

Basics Of Lasers:



Definition:

“LASER” is an acronym that stands for **L**ight
Amplification by the **S**timulated **E**mission of
Radiation.

Laser is an instrument that generates a beam of light of a **single wavelength** or color that is both highly **collimated** and **coherent**.

Difference between LED and Laser

	LED	Laser
Principle	Spontaneous Emission (Random) Photon Emission	Stimulated Emission
Coherence	Incoherent	Coherent
Spectral Width/LineWidth	50nm	Less than 5nm
Directionality	Not directional	Highly directional
Output Power	Low	High

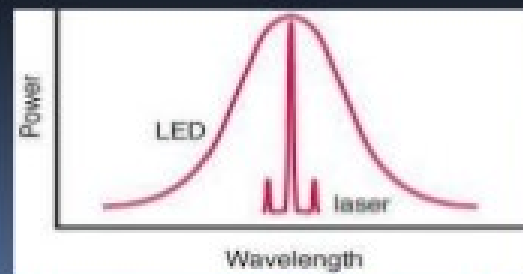


Fig 2: Wavelength of LED and Laser

>>LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

>>The most important optical device to be developed in the past 50 years.

>>Invented in 1958 by Charles Townes and Arthur Schawlow of Bell Laboratories

>>Was based on Einstein's idea of the "particle-wave duality" of light.

There are several important conditions that our laser must satisfy.

- ❑ First of all, the light that it produces must be coherent. That is to say, it must emit photons that are in-phase with one another.
- ❑ Secondly, it should emit monochromatic light, i.e. photons of the same frequency (or wavelength).
- ❑ Thirdly, it would be desirable if our laser's output were collimated, producing a sharply defined "pencil-like" beam of light (this is not crucial, but clearly a desirable condition).
- ❑ Lastly, it would also be desirable for our laser to be efficient, i.e. the higher the ratio of output energy - to - input energy, the better.

Principle of lasers

The principle of a laser is based on three separate features:

- a) stimulated emission within an amplifying medium,
- b) population inversion
- c) an optical resonator.

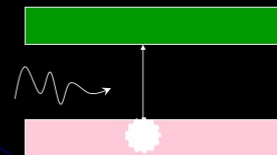
Einstein's quantum theory of radiation

According to Einstein, the interaction of radiation with matter could be explained in terms of three basic processes:

- absorption
- spontaneous emission
- stimulated emission.

- An incoming photon excites the atomic system from a lower energy state into a higher energy state. This is called **absorption** or sometimes **stimulated absorption**.
- It is called stimulated absorption because of the fact that the atoms absorb the incident energy at certain frequencies only.

• **Absorption**



- Consider an atom (or molecule) of the material is existed initially in an excited state E_2 . Since $E_2 > E_1$, the atom will tend to spontaneously decay to the ground state E_1 , releasing a photon of energy $h\nu = E_2 - E_1$ in a random direction. This process is called “spontaneous emission”

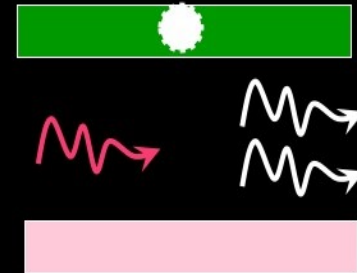
Spontaneous emission



stimulated emission

- When an incident photon of energy $h\nu = E_2 - E_1$ passes by an atom in an excited state E_2 , it stimulates the atom to drop or decay to the lower state E_1 . In this process, the atom releases a photon of the same energy, direction & phase as that of the photon passing by.
- The net effect is two identical photons ($2h\nu$) 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

Stimulated emission



Population Inversion and Laser Operation

- If the higher energy state has a greater population than the lower energy state, then the light in the system undergoes a net increase in intensity.

$N_2 > N_1$ Population Inversion

- Can be created by introducing a so called metastable centre where electrons can pile up to achieve a situation where more N_2 than N_1

Einstein's coefficient and Einstein's relation

Let N_1 & N_2 be the no. of atoms in the ground state and excited state and $\rho(r)$ is the energy density per unit volume

Then the ratio of absorption per unit volume = $B_{12} \cdot \rho(r) \cdot N_1$

Ratio of spontaneous emission per unit volume = $A_{21} \cdot N_2$

Ratio of stimulated emission per unit volume = $B_{21} \cdot \rho(r) \cdot N_2$

Where B_{12} , B_{21} and A_{21} are Einstein's coefficient under thermal equilibrium, the rate of absorption = rate of emission

$$B_{12}.N_1.\rho(r) = A_{21}.N_2 + B_{21}.\rho(r).N_2$$

$$\rho(r)[B_{12}.N_1 - B_{21}.N_2] = A_{21}.N_2$$

$$\rho(r) = \frac{A_{21}.N_2}{B_{12}.N_1 - B_{21}.N_2}$$

$$\rho(r) = \frac{\frac{A_{21}}{B_{21}}}{\frac{B_{12}}{B_{21}} \frac{N_1}{N_2}} - 1$$

$$N_1 = N_0. e^{\frac{-E_1}{KT}} \quad N_2 = N_0. e^{\frac{-E_2}{KT}}$$

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

$$\rho(r) = \frac{A_{21}}{B_{21}} \left[\frac{1}{\frac{B_{12}}{B_{21}} [e^{\frac{(E_1 - E_2)}{KT}}] - 1} \right]$$

Plank's radiation formula yields energy density of radiation

$$u(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{\left(e^{\frac{h\nu}{kT}} - 1\right)}$$

Relation Between Einstein Coefficients A and B

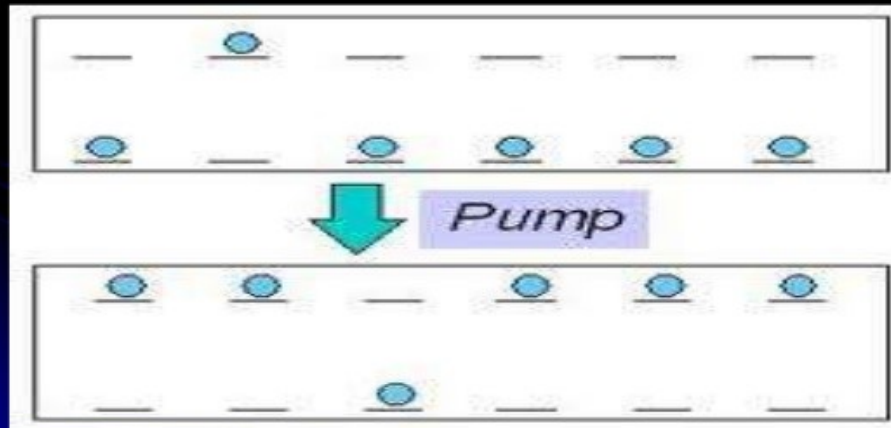
$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$



$$\frac{B_{21}}{A_{21}} = \left(\frac{c^3}{8\pi h}\right) \frac{1}{\nu^3}$$

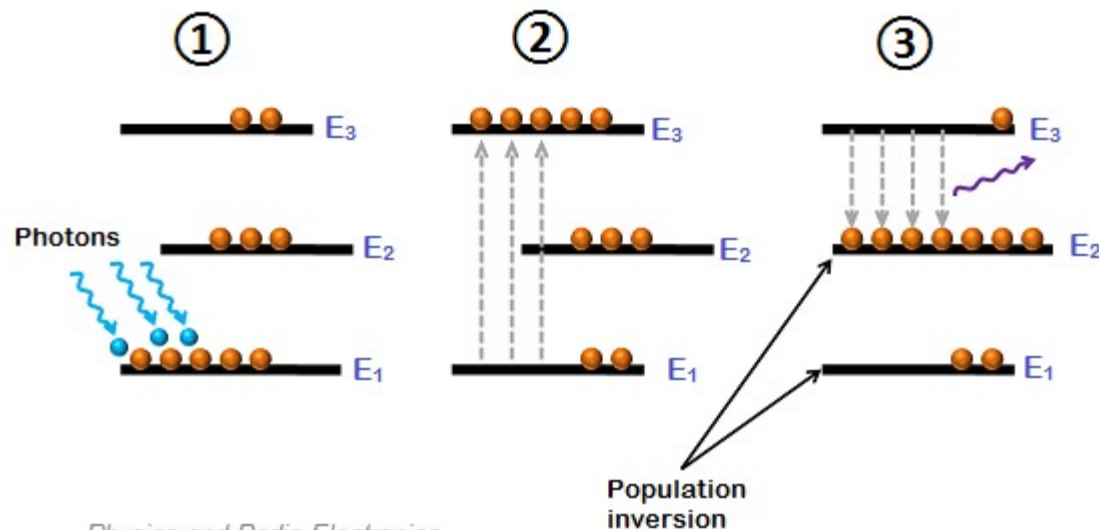
That is B_{21}/A_{21} is inversely proportional to frequency of the resonant radiation. **Therefore, higher the frequency smaller is the value of B_{21} . That is, it is comparatively difficult to obtain the stimulated emission of higher frequencies.**

- The process of attaining a population inversion is called **pumping**



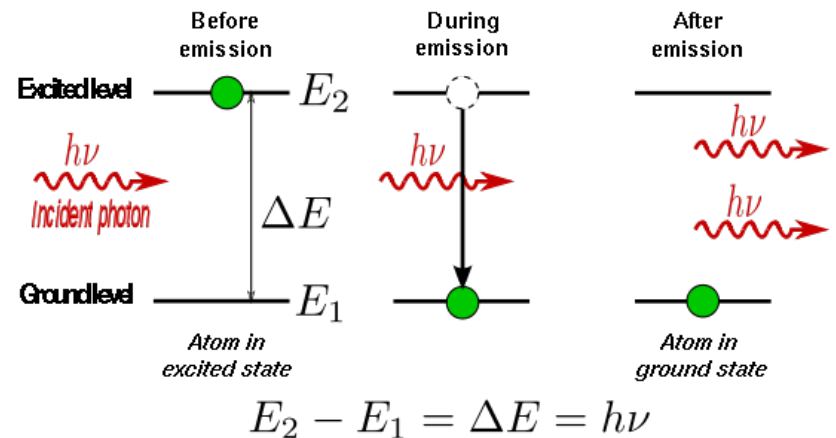
Optical pumping

- To create population inversion, a 3-state system is required.
- The system is pumped with radiation of energy E_{31} then atoms in state 3 relax to state 2 non radiatively.
- The electrons from E_2 will now jump to E_1 to give out radiation.



