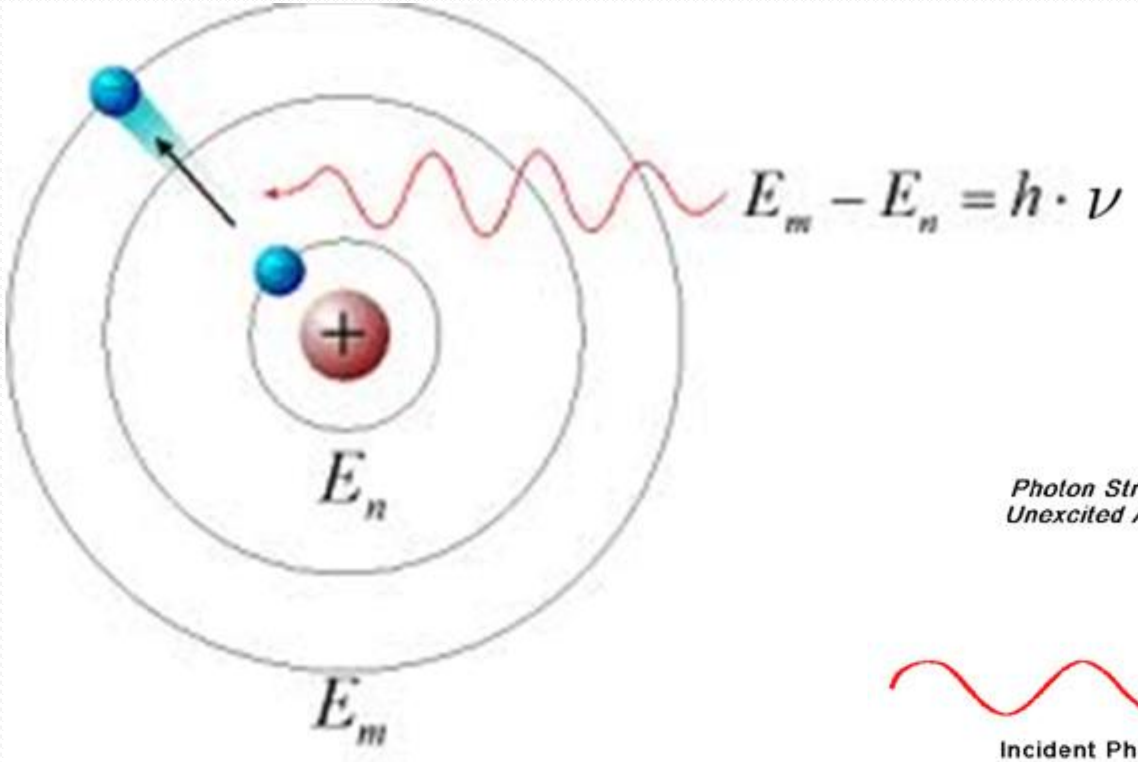
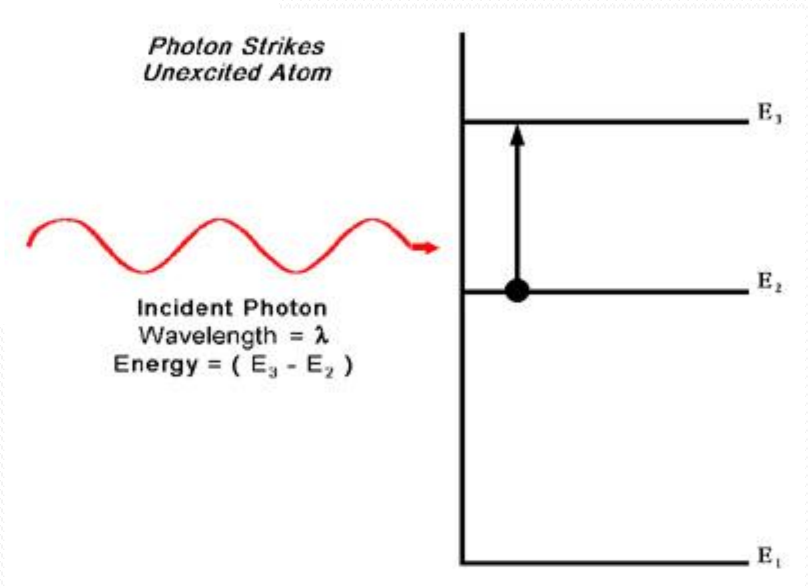
L ight
A mplification through
S timulated
E mission of
R adiation

