APPLIED PHYSICS (16SACAPH2)

Unit – III - LASER

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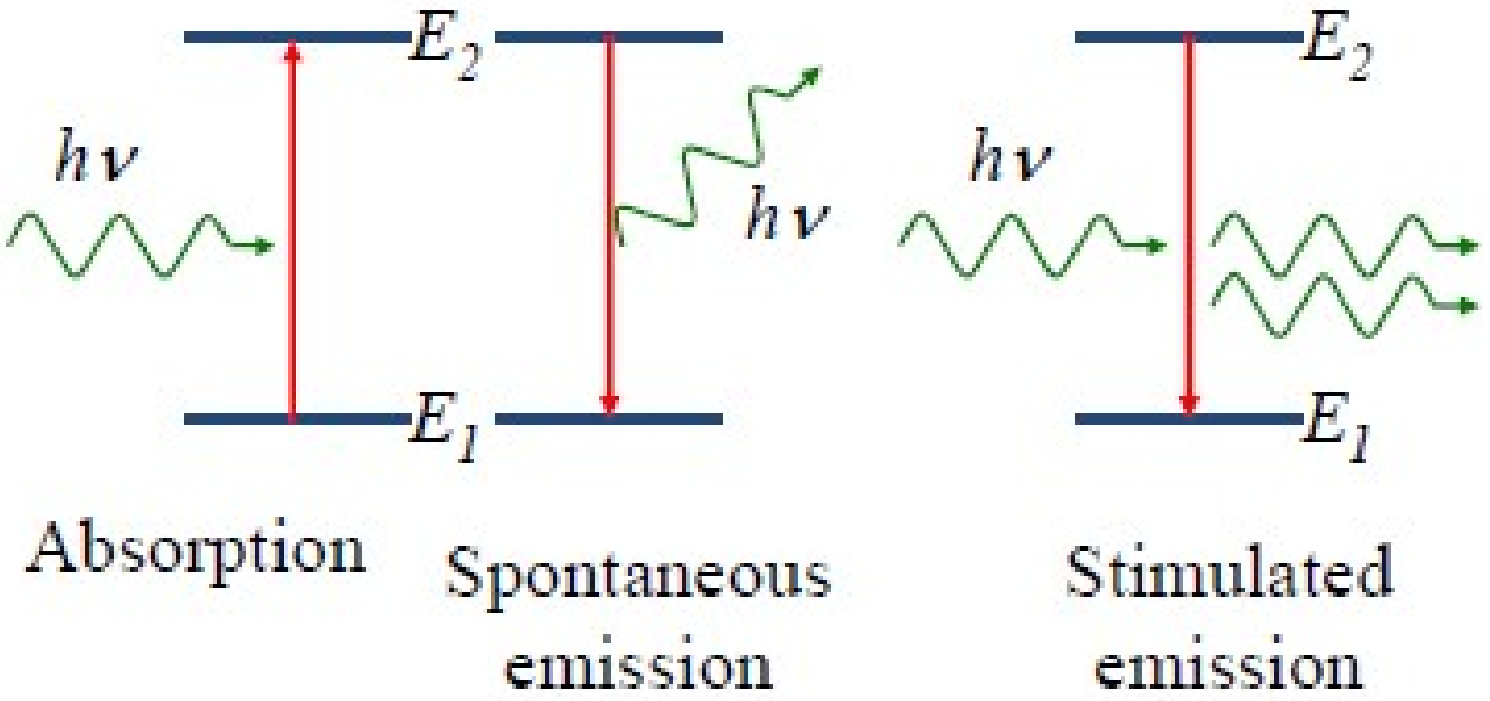
Introduction of laser

- The word laser is an acronym for
  - L - Light
  - A - Amplification by
  - S - Stimulated
  - E - Emission of
  - R - Radiation
- Lasers are essentially highly directional, highly intense, highly monochromatic and highly coherent optical sources.
- Stimulated emission was postulated by Albert Einstein as early as in 1917.