Why not Two level laser systems is possible?

- ✓ Achieving population inversion in a two-level atom is not very practical. Such a task would require a very strong pumping transition that would send any decaying atom back into its excited state.
- ✓ This would be similar to reversing the flow of water in a water fall. It can be done, but is very energy costly and inefficient.
- ✓ In a sense, the pumping transition would have to work against the lasing transition.
- ✓ That is to say, once the population inversion is achieved the laser would lase. But immediately it would end up with more atoms in the lower level. Such two-level lasers involve a more complicated process.



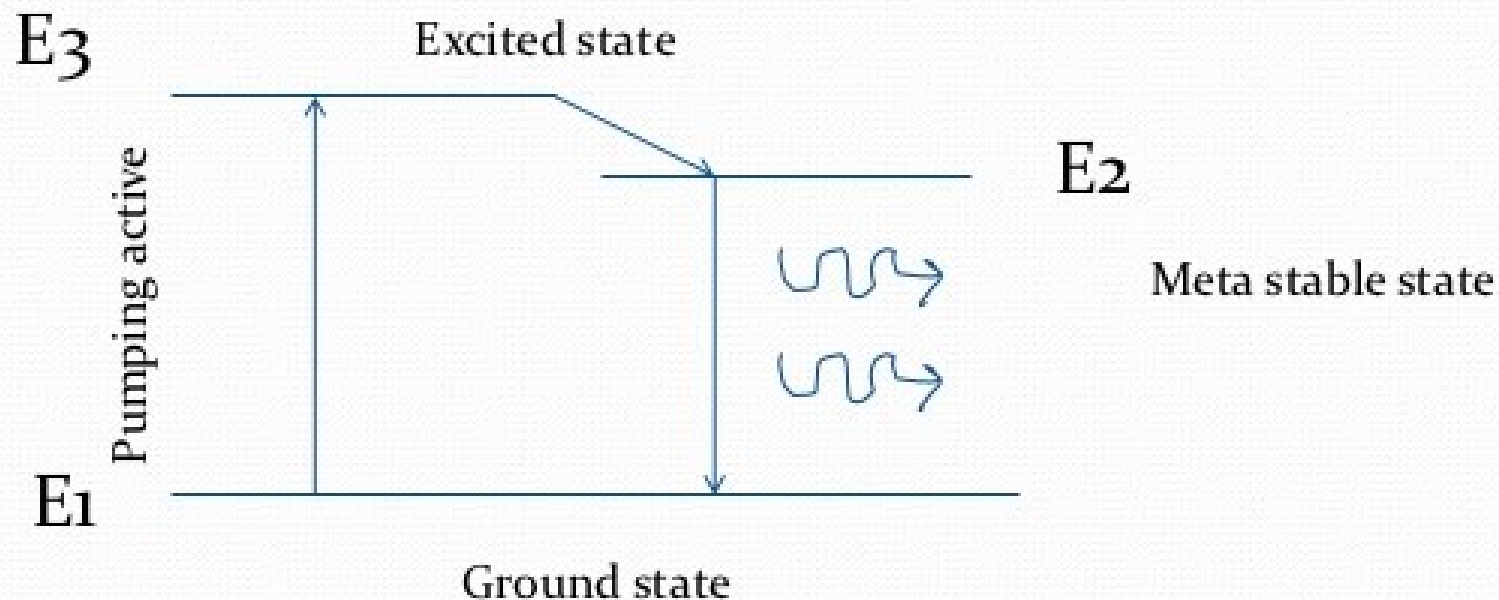
Three level and four level laser

The simplest kind is three level laser which uses an assembly of atom or molecules that have three energy states E_1, E_2, E_3 .

Where, $E_1 \rightarrow$ ground state

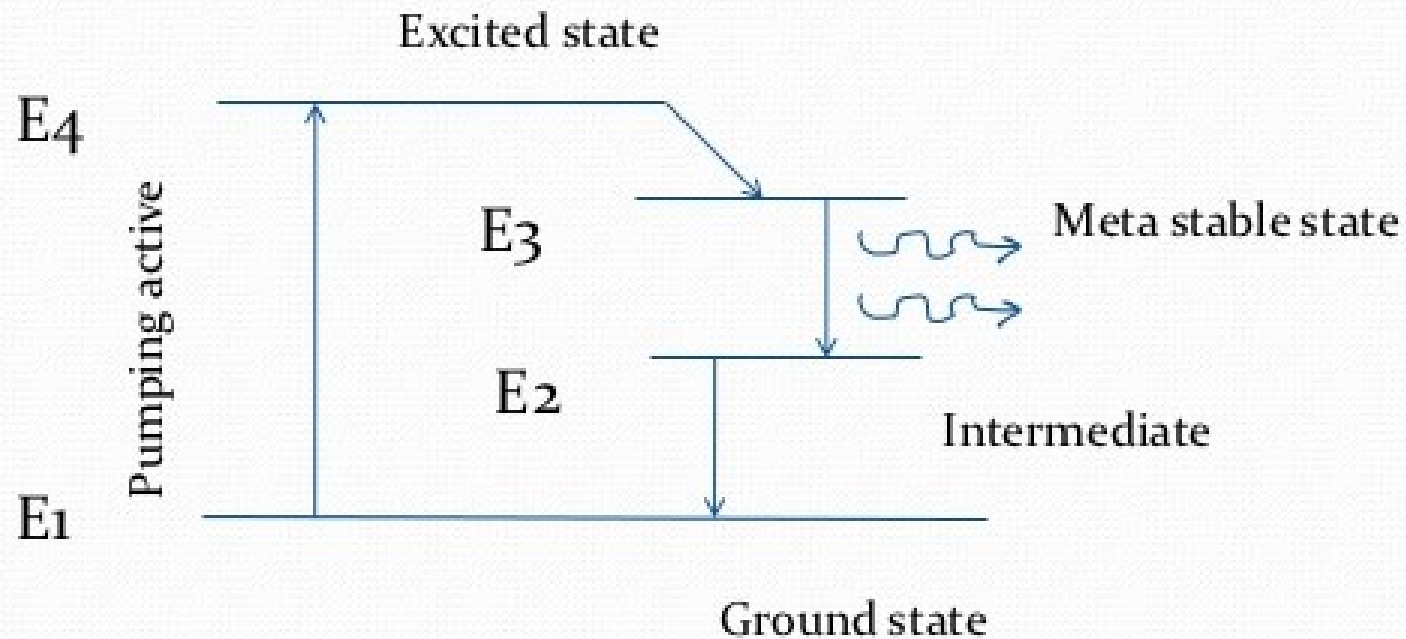
$E_2 \rightarrow$ meta stable state

$E_3 \rightarrow$ higher excited state



Four level laser

$E_1 \rightarrow$ ground state, $E_2 \rightarrow$ intermediate, $E_3 \rightarrow$ metastable, $E_4 \rightarrow$ excited state



Four level laser system Vs Three level laser systems

- ❖ One of the advantage of four level atomic system on three level is that in four level there occurs more transition as compared to three level and hence probability of transition is large in four level atomic system and hence analyzing four level or higher level atomic system gives more advancement to technology and gives new ideas and high approach to certain problems.
- ❖ Moreover four level or higher level atomic system is more complex to analyze.
- ❖ Also **four level atomic system** is more suitable for laser action than three level because in four level atomic system population inversion can be easily achieved because the transition from metastable state is not directly to ground state as in three level.

It consists of three basic parts:-

- **An active medium** with a suitable set of energy levels to support laser action.
- **A source of pumping energy** in order to establish a population inversion.
- **An optical cavity** or resonator to introduce optical feedback and so maintain the gain of the system overcoming all losses.

