SRI AKILANDESWARI WOMEN'SCOLLEGE, WANDIWASH

LASER PHYSICS

CLASS:IIPG PHYSICS

Ms.P.ARCHANA
ASSISTANT PROFESSOR
DEPARTMENT OF PHYSICS

SWAMY ABEDHANANDHA EDUCATIONAL TRUST

LASERS

Light

Amplification by

Stimulated

Emission of

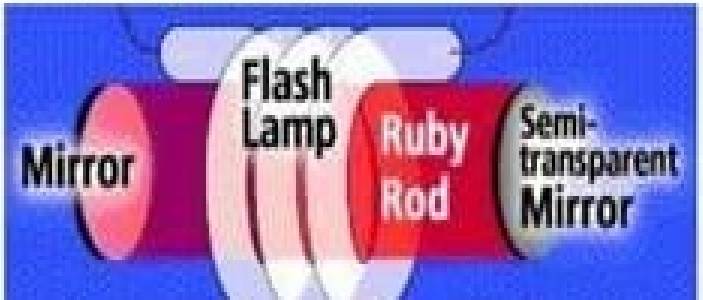
Radiation

R@ju V@ghela

Lasers

(Light Amplification by Stimulated Emission of Radiation)

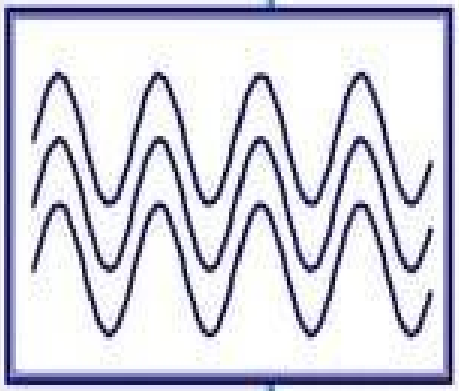
- A laser is a device that can produce a very narrow intense beam of monochromatic coherent light.
- The emitted beam is nearly perfect plane wave.



CHARACTERISTICS OF LASER LIGHT

R@ju V@ghela

- HIGH MONOCHROMATICITY
- HIGH DIRECTIONAL
- HIGH INTRNSITY
- COHERENT



The combination of these Four properties makes laser light focus 100 times better than ordinary light

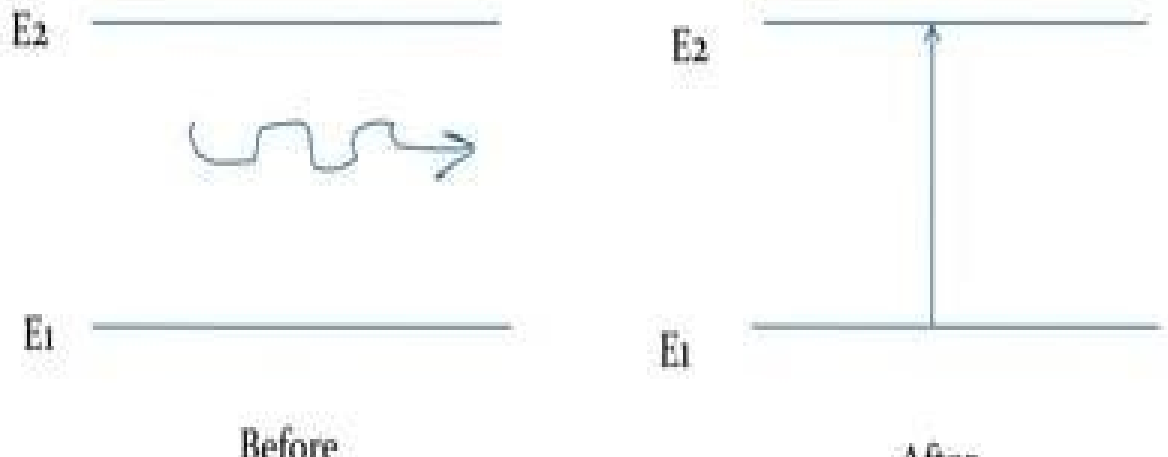
EINSTEIN'S THEORY

a) Induced Absorption
b) Spontaneous Emission
c) Stimulated emission

Induced absorption (stimulated absorption)

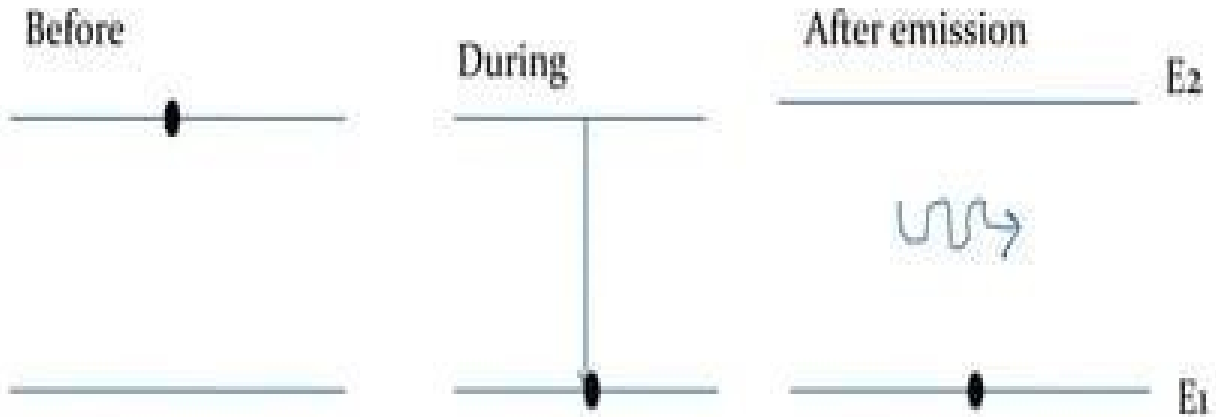
The process in which an atom sized system in lower energy state is raised in to higher energy state by electro magnetic radiation which is quanta of energy is equal to the difference of energy of the two states is called stimulated absorption.

i.e., $h\nu = E_2 - E_1$



Spontaneous emission

In the atom initially at upper state E_2, it can brought to E_1 by emitting photon of energy hv.This is known as spontaneous emission.



Stimulated emission

According to Einstein's, under certain condition it is possible to force an excited atom emit a photon by another photon and the incident light wave must be in same phase .hence we get an enhance beam of coherent light

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 $= B12.\rho(r).N1$

Ratio of spontaneous emission per unit volume $= A21.N2$

Ratio of stimulated emission per unit volume $= B21.\rho(r).N2$

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

$$B12.N1.\rho(r) = A21.N2 + B21.\rho(r).N2$$

$$\rho(r)[B12.N1 - B21.N2] = A21.N2$$

$$\rho(r) = \frac{A21.N2}{B12.N1 - B21.N2}$$

$$\rho(r) = \frac{A21/B21}{\frac{B12}{B21}.\frac{N1}{N2}} - 1$$

$$N1 = \text{No.}\, e^{\frac{-E1}{KT}} \qquad N2 = \text{No.}\, e^{\frac{-E2}{KT}}$$

$$\frac{N1}{N2} = e^{\frac{(E2-E1)}{KT}}$$

$$\rho(r) = \frac{A21}{\left[\frac{B12}{} \quad \frac{(E1-E2)}{KT}\right.}$$

$$B21 = B12 = 1 \qquad E2 - E1 = h\upsilon$$

$$\rho(r) = \frac{A21}{B21}\left[\frac{1}{e^{\left(\frac{h\upsilon}{KT}\right)} - 1}\right]$$

$$\rho(r) = \frac{8\pi h\upsilon^3\mu^3}{c^3}\left[\frac{1}{e^{\left(\frac{h\upsilon}{KT}\right)} - 1}\right]$$

$$\frac{A21}{B21} = \frac{8\pi h\upsilon^3\mu^3}{c^3}$$

R@ju V@ghela

diffrencce

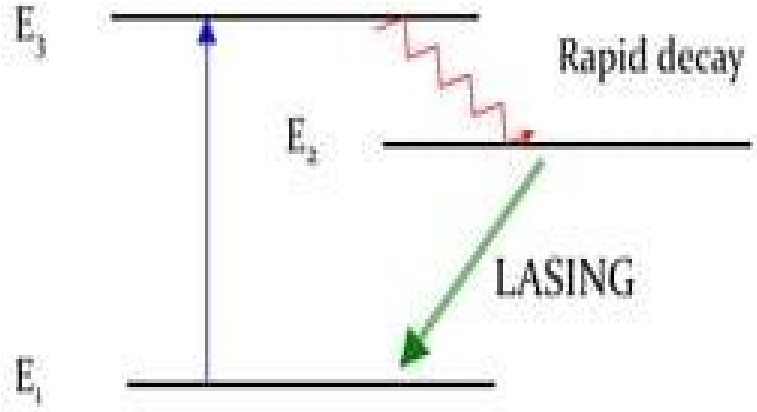
Stimulated emission

1. Emission of a light photon takes place through an inducement i.e. by an external photon.
2. It is not a random process.
3. The photons get multiplied through chain reaction.
4. It is a controllable process
5. More intense
6. Monochromatic radiation

