UNIT - II

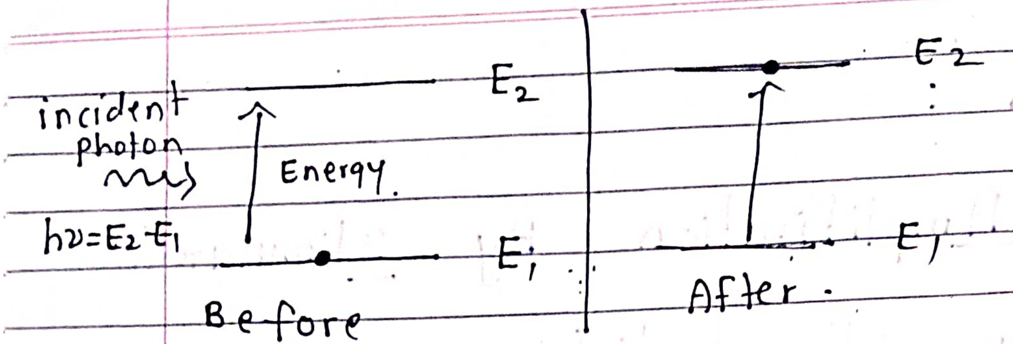
* LASERs :

Light Amplification By Stimulated Emission of Radiation.

* Laser → amplifier & generator of light.
In 1916, Einstein gave theoretical basis for development of Lasers, he predicted possibility of stimulated emission.
* In 1954, C.H. Townes & his ~~cover~~ coworkers used Einstein's idea & developed MASERS (microwave Amplification by Stimulated Emission of Radiation)
In 1958, A. Schawlow & ~~H~~ C.H. Towens extendeal it to visible light. &
T.H. Maiman built 1st LASER device in 1960.

* Interaction of Light with matter & Three quantum processes :-
When light passes through matter, it interacts with matter (as light also behaves as matter)
* Three processed during this interactions:

① Absorption :
Suppose an atom is in lower energy level E_1, If photon of energy equal to difference of energy between these levels falls on it, it imparts (gives) its energy & disappear.



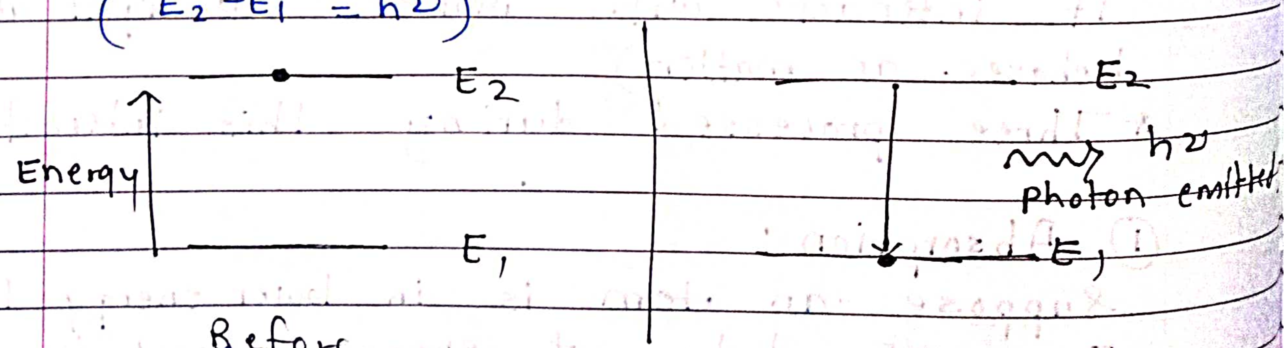
Absorption:

We can say that incident photon is absorbed by atom. Because of which atom will go to excited state (E_2) (due to extra energy from photon) Such transition is called as Absorption transition & process is called ~~as~~ Absorption.

(ii) Sponatanеous Emission:

When an atom at lower energy state is excited to higher energy state, it can not remain in that excited state for longer time.

In time about 10^{-8} sec. $- 10^{-10}$ sec, atom comes back to lower energy state by emission of energy $h\nu$ (photon energy) ($E_2 - E_1 = h\nu$)



Emission of photon occurs on its own & without any external ~~en~~ supply of energy given to excited atom.

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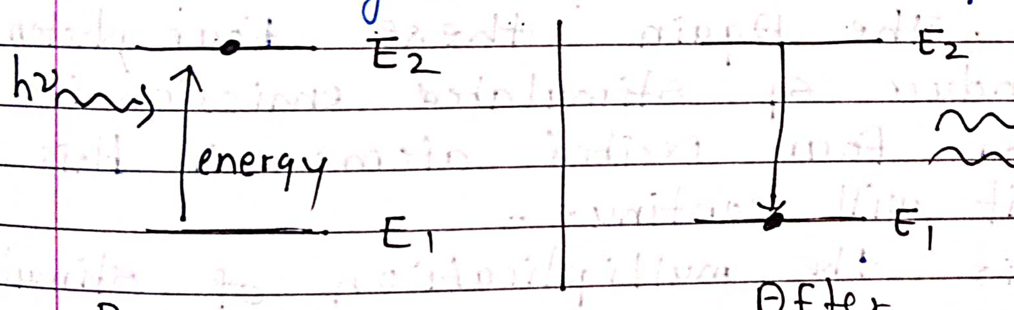
Such emission of photon by an atom without any external impetus is called "Spontaneous Emission"

- Process of spontaneous emission dominates in conventional light sources.
- Spontaneous emission is essentially probabilistic. The instant of transition, direction of emission of photon, phase of photon, polarization state of photon these are random quantities.
- Light emitted during spontaneous emission is not monochromatic & is incoherent.

(iii) Stimulated Emission :-

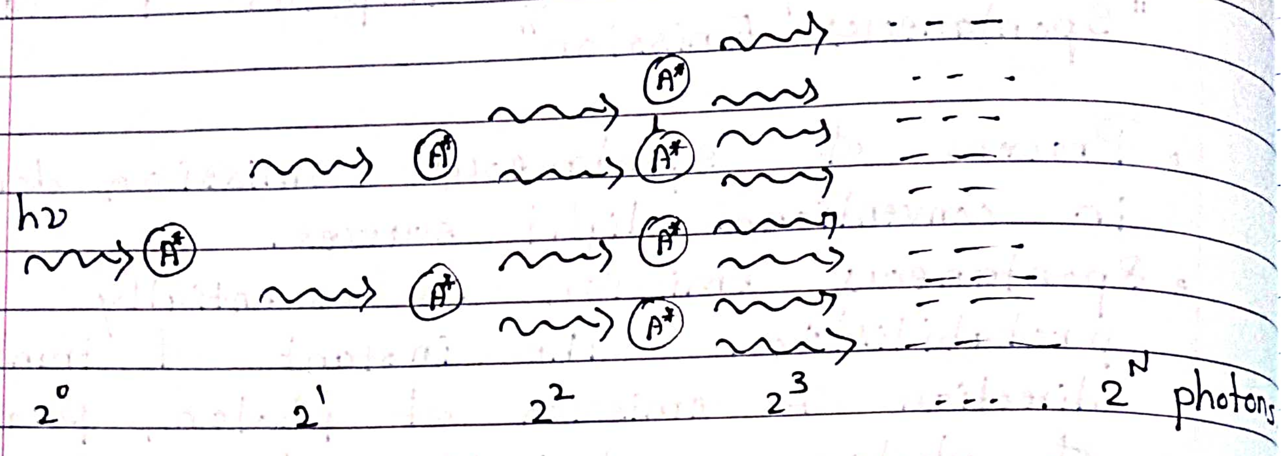
The atom in excited state is forced to return back to lower energy state. Atom in excited state, when photon of energy $h\nu$ ($E_2 - E_1 = h\nu$) incident on it, it will come to lower energy state by emission of photons.