Active laser medium or gain medium:

- Laser medium is the heart of the laser system and is responsible for producing gain and subsequent generation of laser. It can be a crystal, solid, liquid, semiconductor or gas medium and can be pumped to a higher energy state.
- it must have a metastable state to support stimulated emission

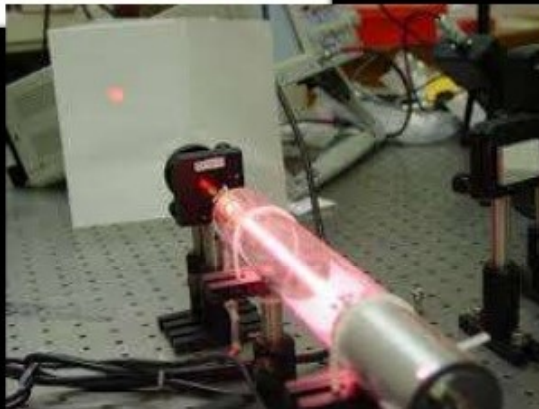
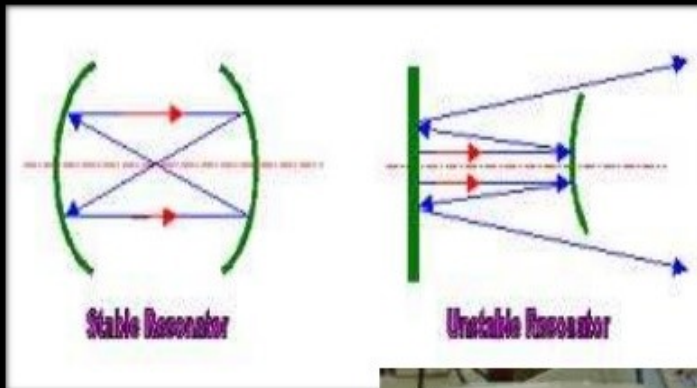
Excitation or pumping mechanism:

- >> There are various types of excitation or pumping mechanisms available, the most commonly used ones are optical, electrical, thermal or chemical techniques, which depends on the type of the laser gain medium employed.
- >> eg: Solid state lasers usually employ optical pumping from high energy xenon flash lamps
Gas lasers use an AC or DC electrical discharge through the gas medium

Methods of Achieving Population Inversion

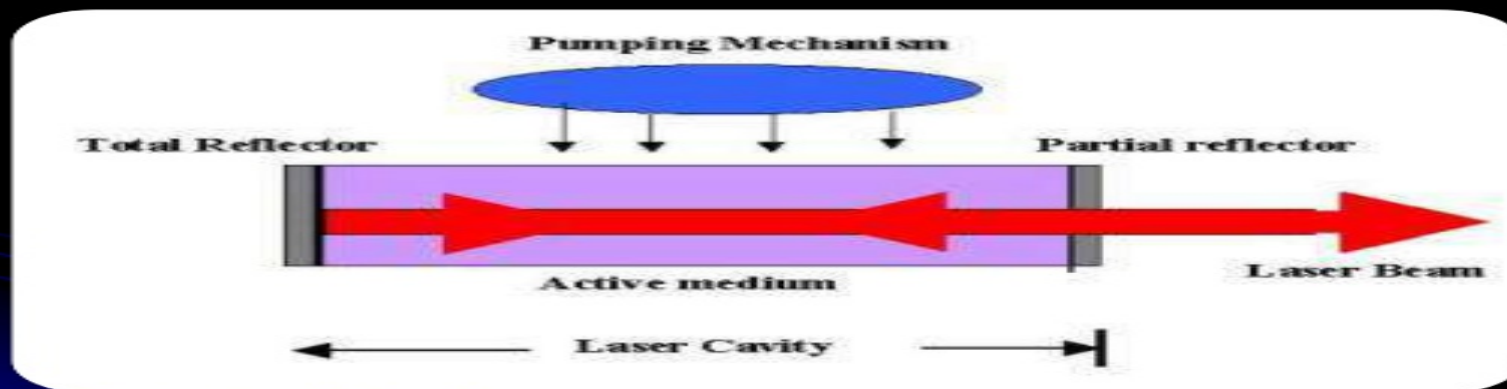
- ☐ **Optical pumping**
- ☐ **Electric discharge or excitation by electrons**
- ☐ **Inelastic atom-atom collisions**
- ☐ **Thermal pumping**
- ☐ **Chemical reactions**

Optical cavity or resonator



- As there are certain losses of the emitted photons within the material itself one has to think about the geometry that can overcome these losses and there is overall gain. This requires an **optical cavity or resonator**.
- A pair of mirrors placed on either side of the active medium .
- One mirror is completely silvered and the other is partially silvered.
- The laser beam comes out through the partially silvered mirror.

Construction & working of laser



A representative laser system is shown in Figure



Different types of lasers

There are basically four types of lasers

- Solid state laser
- Gas laser
- Liquid laser or dye laser
- Semi conductor laser

RUBY LASER

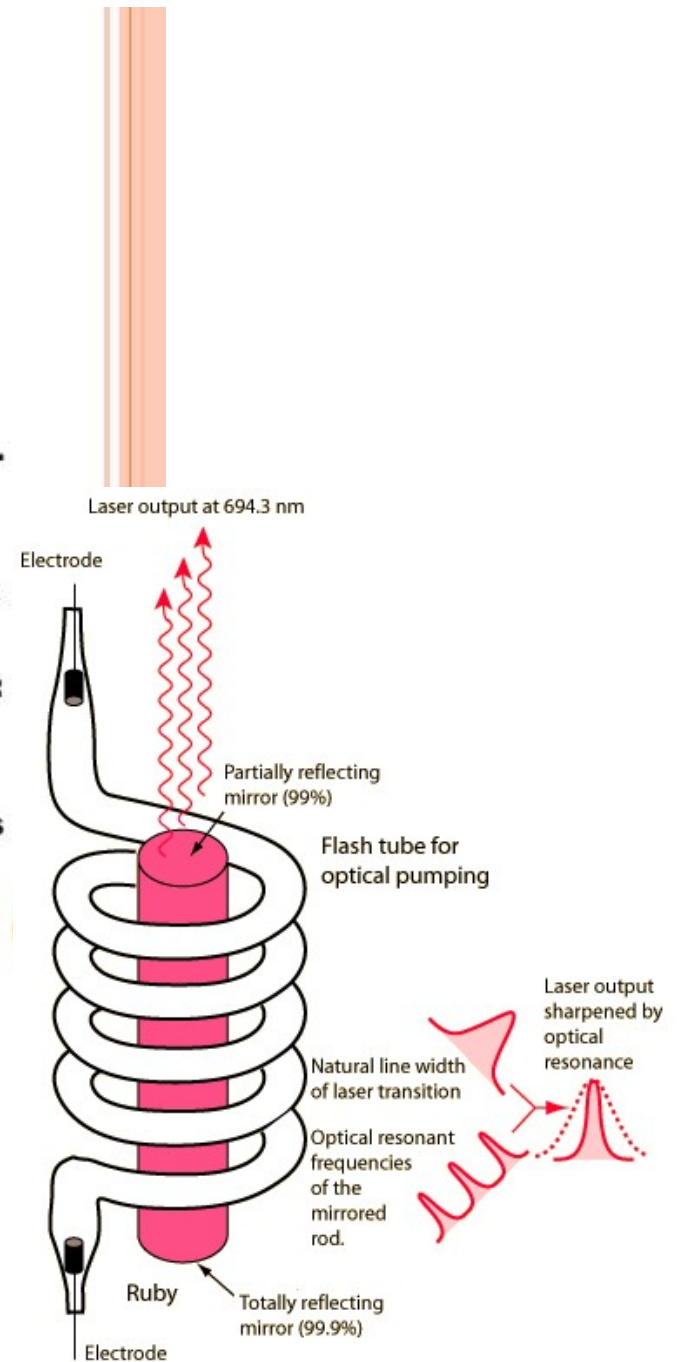


INTRODUCTION

- a. A Ruby laser is a solid-state laser that uses a synthetic ruby crystal as its gain medium.
- b. It was the first type of laser invented and was first operated by Theodore H. “Ted” Maiman at Hughes Research Laboratories on 1950-05-16.
- c. The ruby mineral is a combination of aluminum oxide with a small amount (0.05%) of Chromium which gives its characteristic pink or red color by absorbing green and blue light.
- d. The Ruby laser is a pulsed laser, producing red light at 694.3 nm. After receiving pumping flash tube, the laser light emerges for as long as the excited atoms persist in the ruby rod, which is typically about a millisecond.

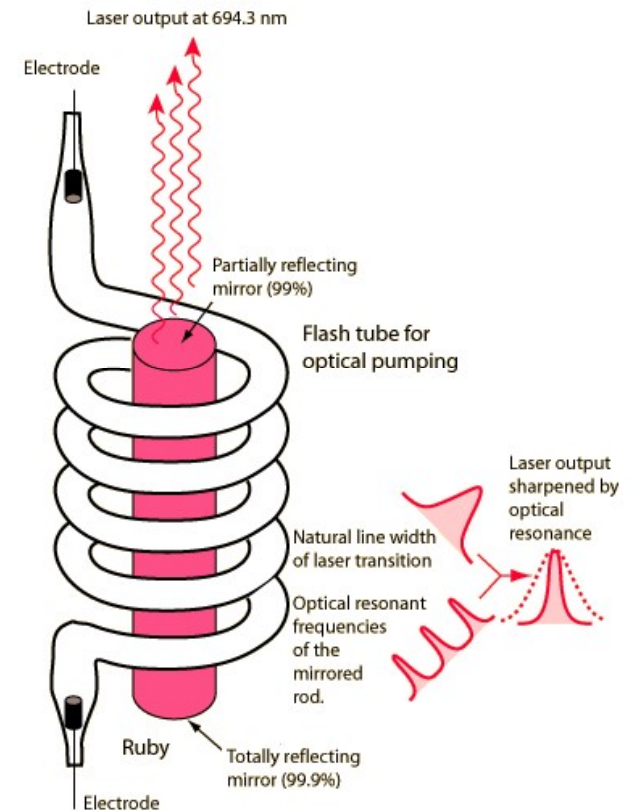
LASER CONSTRUCTION

- The active laser medium (laser gain/amplification medium) is a synthetic ruby rod. Ruby is an aluminum oxide crystal in which some of the aluminum atoms have been replaced with chromium atoms (0.05% by weight). Chromium gives ruby its characteristic red color and is responsible for the lasing behavior of the crystal. Chromium atoms absorb green and blue light and emit or reflect only red light. For a ruby laser, a crystal of ruby is formed into a cylinder.
- The rod's ends had to be polished with great precision, such that the ends of the rod were flat to within a quarter of a wavelength of the output light, and parallel to each other within a few seconds of arc. The finely polished ends of the rod were silvered: one end completely, the other only partially. The rod with its reflective ends then acts as a Fabry-Pérot etalon (or a Gires-Tournois etalon).
- A xenon lamp is rolled over ruby rod and is used for pumping ions to excited state.