Spontaneous emission

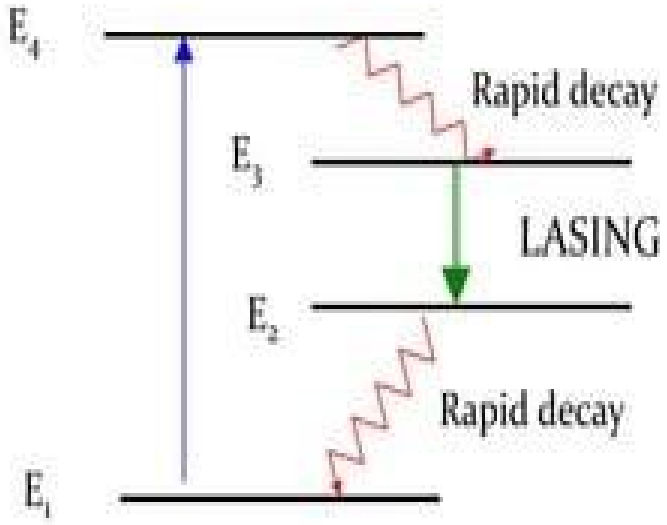
1. Emission of a light photon takes place immediately without any inducement.
2. It is a random process.
3. The photons do not get multiplied through chain reaction.
4. It is an uncontrollable process
5. less intense
6. Polychromatic radiation

Example of a 3 level system



- 1→3 transition is pumped.
- Rapid decay from 3 →2.
- State 2 is metastable, excited molecules can remain in state 2 for an extended time period, population of state 2 builds up.
- Decay from state 3 means absorption from 1 →3 is favoured, creating population inversion between 2 and 1.

Example of a 4 level system



- 1→4 transition is pumped.
- Rapid decay from 4 →3.
- A population inversion is produced between states 3 and 2.
- Laser action is therefore possible between 3 →2.
- Molecules decay rapidly from 2 →1, replenishing population of 1

PUMPING

R@ju V@ghela

Pumping is the mechanism of exciting atoma from the lower energy state to a higher energy state by supplying energy from an external source

i. ***Optical pumping :*** Exposure to electromagnetic radiation of frequency $\upsilon = (E_2-E_1)/h$ obtained from discharge flash tube results in pumping Suitable for solid state lasers.

ii. ***Electrical discharge :*** By inelastic atom-atom collisions, population inversion is established.

Suitable for Gas lasers

iii. ***Chemical pumping :*** By suitable chemical reaction in the active medium, population of excited state is made higher compared to that of ground state Suitable for liquid lasers.

Active medium

R@ju V@ghela

- A medium in which population inversion is achived for laser laser action is called active medium. The medium can be solid,liquid,gas and plasma.

Active medium or working substance

- This is the basic material in which atomic and molecular transitions take place leading to laser action.
- It is the medium where the stimulated emission take place
- Depending the active medium lasers are classified in to different types like solid, gas, dye or liquid, semiconductor laser

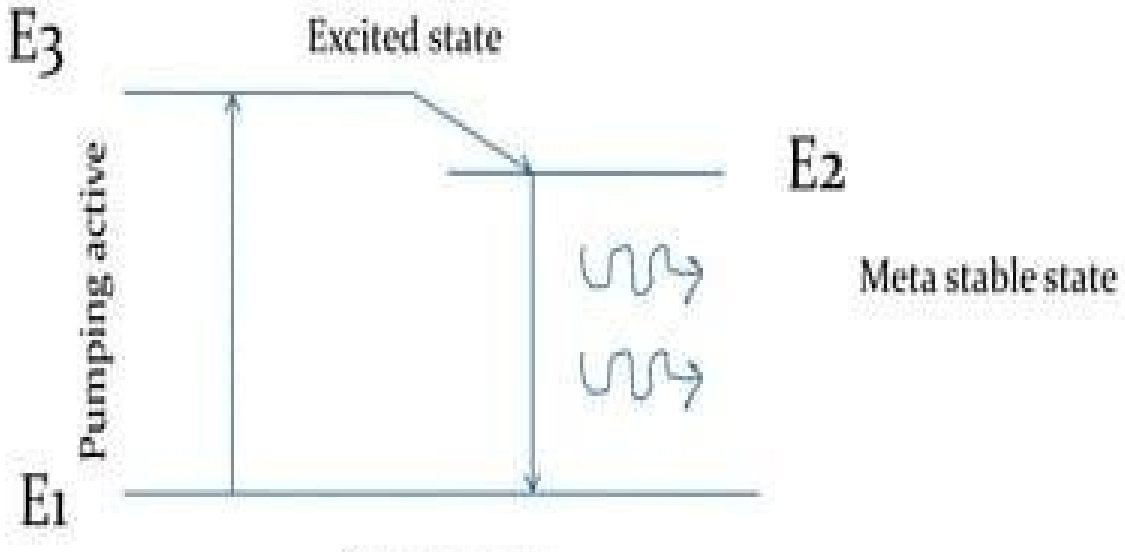
Pumping source or energy source

With the help of energy source the system can be raised to an excited state, with the help of this source the no. of atoms in higher energy state may be increased and hence the population inversion is achieved. the energy source may also be called pumping source.

Three level and four level laser

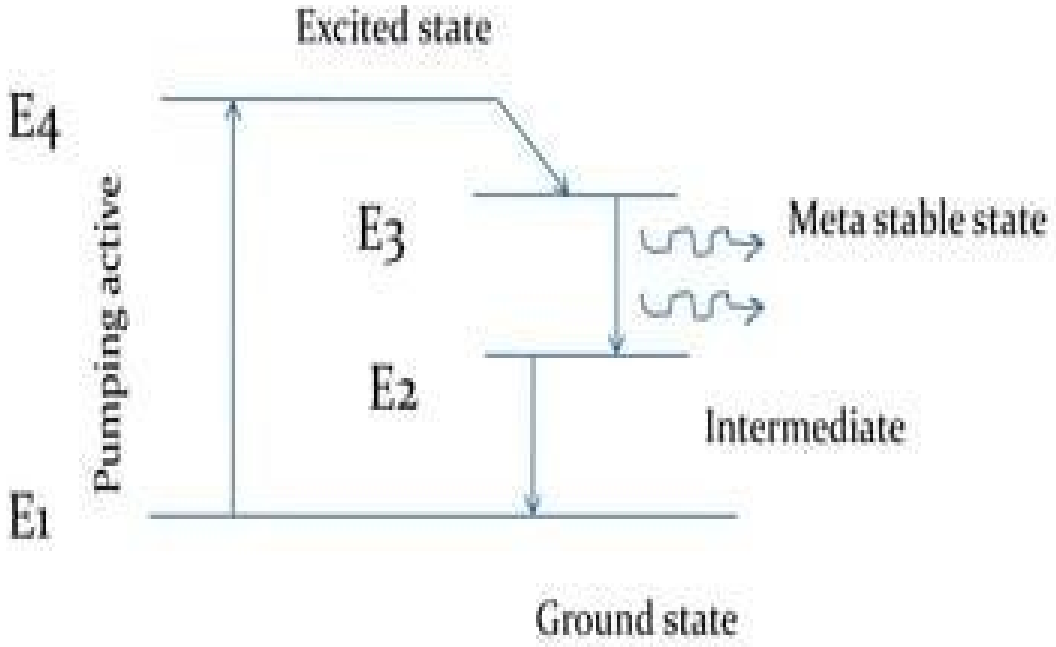
R@ju V@ghela

The simplest kind is three level laser which uses and assembly of atom or molecules that have three energy states E_1, E_2, E_3.
Where, E_1-> ground state
E_2->meta stable state
E_3->higher excited state



