UNIT – II LASER AND FIBER OPTICS

TOPIC – III: Types of lasers – Nd:YAG Laser

Different types of lasers

Introduction

There are many different types of lasers. The laser medium can be a solid, gas, liquid or semiconductor. Lasers are commonly designated by the type of lasing material employed:

Solid-state lasers have lasing material distributed in a solid matrix (such as the ruby or neodymium: yttrium-aluminum garnet "YAG" lasers). The neodymium-YAG laser emits infrared light at 1,064 nanometers (nm). A nanometer is $1x10^{-9}$ meters.

Gas lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a primary output of visible red light. CO_2 lasers emit energy in the far-infrared, and are used for cutting hard materials.

Semiconductor lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, such as the writing source in some laser printers or CD players.

Types of Lasers

Laser systems are generally classified on the basis of active material used as follows:

1. Solid State Laser (Example, Nd:YAG laser)
2. Gas Laser (Example, CO_2 laser)
3. Semiconductor Laser (Example, Diode laser)

Nd - YAG Laser

Nd - YAG Laser is a neodymium based laser. Nd stands for Neodymium (rare earth element) and YAG stands for Yttrium Aluminium Garnet which is ($Y_3Al_4O_{12}$). It is a four - level solid state laser.

Principle

The active medium (Nd - YAG rod) is optically pumped by krypton flash tubes and neodymium ions (Nd^{3+}) are raised to excited levels. During the transition from metastable state to ground state, laser beam of wavelength 1.064 μm is emitted.

Construction

The construction of Nd - YAG laser is shown in fig 4.10. In the active element (Nd - YAG crystal), a small amount of Yttrium ions (Y^{3+}) is replaced by neodymium ions (Nd^{3+}). The active element is cut into a cylindrical rod. The laser rod and a pumping source (flash tube) are placed inside a highly elliptical reflector cavity. The flash tube is controlled with the help of a capacitor.

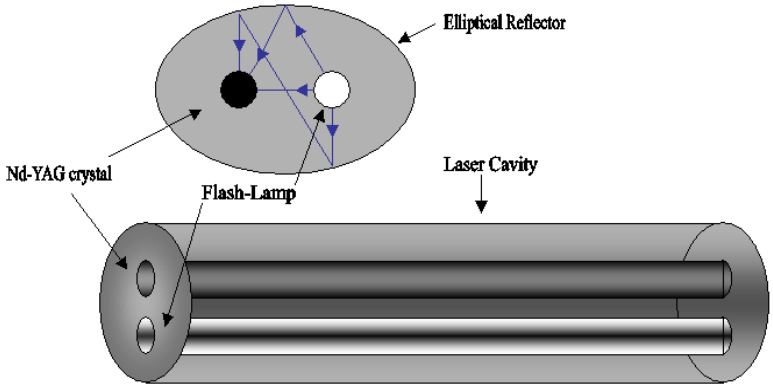

Fig .10 Nd - YAG Laser

The ends of the rod are polished and made optically flat and parallel. The optical resonator is formed by using two external reflecting mirrors.. One mirror is made 100 % reflecting while the other is partially reflecting. The system is cooled by air or water circulation.

Working

The energy level diagram for Nd - YAG is shown in fig. 10. The energy levels are those of neodymium (Nd^{3+}) ions.

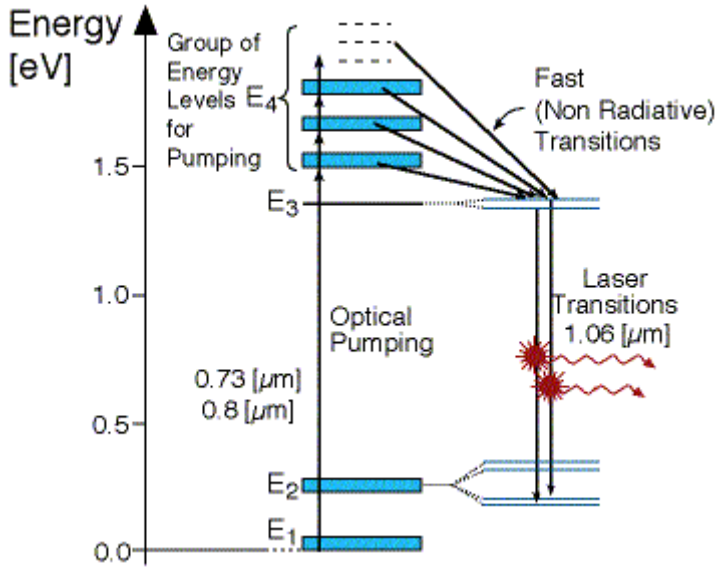

Fig .11 Energy level diagram of Nd - YAG Laser

- When the krypton flash lamp is switched on, the neodymium atoms are raised form the ground level E_0 to upper levels E_3 and E_4 (Pump band) by the absorption of radiation of wavelength 0.73 μm and 0.80 μm.
- The neodymium atoms make a transition from these energy levels to level E_2 by non - radioative transition. E_2 is a metastable state.
- The neodymium ions are collected in the level E_2. **Population inversion** is achieved between E_2 and E_1.
- An ion makes a spontaneous transition from E_2 to E_1, emitting a photon of energy *hv*. This emitted photon will trigger a chain of stimulated photons between E_2 and E_1.
- Photons thus generated travel back and forth between the two mirrors and grow in strength. After some time, the photon number multiplies more rapidly.
- After enough strength has been attained (condition for laser satisfied), an intense laser light of wavelength 1.06 μm (10600 Å) is emitted through the partial reflector. It corresponds to the transition from E_2 to E_1.
- The transition from E_1 to E_0 is rapid and non - radiative.

Characteristics

- **Type :** It is a four - level solid state laser.
- **Active medium :** The active element is a Nd - YAG crystal (rod).
- **Pumping method :** Optical pumping is employed for the pumping action.
- **Pumping source :** Xenon or krypton flash tube.
- **Optical Resonator :** Two ends of ND - YAG rod polished with silver (one end fully silvered and the other is partially silvered) are used as optical resonator.
- **Power Output :** The Power output is approximately 70 watt.
- **Nature of Output :** The nature of output is pulsed or continuous beam of light.
- **Wavelength of output :** The wavelength of the output beam is 1.06 μm (infra - red).

Advantages

1. It has high energy output.
2. It has very high repetition rate operation.
3. It is much easy to achieve population inversion.
4. YAG is a crystalline material, and hence, the corresponding line width is much smaller, which implies much lower thresholds.

Disadvantages

The electron energy level structure of Nd^{3+} in YAG is complicated.

Applications

1. It finds many applications in range finders and illuminators.
2. It is widely used in engineering applications such as resistor trimming, scribing, micro - machining operations as well as welding, drilling etc.
3. It finds many medical applications such as endoscopy, urology, neurosurgery, ENT, gynaecology, dermatology, dental surgery and general surgery.