❖ Laser

PHYSICS

Content:

- Introduction Laser

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- Spontaneous and stimulated emission of radiation

- Population inversion

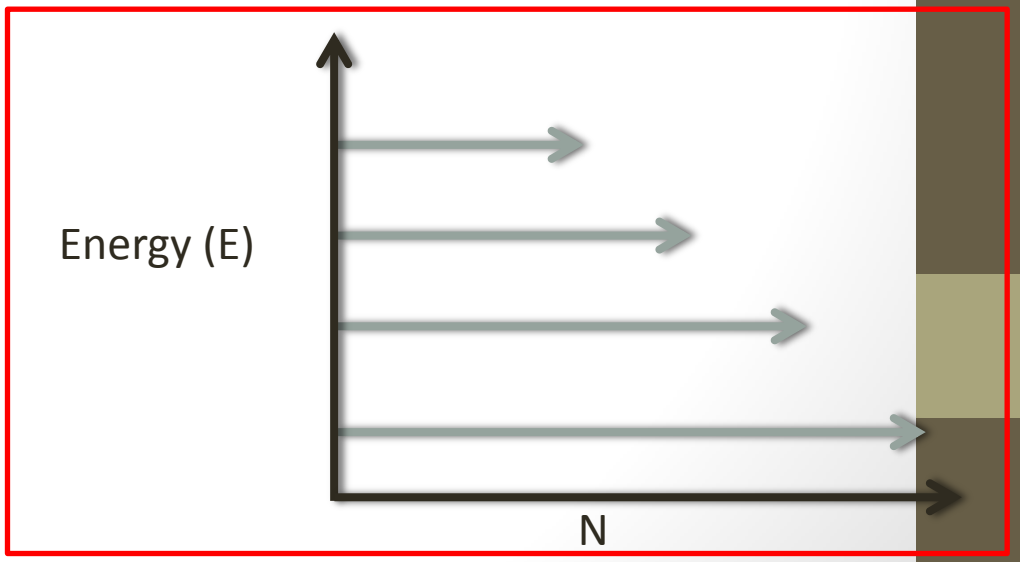
- Concept of 3 and 4 level laser

- Construction and working of ruby laser.
- He-Ne Laser
- Laser application.

The theory of laser

Atoms are characterized by discrete energy states. The distribution of the atoms in their various allowed states is governed by Boltzman's law which states that if an assembly of atoms is in state of thermal equilibrium at an absolute temp. T, the number of atoms N_2 in one energy level E_2 is related to the number N_1 in another energy level E_1 by the equation.

$$N_2 = N_1 e^{-(E_2 - E_1)/KT}$$



Theory of Laser

Introduction (Brief history of laser)

- **Laser is the most beautiful gift of the developing world to the mankind. The laser is an optical amplifier. The word laser is an acronym that stands for "light amplification by the stimulated emission of radiation".**

