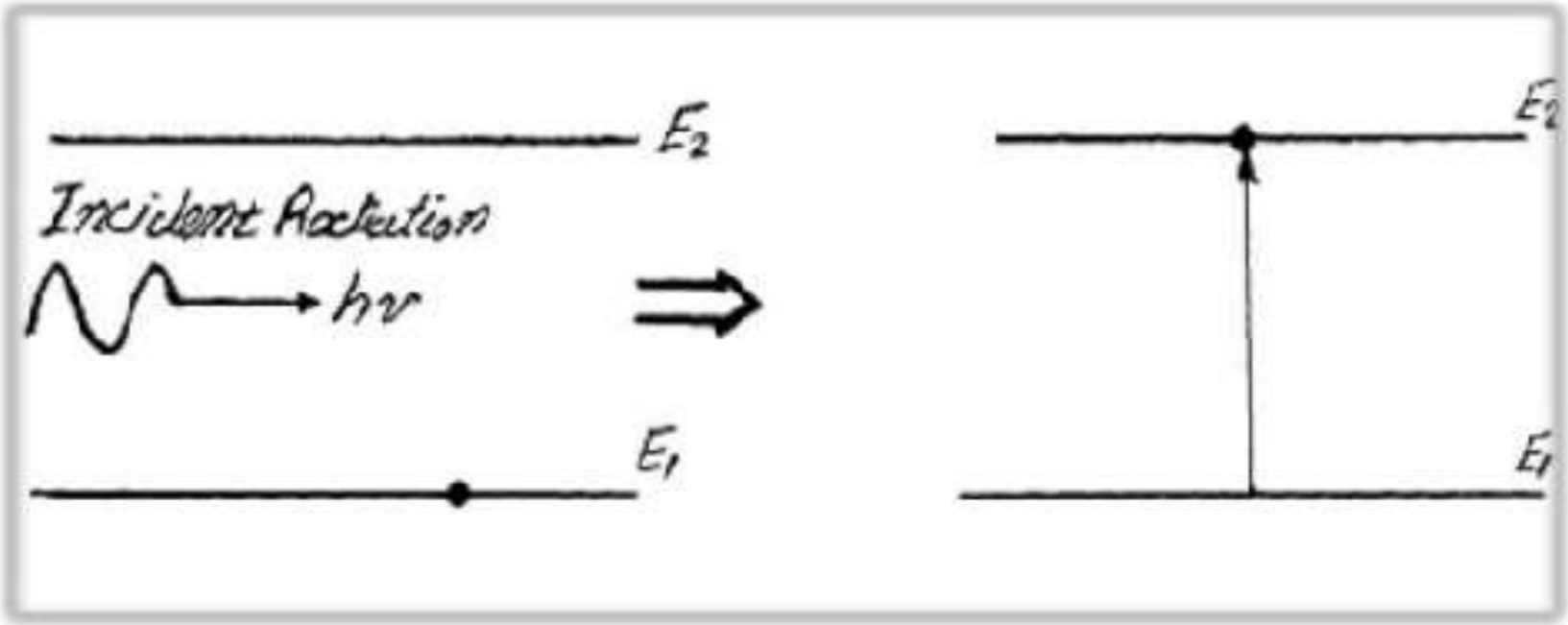

Figure.2*

Spontaneous Emission of Radiation

The transition of an excited atom by itself after rest time in excited state (10^{-8} sec) to lower energy level is known as ***spontaneous or self emission*** of radiation.

