RUBY LASER

Lecture 3

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RUBY LASER

A ruby laser is a solid-state laser. This is the first successful laser developed by Maiman in 1960. The active material in the Ruby is chromium ion and so energy level of chromium Ions takes part in the lasing action. Ruby laser produces visible light of deep red colour of wavelength 694.3 nm.

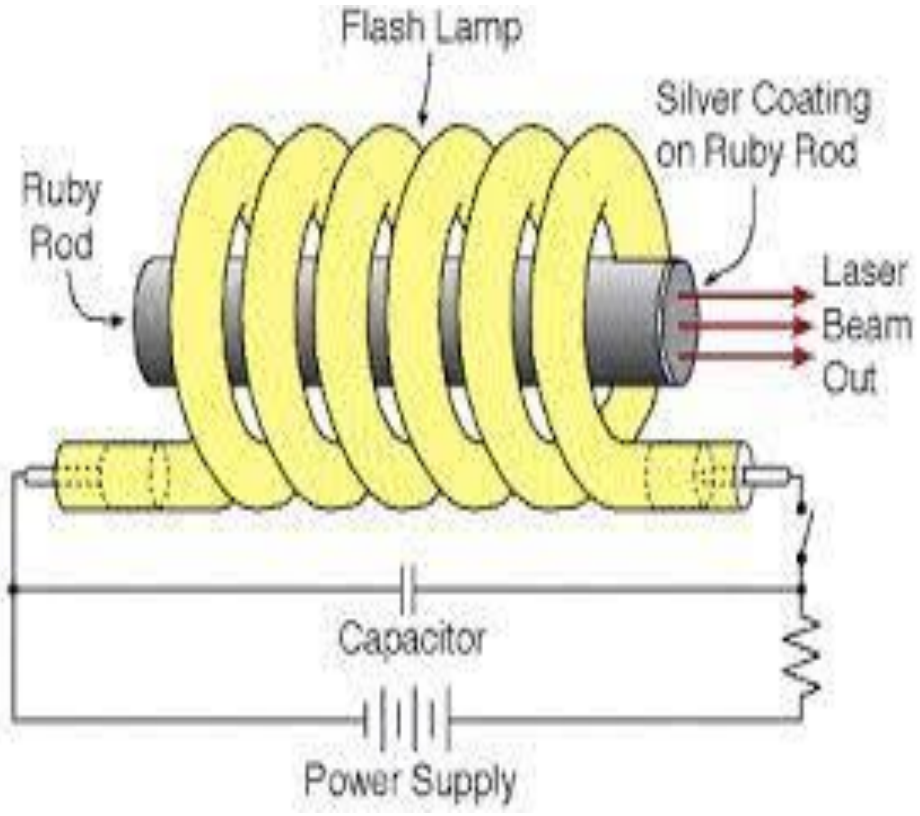
Construction of ruby laser: A ruby laser consists of three important elements (i) laser medium (ii) the pumping source and (iii) the optical resonator.

i. Laser medium or gain medium in ruby laser: In a ruby laser, a single crystal of ruby (Al_2O_3) doped with small (0.05%)percentage of Cr_2O_3 acts as host material.

ii. Pump **source or energy source in ruby laser:**

The pump source in a ruby laser provides energy to the laser medium.