Before.

Phenomenon of forced photon emission by an excited atom due to action of an external agency is called "Stimulated Emission"
Also known as "induced emission"

* Multiplication of Stimulated Photons :-



(A^*) → Atom in excited state.
$h\nu$ → photon incident, ~~w~~ energy $= h\nu$.

- We have induced stimulated emission in one excited atom. Now this ~~emissi~~ will give two photons of energy '$h\nu$' (One from atomic transition & one from that incident photon.)
- Now, these two photons can ~~e~~ induce stimulated emission in two other excited atoms. After this you will have four photons. ~~The~~ Again these four photons will induce ~~st~~ stimulated emission in ~~fou~~ other four excited atoms. in this way it will continue..
- This is the multiplication of stimulated photons.
- All these photons will be in same direction ~~as~~ that of stimulating photon. Also they will have same frequency & plane of polarization as that of stimulating photon. This is outstanding feature of this multiplication of photons.

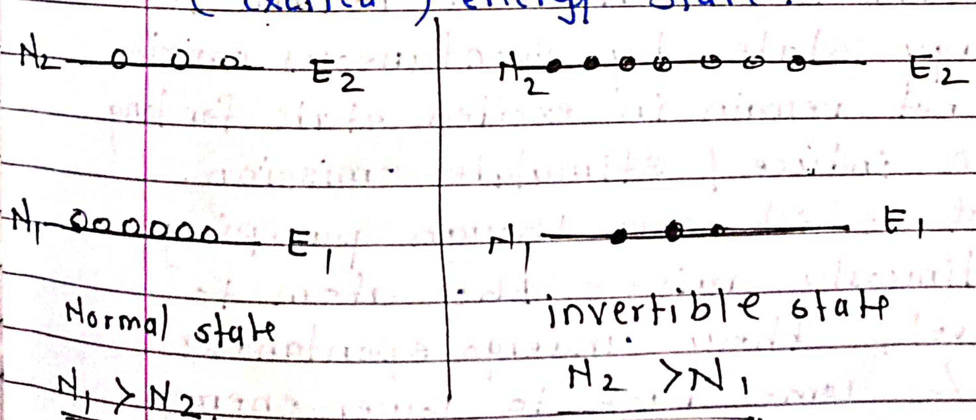
*Light Amplification :-

- When light will incident on matter (atoms) these three processes occur together (absorption, spontaneous emission & stimulated emission).
- Laser operation is achieved when stimulated emission exceeds in large way ~~other~~ than other two processes.
- So we will see the conditions under which number of stimulated transitions can be made larger than other two transitions.

* Conditions for stimulated Emission to Dominate Spontaneous emission :

① ~~Meta~~ Population Inversion :-

- For materials in thermal equilibrium number denisty (i.e. number of atoms per unit volume) for lower~~gy~~ energy state is more than that of higher (excited) energy state.



$N_1 \sim 10^{30} N_2$ ← The condition in which there are more number of atoms in lower energy state than that of higher

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energy state is called "Normal / Equilibrium condition / state"

- Population inversion is the condition of material in which population of upper energy level N_2 far exceeds the population of lower energy level N_1.

$$N_2 >> N_1$$

- This state is called "Inverted / Non-equilibrium state"

- This population inversion can be achieved using technique called "Pumping"

Before going to pumping methods Lets see next condition to get Laser action :

(ii) Metastable State :

- When an atom is excited to higher energy state by supplying external energy. But it can not remain in excited state for longer time (~ nanosec) & it will return to lower energy state by spontaneous emission.

↳ Atom do not remain in excited state for long enough to induce / stimulate emission.

- Because of which even though pumping agent continuosly raises the atom to excited level, they undergo spontaneous emission & come back to lower energy state.

- To achieve the population inversion condition excited atoms are required to "wait" (remain in excited state for longer time)

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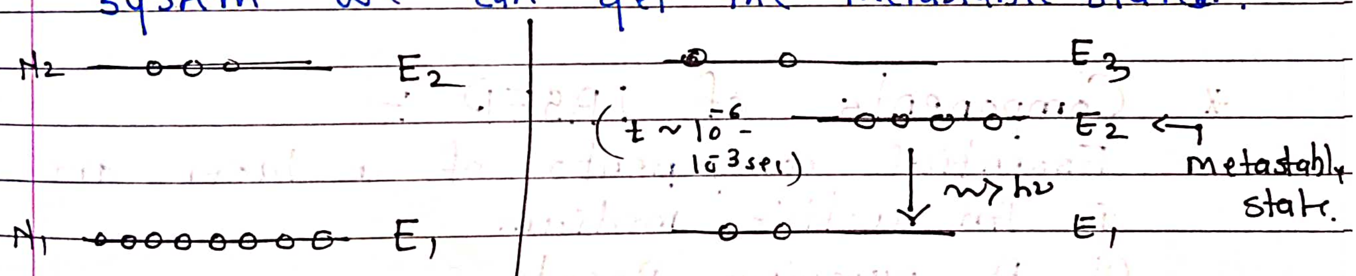
at upper energy level till a large number of atoms accumulate at that level.

- This can be achieved (atom can be made to remain in excited state for longer duration) by exciting / trapping the atoms in a metastable state.
- Atoms excited to metastable state, remain in excited state for duration of order of 10^{-6} to 10^{-3} sec i.e. 10^{3} to 10^{6} times the lifetime of normal excited states.
- Metastable states allows accumulation of a large number of excited at that level.
- The population of this metastable can exceed the population at lower level & estabilish the population inversion condition ($N_2 > N_1$)
- By adding impurity atoms to the crystal system we can get the metastable states.



Normal condⁿ | With the metastable state.

- As these metastable states have longer liftime ($10^{-6} - 10^{-3}$ sec) & there is no competition in filling these levels, ~~so~~ population inversion can be achieved.

* There could be no population inversion & hence no laser action, if metastable states do not exists.

(III) Confining Radiation within the medium:

- To get more stimulated emissions, we require more number of incident photons (in other words the high radiation density)
- We can increase this radiation density by enclosing the laser medium between a pair of optically plane parallel ~~planes~~ mirrors
- Due to rapid reflections of photons, from these mirrors, photons will remain in that laser medium & will induce more stimulated emissions (transitions)
- Such an arrangement of laser medium enclosed between mirrors is called as Optical Resonant cavity / Optical Resonator.