Four level laser

E_1->ground state,E_2->intermediate,E_3->metastable,E_4->excited state



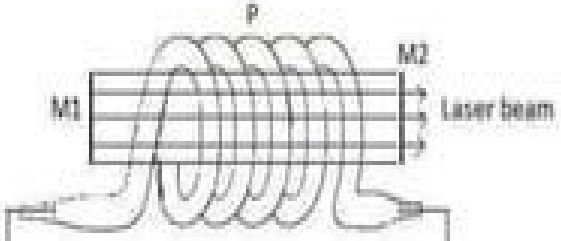
R@ju V@ghela

Different types of lasers

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

Solid state laser

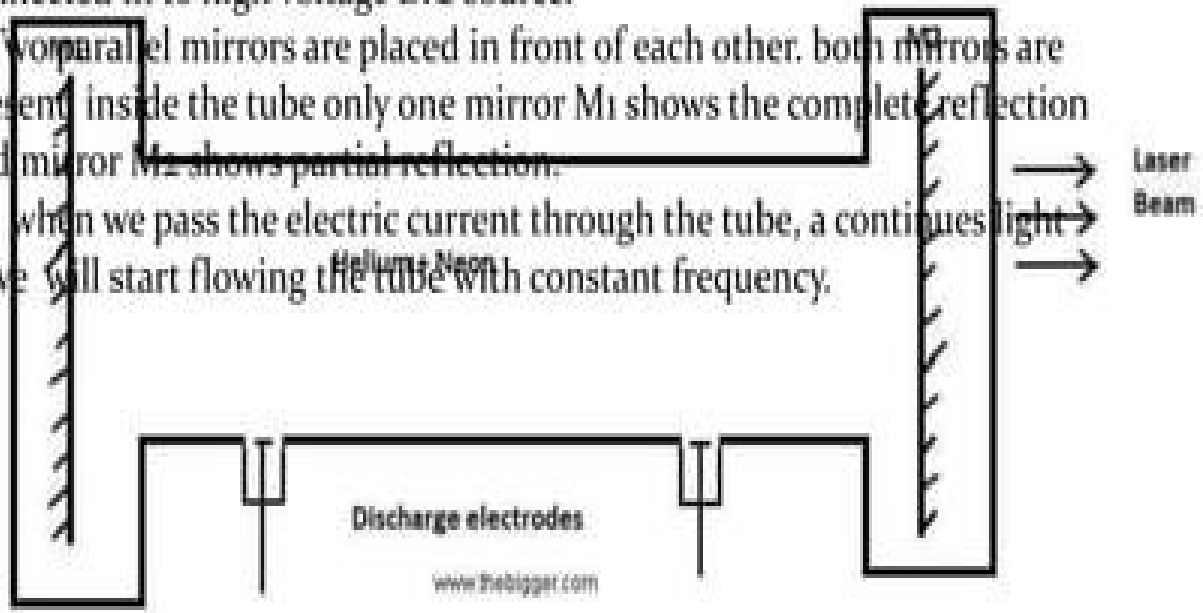
- In this a ruby like crystal is used which acts as an active medium. It is basically cylindrical in shape. This crystal is surrounded by a xenon flash lamp T.
- This flash lamp is of helical shape. In this arrangement this lamp acts as a pumping arrangement. Both the ends E_1 and E_2 of the crystal are properly polished.
- Similar to the gas lasers, the surface M_1 will do the complete reflection but on the other hand M_2 will reflect partially.
- Whenever we will pass the current through the arrangement a laser beam of red color having large intensity will come out.



Gas laser

R@ju V@ghela

- CO_2 & He-Ne lasers are the best e.g. gas laser. The CO_2 lasers was one of the earliest gas laser to be developed, and still of the main useful.
- The He-Ne laser contain a mixture of helium & neon. This mixture is packed in to glass tube and it acts as an active medium. Two electrodes are connected in to high voltage D.C source.
- Two parallel mirrors are placed in front of each other. both mirrors are present inside the tube only one mirror M_1 shows the complete reflection and mirror ~~M_2 shows partial reflection.~~
- when we pass the electric current through the tube, a continues light wave will start flowing the tube with constant frequency.



Liquid laser or dye laser

- In liquid lasers organic dyes are used as active medium inside the glass tube. The complete circulation of dye is done in the tube with the help of a pump. From this organic dye laser light will emerge out.

Semiconductor laser

- In these lasers junction diodes are used. The doping of p-n junction diode is done. Both the acceptors and donors are doped. These are known as ILD(Injection Laser Diodes). Whenever the current is passed then the light modulation from the ILD can be seen. This is used in various electronic equipments

Optical resonator

R@ju V@ghela

- It is specially designed cylindrical tube
- Set of mirrors at the ends of which are silvered one end being completely silvered at which the other is partially silvered
- Photons are emitted parallel to the axis of the active medium undergo multiple reflections between them
- So, the light intensity can be increased

Nd: YAG Laser

Lasing medium :

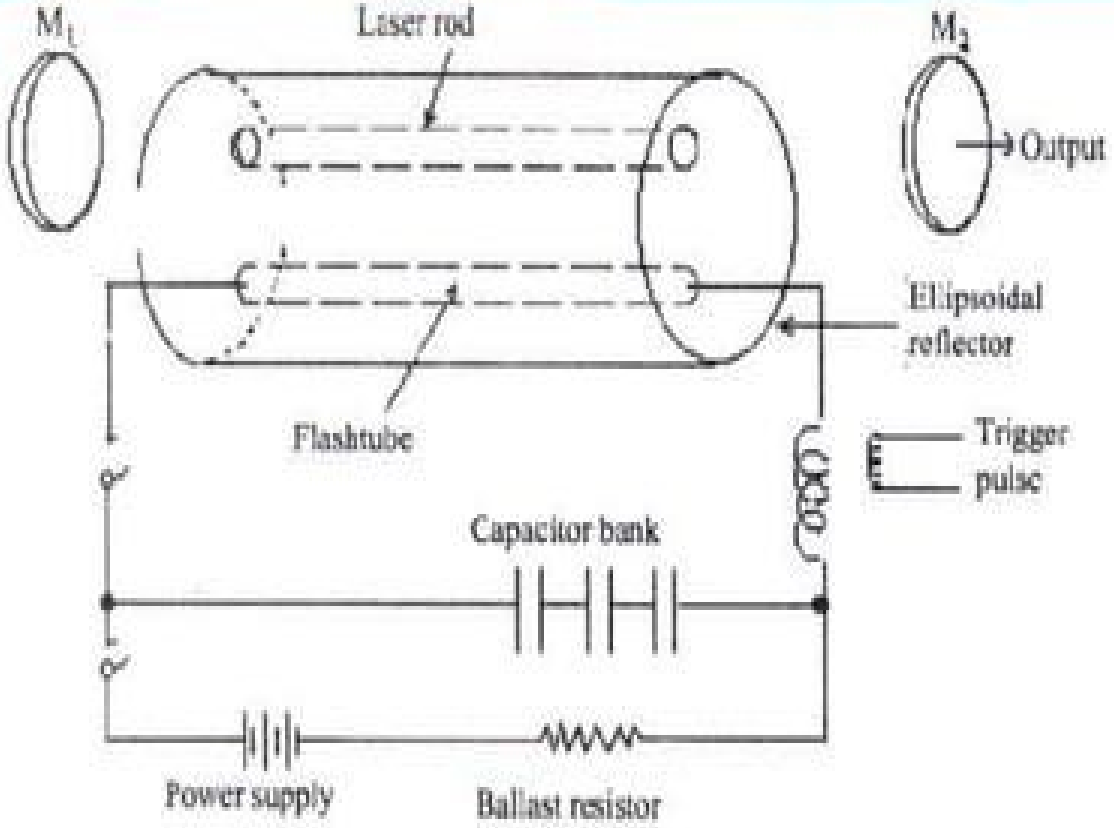
- The host medium for this laser is Yttrium Aluminium Garnet (YAG = $Y_3 Al_5 O_{12}$) with 1.5% trivalent neodymium ions (Nd^{3+}) present as impurities.