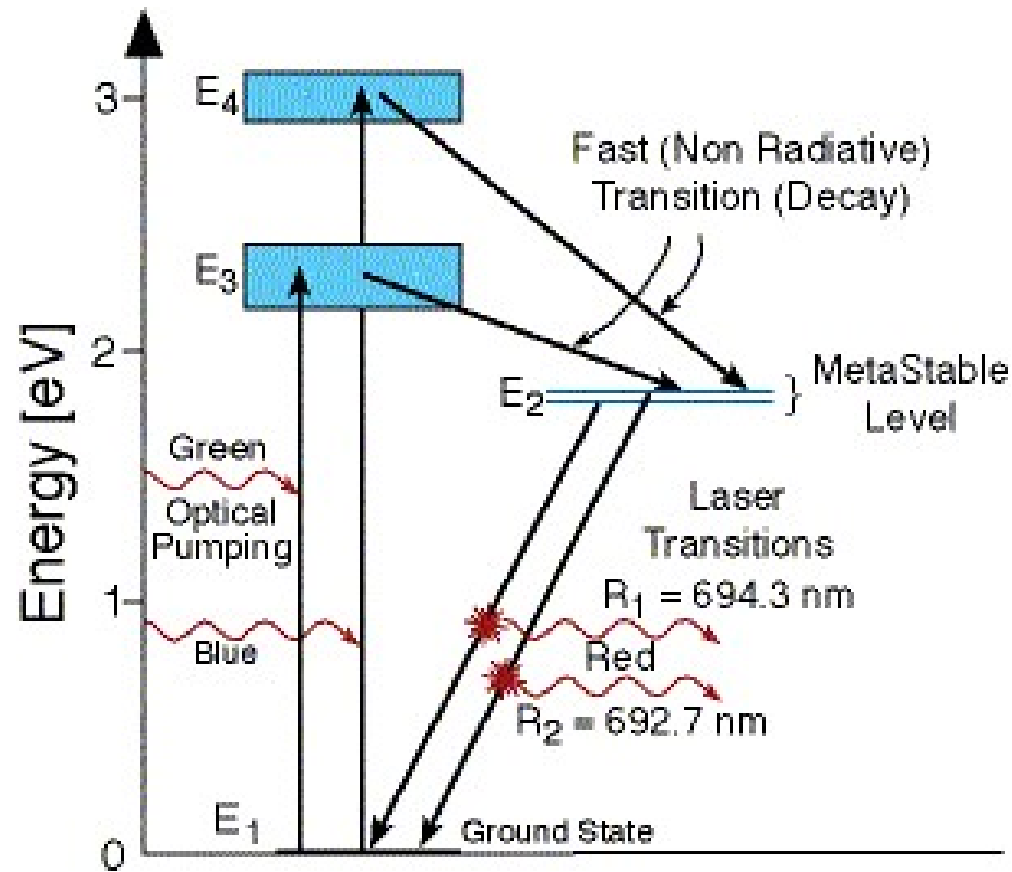


Optical Pumping mechanism in Ruby laser

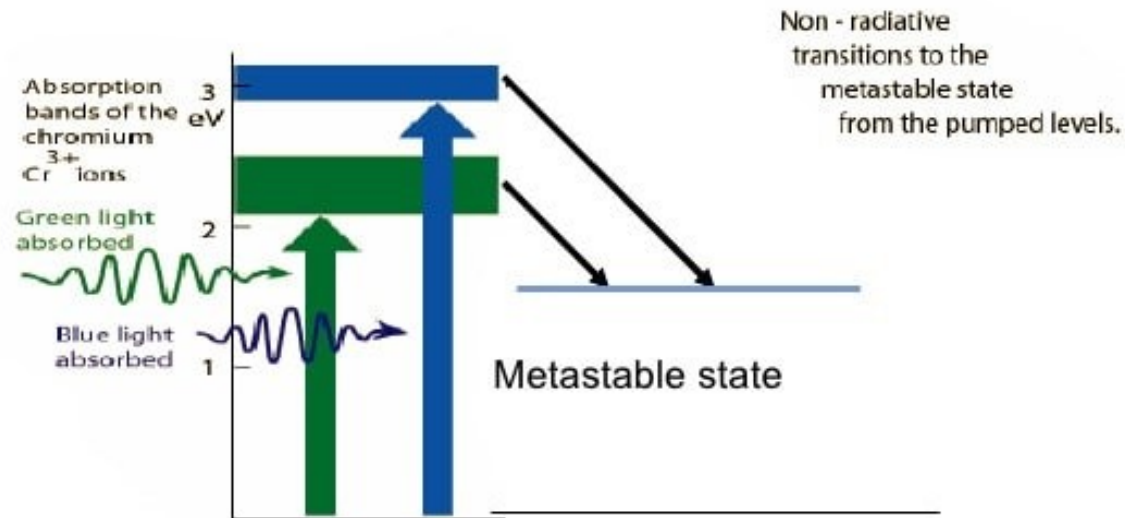
- ❑ Optical pumping is a process in which light is used to raise the atoms from lower energy state to higher energy state to create population inversion.
- ❑ Optical pumping is used in solid lasers: Ruby laser
- ❑ The solid material have very broad absorption band, so sufficient amount of energy is absorbed from the emission band of flash lamp to create population inversion.
- ❑ Xenon flash tubes are used for optical pumping.
Eg: Ruby lase, Nd-YAG lasers.



Energy level diagram

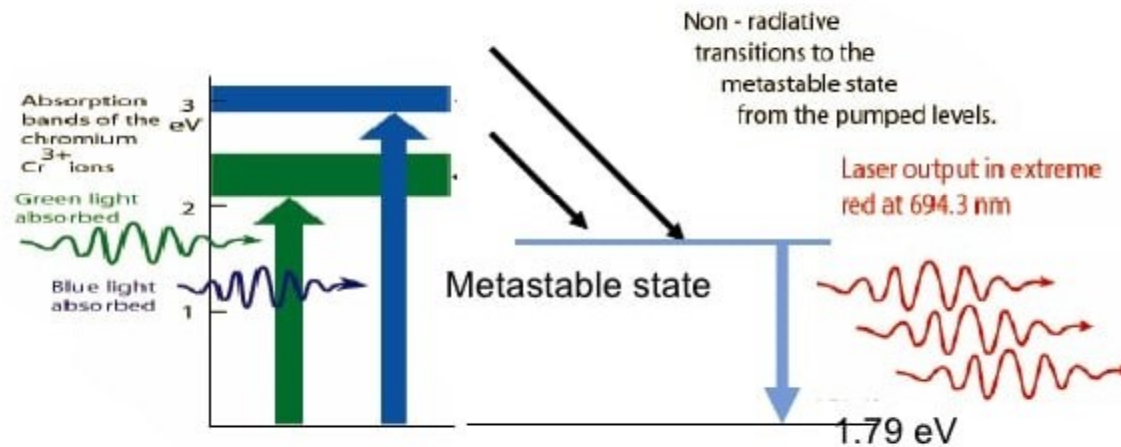


THE IONS AFTER GIVING A PART OF THEIR ENERGY TO CRYSTAL LATTICE DECAY TO E2 STATE UNDERGOING RADIATION LESS TRANSITION.



In metastable state , the concentration of ions increases while that of E1 decreases. Hence, population inversion is achieved.

ION AT E2 LEVEL INITIATES THE STIMULATED EMISSION BY OTHER CR³⁺ IONS IN METASTABLE STATE



APPLICATION

- Ruby lasers have declined in use with the discovery of better lasing media. They are still used in a number of applications where short pulses of red light are required. Holographers around the world produce holographic portraits with ruby lasers, in sizes up to a metre squared.
- Many non-destructive testing labs use ruby lasers to create holograms of large objects such as aircraft tires to look for weaknesses in the lining.
- Ruby lasers were used extensively in tattoo and hair removal



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.
- The efficiency of ruby laser is very low because only green component of the pumping light is used while the rest of components are left unused.
- The laser output is not continuous but occurs in the form of pulses of microseconds duration.
- The defects due to crystalline imperfection are also present in this laser.



He-Ne

- 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.
- The Helium-Neon laser was the first continuous laser.