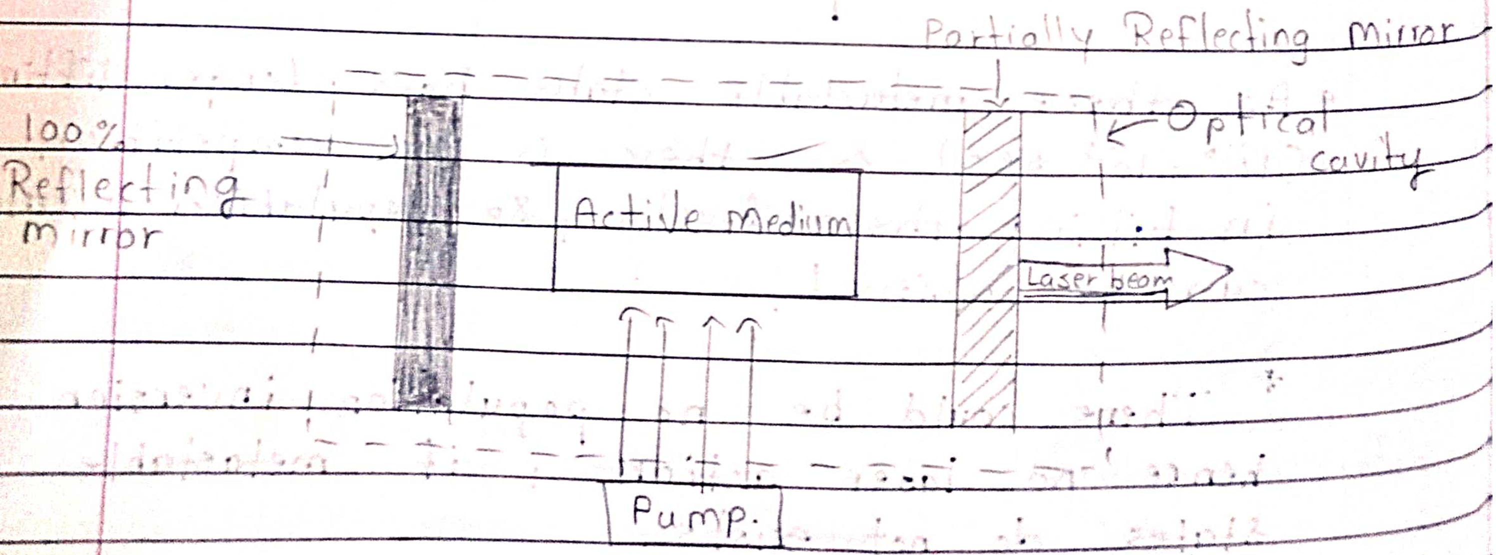
* Components of LASER :-

Essential components of a laser are

(I) An active medium

(II) A pumping Agent

(III) An optical Resonator



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(I) Active Medium:

- Material in which laser action takes place.
- Most important requirement for laser medium is that we should get population inversion in it.
- These atoms are characterized by large number of energy levels in general. But all ~~at~~ types of atoms are not sutaible for laser operation.
- Even in medium having different species of atoms, only a small fraction of atoms of particular type have energy level system which is ~~sut~~ suitable for achieving ~~laser~~ population inversion. Such atoms produce stimulated emission more than th. spontaneous emission.
- ~~Sch~~ Such atoms which causes laser action are called 'Active centres'
- Rest of medium acts ~~a~~ as host & support 'Active centres' that medium is 'Active medium'
- Active medium is medium which when excited ~~car~~ reaches the state of population inversion & promotes stimulated emission leading to amplification.

(III) An Optical Resonator :-

- Laser – light source analogous to an electronic oscillator.
- As we have seen, laser medium with & enclosed between two plane parallel mirrors form a resonating cavity / Optical Resonator.

- One of the mirror is partially reflecting & other is fully reflecting.
- Photons emitted during stimulated emission ~~are~~ when incident on mirror, get reflected back in medium & generate / induce more stimulated emissions in other atoms while moving towards opposite side mirror.
- In this way substantial light amplification takes place because the light beam is reflected several times at mirrors. Ultimately this amplified light will come out (emerges) as laser light.

* ~~In absence of laser light there~~

* In absence of resonator cavity, there would be no amplification of light.

- Also, optical cavity selects & amplifies only certain frequencies causing laser output to be highly monochromatic.

(11) A pumping Agent (The pump)

- To achieve & maintain the ~~p~~ condition of population inversion, we need to raise atoms from lower energy to higher energy levels continuously. So ~~wee~~ we need to supply energy to the system.
  This energy is supplied by the process of <u>pumping</u>.
- The pump is an external source that supplies energy needed to transfer the laser medium into the state of 'population Inversion.'
- We can ~~q~~ supply this energy in different forms like electric discharge, optical pumping

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* Lasing Action :-
Consists of following steps:
Step I :-
① Pumping :
- Atoms in active medium are initially in the ground state.
- By supplying energy from external source atoms are excited from ground level to excited state.

Step II :-
(ii) Population Inversion:
- The lifetime of excited states is very small ($\sim 10^{-9}$ sec). So, excited atoms drop spontaneously from excited state to a metastable state
- As lifetime of metastable state is longer ($\sim 10^{-6} - 10^{-3}$ sec), atoms go on accumulating at metastable ~~stable~~ state
- The number of atoms in metastable state exceeds number of atoms in ground state & population Inversion condition is achieved.

Step III :
(iii) Spontaneous Emission :-
- Some of the atoms in excited state can undergo spontaneous emission & emit photons in various directions.
- Photons emitted from these spontaneous emission can also induce stimulated (emission) transitions.
- Photons emitted during these transitions

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will also move in different directions many of these photons are lost out of cavity.

Step IV

(IV) Amplification:

- The majority of photons traveling along axis in the cavity cause stimulated emissions & these photons will be reflected back by mirrors.
- During their path between two ~~reflected~~ ~~mir~~ reflecting mirrors, they will induce more stimulated transitions in atoms.
- So the amplification of photons will take place.
- Thus mirrors provide positive feed back of light into the medium so that stimulated emission sustained & medium operates as an oscillator.

Step V

(V) Oscillations:

- At each reflection at front-end mirror light is partially transmitted through it.
- This transmitted component is nothing but loss of energy from resonator.
- When the losses at the ~~from~~ ~~front-end~~ mirrors & within medium balance the gain, a steady & strong laser beam will emerge from front end mirror.

* Pumping Methods
- To create the state of population inversion in an active medium, atoms in material have to be excited / pumped to ~~a~~ particular energy levels.

Most common methods of pumping :-

① Optical pumping:
- In this method, atoms are excited / pumped to higher ~~ge~~ energy levels by providing external energy in the form of light (photons).
- Photon of energy equal to energy difference bet^n those levels is incident on the material.
- Optical pumping is suitable for any laser medium that is transperent to pump light.
- Optical pumping is used in solid state lasers.

⑪ Electrical pumping:
- Electric discharge is used to provide energy to pump atoms of medium.