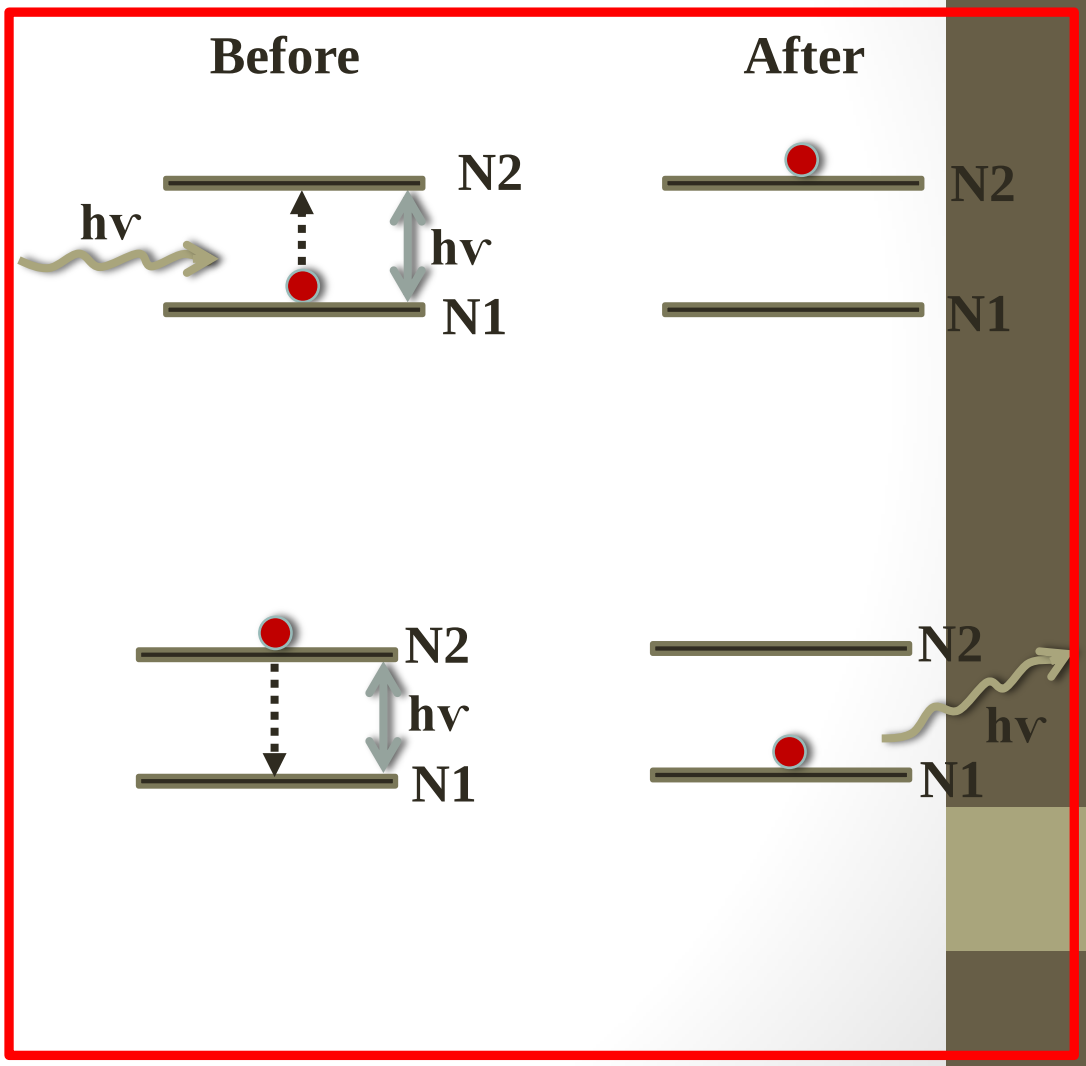
- **1917-The idea of the basic laser was put forward by Albert Einstein, when he first predicted the existence of a new irradiative process called "stimulated emission".**

- **1954- first device MASER (microwave amplification by stimulated emission of radiation) developed by C.H. Townes**

- **In 1960, T. H. Maiman built the first laser device (ruby laser) which emits light of wavelength 694.3 nm,**

According to Einstein there are three different ways in which atoms can interact with eletromagnetic radiation.

(i) Absorption

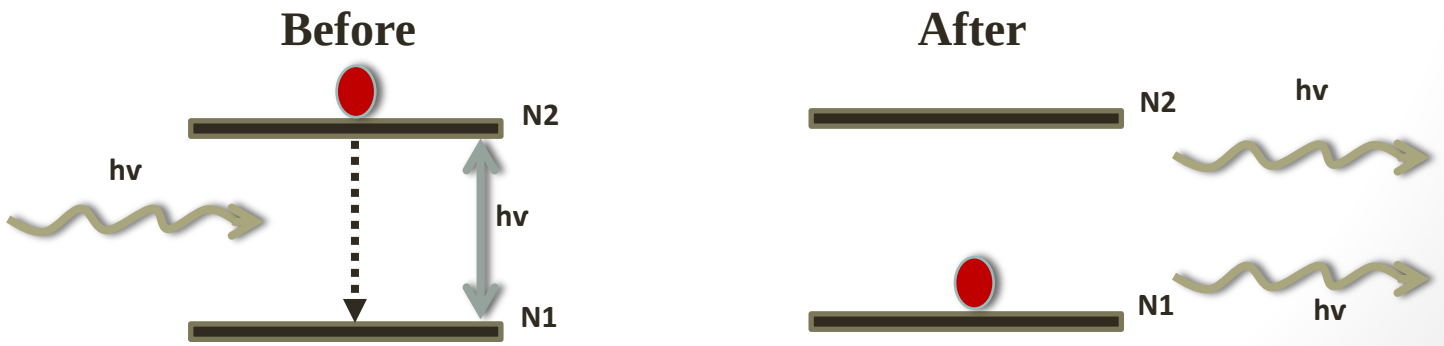


(ii) Spontaneous emission

- No external trigger is required.
- Photon released in the random directon.
- Releases a photon of energy equal to the energy gap inorder to balance coservation energy.

