Unit-II
Lasers and Applications

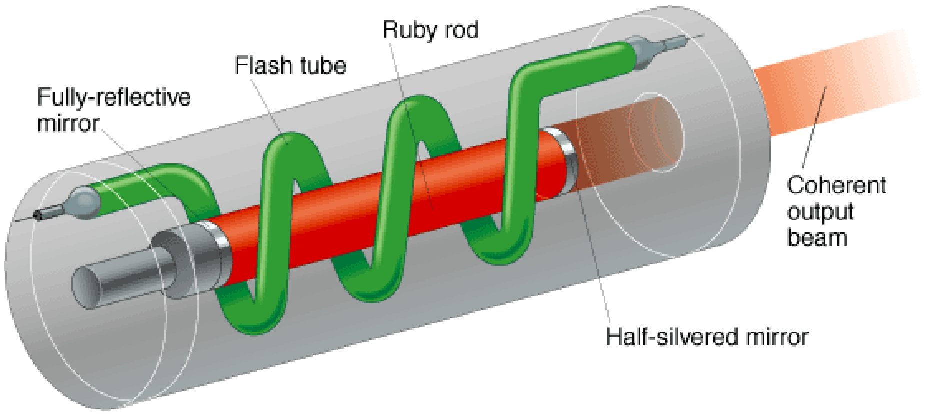
- Introduction
- Fundamentals of laser- energy levels in atoms
- Radiation matter interaction,
- Absorption of light,
- Spontaneous emission
- Stimulated emission
- Metastable state
- Population inversion
- Resonant cavity

Introduction

The term "LASER" is an acronym for: Light Amplification by Stimulated Emission of Radiation.

In 1951, Townes named the device a MASER, for “microwave amplification by the stimulated emission of radiation. (Charles H. Townes, then at Columbia University in New York City)

Theodore Maiman made the first laser operate on **16 May 1960** at the Hughes Research Laboratory in California.



Ruby Laser

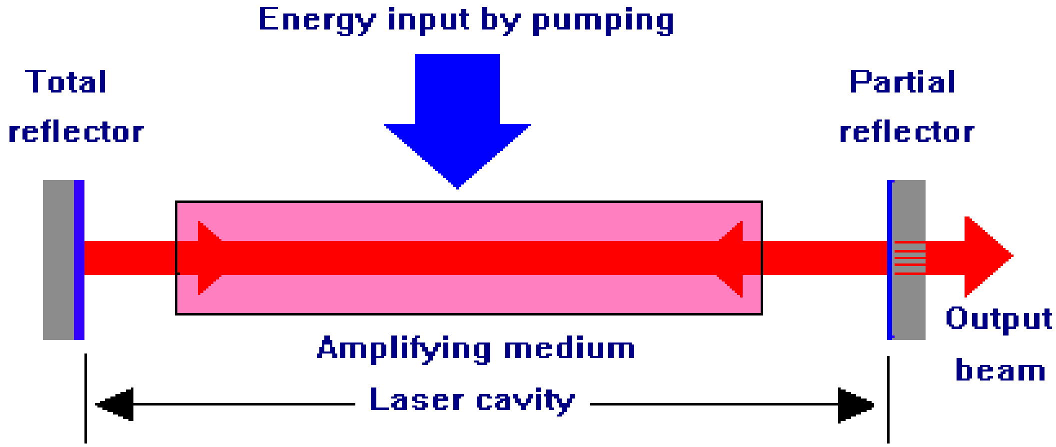
All lasers have three main part:

Gain medium – gas, solid state, liquid – what provides the lasing transition

Pump – source of energy to create population inversion – usually another light source e.g. flashlamp or another laser, can be electrical discharge or current.

Resonant Cavity – need to recirculate photons to stimulate emission on lasing transition often mirrors around gain medium, can be medium itself.

It is also called as optical cavity, it is made of two mirrors, one if 100% polished (fully silvered) and one is 95% polished (partially silvered).