It can be used only in case of laser materials that can conduct electricity without destroying lasing activity.

This method is limited to gas lasers.

In gas lasers, a high voltage pulse initially ionize ~~at~~ gas so that it conducts electricity. An electric current flowing through it excites atoms to higher level from where they drop to metastable level leading to population inversion.

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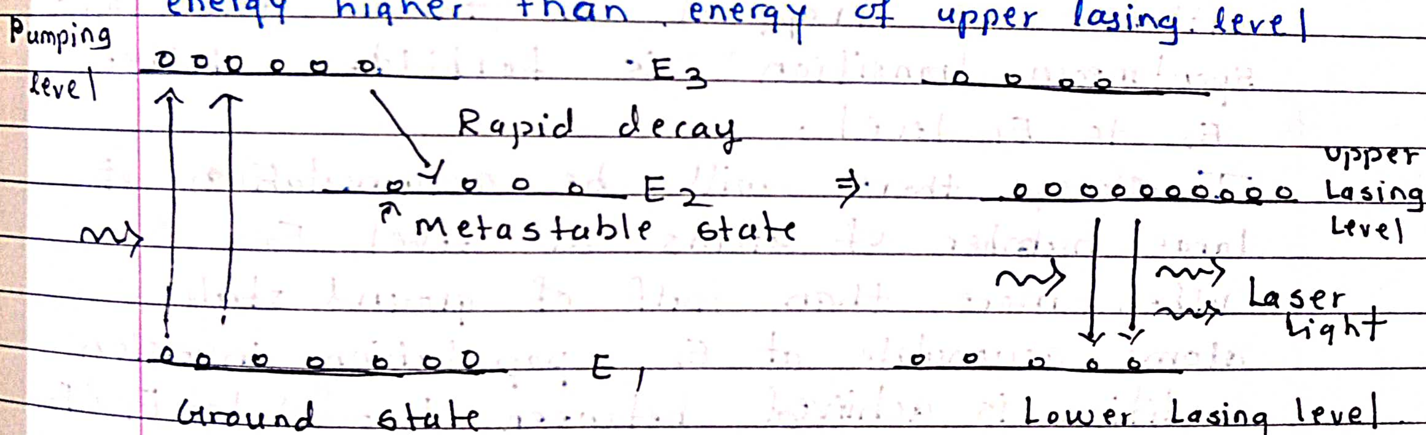
* Principal Pumping Schemes:

Atoms are characterized by a large number of energy levels. Among them only ~~2 - 4~~ 3 or 4 levels will be pertinent to pumping process.

- Two level scheme is not generally feasible for laser action. In two level scheme, there will be excited state & a groud state. We know, lifetime of excited level is very small hence atoms will not remain in excited state for long time & we will not get population inversion condition.

① Three level Pumping Scheme:

- In three level pumping, first atoms which are ~~excited~~ in excited state which has energy higher than energy of upper lasing level



- ~~The~~ As liftetime of these excited state is very small atoms undergo ~~radit~~ rapid decay & comes to upper lasing level. (metastable state)
- Pumped state should have shorter lifetime to undergo spontaneous emission compared to upper lasing state (metastable state)

- The upper laser state should have lifetime as long as possible so that atoms stay there long enough to be stimulated.

From above diagram:

$E_1 \rightarrow$ ground state

$E_3 \rightarrow$ Pump state

$E_2 \rightarrow$ upper lasing level (metastable state)

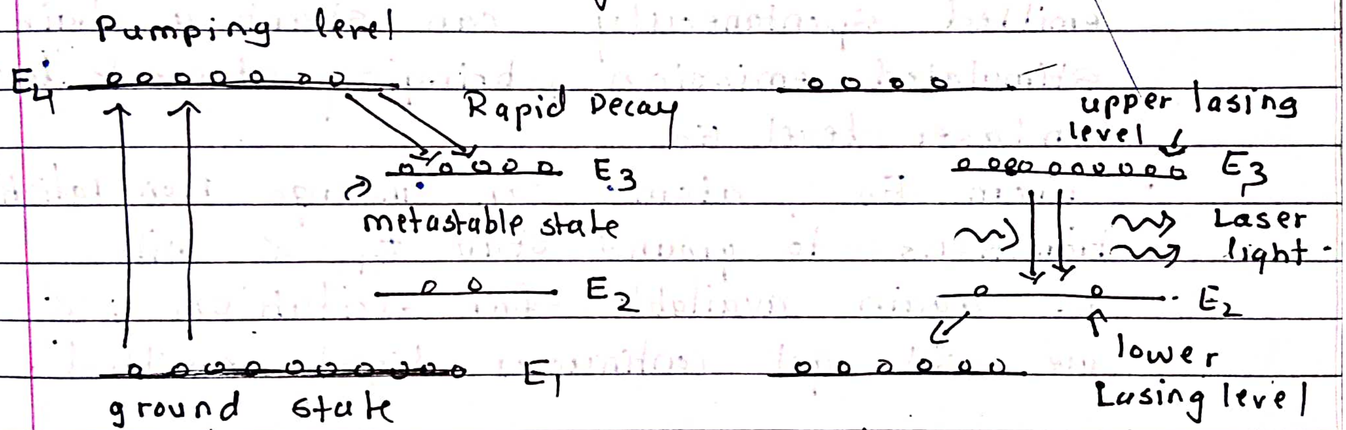
- When energy equal to difference in energy level bet^n E_1 & E_3 ($\Delta E = |E_1 - E_3|$) is provided, atoms will be excited to E_3 level
- However they do not stay at that level but rapidly undergo downward transitions to a metastable state E_2 level through non-radiative transition (without emitting any light)
- Atoms are trapped at this state since spontaneous transition is forbidden between E_2 to E_1 level.
- Therefore, there will be accumulation of large number of atoms at level E_2.
- When more than half of ground state atoms accumulate at E_2, population inversion condition is achieved between two states E_1 & E_2
- Incident photons will trigger stimulated emission & there will be stimulated emission/transition from E_2 to E_1

- In three level pumping, the terminal state of laser transition & ground state is same. Population inversion is achieved only when population of upper lasing level is more than half of ground state level population

- Hence scheme require very high pump power.
- Three level scheme produces light in pulses.
- After event of stimulated emission, metastable state is quickly emptied & population of ground state increases rapidly so population inversion ends.
- One has to wait till population inversion is re-estabilished.

Hence, three-level lasers operate in pulsed mode.