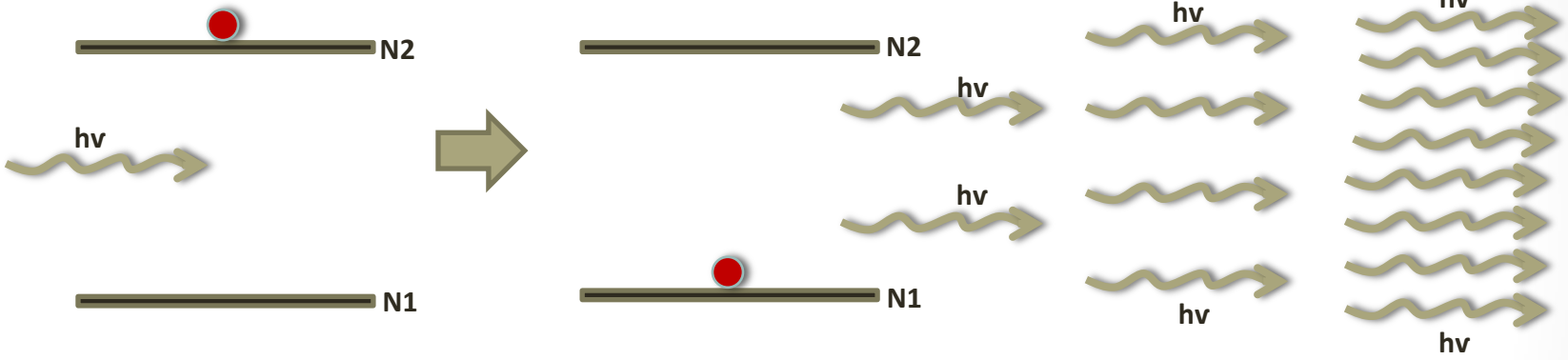
(iii) Stimulated emission

- Requires an external force which stimulates the atom at higher state to drop or decay to the lower state E_1.
- In this process, the atom releases a photon of the same energy, direction, phase and polarization as that of the photon passing by, the net effect is two identical photons (2hν) in the place of one, or an increase in the intensity of the incident beam.
- It is precisely this processes of stimulated emission that makes possible the amplification of light in lasers.



