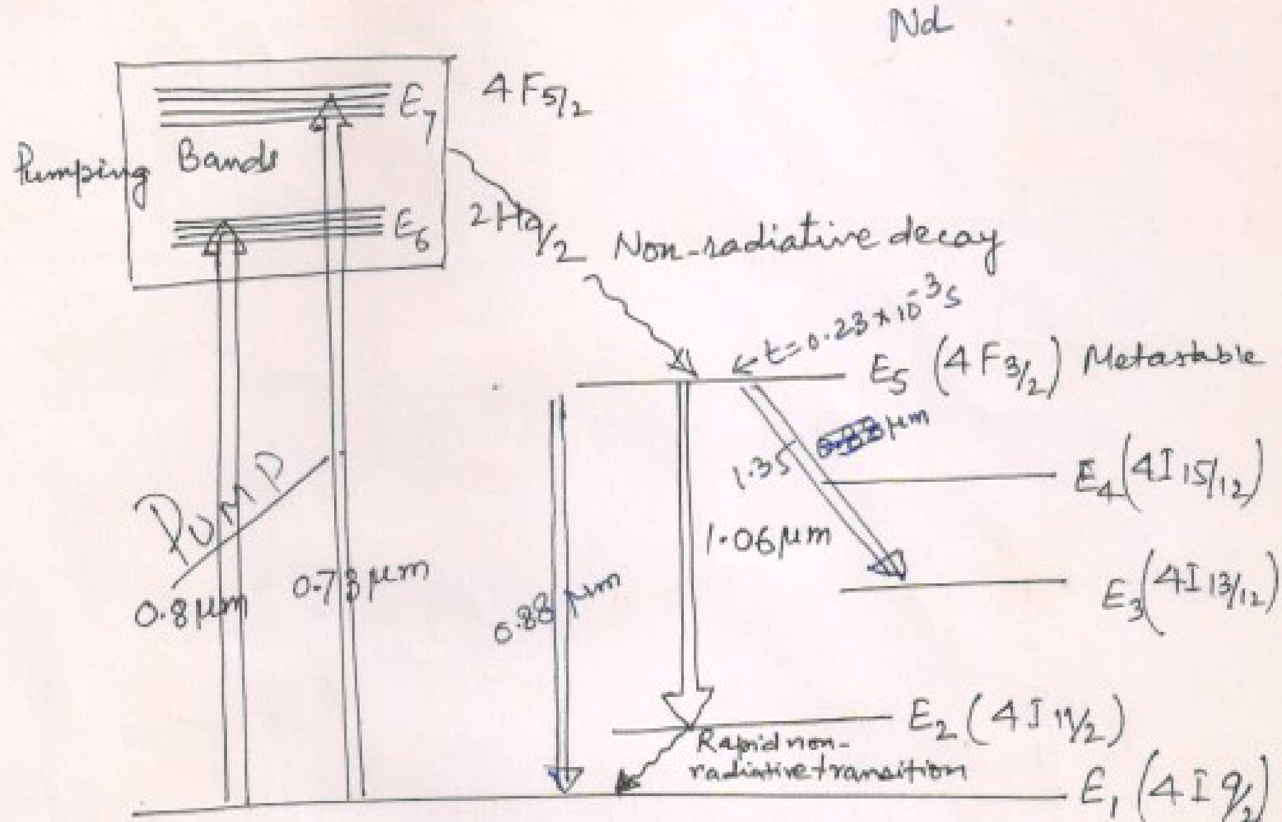
# Nd : YAG LASERS




- Nd : YAG is a four level system.
- Excitation bands : Blue and green regions. Pumping by arc lamps.
- A non-radiative or collisional transition of pump energy to upper laser level $4F_{3/2}$. The lasing action gets terminated at lower level $4I_{11/2}$. From here by collisional transition to $4I_{9/2}$ (Ground state).
- There are two other radiative transitions coming from the same upper laser level : $4F_{3/2}$.

(i) 1.06 μm ~~transition to $4I_{13/12}$ level. transition~~ and decay to $4I_{13/12}$ level.

$$4F_{3/2} \longrightarrow 4I_{13/12} \longrightarrow 1.35\ \mu m$$
$$4F_{3/2} \longrightarrow 4I_{9/12} \longrightarrow 0.88\ \mu m$$

These two transitions have lower levels of gain than the 1.06 μm transition. Hence these lasing actions are not easy to achieve.

- Maximum concentration of $Nd^{3+}$ ions in YAG is 1-1.5%.
- If the concentration is increased, it will result in increase of collisional transition (decay), which will result in a reduction of lifetime of the upper laser level.