(ii) Four-level Pumping Scheme:



- $E_1 \rightarrow$ Ground state.
  $E_4 \rightarrow$ Excited state (pumping level)
  $E_3 \rightarrow$ metastable upper lasing level
  $E_2 \rightarrow$ Lower lasing level
- E_3, E_2, E_4 are excited states.
- When light of ~~ere~~ energy equl to energy difference bet^n E_1 & E_4 is incident on atom of lasing medium;
- Active centrs / atoms excite from ground state to E_4 level. As lifetime of this E_4 level is very small $\sim 10^{-8} - 10^{-9}$ sec, atoms quickly drop to upper lasing level /

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metastable state. (E_3)

- Spontaneous emission is not possible between levels E_3 & E_2. hence atoms get trapped in state E_3.
- Population of E_3 state increases rapidly. Level E_2 is well above ground state ($E_2 - E_1 > kT$) Hence, at normal temperature atoms can not jump from E_1 to E_2 on strength of thermal energy. As a result we can say E_2 is virtually empty.
- Hence population inversion is attained betn states E_3 & E_2
- A photon of energy ($h\nu = E_3 - E_2$) emitted spontaneously can start a chain of stimulated emission, bringing atoms to lower ~~en~~ laser level E_2
- From E_2, atom's can undergo non-radiative transitions to ground state E_1 & will be again available for excitation, & we will get continuous light emitted.

* Lower laser transition level in this scheme is nearly vacant. Hence less pump power is sufficient to achieve population inversion.

- Four level lasers operate in continuous wave (cw) mode.

* Types of LASER :-

(I) Solid-state Lasers :
Ex - Ruby laser, Nd:YAG Laser etc

(II) Gas Lasers :
Ex - Helium-Neon Laser, CO_2 Laser etc.

(iii) Semiconductor diode Lasers :
Ex - A GaAs Laser, InP Laser etc.

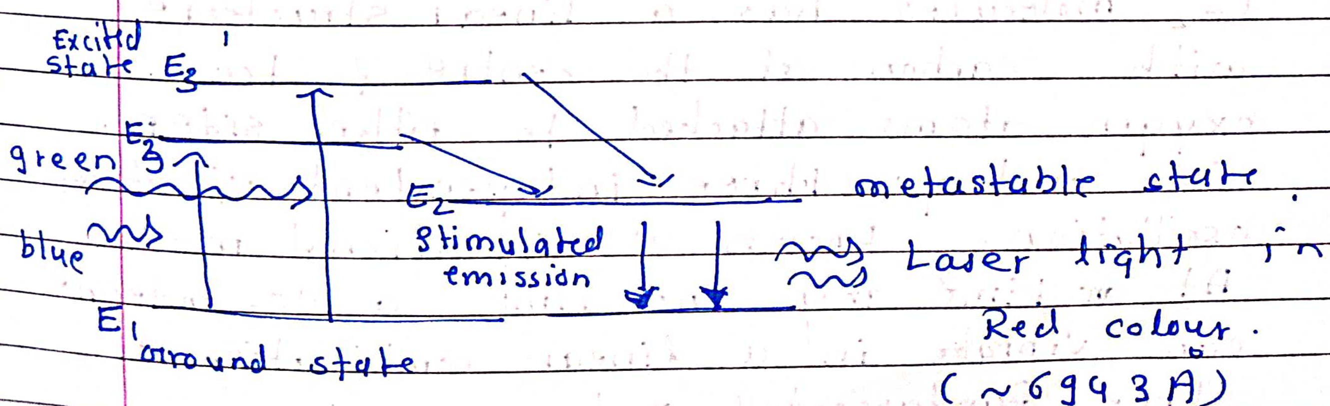
(I) Solid State Lasers :

(a) Ruby Laser :

- Ruby → Al_2O_3 crystal containing about 0.05% of Chromium atoms.
- Chromium (Cr^{3+}) ions → Active centres.
- Al & oxygen atoms are inert.
- Cromium atom absorption bands are in blue & green regions.

Construction:
Cylindrical rod of about 4 cm length of Ruby, & 1 cm diameter.
End surfaces polished (one is partially reflecting & other fully reflecting) & these are grounded.
- Laser rod is surrounded by a helical photographic flash lamp filled with xenon.

Cr^{3+} ions in crystal act as active centres

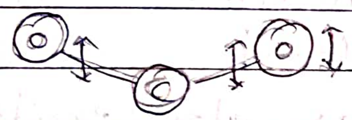


Features of Ruby lasers:
(i) Uses three level pumping scheme
(ii) Cr^{3+} ions are active centres
(iii) Light from xenon flash lamp is pumping agent.
(iv) Poor efficiency
(v) Operates in pulsed mode

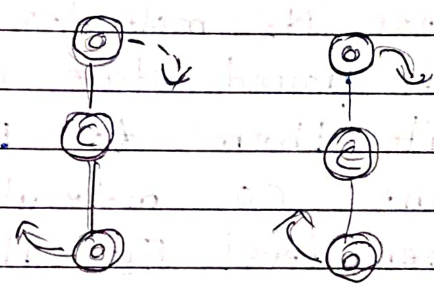
* Gas Lasers:
* Carbon Dioxide Laser:
Energy levels of CO_2 :-
As we know, inside an atom there are atomic energy levels.
For molecules (combination of two / more atoms) in addition to electronic energy levels, other energy levels are also present.
In a molecule atoms are not stationary but the atoms are continuously vibrating & rotating about each other.
Because of these vibrations & rotations molecule possess vibrational & rotational energy levels.
In case of CO_2 molecule:
CO_2 molecules has a linear structure with carbon at the centre & two oxygen atoms attached to either sides.
CO_2 undergo three independent vibrational oscillations known as vibrational modes.
At ~~an time~~ any one time, a CO_2 molecule can vibrate in a linear combination of three fundamental modes.
Energy states of molecule are represented by three quantum numbers (m, n, q).

These numbers represent amount of energy associated with each ~~of~~ mode.
Ex number (020) indicates that molecule in this state is in pure bending mode with two units of energy.
There are rotational states corresponding to each vibrational ~~state~~.
Seperation between vibrational - rotational states are much smaller than seperation between electron energy levels.
Nitrogen molecules is also characterized by similar vibrational levels.