- The (Nd^{3+}) ions occupy the lattice sites of yttrium ions as substitutional impurities and provide the energy levels for both pumping and lasing transitions.

- *Contd.*

- When an (Nd^{3+}) ion is placed in a host crystal lattice it is subjected to the electrostatic field of the surrounding ions, the so called crystal field.

- The crystal field modifies the transition probabilities between the various energy levels of the Nd^{3+} ion so that some transitions, which are forbidden in the free ion, become allowed.



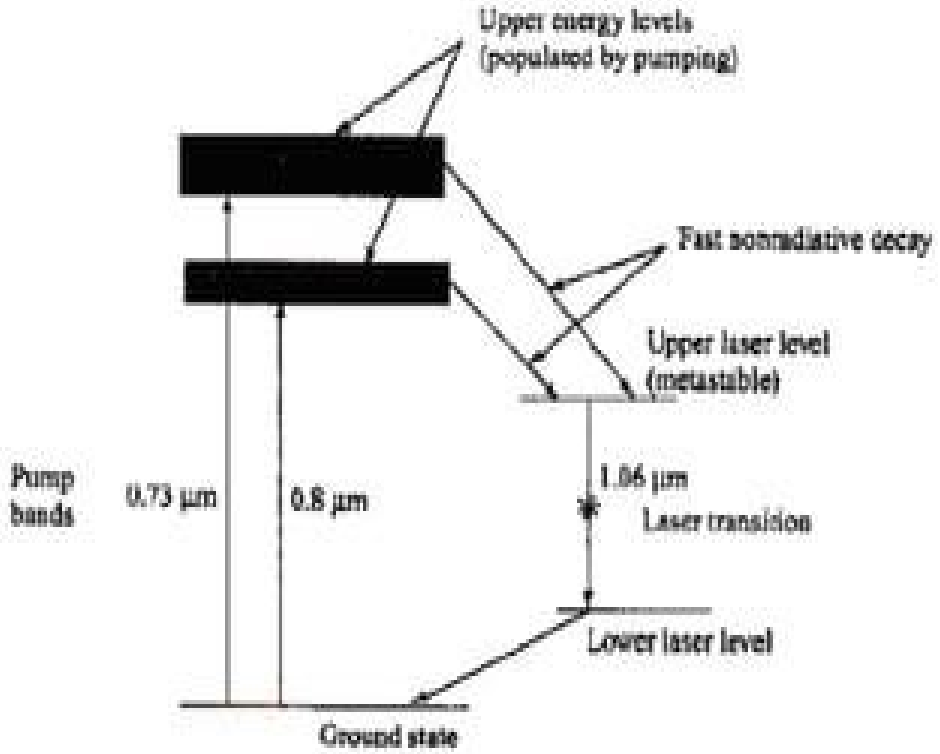
Nd: YAG laser

Nd: YAG laser

R@ju V@ghela

- The length of the Nd: YAG laser rod various from 5cm to 10cm depending on the power of the laser and its diameter is generally 6 to 9 mm.
- The laser rod and a linear flash lamp are housed in a elliptical reflector cavity
- Since the rod and the lamp are located at the foci of the ellipse, the light emitted by the lamp is effectively coupled to the rod.
- The ends of the rod are polished and made optically flat and parallel.

ENERGY LEVEL DIAGRAM



- This laser system has two absorption bands (0.73 μm and 0.8 μm)
  Optical pumping mechanism is employed.
  Laser transition takes place between two laser levels at 1.06 mm.

CO_2 LASER

Introduction :

- CO_2 lasers belong to the class of molecular gas lasers.
- In the case of atoms, electrons in molecules can be excited to higher energy levels, and the distribution of electrons in the levels define the electronic state of the molecule.
- Besides, these electronic levels, the molecules have other energy levels.
- C.K.N. Patel designed CO_2 laser in the year 1964.

rotational levels of vibrational bands of the electronic ground state.

Optical resonators :

A pair of concave mirrors placed on either side of the discharge tube, one completely polished and the other partially polished.

Pumping

- Population inversion is created by electric discharge of the mixture.
- When a discharge is passed in a tube containing CO_2, electron impacts excite the molecules to higher electronic and vibrational-rotational levels.
- This level is also populated by radiationless transition from upper excited levels.
- The resonant transfer of energy from other molecules, such as, N_2, added to the gas, increases the pumping efficiency.

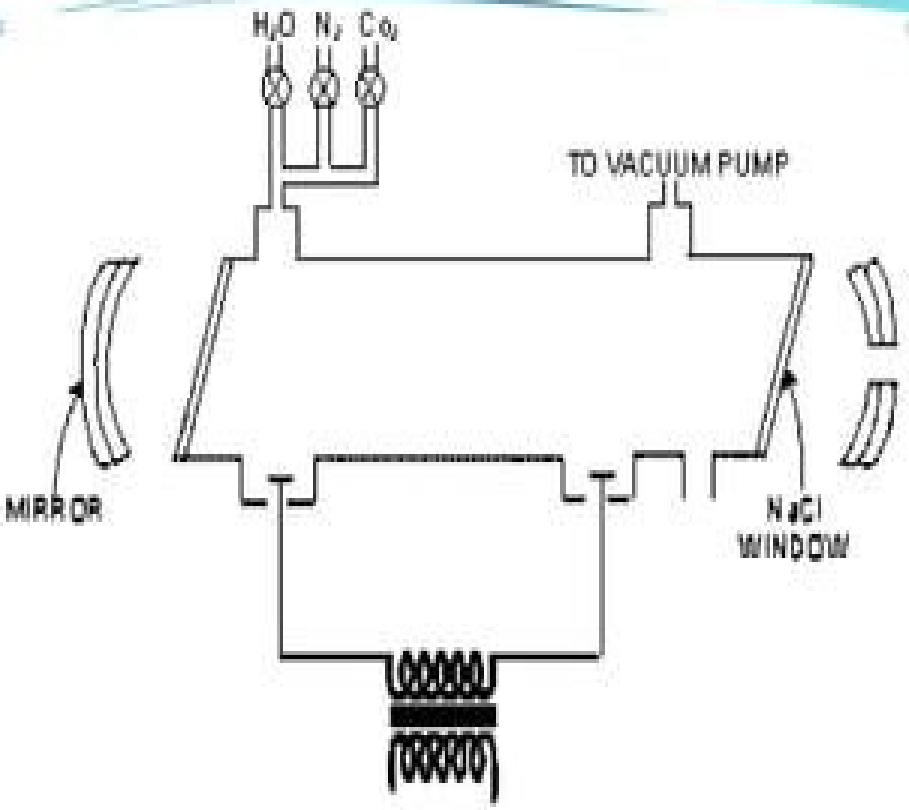
Fundamental Modes of vibration of CO_2

- Three fundamental modes of vibration for CO_2
  - Symmetric stretching mode (frequency ν_1),
  - Bending mode (ν_2) and
  - Asymmetric stretching mode (ν_3).