by

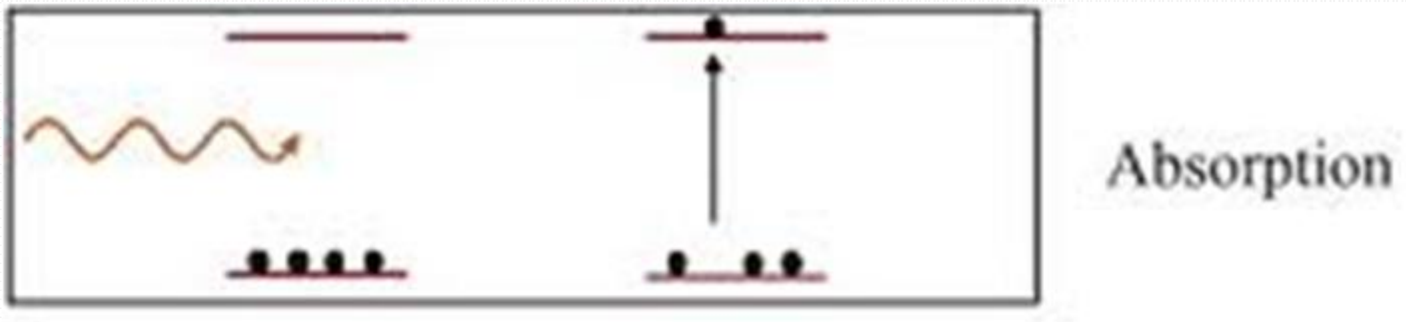
Dr. M. Mishra

Atomic Orbits and electron Transition





Absorption of Radiation



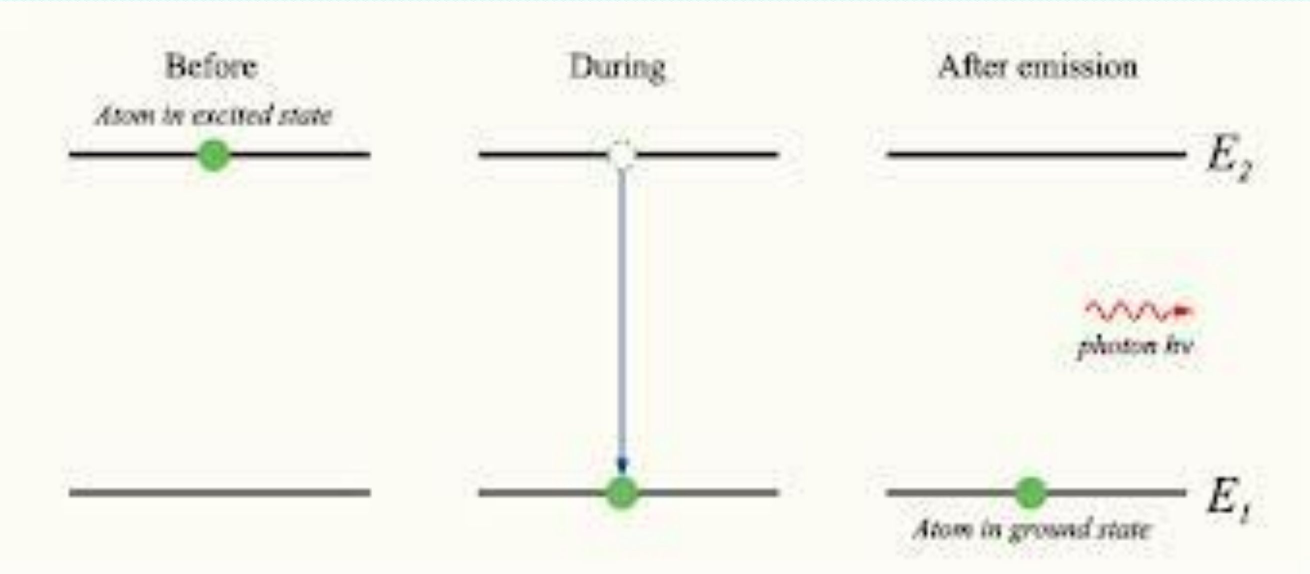
$$E_2 - E_1 = h\nu \quad \Rightarrow \quad \nu = \frac{E_2 - E_1}{h}$$