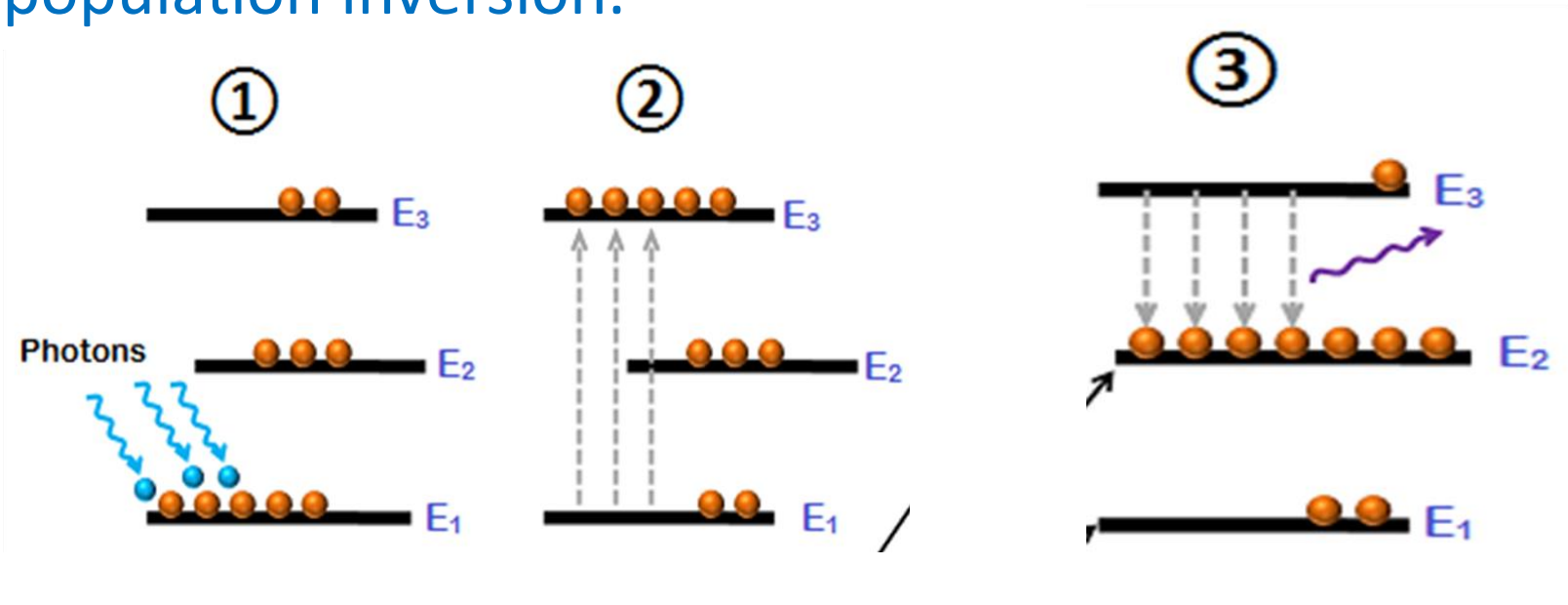
In a ruby laser, we use flashtube as the energy source or pumping source. The flash of the tube lasts several milliseconds. During this period of time, the tube absorbs energy amounting to Several thousand joules and most of the energy is spent on heating the Apparatus.



This heat produced is removed by liquid nitrogen circulating around the Ruby rod.

The remaining part of the energy in the form of blue and green radiation is absorbed by the Ruby.

This energy ensures the excitation of chromium Ion from the ground state to the excited energy state for achieving population inversion.



iii. Optical resonator: The two ends of the cylindrical ruby rod are flat and parallel. The ruby rod is placed in between two mirrors having optical coating. At one end of the rod, the mirror is fully silvered whereas, at another end the mirror is partially silvered.

The fully silvered mirror will completely reflect the light whereas the partially silvered mirror will reflect most part of the light but allows a portion of light to pass out as output laser light.

The optical pumping result when incident photons of wavelength 5500Å raise the chromium Ion from ground state E1 to higher excited state E3.

These ions interact with the crystal lattice and decay to metastable state E2 by non radiating transition where they can stay for a longer period (3 x 10^{-3}sec) producing population inversion.

Working of ruby laser:

The ruby laser is a three level solid-state laser. In this laser, optical pumping is done by a helical xenon flash lamp which provides energy to the atoms to raise electrons from lower energy level to the higher energy levels.