Main components of a lasers

Fundamentals of Laser- Energy Levels in Atoms and Radiation Matter Interactions

The atoms of the gain medium can be excited by supplying energy with an amount equal to the difference of its two energy levels. The gain medium can be liquid, gases, solids.

Examples: Liquid laser: sodium fluorescein, rhodamine B and rhodamine 6G

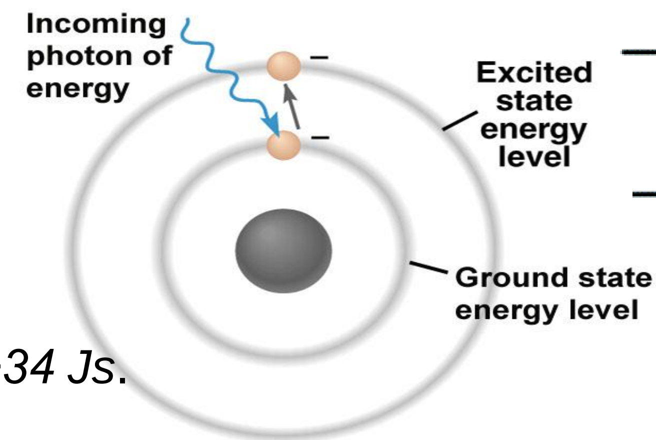
Gas Laser: He-Ne laser, CO_2 laser, Argon laser

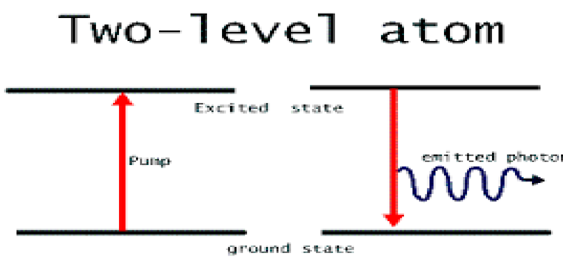
Solid Lasers: Ruby laser, Nd-YAG laser

Photon: Photon is an elementary particle and is a minute energy packet of electromagnetic radiation.

Each photon has momentum p (= h ν/c), energy, E (=hν) and speed c, the speed of light.

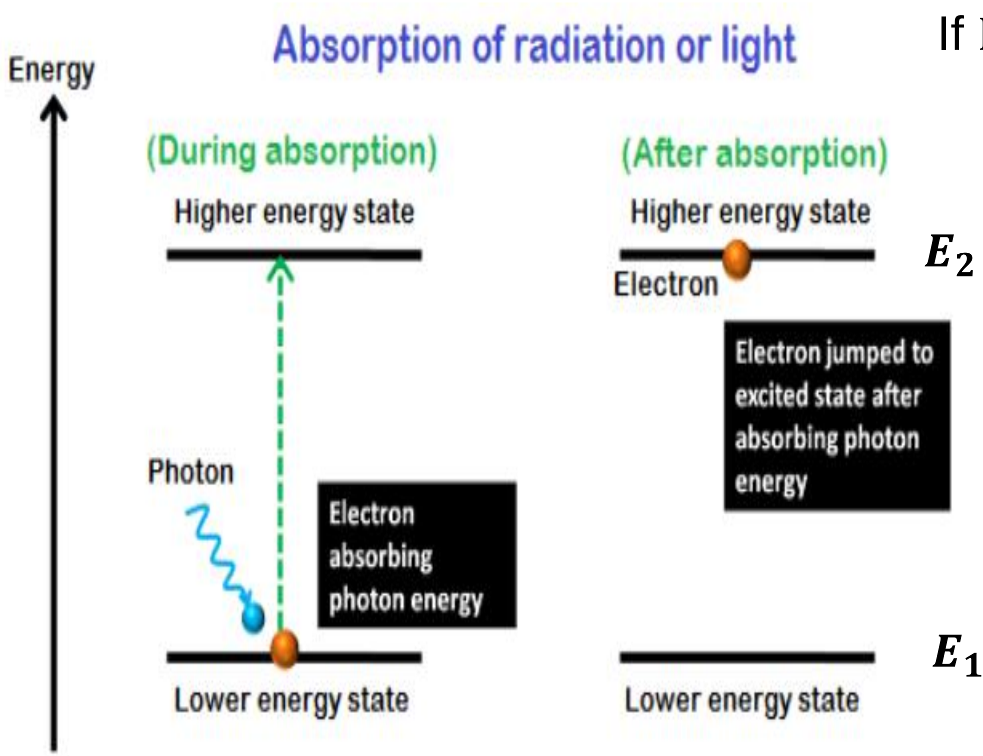
ν=frequency of photon
h=Plank's Constant=*6.626×10−34 Js*.