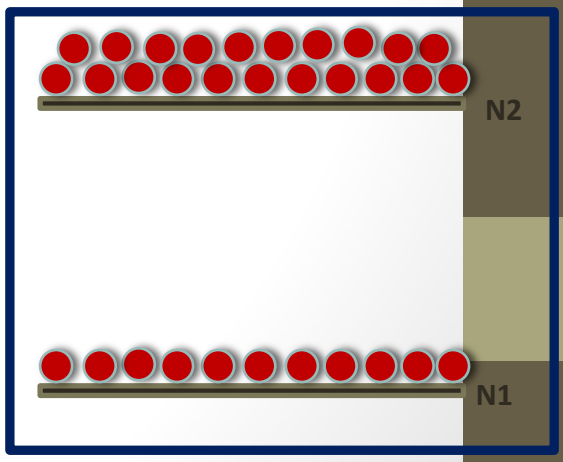
Principle of laser

Stimulated emisssion

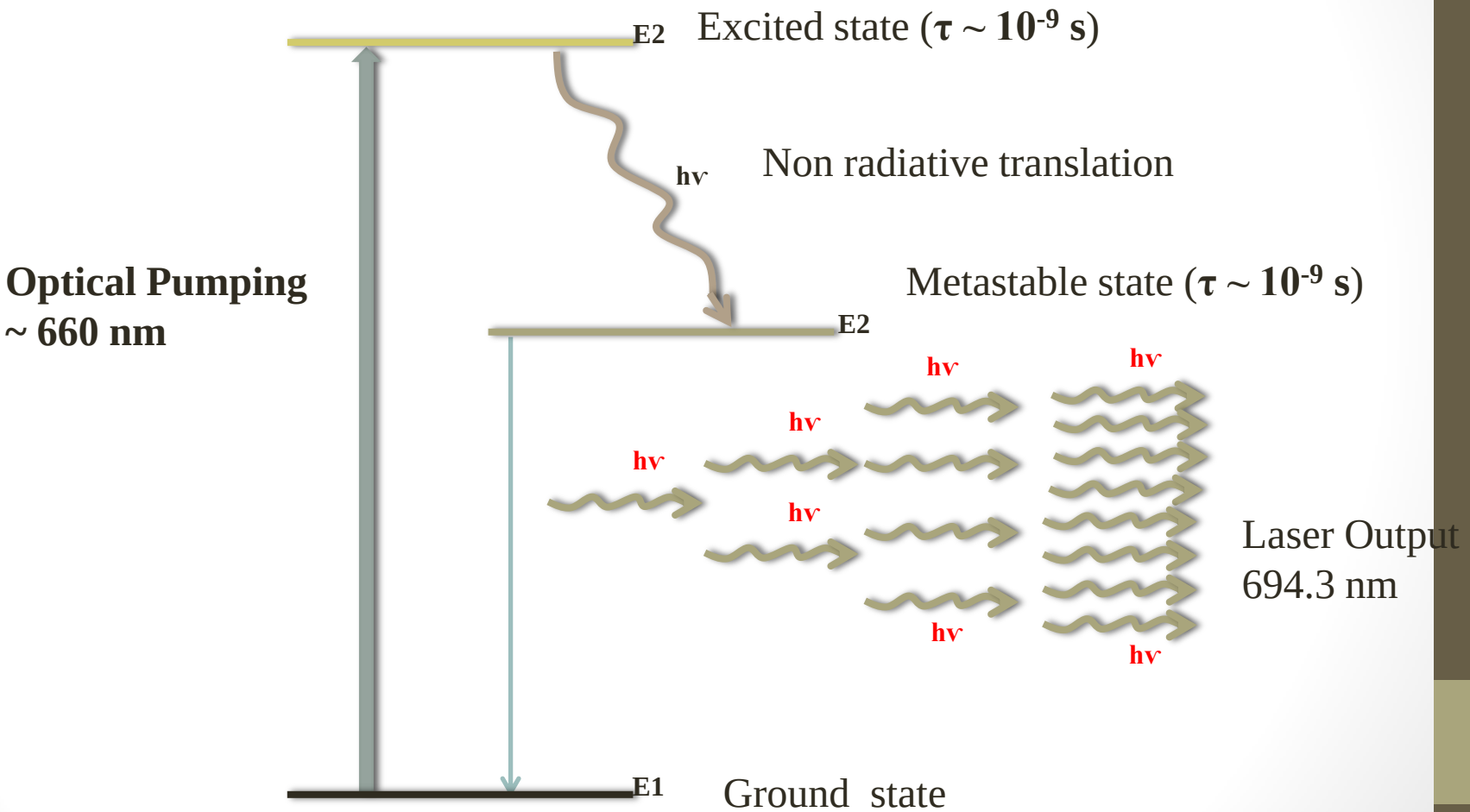


Population Inversion

Condition in which the higher energy state population is greater than the lower energy state. This is achieved by optical pumping ($N_2 > N_1$).