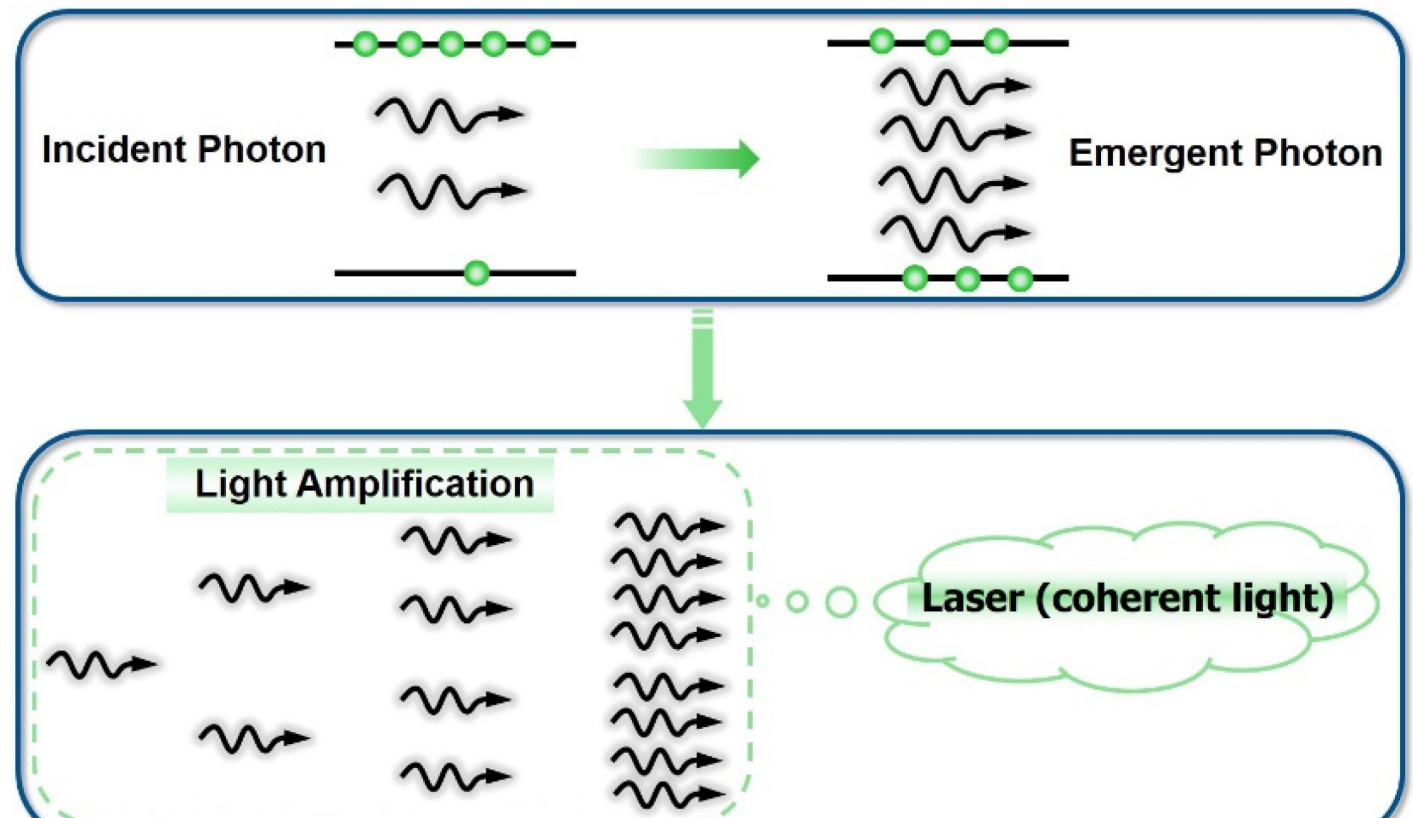
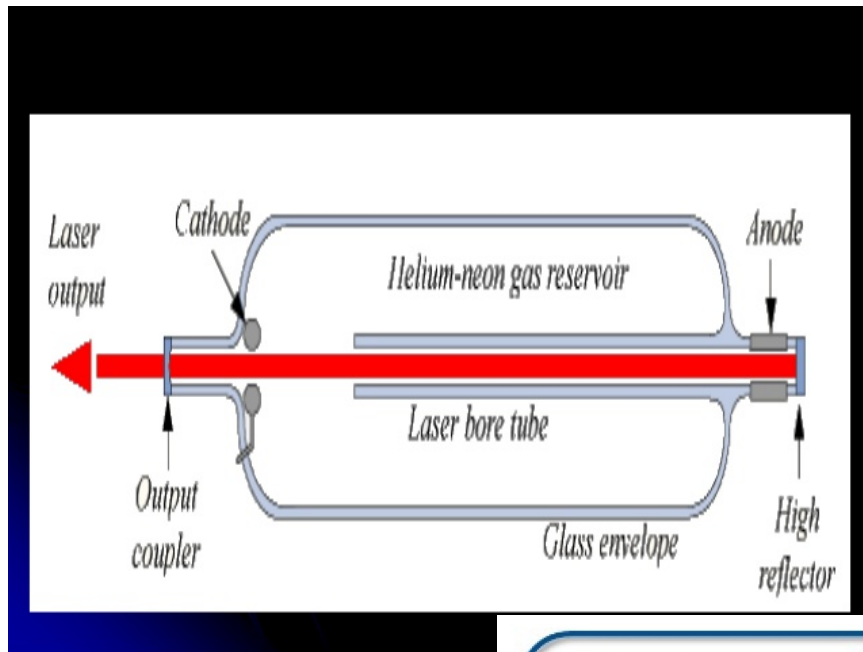
Construction of He-Ne laser

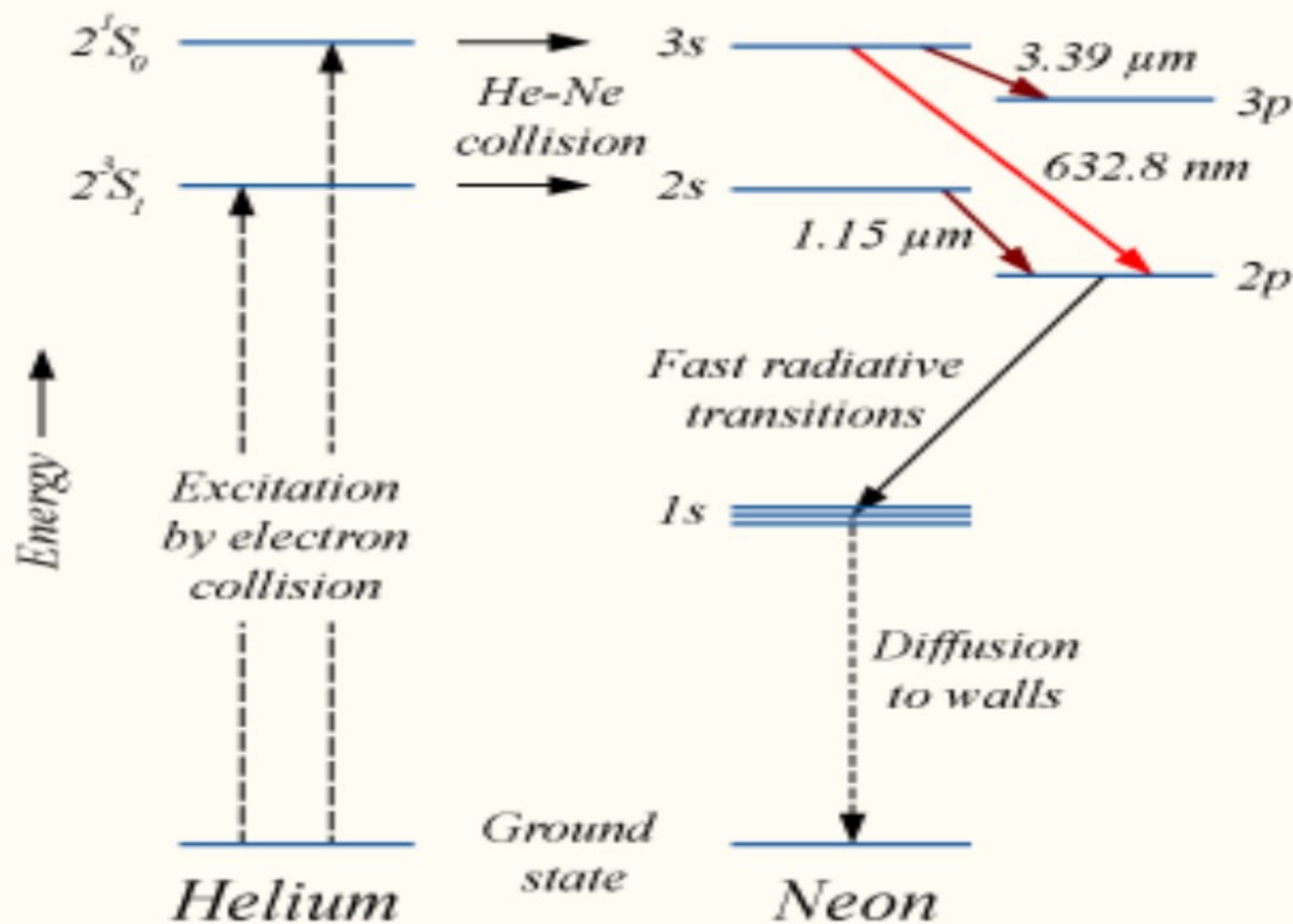
- The setup consists of a discharge tube of length 80 cm and bore diameter of 1.5cm.
- The gain medium of the laser, as suggested by its name, is a mixture of helium and neon gases, in a 5:1 to 20:1 ratio, contained at low pressure (an average 50 Pa per cm of cavity length) in a glass envelope.
- The energy or pump source of the laser is provided by an electrical discharge of around 1000 volts through an anode and cathode at each end of the glass tube. A current of 5 to 100 mA is typical for CW operation.
- The optical cavity of the laser typically consists of a plane, high-reflecting mirror at one end of the laser tube, and a concave output coupler mirror of approximately 1% transmission at the other end.
- He Ne lasers are normally small, with cavity lengths of around 15 cm up to 0.5 m, and optical output powers ranging from 1 mW to 100 mW.