The probable rate of transition

$$P_{12} = B_{12} \cdot u(\nu)$$

B_{12} Einstein's coefficient for absorption of radiation

Spontaneous Emission of Radiation



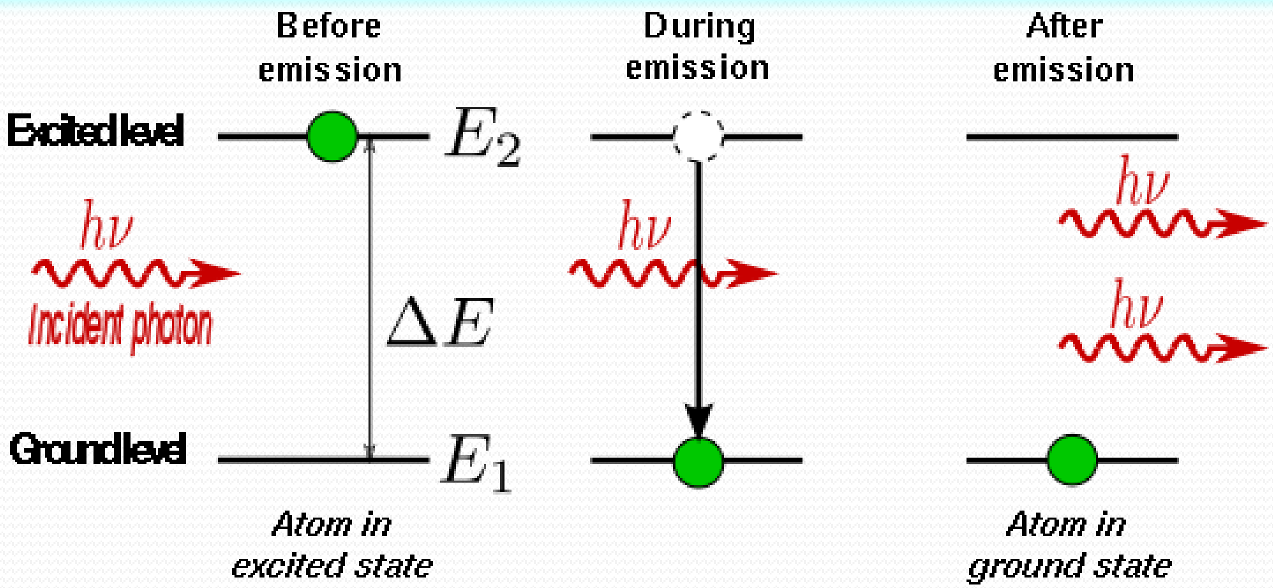
$$E_2 - E_1 = h\nu \quad \Rightarrow \quad \nu = \frac{E_2 - E_1}{h}$$

