LASER

LASER - Light Amplification by Stimulated emission of radiation

LASER is one of the most useful device in the Modern world which find its application in All types of field in this unit we are going to learn How Laser is produced?
How Laser can be used in industry?
How Laser is different from ordinary light?

Before that we are going to study few important terms.

Coherence - Two waves are said to be coherent if the phase diff. between them remains constant.

Coherence length & time - The distance and time upto which phase difference remains constant.

Energy levels of Atoms & Molecules.

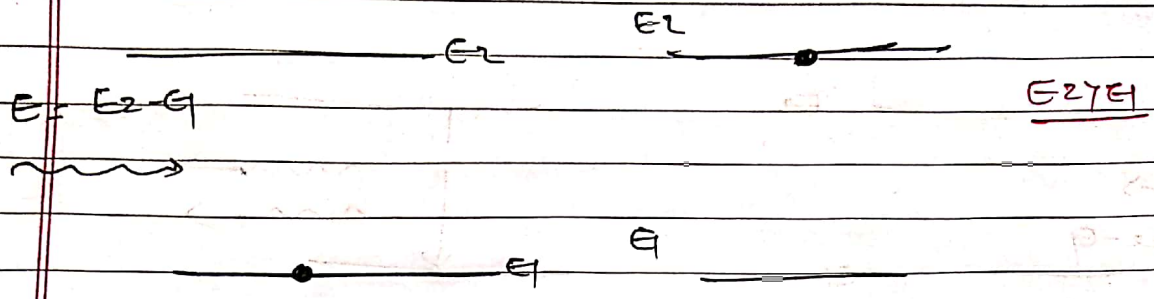
Ground state - state in which Atom can stay for infinite Amount of time
- Highly stable state.

Meta-stable state - Atom can stay in this level for 10^{-3} sec

Excited state - Atom can stay for 10^{-8} sec.
- Highly unstable state.

Apart from this Rotational, Vibrational and Electronic energy levels are also present.

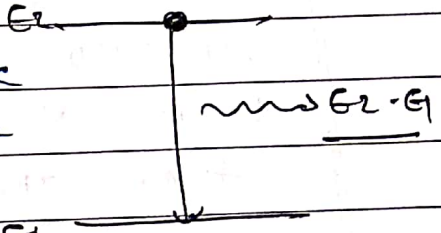
Stimulated Absorption - The process of raising atoms to an excited state by a photon.



When Radiation is emitted ?

Whenever an Atom/ Electron is in excited state makes Transition to ground state by emitting a photon of Energy E2 - E1 - emission takes place.

Spontaneous Emission of Radiation



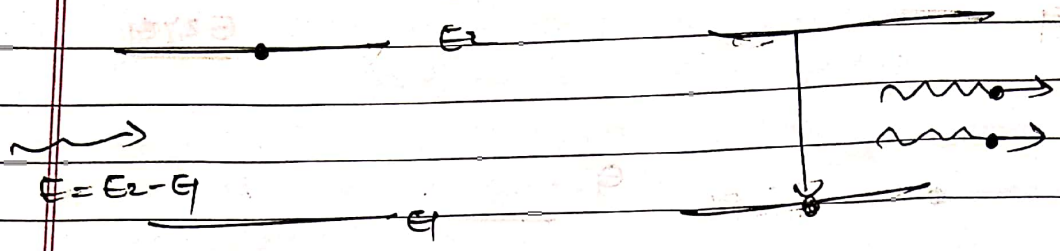
When an atom in its excited state E2 makes a Transition to the ground state E1 on its own without any external stimulus, this is known as spontaneous Emission.

Stimulated emission of Radiation.

If a photon having Energy E2-E1 interact with an atom in the Energy state E2, the photon forces the atom to undergo Transition

to the ground state E_1 giving 2 photons of same energy and frequency, Also both photons have same direction and are in phase with Each other.

- Stimulating photon / incidence photon $\Rightarrow E_2 - E_1$
- Emission photon / emitted photon $\Rightarrow E = E_2 - E_1$



Population Inversion.

