PH201 – Optics and Lasers

Assignment – 2

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Explain the operation of a laser with diagram showing essential components. Also show the corresponding energy level diagram. Mention the lasing wavelengths.

Ruby Laser

Ruby Laser was the first successful laser developed by Theodore H. Maiman in 1960. It is a solid-state laser that uses the synthetic ruby crystal as its active medium. It operates in a pulsed mode at 694.3 nm with an emission linewidth of 0.53 nm. It emits red colour.

Parts of a Ruby Laser

A Ruby Laser consists of three important parts:

1. Active Medium
2. Energy Source
3. Resonating Cavity

Active Medium

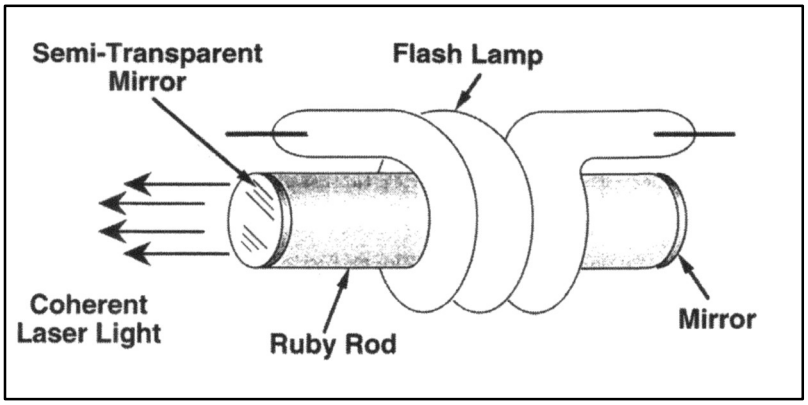
The Active Medium is a source of gain within the Ruby Laser. It comprises of a host of sapphire crystal (Al_2O_3), cast in the form of a cylinder, with Chromium (Cr^{3+}) ions doped in at a typical concentration of 0.05 % by weight. The Ruby crystal is hard, durable, has good thermal conductivity and is chemically stable.

Energy Source

Population inversion is the process of achieving the greater population of higher energy state than the lower energy state. It is a necessary condition for any laser to produce amplification of light beam. In order to achieve population inversion, we need to supply energy to the active medium.

The energy source or pump source supplies energy to the active medium. Xenon flash lamps act as the pump source in ruby laser. The pumping absorption bands occur at 400nm and 550nm with an approximate bandwidth of 50nm at each wavelength and thus match very well with the pumping spectrum of the Xenon flashlamps. When lower energy state

electrons in the laser medium gain sufficient energy from the flashlamps, they jump into the higher energy state or excited state causing population inversion.



Components of a Ruby Laser

Resonating Cavity

A resonating cavity is an arrangement of mirrors that surround the active medium and provide feedback of the laser light. It is a major component of a laser.

The ends of the ruby laser rod are flat and parallel to each other. The rod is placed in a double elliptical cavity with two linear flashlamps for the pumping source, as shown in figure.

Two mirrors are attached to either ends of the rod. One of them, called as rear mirror is fully silvered and hence has high reflectivity. The other one, called as output mirror is partially silvered or semi-transparent, therefore partially transmits light.

The rear mirror will completely reflect the light whereas the output mirror will reflect most part of the light but allows a small portion of light through it to produce output laser light.

Working of Ruby Laser

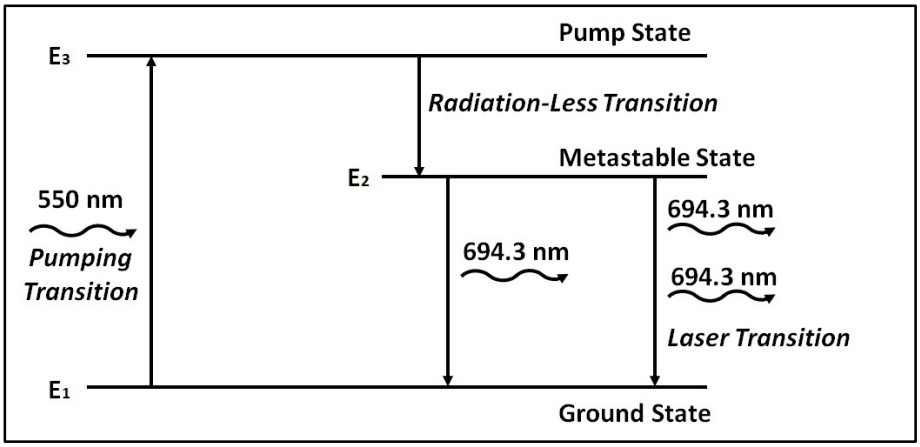
The ruby laser is a three-level solid-state laser. The energy source supplies energy to the active medium through technique called Optical Pumping. Optical pumping is a technique in which light is used as energy source to achieve population inversion.

Consider a ruby laser medium consisting of three energy levels E_1, E_2, E_3 ($E_1 < E_2 < E_3$). The energy levels E_1 is known as ground state or lower energy state, E_2 is known as metastable state, and E_3 is known as pump state.

Assume that initially most of the electrons are in the lower energy state (E_1) and only small fraction of electrons is present in the excited states (E_2 and E_3).

When the active medium is supplied with light energy, excitation of electrons from ground state (E_1) to the pump state (E_3) takes place.

The lifetime of the pump state E_3 is very small, it is of the order of 10^{-8} sec. So, after a short period, the electrons in pump state E_3 fall into the metastable state E_2 by releasing radiation-less energy. The lifetime of the metastable state E_2 is 10^{-3} sec which is much greater than the lifetime of pump state E_3. Therefore, the electrons reach E_2 much faster than they leave E_2. This results in population inversion between levels E_1 and E_2 because the population of electrons in E_2 level is greater than E_1 level.



Energy Level Diagram for Ruby Laser

After the lifetime of metastable state E_2 is finished, spontaneous emission of radiation takes place, because the electrons in E_2 level fall into the lower energy state E_1.

When the emitted photon interacts with the electron in the metastable state, it forces that electron into the ground state E_1. As a result, two photons are emitted. This light being produced within the laser medium will bounce back and forth between the two mirrors. This stimulates other electrons to fall into the ground state by releasing light energy. This is called stimulated emission of radiation.

Similarly, millions of electrons are stimulated to emit light. Thus, light is amplified and gain is achieved. The amplified light escapes through the output mirror to produce laser light.