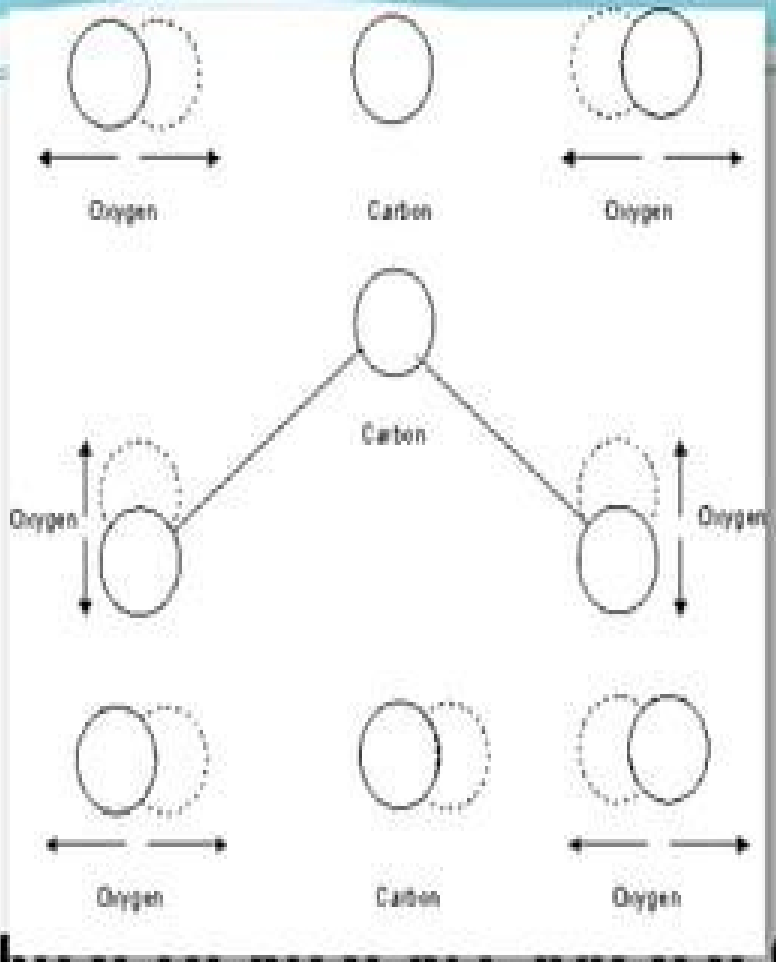
- In the symmetric stretching mode, the oxygen atoms oscillate along the axis of the molecule simultaneously departing or approaching the carbon atom, which is stationa

three atoms oscillate: but while both oxygen atoms move in one direction, carbon atoms move in the opposite direction.

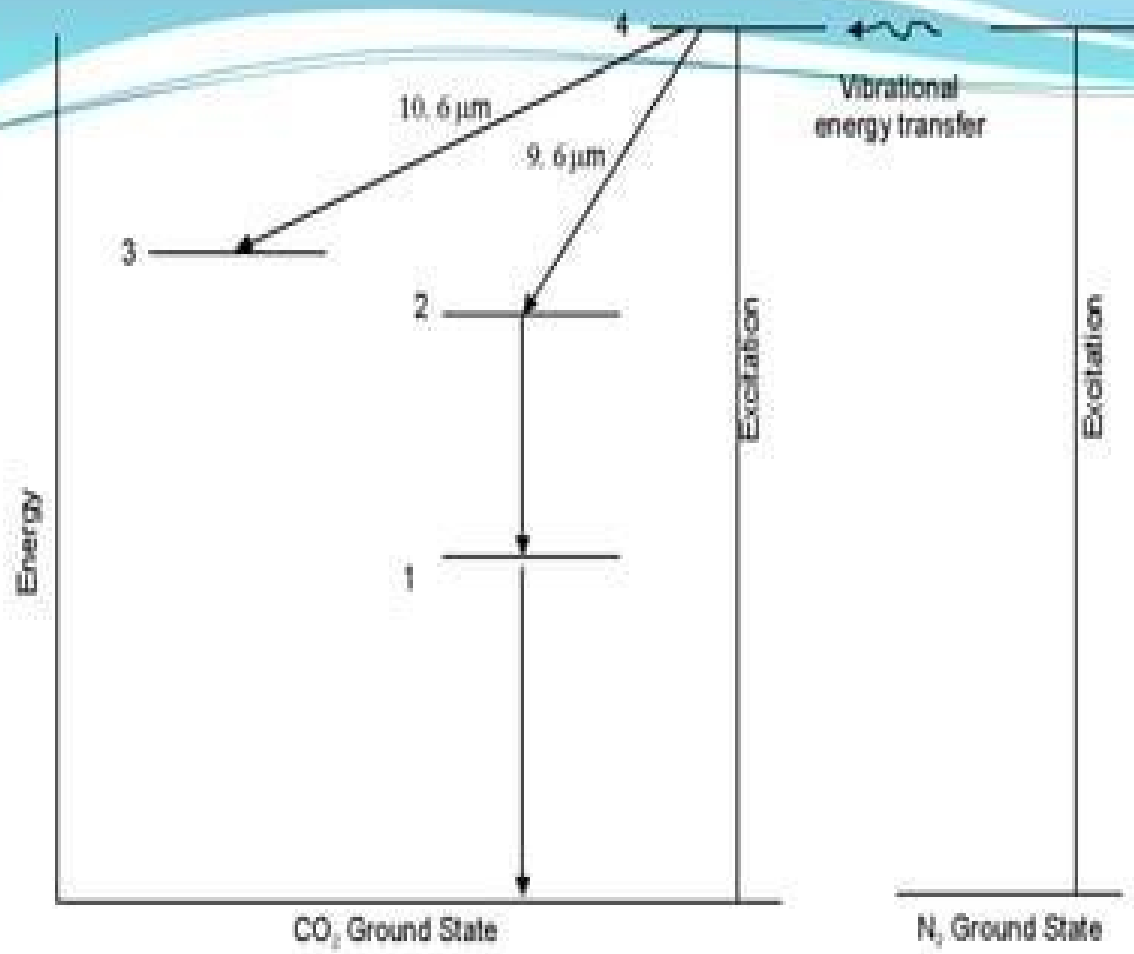
The 'internal vibrations' of carbon dioxide molecule can be represented approximately by linear combination of these three normal modes.



CO_2 LASER



INDEPENDENT MODES OF VIBRATION OF CO_2 MOLECULE



R@ju V@ghela

ENERGY LEVEL DIAGRAM

Applications

- Modulated laser beam have been used for communication
- In medical field
- High power laser have been used for cutting & drilling holes in hard metal and diamonds
- They have been used in the production and research with holograms, they are also used in high speed photography and fiber optics