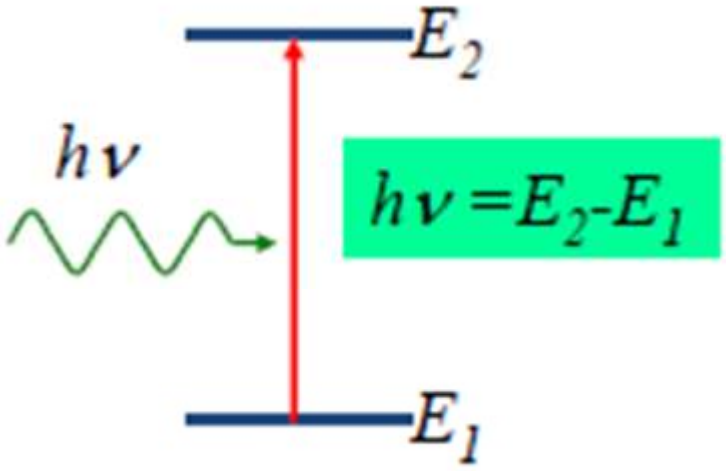
Types of radiation



$$h\nu = E_2 - E_1$$

Types of radiation (Cont.)

Absorption

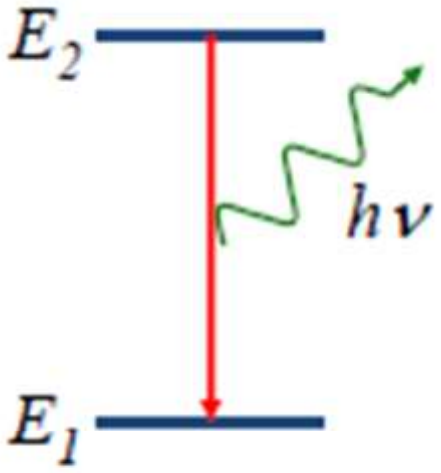


- E_1 – Energy of lower energy level
- E_2 – Energy of higher energy level
- A – Atom in lower energy level
- A* – Atom in excited state

- An Atom in the lower energy level may absorb that energy and go to the higher energy level, this process is called Absorption.
- $A + h\nu \longrightarrow A^*$

Types of radiation (Cont.)

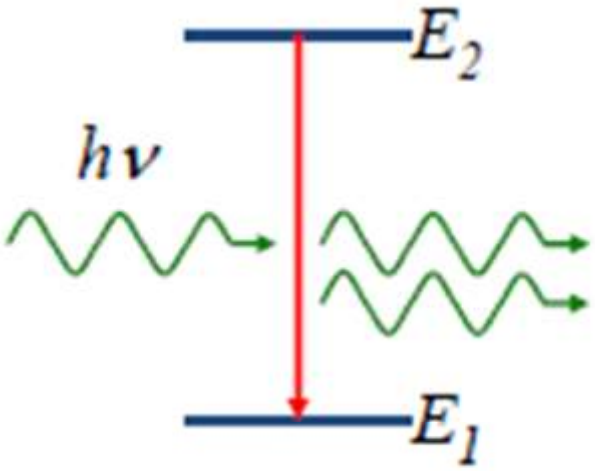
Spontaneous emission



- The transition of an excited atom by itself to lower energy level is known as spontaneous emission of radiation.
- $A^* \longrightarrow A + h\nu$

Types of radiation (Cont.)

Stimulated emission



- The excited atom after getting stimulated by the incident photon transits to lower energy level by emitting photons is known as stimulated emission of radiation.
- $A^* + h\nu \longrightarrow A + 2h\nu$

Types of radiation (Cont.)

- **Pumping**
  - For laser action it is necessary to find a technique by which the upper level is more populated.
  - This was achieved by pumping the atom at the lower level to higher energy level.
- **Population Inversion**
  - The process of achieving greater population density of atom in the higher energy state as compared to a lower energy state is called Population inversion.