The frequency of emitted photon is given by

$$\nu = E_2 - E_1 / h$$

Where $h = 6.63 \times 10^{-34}$ J sec=Plank's constant

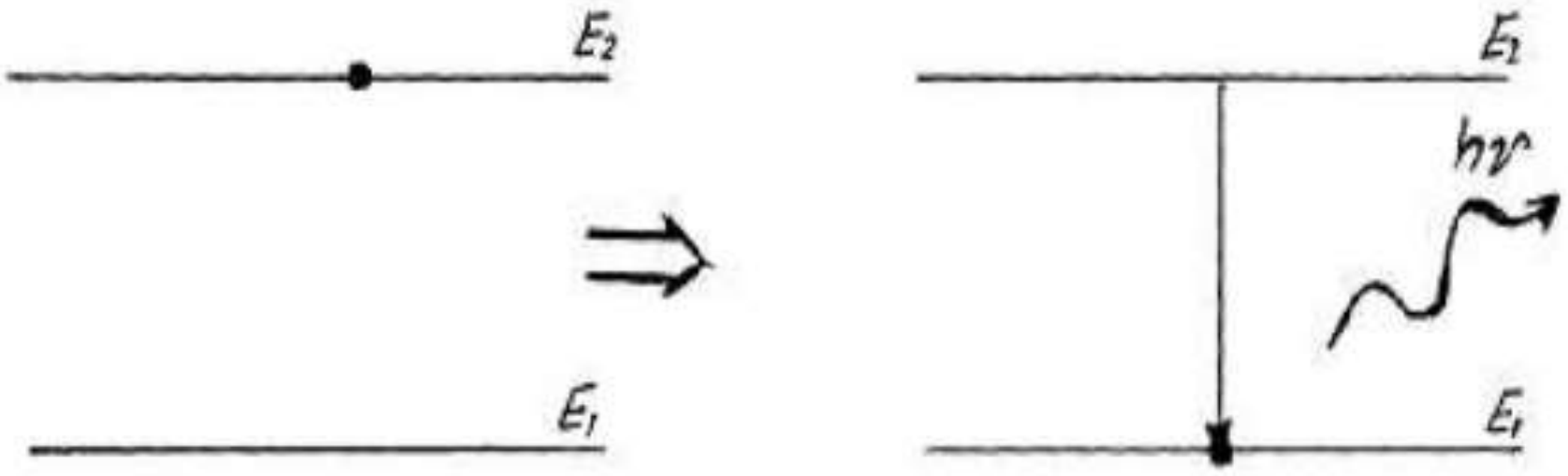

Figure.3*

Stimulated Emission of Radiation

The excited atom after getting stimulated by the incident photon jumped to lower energy state by emitting photons is known as *stimulated emission* of radiation.