The probable rate of transition

$$(P_{21})_{Spon} = A_{21}$$

A_{21} Einstein's coefficient for spontaneous emission

Stimulated Emission of Radiation



$$E_2 - E_1 = \Delta E = h\nu$$

$$E_2 - E_1 = h\nu \quad \Rightarrow \quad \nu = \frac{E_2 - E_1}{h}$$

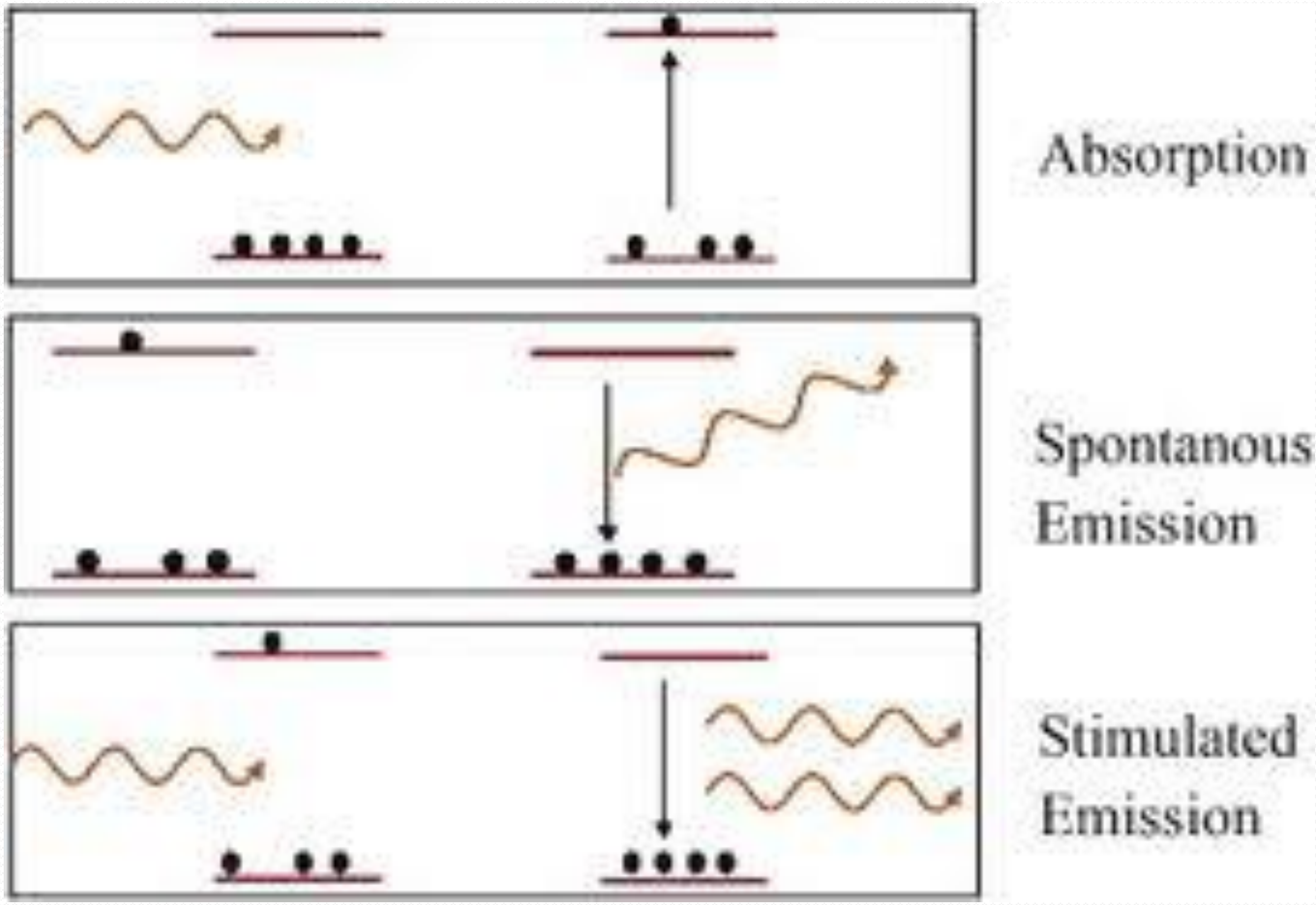
The probable rate of transition

$$(P_{21})_{Stim} = B_{21} \cdot u(\nu)$$

B_{21} Einstein's coefficient for Stimulated Emission

Summary