Absorption of Radiation

Absorption of radiation is the process by which electrons in the ground state absorbs energy from photons to jump into the higher energy level.



If E_1, E_2 energies of level 1 and 2 resp.

$$E_1 + h\nu = E_2$$

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

The probability of occurrence (P_{12}) from 1 to 2 level is proportional to energy density of radiation u(ν)

$$P_{12} \propto u(\nu)$$

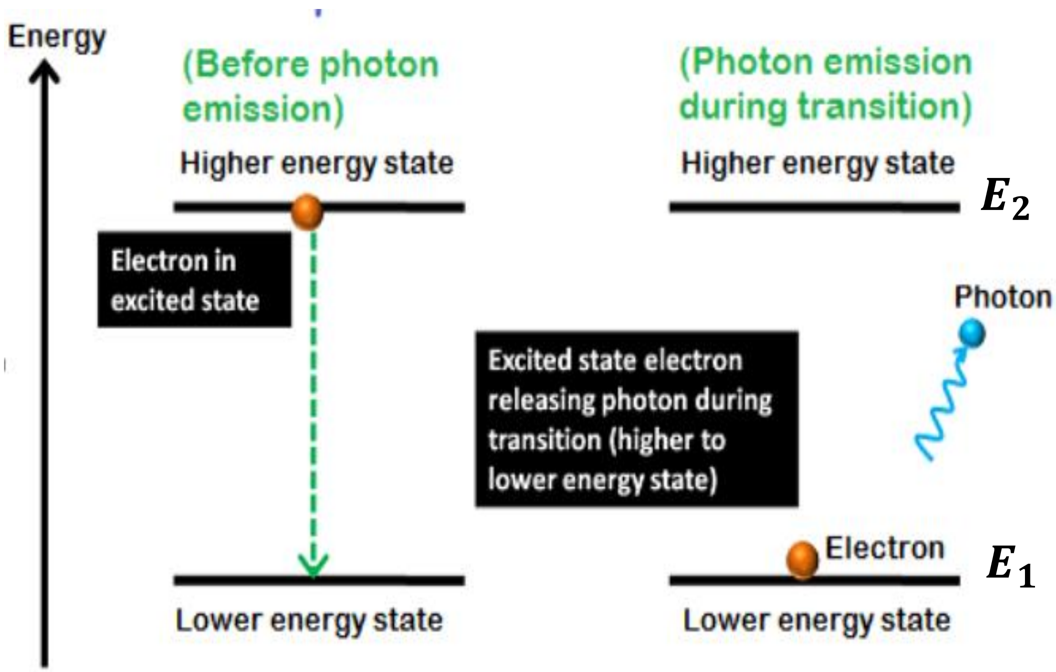
$$P_{12} = B_{12} u(\nu)$$

B_{12} =called as Einstein Coefficient of absorption of radiation

Spontaneous Emission.

Electrons in the excited state return to the ground state by emitting photons.

The electrons in the excited state can stay only for a short period **10^{-8} second**. The time up to which an excited electron can stay at higher energy state (E_2) is known as the **lifetime of excited electrons**.



