Nd-YAG LASER

Introduction:

- Nd-YAG is a 4-level solid state Neodymium continuous wave Laser and was invented by J.E. Geusic, R.G. Smith and L.G. Van Uitert in 1964.
- Nd-YAG stands for Neodymium doped Yttrium Aluminium Garnet ($Y_3Al_5O_{12}$:Nd^{3+}).
- Here YAG is a synthetic Garnet made using Aluminium in the place of Silicon and Garnets are groups of silicate minerals with molecular formula $X_3Y_2(SiO_4)_3$

Where: X → Divalent cations like Ca, Mg, Fe^{2+}, Mn^{2+}

Y → Trivalent cations like Al^{3+}, Fe^{3+}, Cr^{3+}

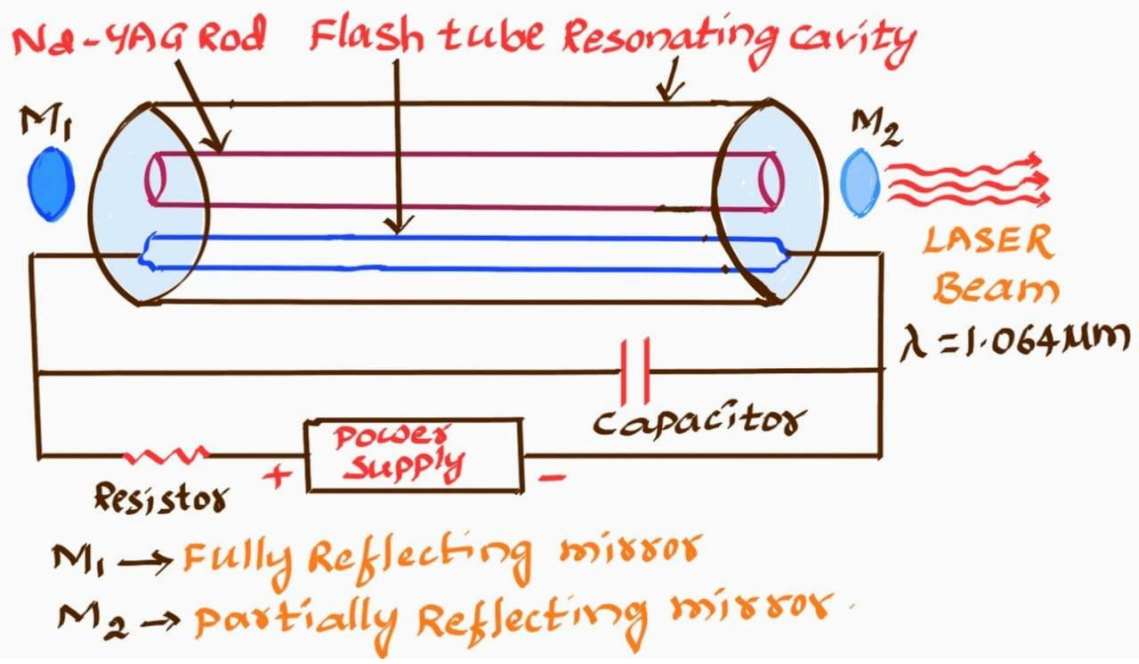
Principle:

The Nd:YAG laser operates by exciting neodymium ions within a YAG crystal, causing them to emit photons of infrared light at a wavelength of 1064 nm or 1.064 μm.

Main components:

* **Active medium**: Nd-YAG ($Y_3Al_5O_{12}$) crystal.
* **Pumping source**: Flash tube of Xe or Kr.
* **Resonating cavity**: Arrangement of reflectors.
* **Pumping mechanism**: Optical pumping.