Electrical Discharging pumping mechanism in He-Ne Laser

- ✓ In this process atoms are excited in to the excited state by collision with fast moving electrons in discharge tube.
- ✓ This process generally used in gas lasers.
- ✓ Since gas lasers have very narrow absorption band so optical pumping is not suitable for gas lasers

Eg: He- Ne Laser , CO₂ Laser, and Argon- Ion laser





Description of Energy level diagram

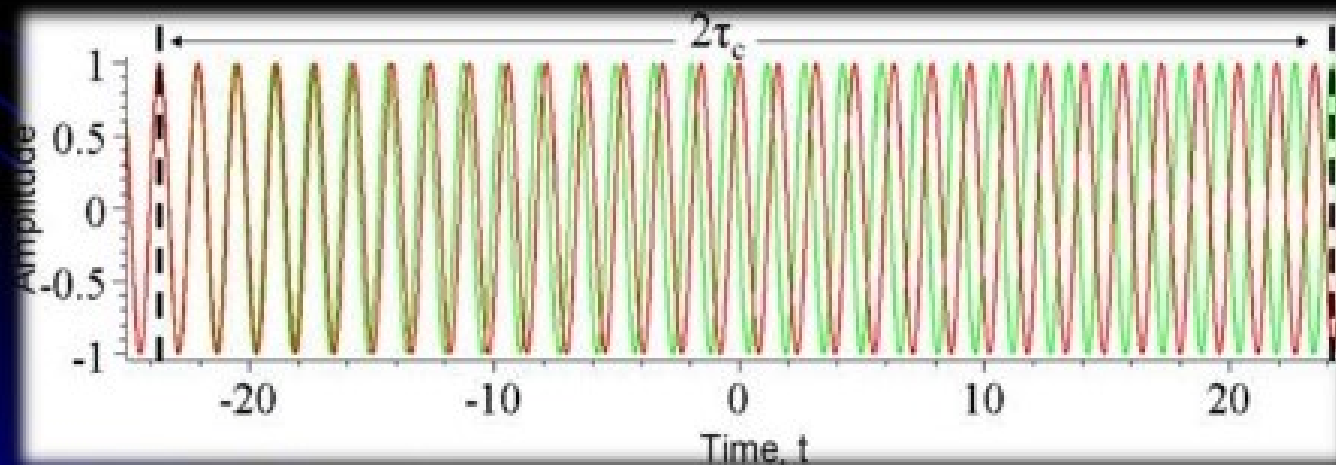
- When the excited Ne atom passes from metastable state(3s) to lower level(2p), it emits photon of wavelength 632 nm.
- This photon travels through the gas mixture parallel to the axis of tube, it is reflected back and forth by the mirror ends until it stimulates an excited Ne atom and causes it to emit a photon of 632nm with the stimulating photon.
- The stimulated transition from (3s) level to (2p) level is laser transition.
- This process is continued and when a beam of coherent radiation becomes sufficiently strong, a portion of it escape through partially silvered end.
- The Ne atom passes to lower level is emitting spontaneous emission. and finally the Ne atom comes to ground state through collision with tube wall and undergoes radiation lesss transition.

COHERENCE

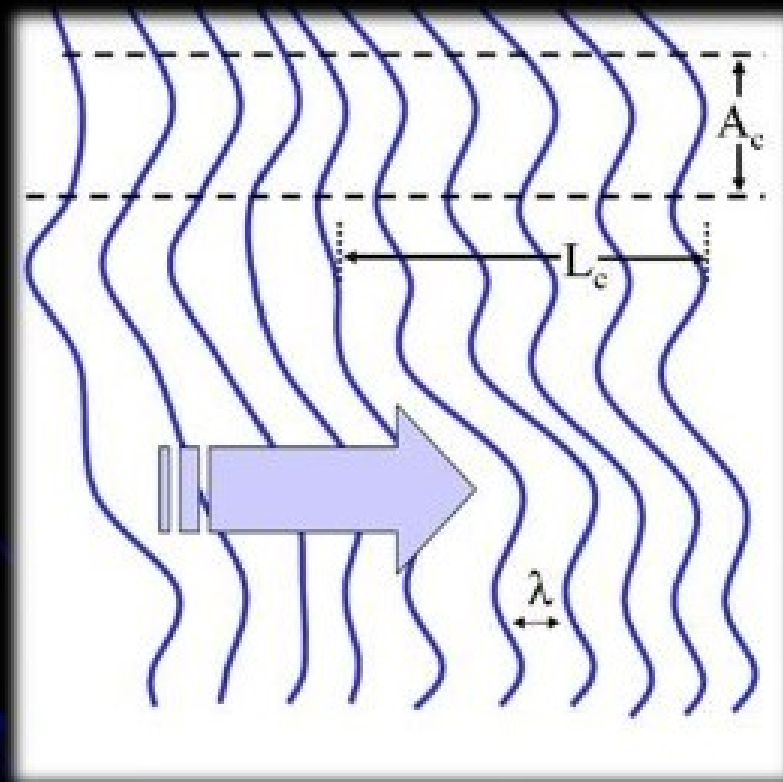
- means that the wavelengths of the **laser** light are in phase in space and time.
- Factors that compromise coherence:
 1. thermal fluctuations
 2. vibrational fluctuations
 3. emission of multiple wavelengths

- Temporal Coherence – How long do the light waves remain in phase as they travel?

$$\text{Coherence Length} = \lambda^2 / n \Delta \lambda$$



- Spatial Coherence – Over what area does the light remain in phase?



Advantages of He-Ne Laser

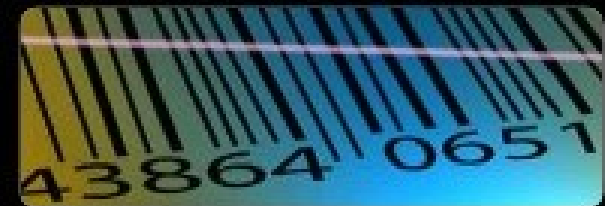
- He-Ne laser has very good coherence property
- He-Ne laser tube has very small length approximately from 10 to 100cm and best life time of 20.000 hours.
- Cost of He-Ne laser is less from most of other lasers.
- Construction of He-Ne laser is also not very complex.
- He-Ne laser provide inherent safety due to low power output.

Disadvantages of He-Ne Laser

- It is relatively low power device means its output power is low.
- He-Ne laser is low gain system/ device.
- To obtain single wavelength laser light, the other two wavelengths of laser need suppression, which is done by many techniques and devices. So it requires extra technical skill and increases the cost also.
- High voltage requirement
- Escaping of gas from laser plasma tube.

Applications of He-Ne laser

- The Narrow red beam of He-Ne laser is used in supermarkets to read bar codes.



- Measuring distances

- Red HeNe lasers have many industrial and scientific uses. They are widely used in laboratory demonstrations of optics in view of their relatively low cost and ease of operation .



Nd- YAG Laser

INTRODUCTION:

- ❑ It is four-level solid state laser system.
- ❑ In Nd:YAG Laser , Nd stands for neodymium ions Nd^{3+} and YAG for Yttrium Aluminium Garnet($\text{Y}_3\text{Al}_5\text{O}_{12}$).
- ❑ Nd YAG is a crystal that is used as a lasing medium for solid state lasers.
- ❑ It is developed by scientist J. E. Geusic, H.M. Marcos and L.G. Van Vliet in 1964.

ACTIVE MEDIUM:

- Nd^{3+} ions act as active medium or active centres. YAG is just the host.

RESONATOR CAVITY:

- The end faces of the Nd:YAG rod are ground polished and silvered to act as the optical resonator mirrors, or the optical cavity can be formed by using two external reflecting mirrors M_1 and M_2 .

OPTICAL PUMPING

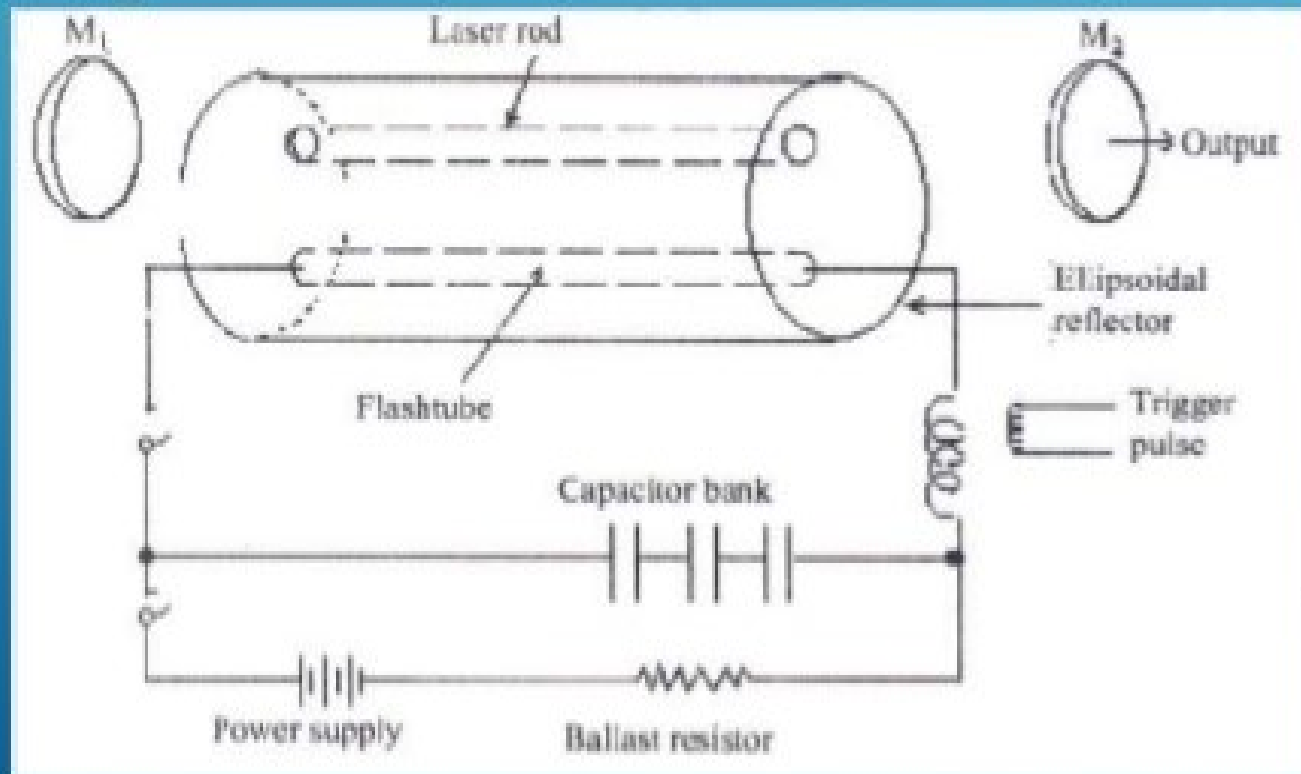
- ❑ A xenon flash lamp or a krypton flash is used as a pumping source.
- ❑ The optical pumping is used to achieve population inversion.