Types of Laser

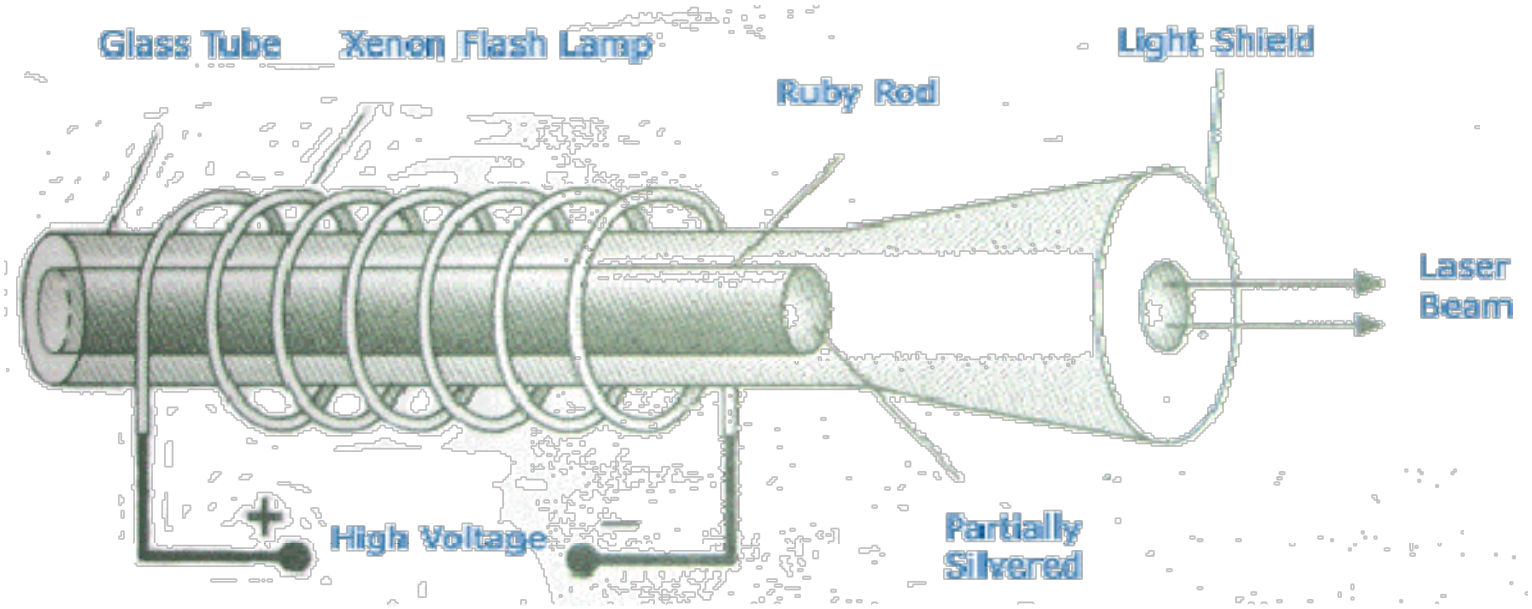
Solid State lasers	:	Ruby laser, Nd:YAG laser, Nd:Glass laser
Gas lasers	:	He-Ne laser, CO_2 laser, Argon laser
Liquid/Dye lasers	:	Polymethene dye, Courmarine dye, Rhodamine laser
Semiconductor laser	:	GaAs laser, InP laser

Ruby Laser

- Definition
  - A ruby laser is a solid-state laser that uses the synthetic ruby crystal as its laser medium. Ruby laser is the first successful laser developed by Maiman in 1960.
  - Ruby is a combination of Aluminium oxide and Chromium atom. ($Al_2O_3 : Cr^{3+}$)
  - T.H.Maiman used 0.05% of Cr^{3+} to get a pink colour.