APPLICATIONS OF LASERS

- In medical
- Military
- Industrial and commercial
- Atmospheric

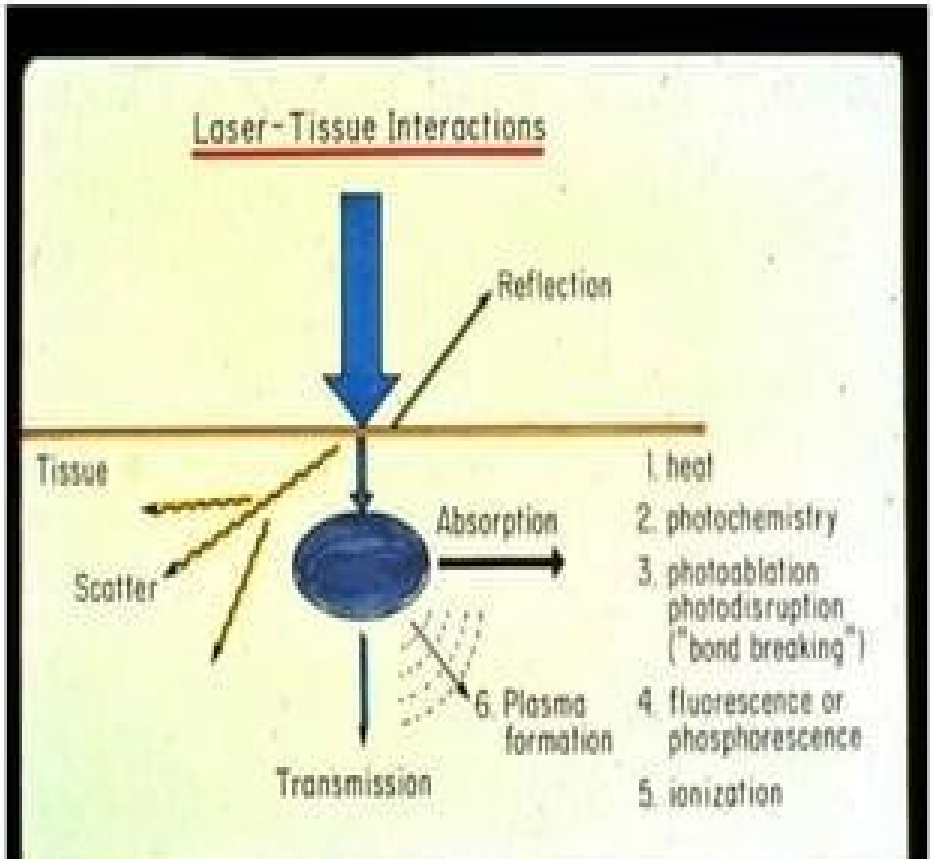
MEDICAL USE

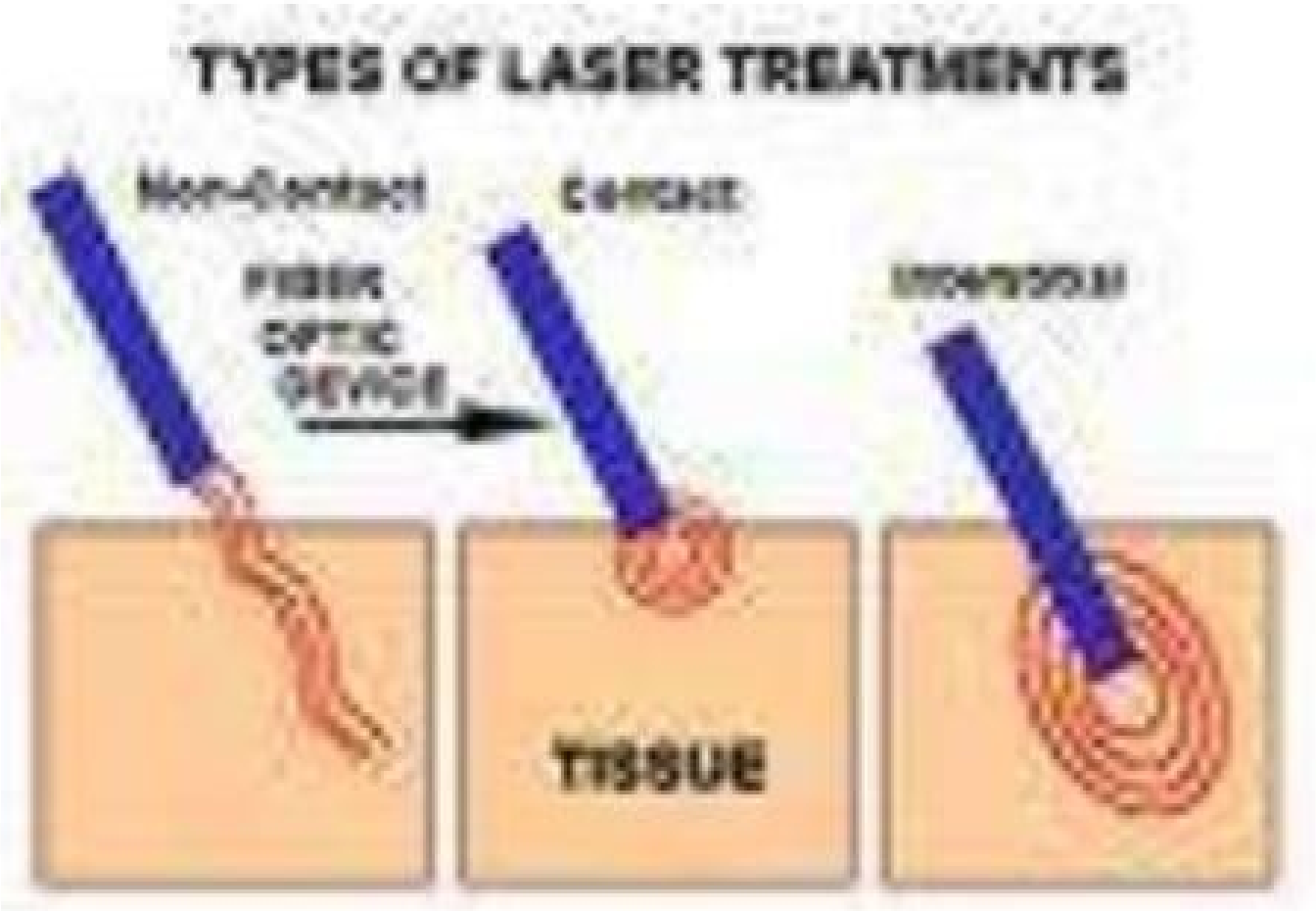
- The use of lasers has revolutionized medicine because lasers are accurate, quick, and minimally invasive. There are six different types of laser-tissue interaction illustrated in figure .
- The accuracy of the laser assures that only the desired portion of a specimen is affected by the laser.
- The strength of the laser provides any medical treatment with adequate power to ablate the plaque, no matter how large the obstruction may be.
- The efficiency of the laser provides a better medical treatment because it takes less repetitions of the treatment to complete the procedure.

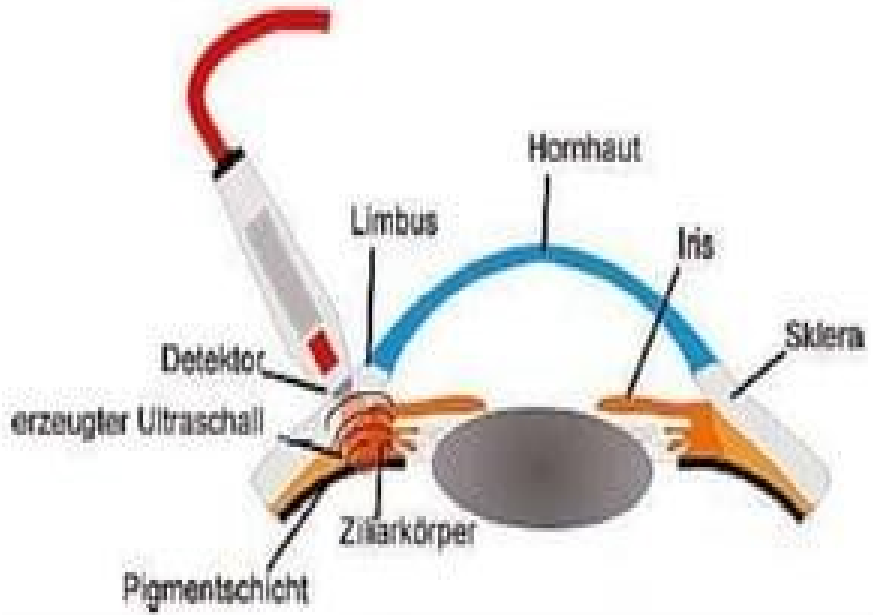
TYPES OF LASER TISSUE INTERACTION

- There are six different types of laser-tissue interaction illustrated as.
- Heat
- Photochemistry
- Photoablation.
- Florescence
- Ionization.

IN MEDICAL


Laser-Tissue Interactions
Reflection
Tissue
Absorption
Scatter
6. Plasma formation
Transmission
1. heat
2. photochemistry
3. photoablation photodisruption ("bond breaking")
4. fluorescence or phosphorescence
5. ionization


TYPES OF LASER TREATMENTS
TISSUE


Hornhaut
Limbus
Iris
Sklera
Detektor
erzeugter Ultraschall
Ziliarkörper
Pigmentschicht

HEART TREATMENT

A laser beam fired into the heart can help people suffering from angina pectoris.