Normally Let $N_1 = N_0$ of Atoms in ground state
$N_2 = N_0$ of Atom in Excited state

What we see Normally is $N_1 > N_2$.

population inversion is a state in which there is a large No. of Atoms in higher energy state than the lower energy state is called population inversion.

Population Inversion $\Rightarrow N_2 > N_1$, $E_2 > E_1$

Population inversion increases probability of stimulated emission For lasing Action population inversion is Nessesary.

Pumping.

The process of raising the atoms from ground state to higher Energy state by providing Energy to create population inversion is called pumping.

Types of pumping

Energy can be supplied to Atoms in diff. forms.

optical Pumping – light Energy from gas discharge is used to raise atoms to higher Energy state.

Electrical pumping The gas is ionized by applying a suitable potential difference across it. The Atoms in the ionized gas ~~collide~~ collide with free electrons causing transfer of energy.

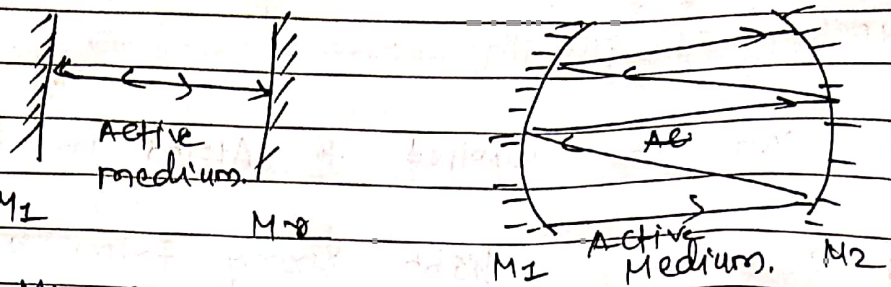
Chemical pumping. uses Exothermic chemical reactions to pump the Atoms to higher energy levels.

Resonant Cavity.

Resonant cavity consist of 2 parallel mirrors 1 Mirror is partially silvered through which light can pass. & other one is completely silvered so that light can be reflected towards Active

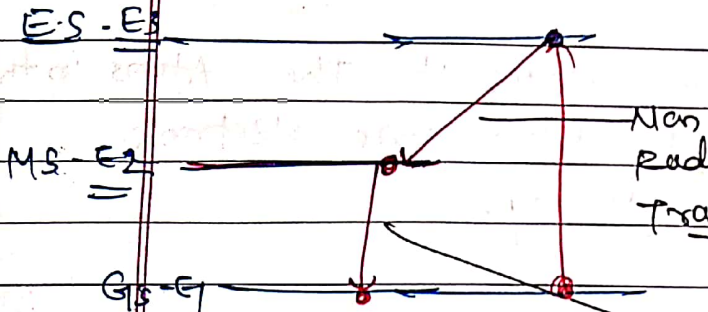
medium.

In between this 2 Mirrors Active Medium is placed from which we have to generate laser light



M1 & M2 are 2 Mirrors.

Levels of LASER SYSTEM

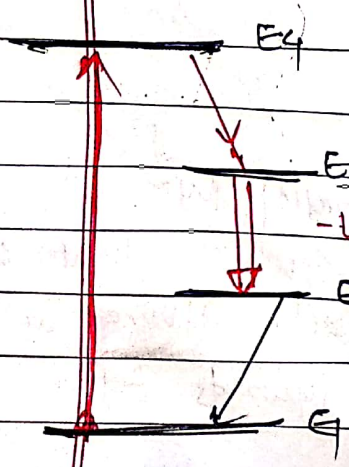


2 - Transitions

E3 - E2 - Non- Radiative

E2 - E1 - Radiative / LASING Transition

3 Level LASER SYSTEM



Transitions.

E4 - E3 - Non Lasing Transition.

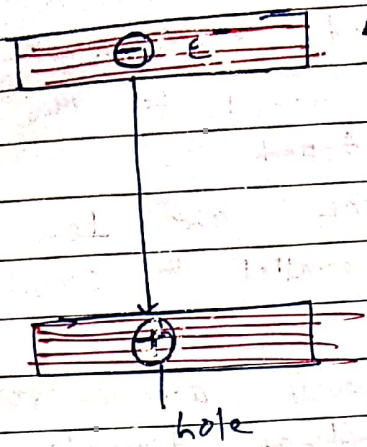
E3 - E2 - Lasing Transition.