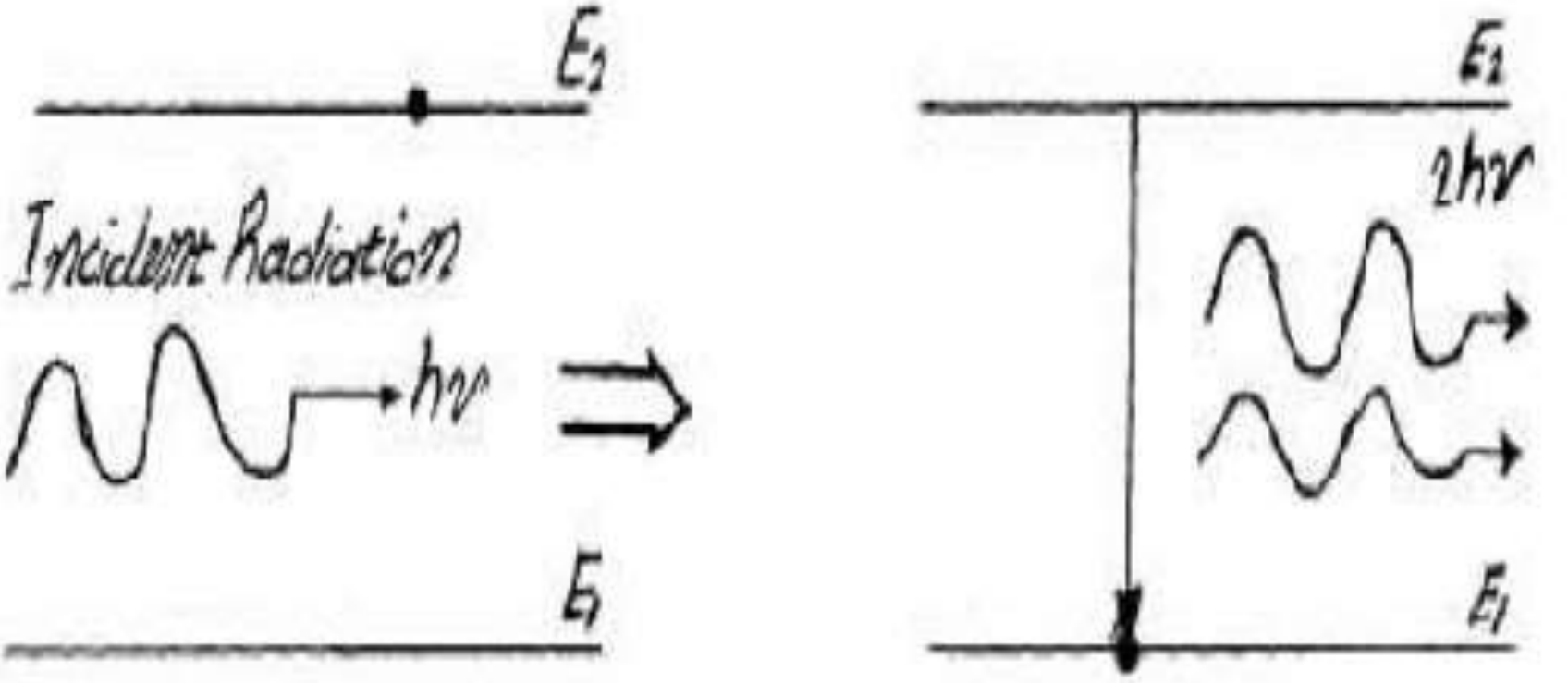

Figure.4*

Einstein's coefficients

Einstein's coefficients are of three types.

- coefficient of ***Absorption (B_{12}):***

$$P_{12}=B_{12}u(\nu)$$

- coefficient of ***Spontaneous emission (A_{21}):***

$$P_{21}=A_{21}$$

- coefficient of ***Stimulated emission (B_{21}):***

$$P_{21}= B_{21}u(\nu)$$

Where $u(\nu)$=Energy density of the radiation

Relation between Einstein's coefficients

If A_{21} & B_{21} are the coefficient of spontaneous & stimulated emission respectively, then

$$A_{21}/B_{21} = 8\pi h\nu^3/c^3$$

Where $c=3*10^8$ m/sec=velocity of light

Which conclude that probability of spontaneous emission increase rapidly with energy difference($E_2-E_1=h\nu$) between two states.

Terms related to Laser

- ***Population Inversion***:-This is the state in which larger number of atoms in the higher energy level than that the lower energy level.

$$N_2 >> N_1$$

- ***Pumping***:- The process of achieving population inversion is known as pumping. Most commonly used methods are as follows.

  Optical Pumping- (used in Ruby/Nd YAG Laser)

  Electric Discharge (used in He- Ne Laser)

  Chemical reaction (used in CO_2 Laser)

  Direct conversion (In semi conductor Laser)

Main components of Laser

- ***Energy Source***:- It is used to raise the system to an excited state.
- ***Active Medium***:- This is the material/medium in which population inversion achieves. This may be solid, liquid or gas.

  for example- In He-Ne Laser mixer of He-Ne gas, in Ruby laser ruby crystal, in Nd YAG laser Nd YAG crystal, in CO_2 laser CO_2 gas is active medium.
- ***Optical Resonator*** :- It consists of two mirrors facing each other. The active medium is enclosed by this cavity. One of the mirror is fully reflecting while other mirror is partially transparent.

Importance of third energy level

With two energy levels rate of stimulated emission will equal to the rate of induced absorption. Therefore, condition of population inversion will not take place and laser amplification will not occur. So, third energy level is necessary for laser action. This is known as ***metastable state***.

Metastable state:- It is a long lived energy state (10^{-3} sec) in which atom can stay much longer time as compared to excited energy state. It is exist above the ground energy state. This is necessary to achieve population inversion.

Types of Lasers

Among the various kinds of lasers some important types of lasers are listed below:

- Solid state laser : Ruby laser, Nd YAG Laser
- Gas laser : He-Ne laser, CO_2 laser
- Liquid laser : Europium chelate laser
- Semiconductor laser : Inp laser

References:
*Figure1-4**Laser & Its applications by G. Hemanth & G. Guru Prasad
https://www.slideshare.net/8121743624/lasers-ppt