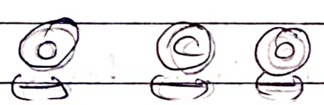
stretch mode



Bending Mode

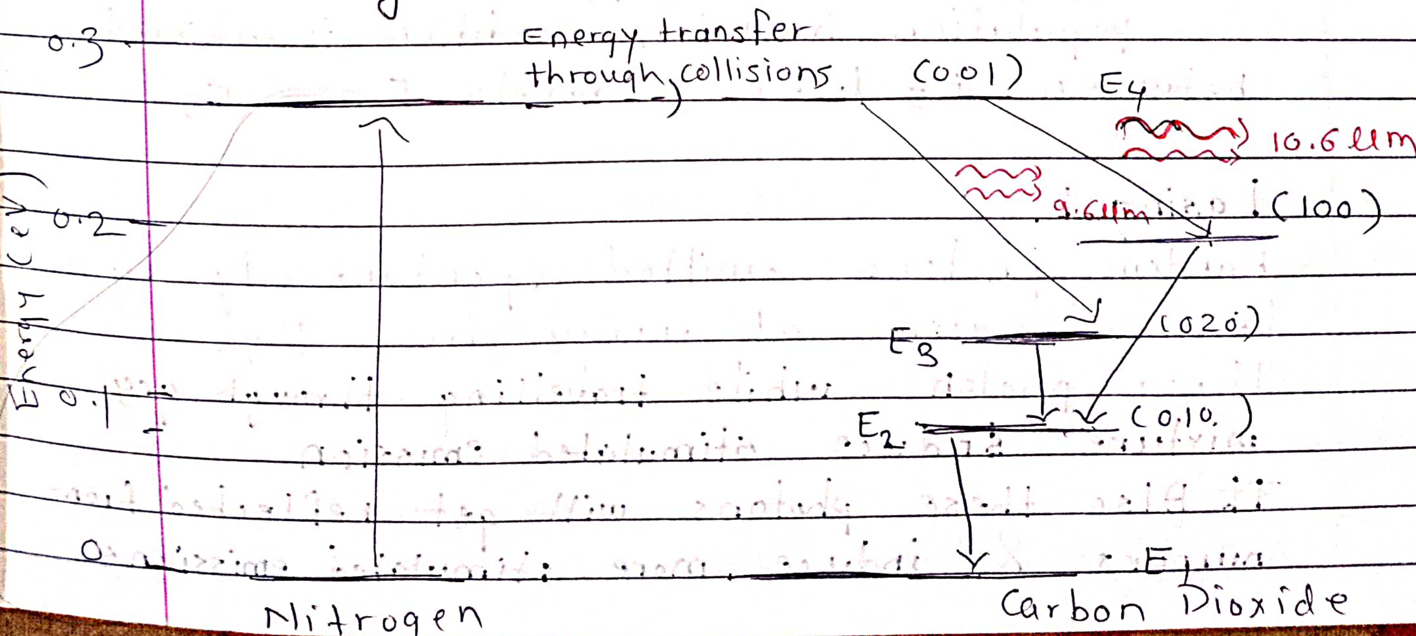


Rotational mode



Assymetric mode
mode

* Working of CO_2 Laser :-



In the above diagram, lowest vibrational level of ground state electron energy of CO_2 & N_2 molecules are shown.
Excited state of N_2 is metastable state & is identical in energy to (0 0 1) vibrational level of CO_2

Pumping mechanism :-
When a current is passed through mixture of gases, N_2 molecule get excited to metastable state (life time is more).

- The N_2 molecules in metastable state cannot lose their energy & hence number of N_2 molecules at metastable state buidds up.
- These N_2 molecules undergo inelastic collisions with ground state CO_2 molecules & excite them to E_5 level

Some CO_2 molecules are also excited to upper level E_5 through collisions with electrons.
The E_5 level is upper lasing level while E_4 (1 0 0) & E_3 (0 2 0) acts as lower lasing levels.
The population of CO_2 in upper level E_5 increases & population inversion condition is achieved between E_5 level & levels E_4 & E_3.

Lasing :

- Random photons emitted spontaneously by a few of atoms at energy level E_5.

These photons while travelling through gas mixture induce stimulated emission
~~Th~~ Also these photons will get reflected from mirrors & induce more stimulated emissions

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Number of Stimulated photons travelling along optic axis (cavity) increases & photons travelling at angles to axis are lost.

Population inversion achieved between levels E_5 & E_4 & E_5 & E_3.

Laser transition between $E_5 \rightarrow E_4$ levels produces far IR radiation at wavelength 10.6 μm (1,06,000 Å).

Laser transition between $E_5 \rightarrow E_3$ levels produces far IR radiations at 9.6 μm (96,000 Å) wavelength.

E_3 & E_4 are also have lifetime more (metastable) & CO_2 molecules at these levels fall to lower level E_2 through inelastic collisions with normal (unexcited) CO_2 molecules. Because of which accumulation of CO_2 at E_2 level starts.

Due to IR radiations, mixture of gases heats up & E_2 level is close to ground state level. Due to this thermal energy atoms will remain in E_2 level instead of going to ground state level.

Hence there is a problem for de-excitation of CO_2 molecules & inibits laser action.

We use Helium to de-excite these CO_2 molecules from E_2 to E_1 by inelastic collisions of He atoms with CO_2 atoms.

It also helps in cooling the gas mixture heated due to IR radiation.

Thus CO_2 molecules are once again available for excitation to higher state & participate in laser action.

CO_2 molecules are excited to upper lasing level continuously through collision. The population inversion can be maintained & there will be continuous emission of laser light & hence laser operates in continious wave mode

* Salient Features :
- CO_2 laser uses four level pumping scheme
- Active centres are CO_2 molecules.
- Pumping (external energy) is through electric discharge
- High efficiency (40%) & high power output (several kilowatts)
- Operates in Continuous wave (cw) mode.

* Semiconductor Diode Laser :-
- Semiconductors - materials having properties in between conductors & insulators eg Ge, Si
- At normal (temperature & all) conditions, semiconductors act as insulators.
- But properties of semiconductors can be enhanced / modified if we dope it with impurities.
- Depending on impurities added two types of semiconductors:

(I) N-type semiconductors :
- Impurity added to semiconductor is of pentavalent (5 e^- in valance shell)
- Electrons are majority carriers.

(II) P-type semiconductors.
- Impurity added to semiconductor is of trivalent (3 e^- in valance shell)

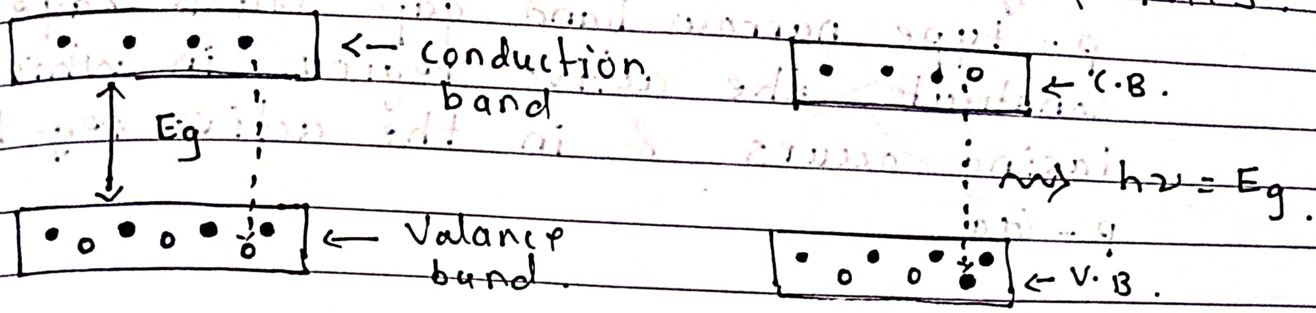
- Holes (absence of electrons) are majority corriers.

* Semiconductor Diode Laser:
- Specially fabricated p-n junction device, which emits coherent light during forward bias.
- R.N. Hall & his co-workers made 1st semiconductor diode laser in 1962.
Diode lasers are smaller in size (0.1 mm long)
Have high efficiency ~ 40%
Operate at low powers

* There are two types of semiconductor materials:
(I) Direct band gap semiconductors &
(II) Indirect band gap semiconductors
In Direct band semiconductors - electrons in conduction band recombine directly with holes in valance band
This recombination process leads to emission of light.
In indirect band gap semiconductors direct recombination of electrons from conduction band with holes from valance band is not possible
Silicon & germanium are examples.
Recombination of e^- & holes produces heat in these materials.