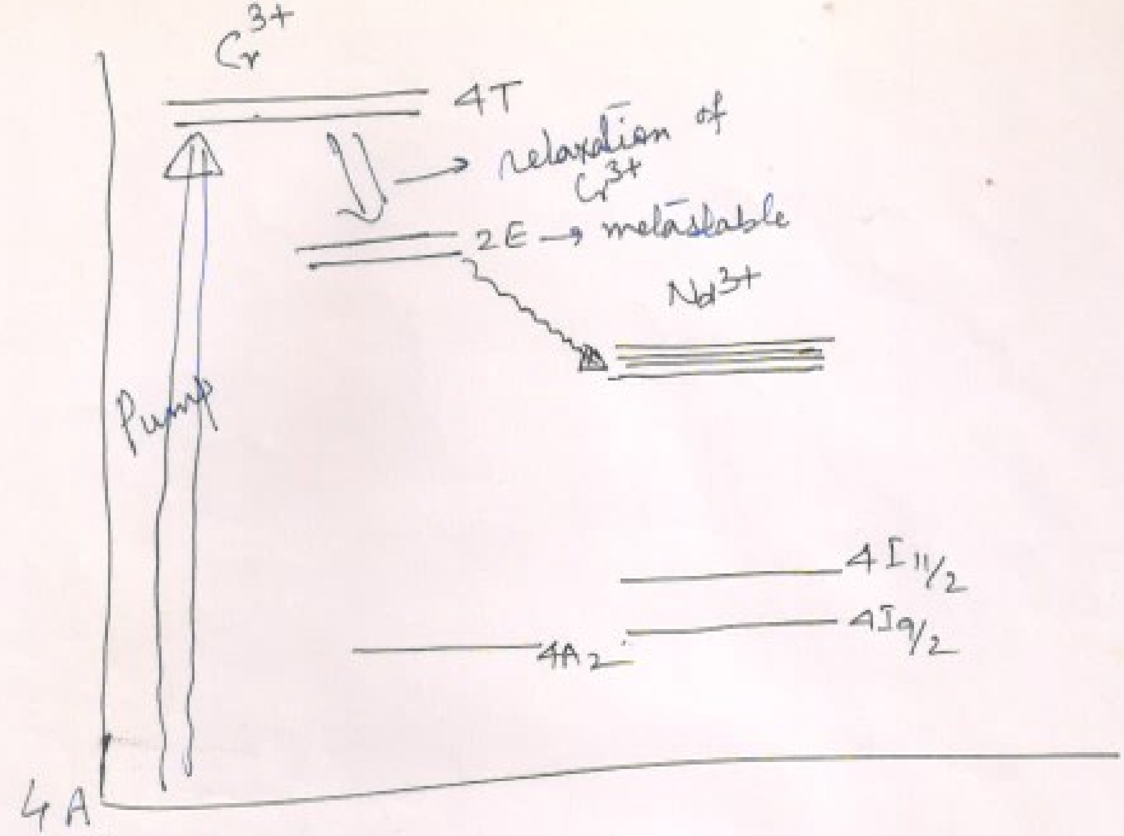
- At ambient temperature, the radiative transition of 1.06 μm gets homogeneously broadened with a narrow emission linewidth of $1.2 \times 10^{11}$ Hz ($\Delta\lambda = 0.45$ nm). Here the lifetime of the upper laser level will be 230 μs.
  [The spontaneous lifetime corresponding to laser transition is 550 μs]

- The energy difference between the lower laser level and the ground level is ~ 0.26 eV, the ratio of its population to that of the ground state at room temperature (T = 300K) is $e^{-\Delta E/kT} \simeq e^{-9} << 1$. Thus the lower laser level is almost unpopulated and hence inversion is easy to achieve.

- 10-50 pulses per second pump the output energy is in the range of 100 mJ per pulse and pulse width ~ 10 ns

- Due to the narrow linewidth, the cross-section of the stimulated emission is large and the threshold of pumping is low. But the absorption bands are also narrow. Hence, the excellent radiation emitted by flashlamps is not fully utilised. Hence, gases like krypton is used in the pumping lamp, which matches the emission bands.

- The transition $4F_{3/2} \rightarrow 4I_{11/2}$ at 1.06 μm has a Lorentzian line shape at 195 GHz. The upper level lifetime is $0.23 \times 10^{-3}$ s.