Nd:YAG Laser rod

CONSTRUCTION:

- The schematic diagram of a Nd:YAG laser is shown in figure given below:



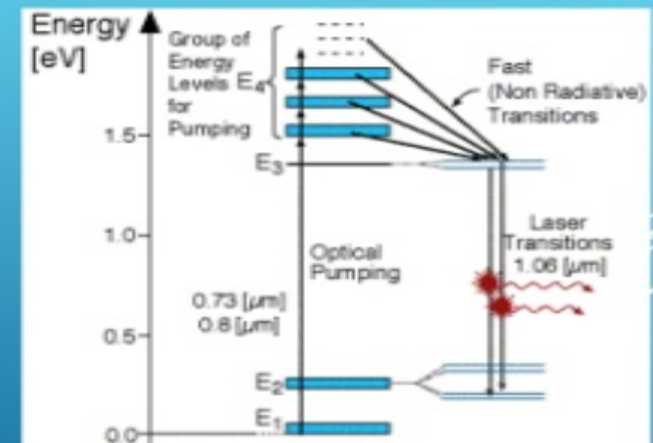
- ❑ A Nd:YAG rod and a krypton flash lamp are enclosed inside an ellipsoidal reflector.
- ❑ In order to make the entire flash radiation to focus on the laser rod, the Nd:YAG rod is placed at one focal axis and the flash lamp at the other focal axis of the ellipsoidal reflector.



WORKING:

- ❑ When the flash lamp is switched on the optical pumping excites the Nd^{3+} ions from the ground energy state E_0 to the higher energy level E_3 and E_4 by absorbing radiations of wavelength $0.80\mu\text{m}$ and $0.73\mu\text{m}$, respectively.
- ❑ Then the excited Nd^{3+} ions then make a transition from energy level E_4 to E_2 and it is a non-radioactive transition.
- ❑ The E_2 is the metastable state.
- ❑ Upon continues excitation, population inversion of Nd^{3+} ions is achieved at the metastable state E_2 .
- ❑ Any of the spontaneously emitted photon will make the excited Nd^{3+} ions to undergo a transition between E_2 to E_1 state and during this the stimulated photon is generated.
- ❑ The photons travelling parallel to the resonator axis experience multiple reflections at the mirrors.
- ❑ As a result, the transition E_2 to E_1 yields an intense and coherent laser beam of wavelength $1.064\mu\text{m}$.

- ❑ The Nd^{3+} ions then make a transition between E_1 to E_0 , which is non-radiative transition.
- ❑ Only a part of the energy by the flash lamp is used to excite the Nd^{3+} ions, while the rest heats up the crystal.
- ❑ Thus, the system can be cooled by either air or water circulation.



APPLICATIONS:

- ❑ These lasers are widely used for cutting, drilling, welding and surface hardening of the industrial products.
- ❑ It is used in military as range finder and target designations.
- ❑ It is used in medical field for cataract surgery, to treat gastrointestinal bleeding and gall bladder surgery.
- ❑ It is also used in haul communication.
- ❑ It is used in the study of inertial confinement fusion.

SEMICONDUCTOR LASER

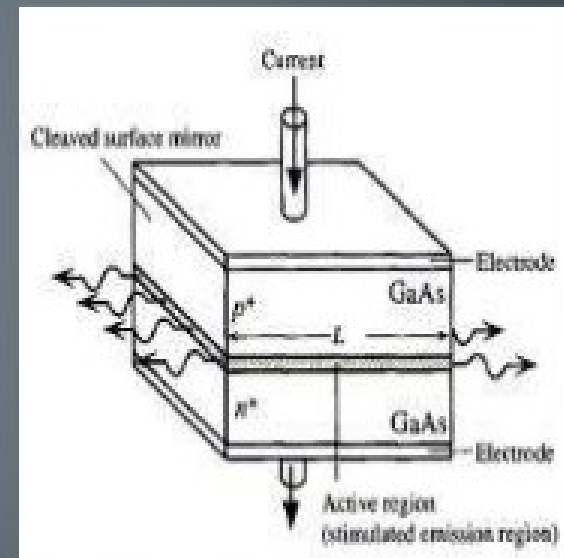
- Stimulated, organized photon emission occurs when two electrons with the same energy and phase meet. The two photons leave with the same frequency and direction.
- In 1916 Einstein devised an improved fundamental statistical theory of heat, embracing the quantum of energy. His theory predicted that as light passed through a substance it could stimulate the emission of more light. This effect is at the heart of the modern laser.
- Mainly there are two types in semiconductor laser:
 - (1) Homojunction laser
 - (2) Heterojunction laser

Homojunction Semiconductor Laser

Homojunction diode lasers are those in which P end and N end of the diode are made of the same semiconductor material.

Example : *Ga As laser*

- *They use Direct Band Gap Semiconductor material.*
- *P-N Junction act as the active medium.*
- *The crystal is cut at a thickness of 0.5 mm*
- *Applied voltage is given through metal contacts on both surfaces of the diode.*
- *Pulse beam of laser of $8400 \text{ \AA}$ is produced*



Construction of Ga - As LASER

- The gallium Arsenide laser is designed in such a way that a piece of N-type Gallium Arsenide material is taken and a layer of natural gallium aluminum arsenide material is pasted, The third layer of p-type gallium arsenide material is pasted over that.
- The two ends of length wise are fully polished in order to amplify the light by cross reflection. Here one ends is partially polished from where we get the laser beam.

Pumping mechanism in Semiconductor Laser

- Injection Current pumping mechanism is generally used in semiconductor lasers.
- In this, by passing high current across the junction, the population inversion will create.
- In semiconductor lasers the population inversion always creates among majority and minority charge carriers.

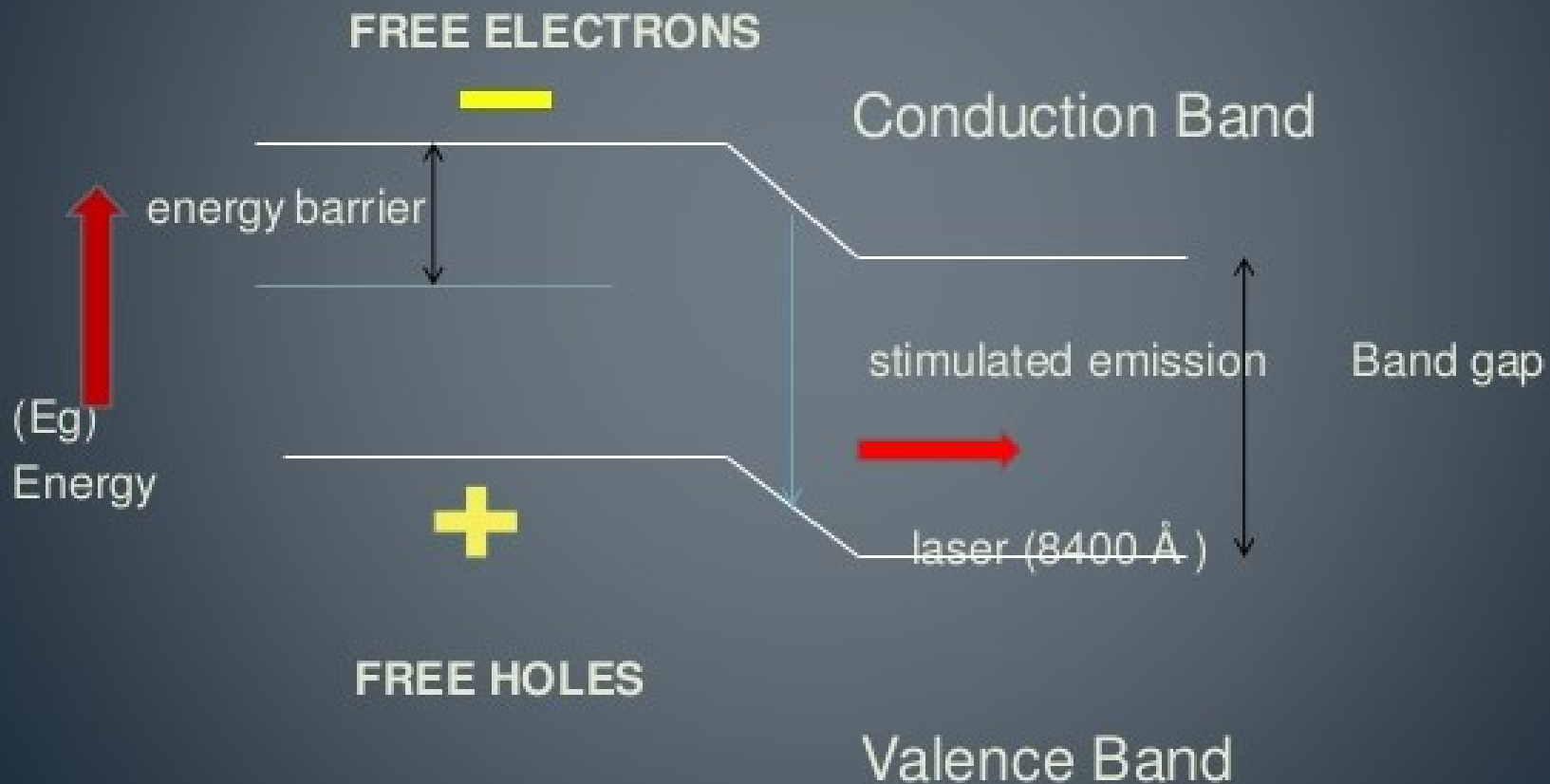
Examples: InP and GaAs semiconducting lasers.