* Basic Principle of Semiconductor diodes:
- In semiconductors there are valance band & conduction band seperated by energy gap, E_g

Conduction band : contains electrons &
Valance band : contains electrons & holes.



• → Electrons &
o → holes.

- When a electron from conduction band jumps into hole of in valance band, Excess energy (Eg) is given out in the form of photons.

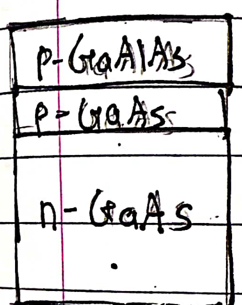
∴ Electron-Hole recombination is basic mechanism responsible for light emission.
& wavelength of light emitted is ⇒ $\lambda = hc/E_g$

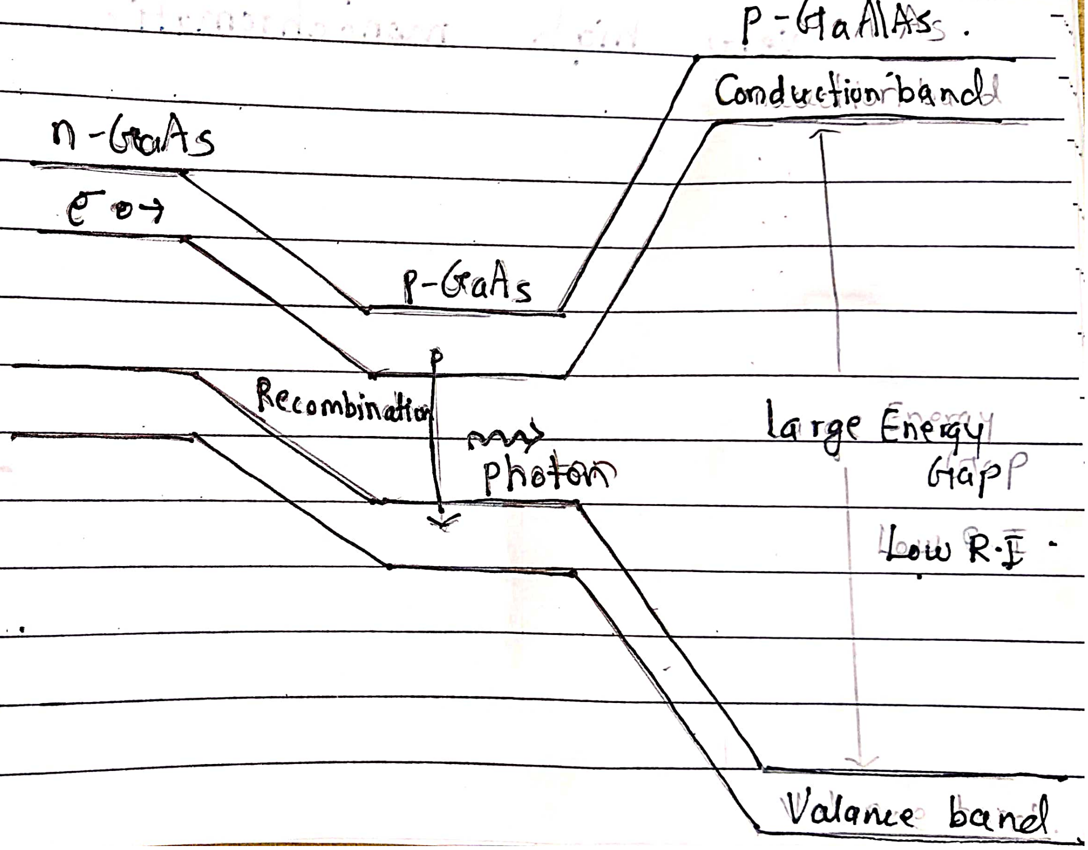
* Two types:

(I) Homojunction Semiconductor Laser
Same semiconductor material on both sides of junction
Ex – Gallium arsenide (GaAs) Laser.

(II) Heterojunction Semiconductor Laser:
Different semiconductor materials on both sides of junction
* Two subtypes:
Single Heterojunction & Double Heterojunction Semiconductor Lasers.

We are going to see Heterojunction semiconductor in detail:


p-GaAlAs
p-GaAs
n-GaAs


p-GaAlAs.
Conduction band
n-GaAs
e⁻ →
p-GaAs
Recombination
photon
large Energy Gap
Low R.I.
Valance band

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Single hetero-junction Laser :-

- Consists of Different materials on either side of active region.

Construction :-

- Fabricated using n-type GaAs & p-type GaAs semiconductors.
- Consists of three layers:
  (I) Substrate : n-type GaAs
  (II) Active layer : thin p-type GaAs in which laser action takes place.
  (III) An additional layer : p-type GaAlAs is grown over the top of p-type GaAs.

GaAlAs material has wide energy gap & lower refractive index.

- Boundary betn p-type GaAs layer & p-type GaAlAs is heterojunction.
- Top & bottom surfaces are metalized & metal contacts are provided to pass current through it.
- Front & back (rear) faces are polished which constitute optical resonator.

Working :-

Pumping is provided by Forward bias

* Population inversion & role of heterojunction:
- Thickness of active region is made small so that drive current required should be small.

- When we apply forward bias, electrons from n-GaAs layer move to active region p-GaAs.
- These electrons can not move to p-GaAlAs as band gap of p-GaAlAs is high ($\sim 2eV$) as compared to p-GaAs ($1.4eV$)
These electrons can not overcome that barrier & hence lots of electrongs get accumulated in p-GaAs (active layer) which also result in large number of holes in valance band.
∴ Population inversion is achieved quickly in active region

Spontaneous emission:
Recombination of electrons ~~in~~ & holes in active region leads to spontaneous emission of photons.
Stimulated emission:
These spontaneou emission photons can stimulate conduction electrons to jump into vacant states in valance bands & produce stimulated photons.
Cavity Resonator:
Reflection of photons from polished surfaces provide feedback for lasing action & laser oscillation starts.
After achieving sufficient strength, laser beam emerge out from diode

Advantages of heterojuction diode laser:-
(I) High efficiency
(II) Less operating current
(III) Continuous laser output

* Applications of Laser :-

① Holography :-

Technique that allows light scattered from an object & to be recorded & later constructed. It appears as if object is in the same position relative to recording medium as it was when recorded.
Image changes as position & orientation of viewing system changes in exactly same way as if object were still present, making recorded image (called holograph) appears three dimensional.

Difference betn holography & photography:
In photography there is point to point recording of intensity of light rays that forms the image.
In holography amplitude & phase of light are recorded by interference.

Use of Laser in Holography :-
Recording of image is based on interference principle
For interference we need a coherent source
Hence laser is used.