Ruby Laser

- Construction



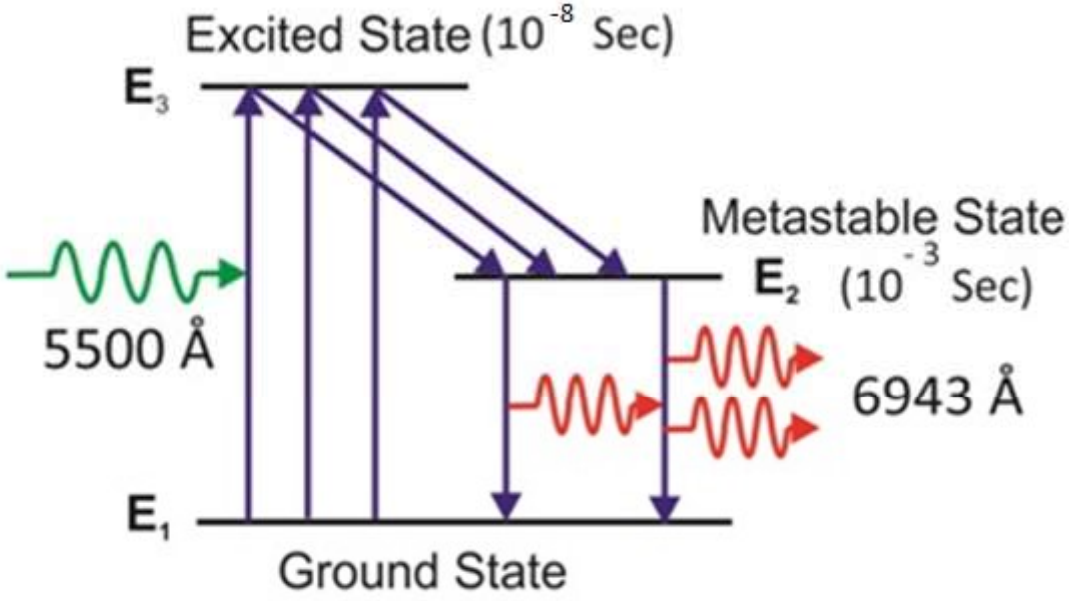
Construction of a Ruby laser

- The ruby crystal is in the form of cylinder. Length of ruby crystal is usually 2 cm to 30 cm and diameter 0.5 cm to 2 cm. As very high temperature is produced during the operation of the laser, the rod is surrounded by liquid nitrogen to cool the apparatus.
- **Active medium or active center**: Chromium ions act as active centers in ruby crystal. So it is the chromium ions that produce the laser.
- **Pumping source**: A helical flash lamp filled with xenon is used as a pumping source. The ruby crystal is placed inside a xenon flash lamp. Thus, optical pumping is used to achieve population inversion in ruby laser.
- **Optical resonator system**: The ends of ruby crystal are polished, grounded and made flat. The one of the ends is completely silvered while the other one is partially silvered to get the output. Thus the two polished ends act as optical resonator system.

Working of a Ruby laser

- When xenon lamp is switched on, the energy is absorbed by the chromium ions and they get shifted to the exited state state.
- These chromium ions they quickly decay to the intermediate meta-stable state through non-radiative transition. the photons released during the stimulated decay of chromium ions are reflected back and forth between the two mirrored end forth of the rod.
- The length of the rod is made exactly equal to an integral multiple of half wavelength so that the radiation trapped in the rod forms an optical standing wave.
- The intensity of this standing wave gradually builds up then pulse of radiation shoots out of the partially silvered end of the ruby rod.
- Ruby laser uses three level pumping scheme. chromium ions absorb energy from the flash lamp and make a transition from E1 to E3. from E3 they undergo non-radiative transfer to E2 which is a meatastable state as shown in below figure.

Energy level diagram



- Once population inversion is achieved in E_2 any spontaneous emission can trigger stimulated emission between E_2 to E_1. red laser light of wavelength 6943 **Å** is given out of the front end mirror.

Application

- Computer devices such as laser mouse, laser presentation, CD ROMs and DVD ROMs
- Astronomy and communication applications
- Medicine, surgery, and health
- War machines, guns and tanks
- Cutting matters in metallurgy industry and related industries
- Robotics, especially in image processing and calculating distances
- Toys

Advantages & Disadvantages of Ruby Laser

- Following are the benefits or **advantages of Ruby Laser**:
  - They are economical.
  - Beam diameter of ruby laser is comparatively less than CO_2 laser type.
  - Output power of ruby laser is not as less as He-Ne laser type.
  - Ruby is in solid form and hence there is no chance of wasting material of the active medium.
  - Due to their low output power, they are known as class-I lasers. Hence they are used as toys for children. They can also be used as decoration piece and artistic display.

- Following are the drawbacks or **disadvantages of Ruby Laser**:
  - No significant stimulated emission occurs in ruby laser until at least half of the ground state electrons have been excited to the meta stable state.
  - Efficiency of this laser type is comparatively lower.
  - Optical cavity of this laser is short as compare to other laser types.