E2 - E1 - Non - Lasing Transition.

FOUR - Level laser system.

SEMI-CONDUCTOR LASER

Concept



In Semiconductor whenever electron from ~~valence~~ C.B Band combine with hole in Valence Band The energy diff erence Ec - Ev is emitted in the form of Laser light.

Materials ~~of~~ ~~Se~~ for semi-conductor laser.

silicon & germanium - Radiation is in IR Region.

Gallium Arsenide / GaAsP - Radiation is in visible Region

Semiconductor laser can be of 2 types.

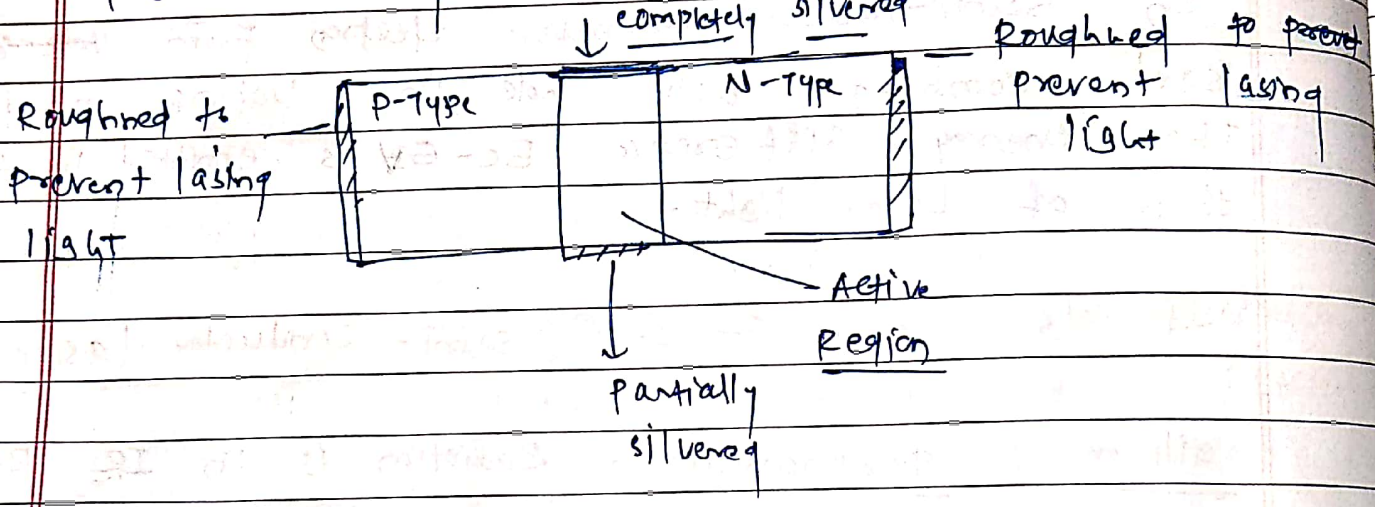
~~Homo~~Junction Semi-conductor LASER

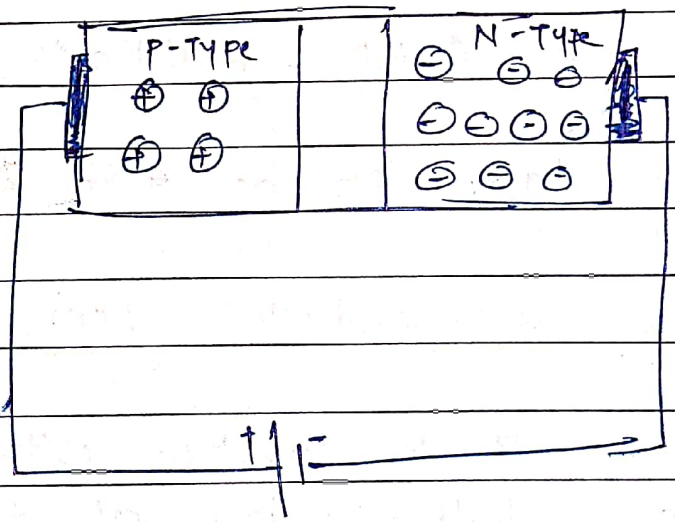
Consist of p-n Junction with the same Material on both sides of the Junction.