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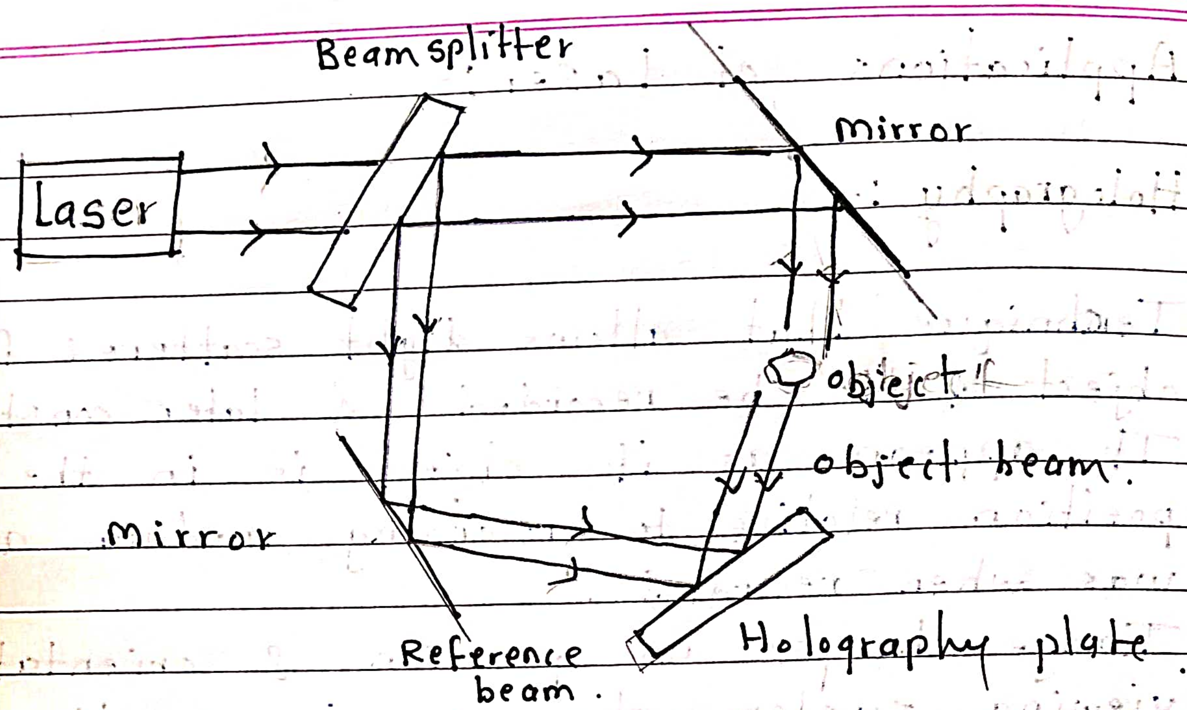


Components:
Laser source, a plane mirror / beam splitter, object & a photographic plate

Beam splitter:
Laser beam from a laser source is incident on beam splitter, beam splitter split the laser beam.

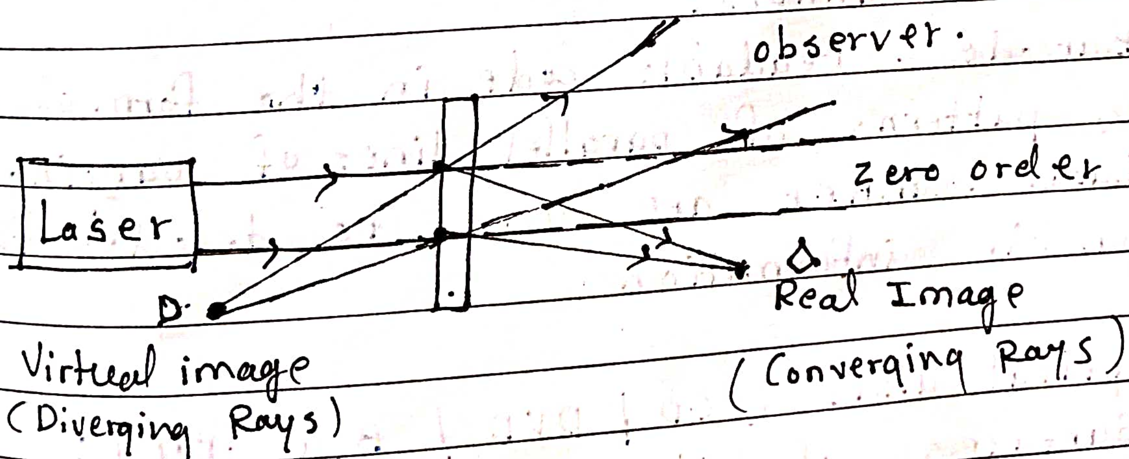
Reference beam:
One of the part of splited beam is incident on a mirror / photographic plate. There is no modification in properties of beam hence called "Reference Beam".

Object beam:
Other part of splited beam (transmitted part) get reflected from a mirror & then get incident on object & then it gets incident on holography plate Beam is called Object beam.

Interference :
Intereference of this object beam & reference beam occurs & give an interference pattern.

Photographic plate :
Interference pattern is recorded on a photographic plate. Photographic plate with recorded interference pattern is 'hologram' Photographic plate is also known as Gabor Zone plate in honor of Denis Gabor who developed the holography.
Each & every part of hologram recieves light from various points of object.
Thus even if hologram is broken into parts, each part is capable of reconstructing whole object.

Reconstruction of holograph



In reconstruction process, hologram is illuminated by a laser beam which is identical to reference beam source.

While passing through hologram, reconstruction beam undergo diffraction, which further produces real as well as virtual image of the object.

Real & Virutal image:
One of the diffracted ray coming out from hologram appears to diverge from an apparent object when traced back.
∴ Virtual image is formed behind the hologram at original site of object & a real image in front of the hologram
Hence observer sees light waves diverging from virtual image & image identical to object.
We get a 3 Dimensional image which is due to these real & virtual images.

(II) Information Technology :-
(1) Barcode Scanners:
Barcode :- readable code in the form of numbers & patterns of parallel lines of varying widths
Laser scanner are used to decode this barcode information.

(ii) Optical discs (CD / DVD / Blue-ray):
Surfaces of these optical discs contains one long spiral track of data.
Along this spiral track there are flat reflective areas & non-reflective bumps.
Flat reflective area represents a binary 1 while non-reflective bump represents binary 0

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When laser is incident on these optical discs, reflected light is detected & data stored in 1s & 0s.
For Audio CD use IR lasers, DVDs use a short wavelength red laser
Blue-ray disc uses blue-light to read & store data at an even higher density

(iii) Lasers are also used in printers | photocopy machines.

Industrial Applications:
(i) Welding:
Mostly used lasers - IR CO_2 & Nd:YAG lasers.
Main advantage of ~~laser~~ using lasers in welding is, it is contact less process, no chance of introduction of impurities.
Require less power for operation.
Reduce heat ~~po~~ losses at point of welding

(ii) Drilling:
(iii) Cutting:

Medical Field:
- Lasers are used for surgical removal of tissue. CO_2 lasers beams are strongly absorbed by water in the tissue & thus burn them.
- Eye surgery
- To correct visual defects
- To destroy kidney stones.
- Treatment of skin conditions, for removal of hair & wrinkles on skin.