This is a natural process and e atom can come to lower state by emitting energy $h\nu$

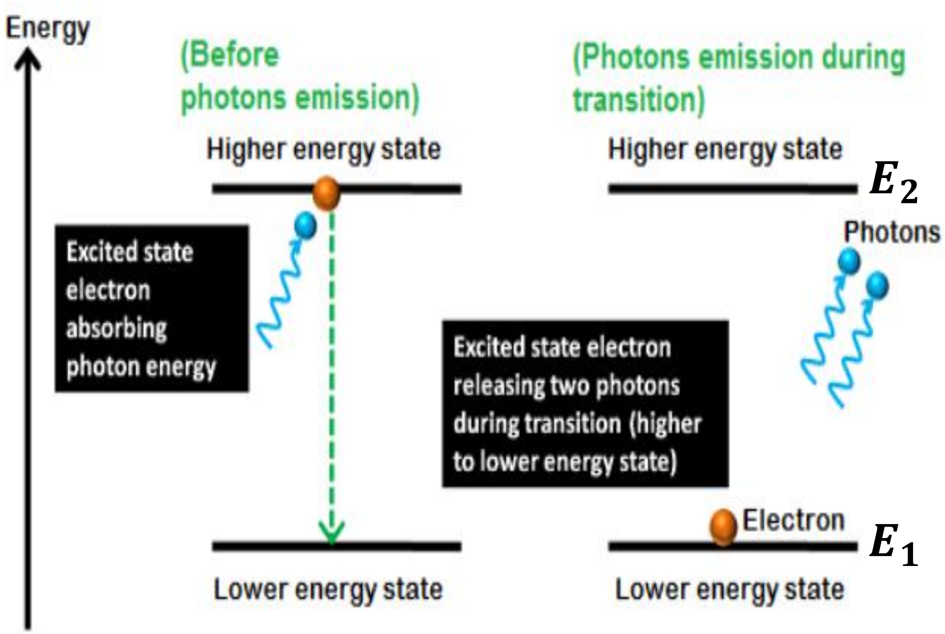
The probability of occurrence (P'_{21}) from 2 to 1 is independent of energy density of radiation u(ν)

$$P'_{21}=A_{21}$$

A_{21}=Einstein's coefficient of spontaneous emission

Stimulated Emission

Is the process by which an incoming photon of a specific frequency can interact with an excited atomic electron causing it to drop to a lower energy level. In stimulated emission, two photons are emitted (**one additional photon is emitted**), one is due to the incident photon and another one is due to the energy release of excited electron.



$$E_2 - E_1 = \Delta E = hv$$

The probability of occurrence (P''_{21}) from 2 to 1 is proportional to energy density of radiation u(v)