$$E_2 - E_1 = h\nu \quad \Rightarrow \quad \nu = \frac{E_2 - E_1}{h}$$

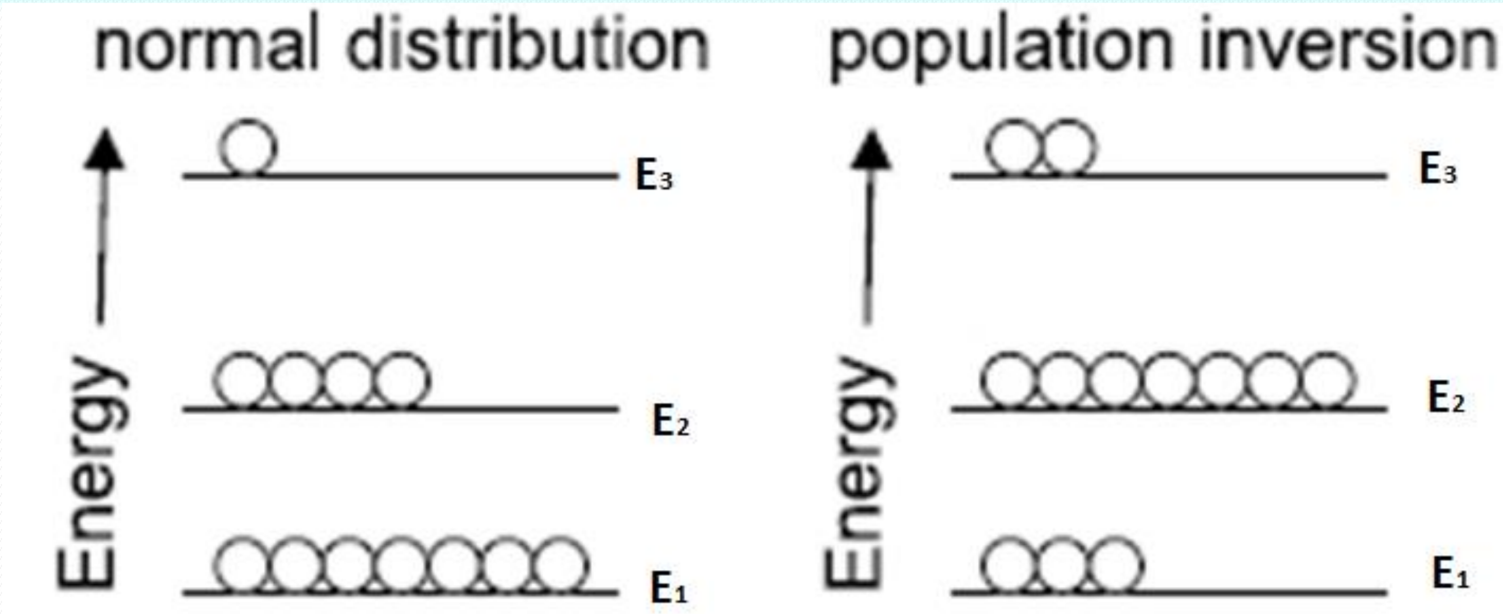


Relationship among Einstein's Coefficients

- $B_{21} = B_{12}$ Probability of stimulated emission is same as that of absorption.

- $\frac{A_{21}}{B_{21}} \propto \nu^3$ It means that the probability of spontaneous emission dominates over induced emission more and more as the energy difference between two states increases.

Population Inversion



As we know the Boltzman Eqn:

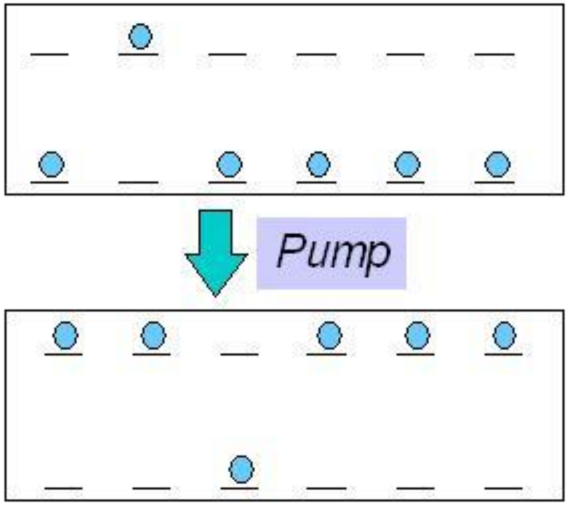
$$N_i = N_0 e^{-E_i/kT}$$

and

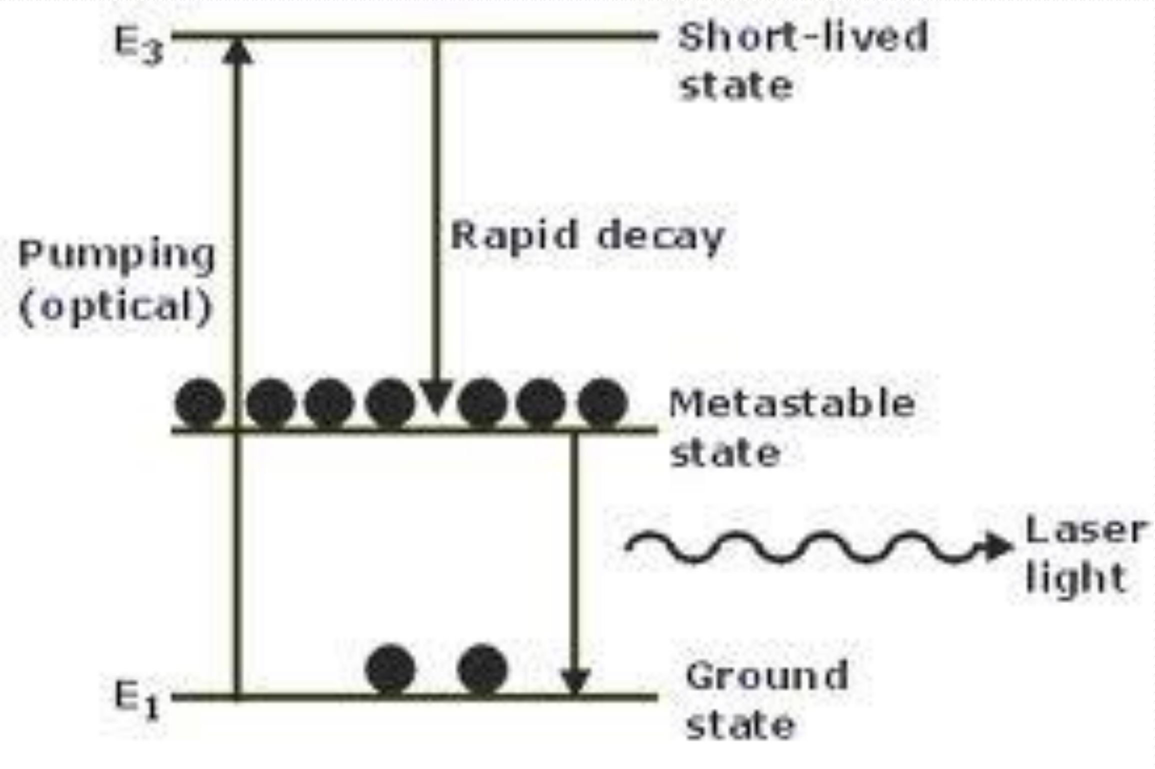
$$E_1 < E_2 < E_3$$

Hence,

$$N_1 > N_2 > N_3$$



Meta-stable State



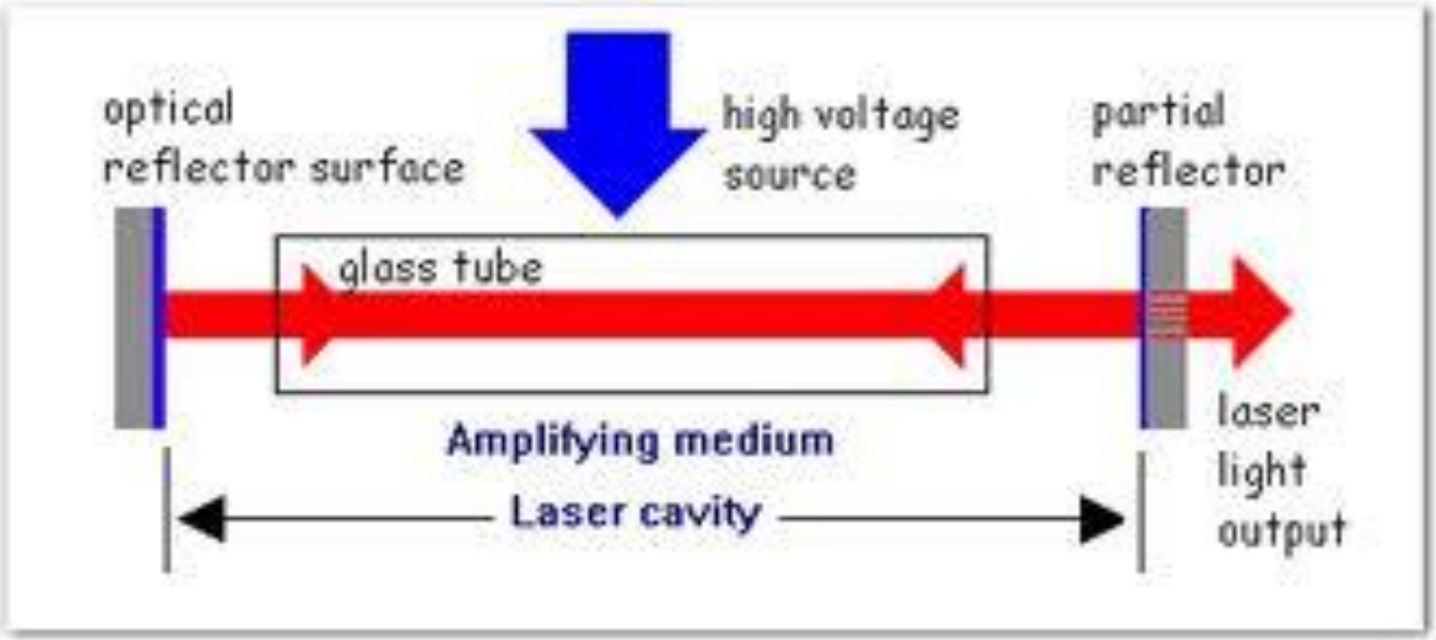
The energy levels, which has the spontaneous lifetime of the order of microseconds to a few milliseconds are called METASTABLE levels. The probability of transitions involving metastable levels is relatively low. If an atom is excited into a metastable state it can stay there long enough for a photon of the correct frequency to arrive.