3 Level Laser

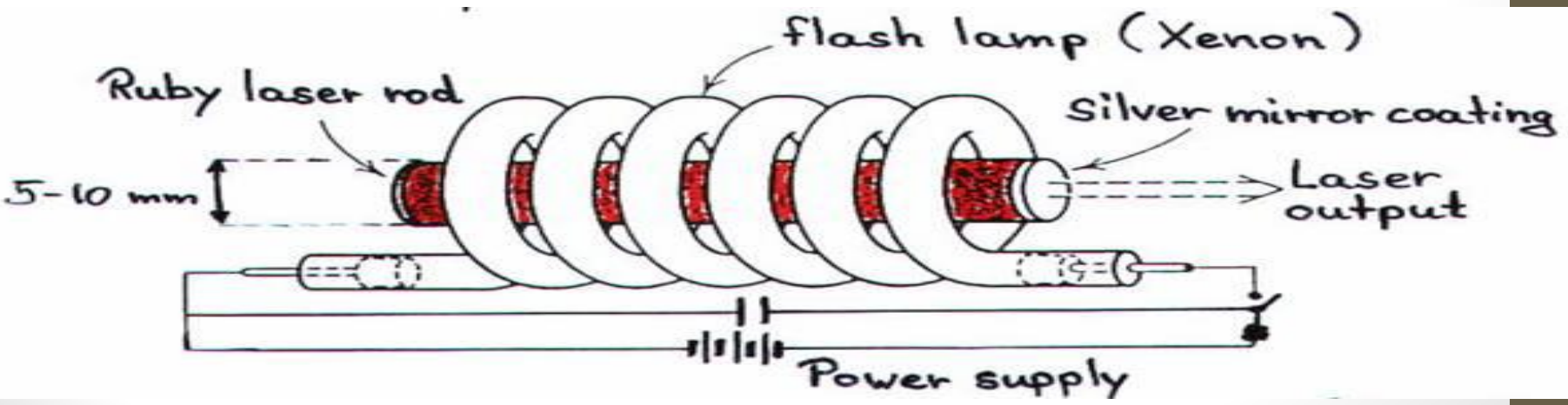


Ruby Laser

- Ruby laser (uses Cr++ ions) ruby (Al_2O_3) monocrystal, Cr doped.
- Developed by Theodore H. Maiman in 1960

Parts of ruby laser

- Lasing medium: Ruby crystal rod consists of AL2O3 mixed with 0.05 of Cr3+ ions
- Resonant cavity: Both ends of rod are perfectly plane And parallel.one end perfect reflector while other partial reflector.
- Pumping source: Xenon flash lamp in the form of helix.



Source: http://chemweb.ucc.ie/courses/RPB/CM4002/4002_L3_files/image002.jpg

Working of Ruby Laser

- **The upper energy level E3 is short-lived, E1 is ground state, E2 is metastable state.When a flash of light falls on ruby rod, radiations are absorbed by Cr3+ which are pumped to level E3.**

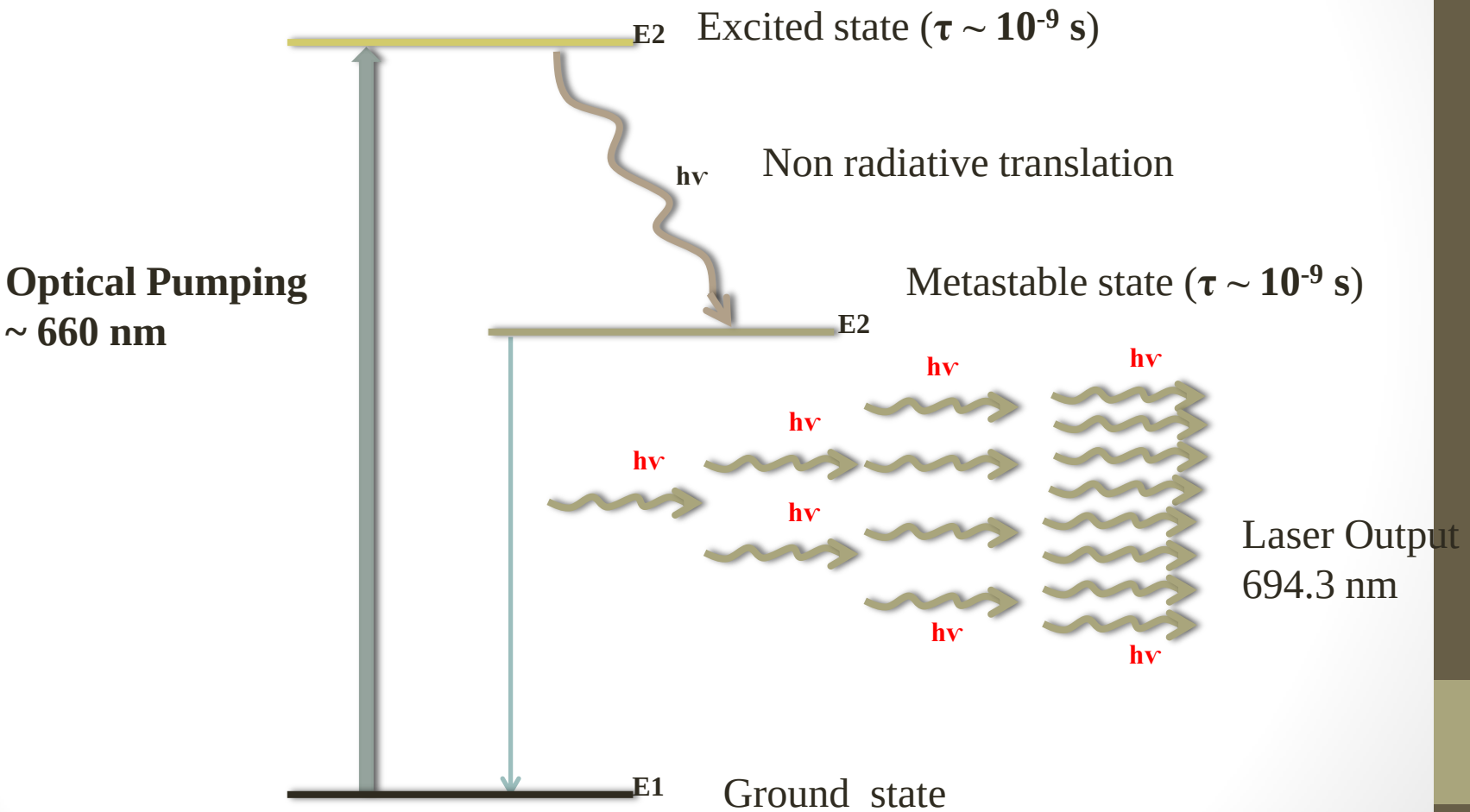
- **Metastable state,here the concentration of ions increases while that of E1 decreases. Hence,population inversion is achieved.**