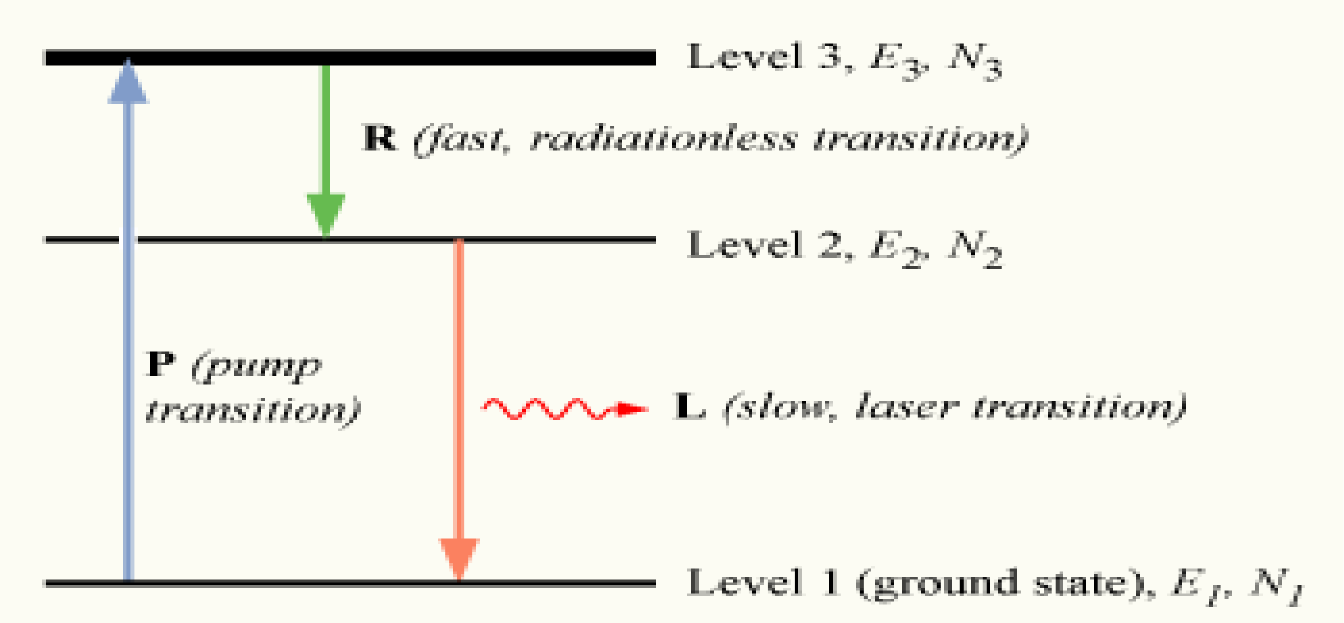
$$P''_{21} \propto u(v)$$

$$P''_{21} = B_{21} u(v)$$

$B_{21} = Eintsein's\ Coeffient\ of\ stimulated\ emission$

Metastable State

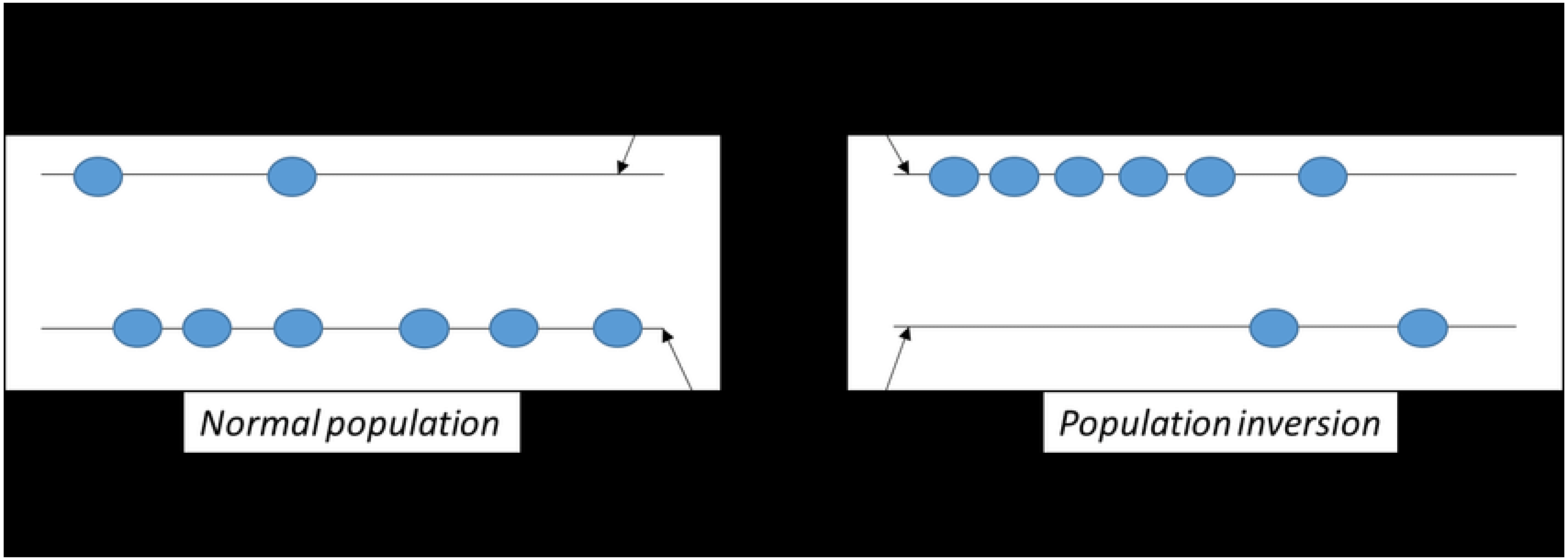
Metastable state is an excited state of an atom or other system with a longer lifetime (10^{-6} to 10^{-3}secs) than the other excited states. However, it has a shorter lifetime than the stable ground state. A large number of excited atoms are accumulated in the metastable state.