Laser Pumping

1. Optical Pumping (Ruby Laser)
2. Electric Discharge (He-Ne Laser)
3. Inelastic-atom-atom-collision (He-Ne Laser)
4. Direct Conversion (Semiconductor Laser)
5. Chemical reactions (CO_2 Laser)

Main components of Laser

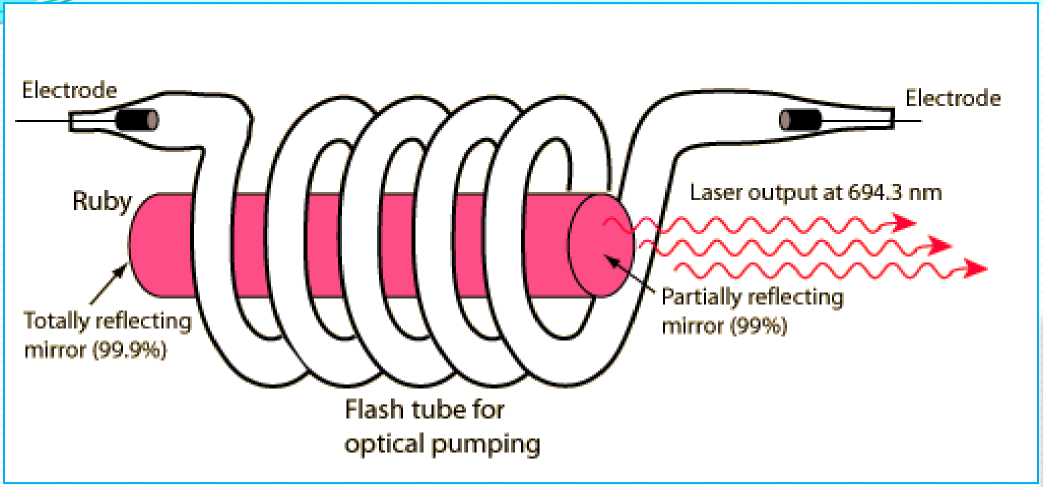
1. Energy source to raise atoms in excited state
2. Active medium: materials (solid, liquid or gas) whose atoms go into excited state.
3. Optical resonator or Laser cavity: See the next slides

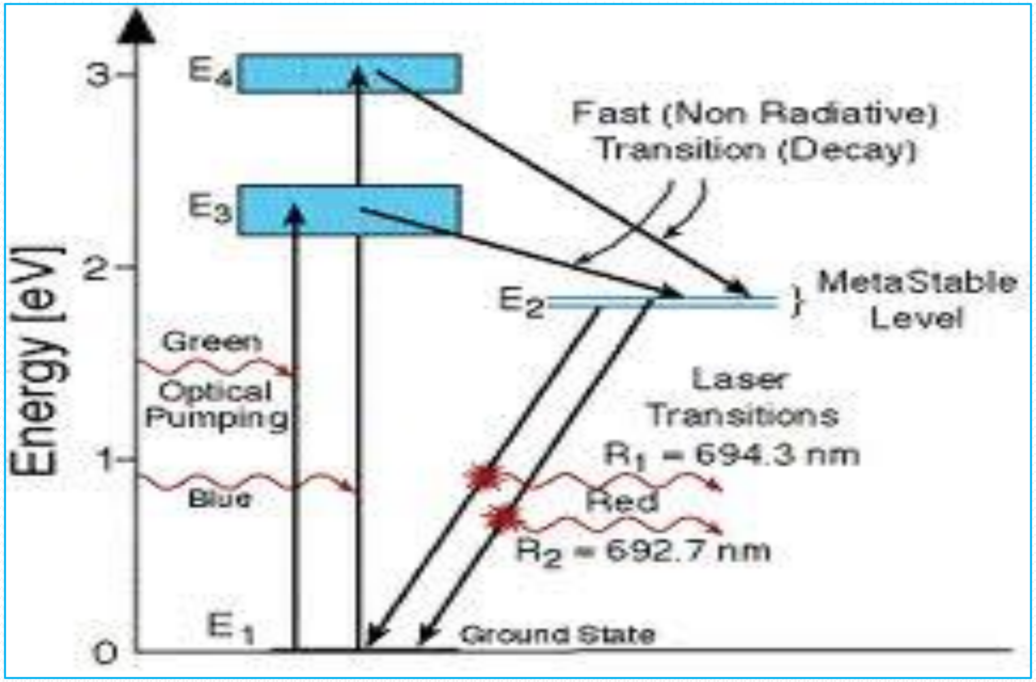


Laser Cavity

1. It is made-up of two mirrors that forms a standing wave cavity resonator.
2. It surrounds the gain medium and provide feedback.
3. It types are distinguished by the focal lengths of the two mirrors and the distance between them.
4. It sets minimum beam waist or having no focal point inside the cavity.

