RUBY LASER

Introduction:

- Ruby is a solid state 3-level Laser and was the first laser, developed by H.T. Maiman in 1960.
- Ruby Laser emits Red light pulses and its pulsing time is 10 nanoseconds.
- Ruby is a crystal of Al_2O_3, in which Al^{+3} ions are doped by 0.05% of Cr^{+3} ions.

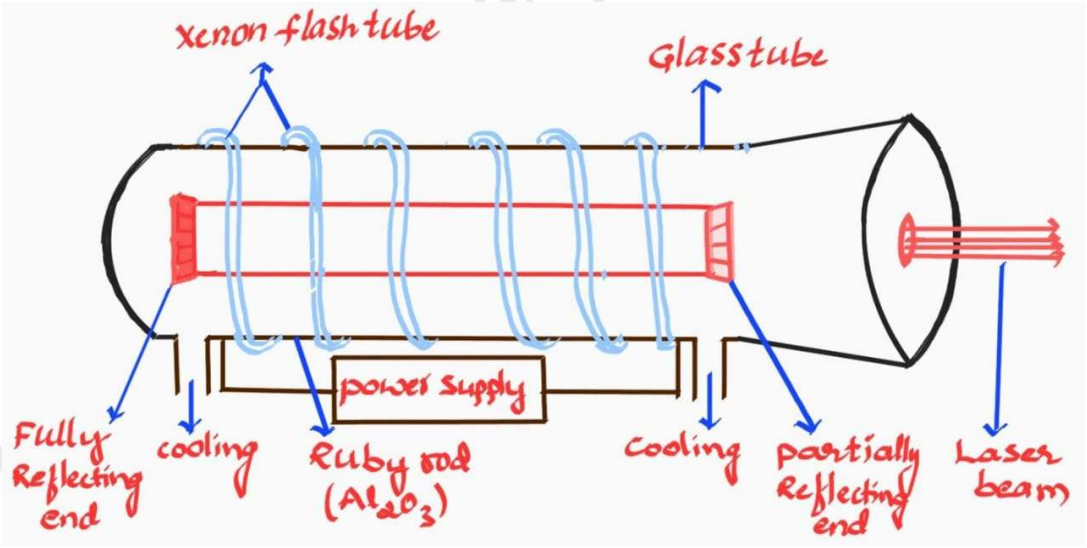
Principle:

- Due to optical pumping, chromium ions (Cr^{+3}) in the ruby crystal are excited to a higher energy level, then undergo a non-radiative transition to a metastable state, from which stimulated emission to the ground state produces a laser beam.

Main components:

- **Active medium:** Chromium ions (Cr^{+3}) in Ruby Crystal Rod.
- **Pumping source:** Xenon flash tube.
- **Optical Resonator:** Mirrors on either side of Ruby rod (Arrangement of Reflectors)
- **Pumping mechanism:** Excitation of Chromium ions (Cr^{+3}) with in Ruby Crystal Rod

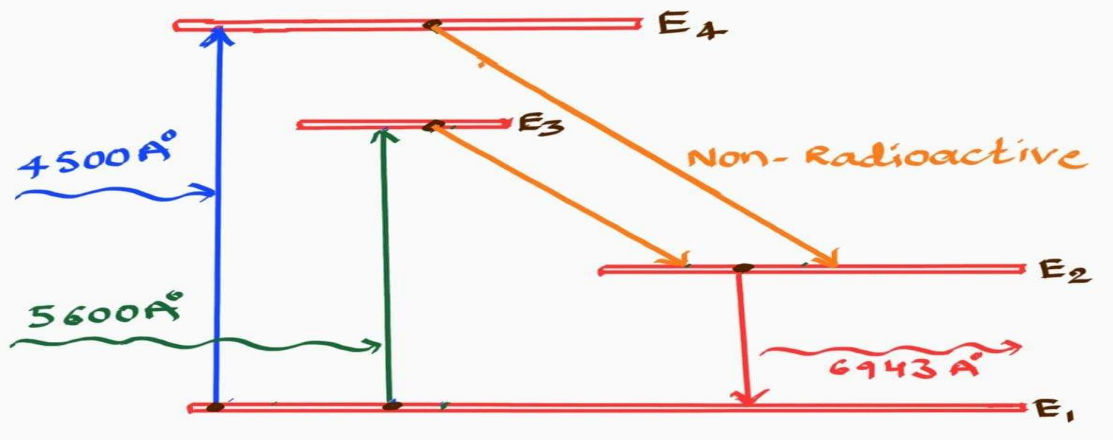
Construction:



- In Ruby Laser, Ruby is taken in the form of a cylindrical rod of 4 cm in length and 1 cm in diameter.
- Ruby crystal is basically Al_2O_3 in which Al^{+3} ions are replaced by 0.05% of Cr^{+3} ions, which will play a main role in the emission of laser beams.

- A Xenon flash tube is arranged around the Ruby rod, which supplies Green-Blue flash light of wavelengths 5600 A° & 4500A° respectively to the active medium, to achieve population inversion and heats up the apparatus.
- The two ends of Ruby are grounded and polished in such a way, one end (face) is silvered to achieve 100% reflection, while the other is partially silvered to make it transparent.
- A cooling arrangement is provided to keep the experimental setup at Normal temperature.

Working:



- Initially, chromium(Cr^{+3}) ions within the Ruby rod are in their ground state E_1.
- When the xenon flash lamp is switched on, the ruby rod is irradiated by flash light of green wavelengths 5600A° and blue wavelengths 4500A°. By absorbing these wavelengths Cr^{+3} ions get excited from E_1 to E_3 & E_4 respectively.
- But the excited Cr^{+3} ions in E_3 & E_4 will stay for a short time of 10^{-8}s. After this lifetime most of the Cr^{+3} ions are deexcited to E_1 at a rate of 10^5 atoms per second and E_2 (metastable state) at a rate of 10^7 atoms per second.
- The metastable state E_2 has a longer lifetime, leading to an accumulation of Cr^{+3} ions at this level as pumping continues.This accumulation of Cr^{+3} ions in E_2 established a population inversion between E_2 and E_1.
- A few Cr^{+3} ions spontaneously transition from E_2 to E_1, emitting incoherent photons in random directions.These spontaneously emitted photons are reflected by mirrors placed at the ends of the ruby rod.
- When these photons traveling along the axis of the rod can stimulate other excited Cr^{+3} ions in the E_2 level to undergo stimulated emission which results in the release of

photons that are coherent (same phase and frequency) and travel in the same direction as the stimulating photon.

- These stimulated photons further cause more stimulated emission as they travel along the axis of the rod, leading to amplification of the light.
- One of the mirrors is partially transparent, allowing a portion of the amplified, coherent light to emerge as a strong laser beam of wavelength 6943A^{o}.
- Once stimulated transition commences, the state of population inversion disappears and lasing action ceases.The laser becomes active once again when the population inversion state is re-established.
- The output of a laser is not a continuous wave but occurs in the form of pulses of microsecond duration.

Advantages/Salient features of Ruby Laser/Characteristics:

(i) Uses a 3-level pumping scheme.

(ii) The active centers are Cr^{+3} ions.

(iii) Light from a xenon flash lamp is the pumping agent.

(iv) High output intensity.

(v) High acceptance band.

(vi) operates in pulsed mode.

Drawbacks of Ruby Laser:

(i) It requires high pumping power.

(ii)The efficiency of the Ruby laser is very poor.

(iii)It has a low repetition rate.

(iv)It has defects due to crystalline imperfections.

(v)It has limited tuning.

Applications/Uses of Ruby Laser:

Ruby Lasers used in variety of applications

(i) Holography

(ii) Diamond drilling

(iii) Medical applications

(iv) Optically pumping dye lasers

(v) Research purpose

NOTE: Ruby Lasers are not widely used nowadays because they are replaced by Nd: YAG Laser.