Population Inversion

The population of metastable state can exceed the population at a lower level thereby establishing **population inversion** in a lasing medium. These can be created by adding dopant to the medium.

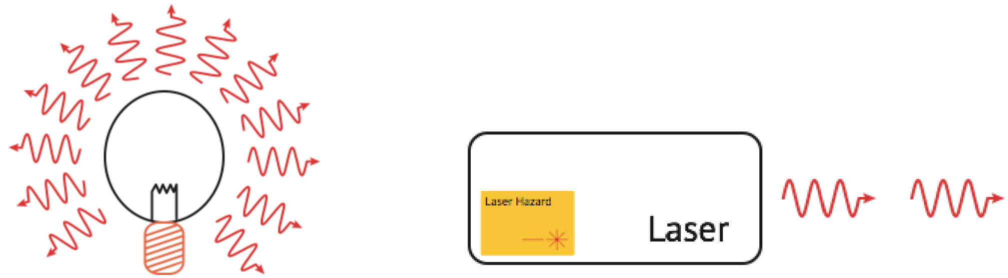
Population inversion could not be created without a metastable state.



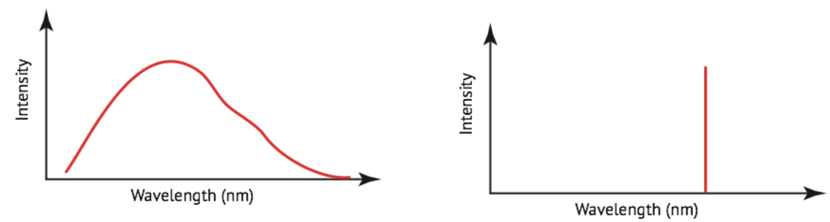
Characteristics of Lasers

- Laser light has three unique characteristics, that make it different than "ordinary" light. It is:
  - Monochromatic
  - Directional
  - Coherent
- Monochromatic means that it consists of one single color or wavelength. Even through some lasers can generate more than one wavelength, the light is extremely pure and consists of a very narrow spectral range.
- Directional means that the beam is well collimated (very parallel) and travels over long distances with very little spread.
- Coherent means that all the individual waves of light are moving precisely together through time and space, i.e. they are in phase.

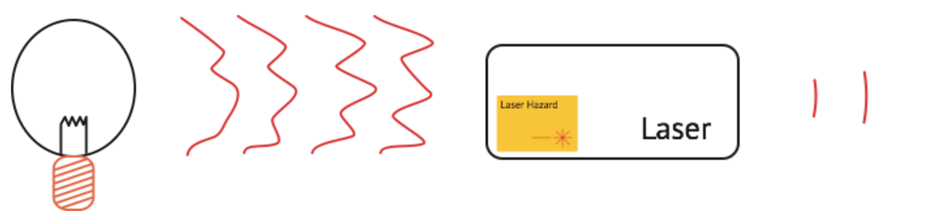
- They produce a directional beam.



- They have a narrow spectrum (or bandwidth).



- They are coherent.



Note that when we are saying single colour and highly direction that is in comparison with the conventional light sources. But, diffraction of light after some kilometers is possible and laser light has also have some bandwidth.

Thank you….