Ruby Laser





1. It is 3 level pulsed laser system.

2. Working substance : Ruby crystal (Al_2O_3) with Cr+++ ions doping (0.3-0.5%). Size (l=10cm, r=0.8cm). N_2 gas is used as coolant.

3. Output: 692.7 nm and **694.3 nm.**

He-Ne Laser

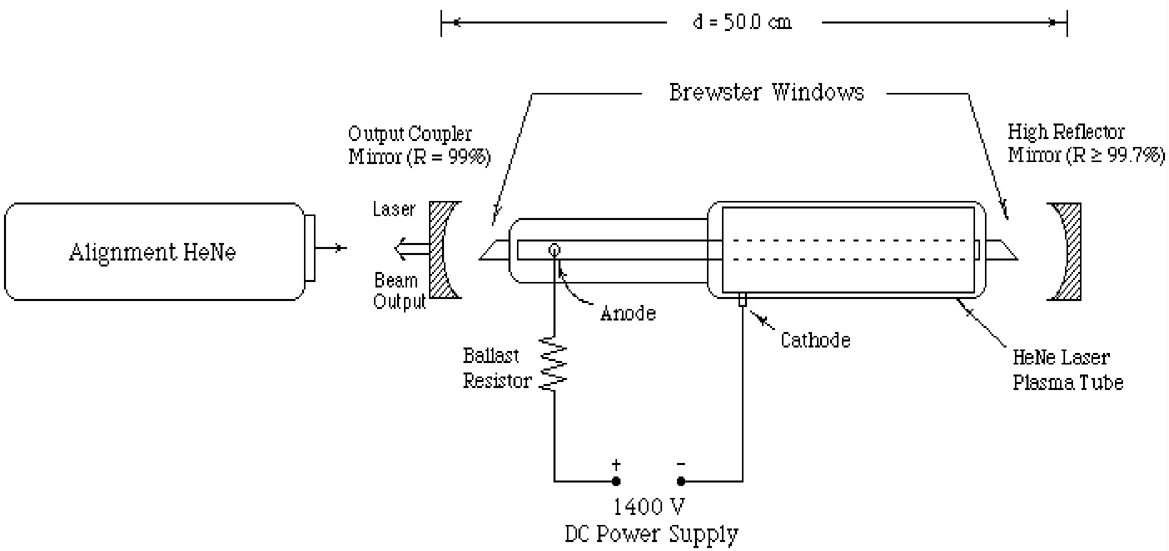
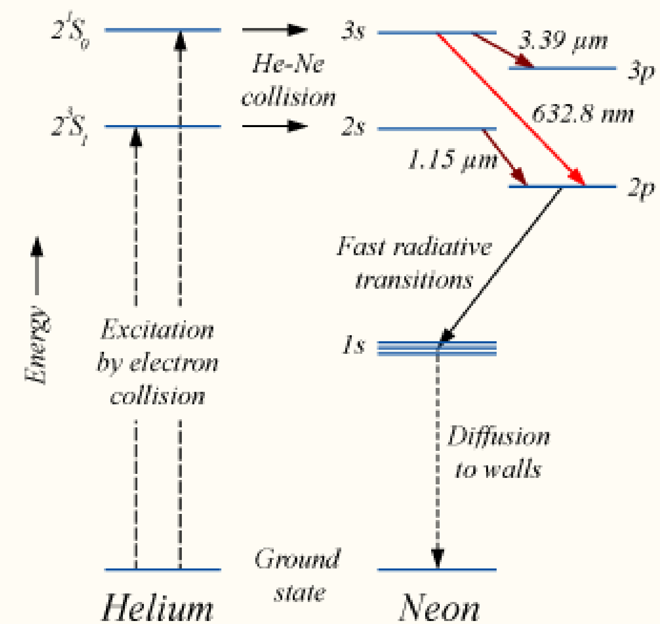


FIG. 2. Diagram of optical and electrical components used in the HeNe laser experiment



- He-Ne laser gives continues laser beam
- Its four stage laser (1 He, 3 Ne).
- For population inversion radio frequency EM field is used.
- Working substance: Mixture of He-Ne (7:1) at 1 mm of Hg.
- Resonant cavity: a quartz tube (l= 0.5m , r= 5mm)
- Two windows cemented at Brewster's.
- Right mirror is fully and left is partially reflective.
- He-Ne lasers operates:

  Red: 632.8 nm, Near infra-red 1150.0 nm and infrared at 3390.0 nm