- **A spontaneous emission photon by cr3+ ion at E2 level initiates the stimulated emission by other cr3+ ions in metastable state.**

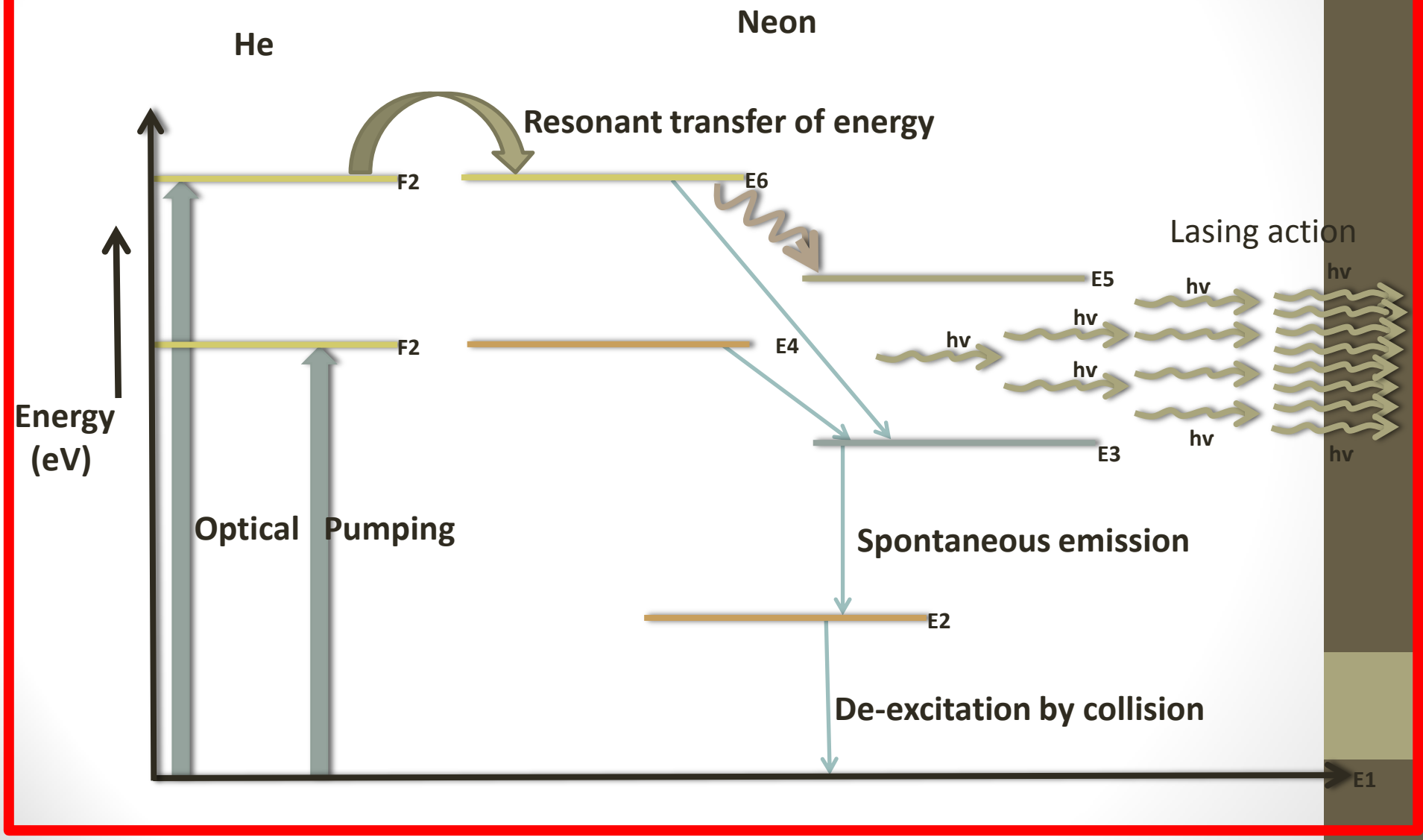
DRAWBACKS OF RUBY LASER

- The laser requires high pumping power because the laser transition terminates at the ground state and more than half of ground state atoms must be pumped to higher state to achieve population inversion.
- It’s tough to achieve and maintain population inversion for the long period of time as lower lasing level is th ground state.
- The laser output is not continuos but occurs in the form of pulses of microseconds duration.
- The defects due to crystalline inperfection are also present in this laser.

3 Level Laser

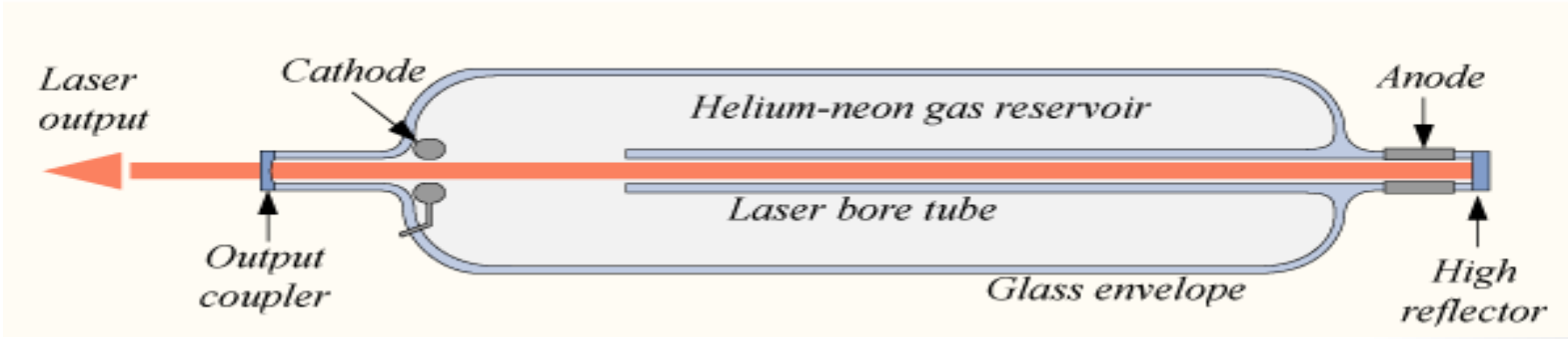


4- Level laser



He-Ne Laser

- A helium-neon laser, usually called a He-Ne laser, is a type of small gas laser. HeNe lasers have many industrial and scientific uses, and are often used in laboratory demonstrations of optics.
- He-Ne laser is a four-level laser.
- Its usual operation wavelength is 632.8 nm, in the red portion of the visible spectrum.
- It operates in Continuous Working (CW) mode.



Source : http://upload.wikimedia.org/wikipedia/commons/a/af/Hene-1.png

How 4-level laser Better than 3-level laser

- Lower Lasing level is not the ground state.
- Population inversion once achieved can be sustained for the longer period of time
- Less amount of energy required for optical pumping.
- It’s a CW laser.

Application of Laser Light

- **Industrial uses**
  - To drill tiny holes in hard materials.
  - Welding and machining.
  - Highly localised heating.
- **In everyday life**
  - Bar-code readers.
  - Compact disc players.
  - To Produce holograms.
- **Surgical uses:**
  - To break up gallstones and kidney stones.
  - To weld broken tissue (e.g. detached retina).
  - To destroy cancerous cells.
  - To remove plaque clogging human arteries.

- **Laser Cooling.**

- **Radio Communication.**