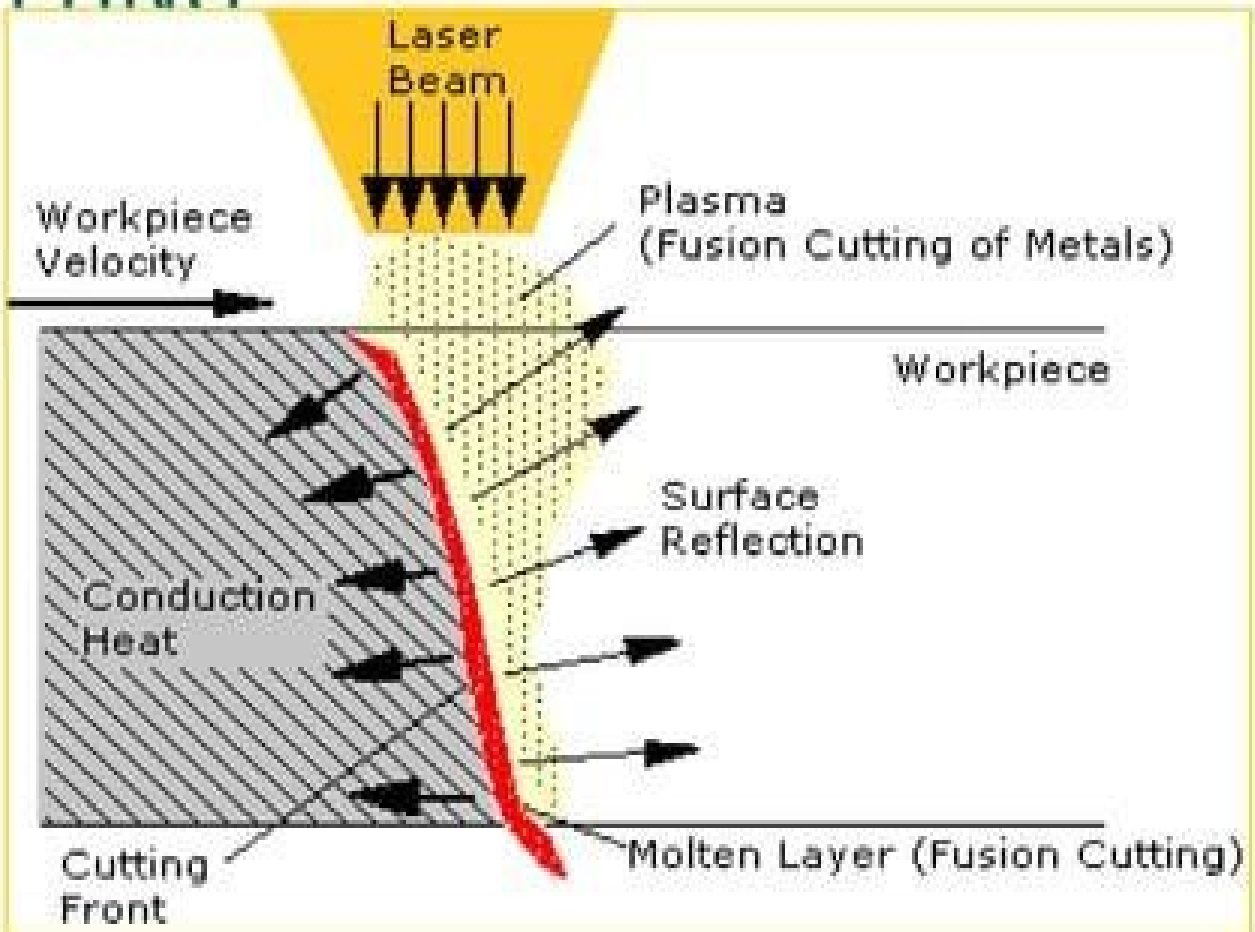
EYE TREATMENT

Lasers can be used to correct defects of the lens and cornea as well as repair tears and holes in

MATERIAL PROCESSING

- Laser cutting,
- Laser welding,
- Laser brazing,
- Laser bending,
- Laser engraving or marking,
- Laser cleaning, weapons etc.

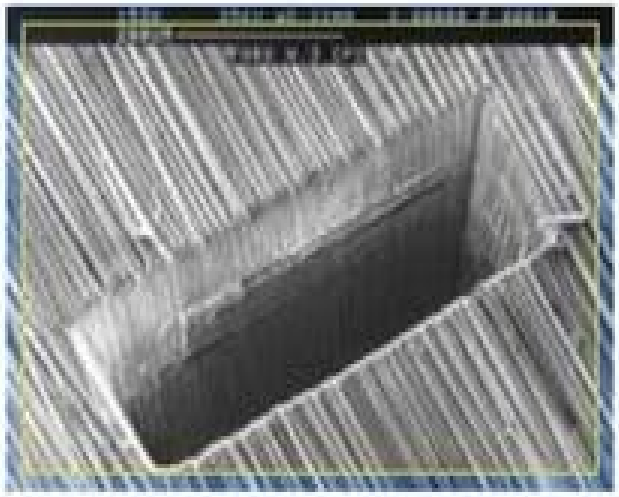
CUTTING


Laser
Beam
Workpiece
Velocity
Plasma
(Fusion Cutting of Metals)
Workpiece
Surface
Reflection
Conduction
Heat
Cutting
Front
Molten Layer (Fusion Cutting)

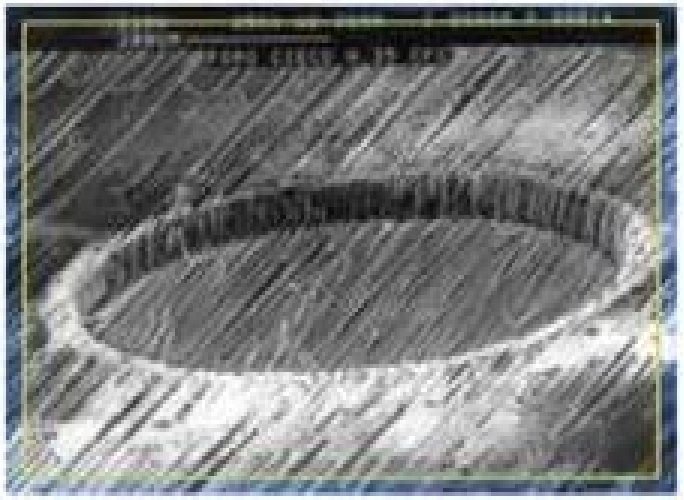
ADVANTAGES OF LASER CUTTING

- Cutting edges are tight and parallels
- Reduced Heat Affected Zone
- Possibility to operate on complex profiles and reduced curving radius
- Absence of mechanical distortion of the laser worked piece
- No influence of the hardness of the material•
- No problems to cut materials prevoiusly coated