SEMICONDUCTOR LASER

- In semiconductor diode lasers
- Conduction band play the role of excited level.
- Valence band play the role of ground level
- Population inversion requires the presence of large concentration of holes in the valence band.
- A simple way to achieve population inversion is to make a semiconductor in the form of a PN junction diode from heavily doped P and N type semiconductors

Energy Level Diagram : Homojunction



Pumping

- When PN junction diode is forward biased, the electrons from 'n' region and holes from 'p' region recombine with each other at the junction .
- During the recombination process light radiations (photons) is released from certain specified direct band gap semiconductors like Ga-As.
- This radiation is called recombination radiation and the corresponding energy is called activation energy.

Achievement of population inversion

- When p-n junction diode is forward biased, then there will be injection of electrons into the conduction band along n-side and production of more holes in valence band along p-side of the junction. Thus, there will be more number of electrons in conduction band comparable to valence band, so population inversion is achieved.
- Therefore, when the electrons and holes are injected into the junction region from opposite sides with forward biasing, then population inversion is achieved between levels near the bottom of the conduction band and empty levels near the top of the valence band.

Working of Ga – As LASER

- When the forward bias is applied to the metallic layer through contact points. The electric field is produced. This electric field causes the electrons to move from lower band of energy towards high band of energy level.
- Population inversion take place at the higher band of energy level and when the electrons falls back at the lower energy band, it emits light, through the polished end of the laser.
- Cross reflection of the light take place which multiplies strength of laser beam. At the end strong beam of laser comes out through the partially polished end.

Working

FORWARD BIASED DIODE LASER

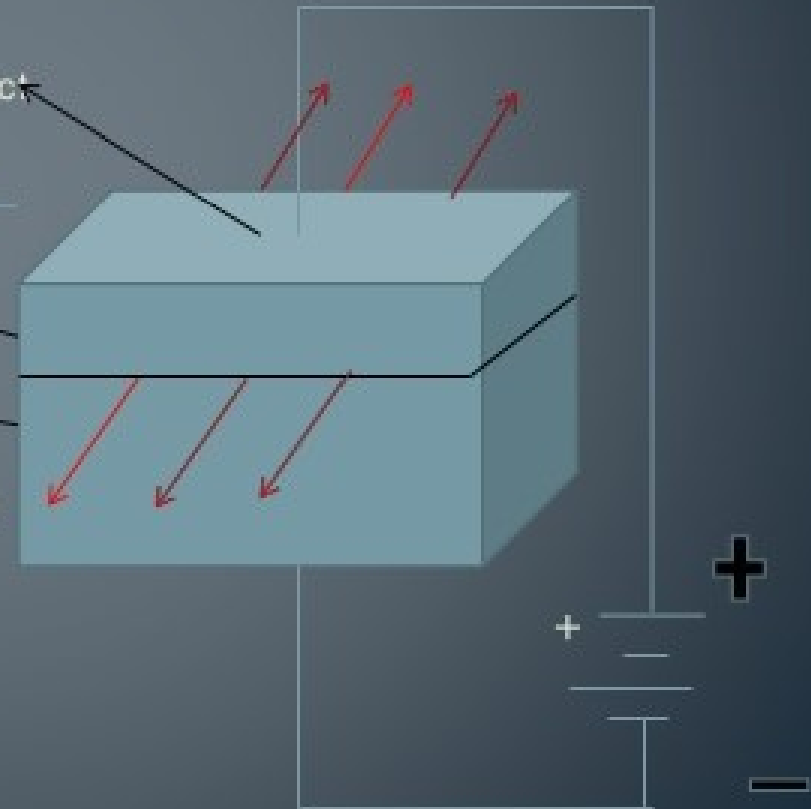
Ga-As material on both ends

P end

N end

Laser beam

metal contact



Achievement of laser

- When electrons recombine with the holes in junction region, then there will be release of energy in the form of photons. This release of energy in the form of photons happen only in special types of semiconductors like Gallium Arsenide (Ga As).
- Otherwise in semiconductors like silicon and germanium, whenever holes and electrons recombine, energy is released in the form of heat, thus Si and Ge can not be used for the production of laser.
- The spontaneously emitted photon during recombination in the junction region of Ga As will trigger laser action near the junction diode. The photons emitted have a wavelength from 8200 Å to 9000 Å in the infrared region.

- *Advantages of semiconductor laser*

- It is very small in dimension.
- The arrangement is simple and compact.
- It exhibits high efficiency.

- *Disadvantages of semiconductor laser*

- ❖ The output is usually in the form of wide beam.
- ❖ The purity & mono chromaticity are poorer than other type of laser.

Applications

- ❖ Semiconductor diode lasers used in CD and DVD players.
- ❖ Fiber optic transceivers are manufactured using alternating layers of various III-V and II-VI compound semiconductors to form lasing hetero structures.
- ❖ Used in laser printers & in laser diodes.

Heterojunction Semiconductor Laser

Heterojunction Semiconductor lasers are those in which P end is made of one type of semiconductor material and the N end is made of another type of semiconductor material.

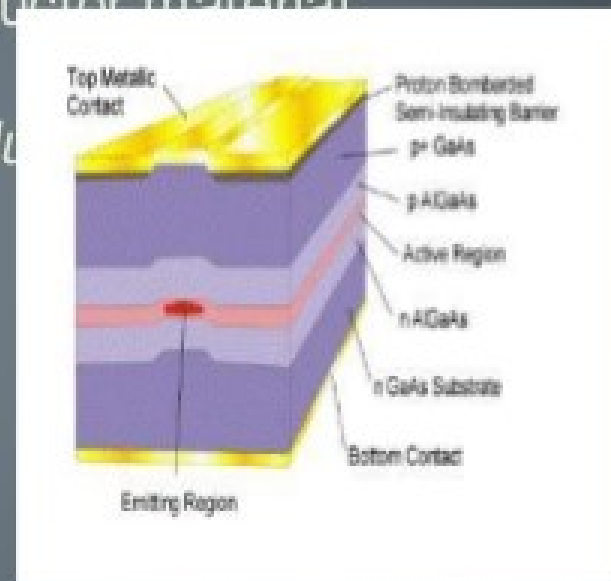
Example : *GaAlAs diode laser*

❖ *Use Direct Band Gap Semiconductor*

❖ *Consist of five layers namely*

- *GaAs – p type*
- *GaAlAs – p type*
- *GaAs – p type (Active Medium)*
- *GaAlAs – n type*
- *GaAs – n type*

❖ *The end faces of the third layer is highly polished and perfectly parallel to each other to reflect the laser beam ; one end is partially polished to release the continuous beam.*



Characteristics Of Semiconductor Laser

- Most SC lasers operate in $0.8 - 0.9 \mu\text{m}$ or $1 - 1.7 \mu\text{m}$ spectral region
- Wavelength of emission determined by the band gap
- Different SC materials used for different spectral regions
- $0.8 - 0.9 \mu\text{m}$: Based on Gallium Arsenide
- $1 - 1.7 \mu\text{m}$: Based on Indium Phosphide (InP)
- **Pumping method** : Direct Conversion
- High power lasers usually (1 mV)

Comparision

HOMOJUNCTION DIODE LASER

- P and N regions are made of the same diode material
- **Active medium** : Single crystal of PN Diode
- Pulse beam
- **Wavelength** : 8300Å-8500Å
- **Example** : GaAs, InP.

HETEROJUNCTION DIODE LASER

- P and N regions are made of different diode material
- **Active Medium** : Third layer of p type material among the five layers
- Continuous beam
- **Wavelength** : 8400 Å
- **Example** : GaAs/GaAlAs, InP/InAlP .

Advantages

- They are light weighted and portable.
- Battery supported ; easily replaceable
- Capability of direct modulation into Gigahertz region
- Small size and low cost
- Capability of Monolithic integration with electronic circuitry
- Compatibility with optical fibres

Disadvantages

- Due to relatively low power production, these lasers not suited to typical laser applications
- The temperature affects greatly the output of the laser
- Beam divergence is much greater as compared to all other lasers
- Cooling system required in some cases

Applications

- Fiber optic communications
- Barcode readers
- Laser pointers
- Disc reader
- Laser printing & scanning
- Directional lighting sources