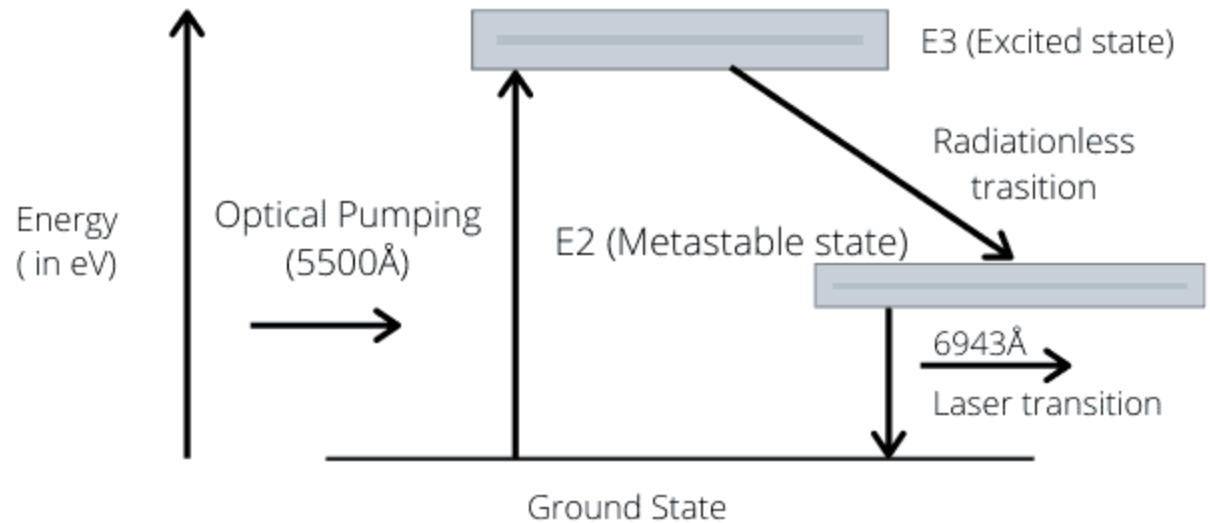
Consider the laser medium consisting of three energy levels E1, E2, E3 with N number of electrons such that E1 < E2 < E3. The energy level E1 is known as ground energy state, the energy level E2 is metastable state and the energy level E3 is known as excited state.

Initially most of the electrons are in the lower energy state (E1) and only a few number of electrons are in the excited states.

When light energy is supplied to the laser medium (ruby) with the flash lamp, the electrons in the lower energy state E_1 gains enough energy and jumps into the excited state (E3).

The excited electrons in the state E3 can not stay for a longer period of time and come back to the lower state within $\sim 10^{-8}$sec. The excited electrons come down to the metastable state E2 by non radiating transition then they can stay there about 3×10^{-3} sec which is much greater than the lifetime of pumping state E3.

As a result of this the number of electrons in the metastable state E2 increase and hence population inversion is achieved.


E3 (Excited state)
Radiationless
trasition
Energy
(in eV)
Optical Pumping
(5500Å)
E2 (Metastable state)
6943Å
Laser transition
Ground State

Since the state of population inversion is not a stable one, hence one or two electrons come down to ground state spontaneously. During this transition, a photon is emitted which induces stimulated emission.

This Photon Travels through the Ruby rod in a direction parallel to the axis of the rod and reflects back and forth (or to and fro) by the reflecting ends of the optical resonator until it Stimulates an excited chromium ion.

Stimulated excited chromium Ion emits a photon exactly in same phase with the stimulating photon.

The Stimulated transition of chromium Ion from metastable state E2 to the ground state E1 is known as laser transition. These in-phase photons stimulate more chromium ions and hence the number of photons emitted increases.

This process repeats and hence the in-phase photos get multiplied. Thus, a strong and coherent laser beam is obtained through the partially reflecting face. So ruby laser has a pulse output and hence called pulse laser.

The metastable state M of ruby is a doublet of separation of 14 A°. So the output of the laser has two lines of wavelength 6943 A° and 6929°. However the line 6943 A° predominates.

Thank you