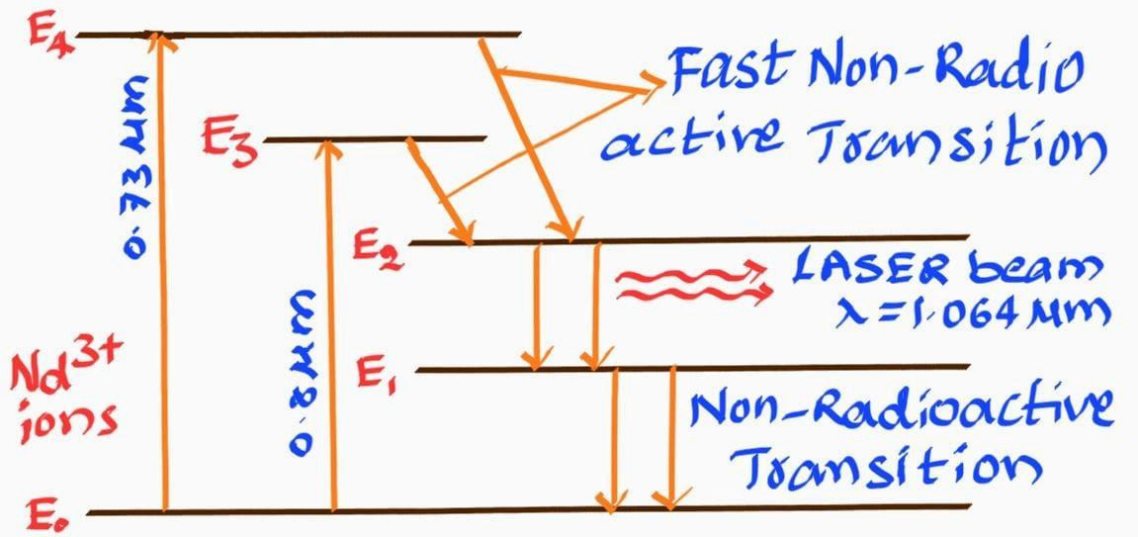
Construction:



- A small amount of Yttrium ions (Y^{3+}) is replaced by Neodymium (Nd^{3+}) in the active element of Nd-YAG crystal and it is cut into a cylindrical rod.
- Xenon flash tube (lamp) is arranged below the Nd-YAG rod (the photons from flash tube excite Nd^{3+} ions to excited states) and both Nd-YAG rod and flash tube are placed inside a highly elliptical reflector cavity.
- The optical resonating cavity is formed by using two external reflecting mirrors, in that one is fully reflecting and the other is partially reflecting.
- This arrangement focuses all the light on the Laser rod (Nd-YAG rod).

Working:

- When the Krypton flash lamp (tube) is switched on, by the absorption of light radiation of wavelength 0.7 μm & 0.8 μm, the Nd^{3+} ions are raised from Ground state (E_0) to excited states E_3 & E_4 respectively.



- The Nd^{3+} ions make a transition from these energy levels(E_3 & E_4) to metastable state E_2 by fast non-radioactive transition.
- But the energy level E_1 is far above the ground level and hence it can not be populated by fast non-radioactive transition.Therefore the population inversion is readily achieved between E_2 & E_1.
- An Nd^{3+} ion make a spontaneous emission from E_2 to E_1 and emitting a photon of energy hv. This emitted photon will trigger a chain of stimulated photons between E_2 & E_1.
- The photons thus travel back and forth between two mirrors and grow in strength. After some time, the photon number multiplies more rapidly.

- After enough strength is attained (which satisfy laser condition) an intense laser light of wavelength 1.06 μm is emitted through the partial reflector, which corresponding to the transition from E_2 to E_1.
- Finally, the Nd^{3+} ions return from E_1 to E_0.,on their own through non-radioactive transition.

Output: The power output is 70 watt. The nature of output is a pulsed or continuous beam of light.

Salient Features:

(i) Uses four-level pumping scheme

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

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

(iv) Low efficiency (1%) and moderate power output (watts)

(v) Operates in CW/pulsed mode

Advantages:

* High energy output.
* Very high repetition rate of operation.
* Easy to achieve population inversion.
* Compact size & Low cost of ownership.
* Good optical finish.

Disadvantages:

* Depth of penetration.
* Low beam quality.
* High investment cost.

Applications:

* Used in ophthalmology.
* Used in oncology to remove skin cancers.
* Used for soft tissue surgeries in the oral cavity in dental hospitals.
* Used for manufacturing for engraving, etching and metal surface enhancement process.
* Used in military services as range finders.
* Used in endoscopy, urology & neurosurgery.
* Used in engineering applications such as resistor trimming, scribing & micro machining operations.
* Also used in welding & drilling purposes.