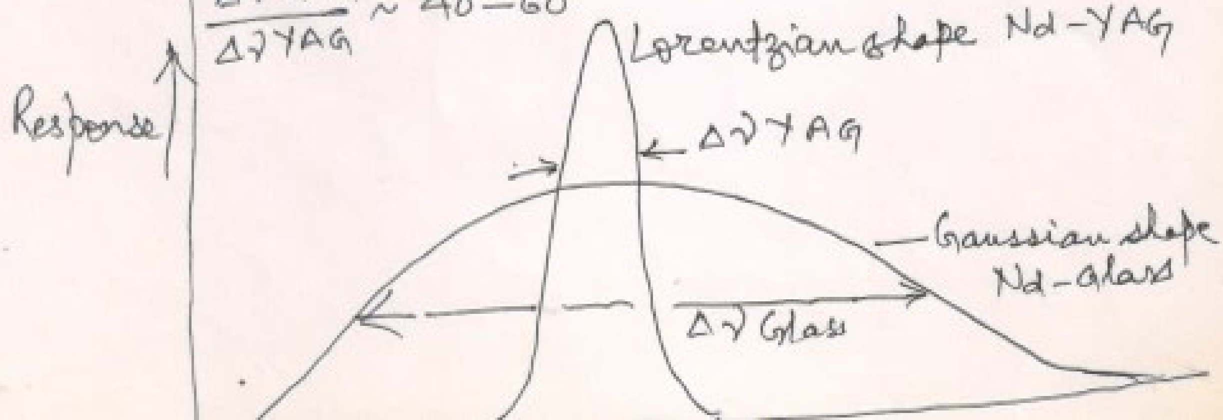

## Sensitised Nd-YAG Lasers

- The efficiency of Nd-YAG lasers can be improved by incorporating a second dopant, which has an absorption that can match the output of optical pump sources better than the active impurity when used alone.
- $Cr^{3+}$-Nd doped $Y_3Al_5O_{12}$ is an example. The energy in the broad $4A \rightarrow 4T$ bands is absorbed by $Cr^{3+}$ ions.
- $Cr^{3+}$ ions relax to the metastable 2E levels. The excitation is then transferred to some excited levels of $Nd^{3+}$. Eventually $Nd^{3+}$ ions return to ground state via the normal $4F_{3/2} \rightarrow 4I_{11/2}$ emission of $Nd^{3+}$.
- Rods of Nd-YAG exhibit excellent properties of conduction of heat. As such they are better bet for laser operation involving high repetition rate.
- However, there is one limitation in these lasers. Growth of crystals is possible only for making small rods of the size of 10 cm in length and 1 cm in diameter.

## Nd : Glass Lasers

- Typical neodymium ion concentration ~ $2.8 \times 10^{20}\ cm^{-3}$
- Various silicates and phosphates are used as host material.
- Glass has an amorphous structure, hence, different neodymium ions situated at different sites have slightly different surroundings. This leads to an inhomogeneous broadening and resultant linewidth is $\Delta\nu \sim 7.5 \times 10^{12}$ Hz which corresponds to $\Delta\lambda \sim 260$ Å. This width is much larger than in Nd:YAG lasers and hence the threshold pump powers are also much higher.
  Spontaneous lifetime of laser transition ~ 300 μs.
- Nd-Glass emission is broadened inhomogeneously having Gaussian shape and is generally much broader than the emission line in a cystalline material like Nd-YAG. where the broadening takes place homogeneously giving Lorentzian form.
- Thus if we consider the same concentration of doping, the maximum emission that occurs at the central frequency of Nd-YAG is much larger than that of Nd-glass. This is due to the fact that there are same number of radiating species and the radiative rates from the upper laser level are the same. However, the upper level lifetimes are different.

$$\frac{\Delta\nu\ Glass}{\Delta\nu\ YAG} \sim 40-60$$



Nd doped glass is largely used as a laser medium for pulsed lasers → due to low thermal conductivity of glass.

Nd-YAG laser can be used in continuous wave mode.

(i) Glass rods having good quality can be made with almost any diameter – from fiber to rods.

(ii) Glass does not absorb the emission of laser

(iii) In crystalline systems, during operation of lasers, the crystals get distorted due to excessive heating. Nd-glass lasers are tough and highly resistant to damage due to high power densities.

(iv) Glass is optically homogeneous and hence it can be doped in high level of concentration of impurities

(v) Nd glass lasers produce high energy outputs, per unit volume, of the material. Thousands of joules per millisecond can be achieved with larger size of glass rods.

(vi) $Nd^{3+}$ doped glass has broad linewidth of laser transision (~30-40 nm). This broadening happens due to non-homogeneity of the environment. Therefore, this laser usually does not operate in single spectral mode.