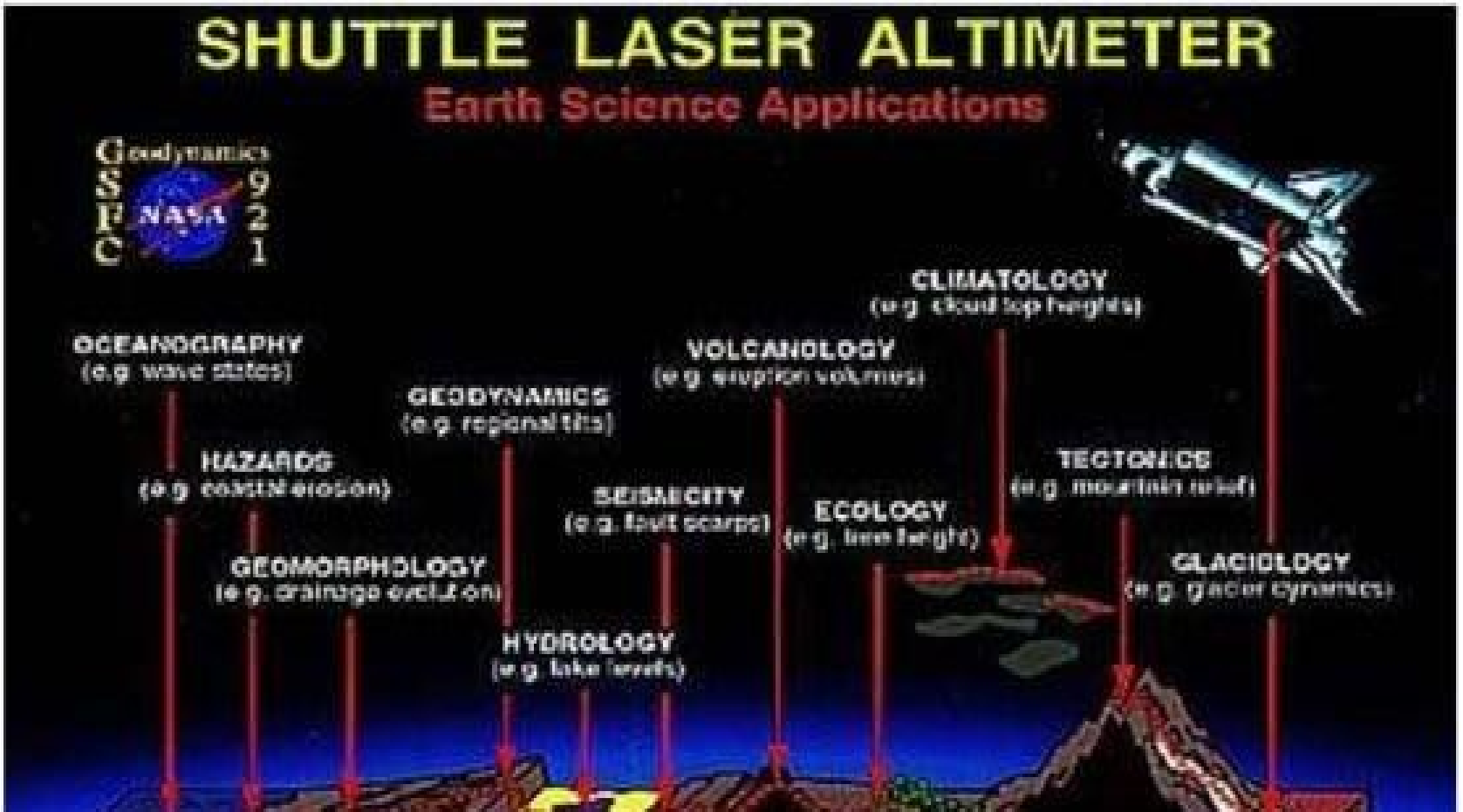
DRILLING



Blind hole obtained by using an excimer laser beam on CFC



Passing hole obtained by using an excimer laser beam on CFC


SHUTTLE LASER ALTIMETER
Earth Science Applications
Geodynamics
SSRC
NASA
921
CLIMATOLOGY
(e.g. cloud top heights)
OCEANOGRAPHY
(e.g. wave states)
VOLCANOLOGY
(e.g. eruption volumes)
GEODYNAMICS
(e.g. regional tilts)
HAZARDS
(e.g. coastal erosion)
SEISMICITY
(e.g. fault scarps)
ECOLOGY
(e.g. tree height)
TECTONICS
(e.g. mountain uplift)
GEOMORPHOLOGY
(e.g. drainage evolution)
GLACIOLOGY
(e.g. glacier dynamics)
HYDROLOGY
(e.g. lake levels)

IN MILITARY

- Target designation and ranging,
- Defensive countermeasures,
- Communications
- Directed energy weapons.

such as Boeing's Airborne Laser which can be mounted on a 747 jet is able to burn the skin off enemy missiles.

LAS

A **laser rangefinder** is a device which uses a laser beam in order to determine the distance to a reflective object. it works on the principle of time of flight.

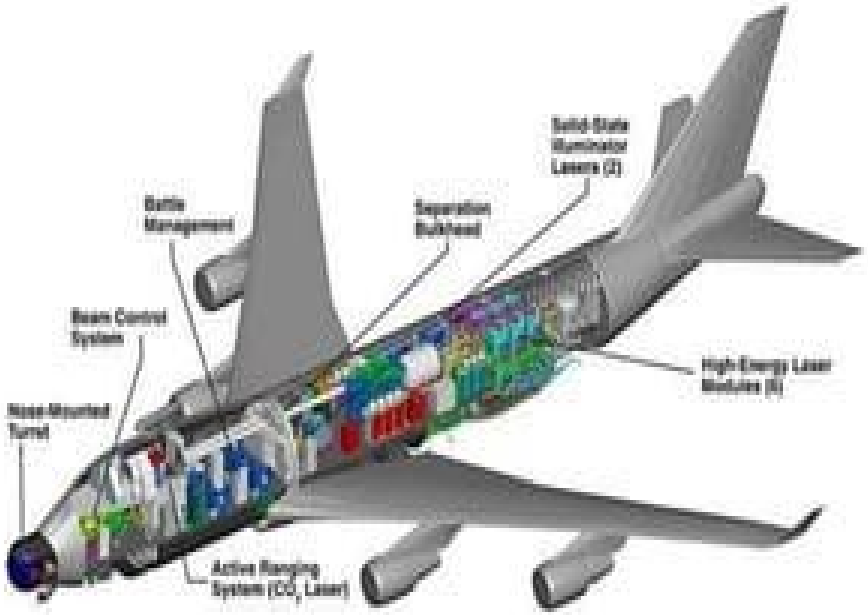
A long range laser rangefinder LRB20000 is capable of measuring distance up to 20 km; mounted on a tripod with

Revolver equipped with laser sight.

The laser has in most military applications been used as a tool to enhance the targeting of other weapon systems. For example, a *laser sight* is a small, usually visible-light laser placed on a handgun or rifle aligned to emit a beam parallel to the barrel. Most laser sights use a red laser diode Others use an infrared diode .

Revolver equipped with laser sight.

Airborne Laser (ABL)



CAPABILITIES

- Operates autonomously, above the clouds, outside the range of threat weapons but sufficiently close to enemy territory
- Engages early, destroying ballistic missiles in their boost phase of flight over launch area
- Cues and tracks targets, communicating with other joint theater assets for layered defense system

LIDAR (**Li**ght **D**etection **a**nd **R**anging)

R@ju V@ghela

This lidar scanner may be used to scan buildings, rock formations, etc., to produce a 3D model. The lidar can aim its

APPLICATIONS OF LADAR

- Geology and Meteorology for detecting faults and measuring uplifts.
- Physics and Astronomy to measures the distance to reflectors placed on moon.
- Biology and conservation
- Military and law enforcement for vehicle speed measurement

COMMERCIAL USE

R@ju V@ghela

Laser printer

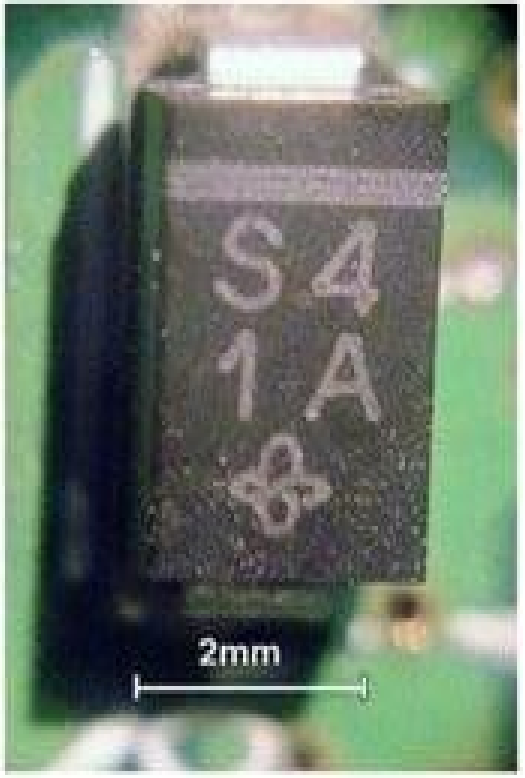
A **laser printer** is a common type of computer printer that rapidly produces high quality text and graphics on plain paper. As with digital photocopiers and MFPs, laser printers employ a xerographic printing process but differ from analog photocopiers in that the image is produced by the direct scanning of a laser beam across the printer's photoreceptor

HP LaserJet 4200 series printer

Laser engraving

R@ju V@ghela

Laser engraving is the practice of using lasers to engrave or mark an object. The technique can be very technical and complex, and often a computer system is used to drive the movements of the laser head. Despite this complexity, very precise and clean engravings can be achieved at a high rate



Laser marked electronic part

conclusion

- Lasers are device which amplify light and produce beams of light which are very intense, directional and

Pure in colour.

- Laser action is preceded by three processes namely absorption, spontaneous emission and stimulated emission.
- They can solid state ,gas, semiconductor or liquid.
- Laser can be used for many applications ,helped people develop in many things in our daily life.