Construction

A p-type and N-type semiconductor obtained by doping with heavy Tri-valent & pentavalent doping joined to form p-n Junction Diode. Metallic contacts are provided to the p & N type in a heavily doped two opposite faces which are ter to Junction are polished & Made parallel to create resonant cavity.

The Remaining two faces are roughned to prevent Lasing Action in that direction.





Pumping Mechanism - Forward Biased | Electrical pumping

Active Region - Depletion Region.

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Date
Page

Working.

When the junction is forward Biased The width of depletion region decreases due to Injection of electrons and holes.

At low forward current The electron - hole recombination causes spontaneous emission is Acheived. As current increases and reaches a particular value known as Threshold value The state of population inversion is Acheived. due to large No of e^- & holes in CB & VB respectively.

Thus lasing Action Takes place in Active Region / Narrow Region.

The photon Traveling in the junction along resonant cavity stimulate Recombination of electron hole pairs due to which laser light intensity build up Along the Axis of cavity.

The laser escape through partially Silvered end.

Advantages

- low power consumption
- Compact
- highly efficient.

Disadvantages

- Less Monochromatic
- Light spread out due to diffraction effect while coming out of Depletion Region.
- More divergent compared to other.
- As Semiconductor is transparent, there is loss of light Energy through side faces.

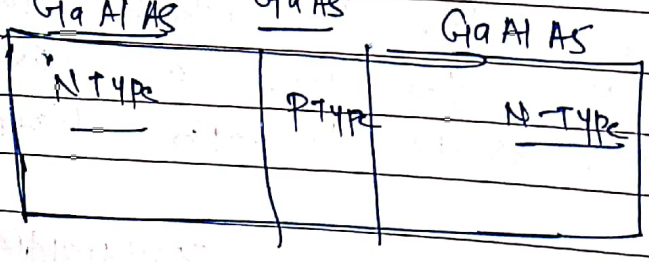
Hetro - Junction Semi - conductor Laser.

Consist of p-n Junction with different Materials on two sides of the junction.

Eg. GaAs GaAlAs - hetojunction.

Construction.

Low Bandgap Material like GaAs is sandwiched between two higher Bandgap layers like GaAlAs. Both layers have different refractive index. Middle layer have diff higher refractive index and outer layer has lower refractive index.



Electrical contacts are provided to the two extreme layers.

Working

- similar Working As that of Homo - Junction laser.

After applying forward Biase the injected charge carriers in the middle P Type layer cause population inversion, A photon produced by spontaneous emission triggers emission of photons by

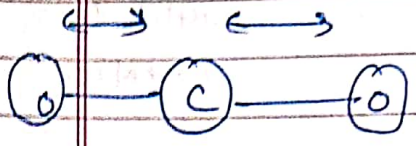
Stimulated emission.
The intensity of laser build up and it will come out from partially silvered end.
As middle layer has large refractive index than the two outer layers light is confined to the middle layer by total internal reflection.
Thus loss of photons / light energy is reduced.

Advantages - Less divergence compared to homojunction laser.
- ~~Most Mono-Chromatic compared to Homo~~

Carbon Di-oxide laser.

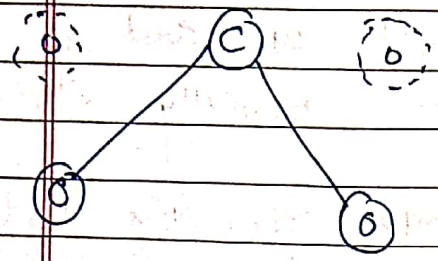
Carbon di-oxide laser makes use of transitions in the molecular vibrational and rotational level.

Vibrations of CO_2 Molecule / Modes of Vibration.



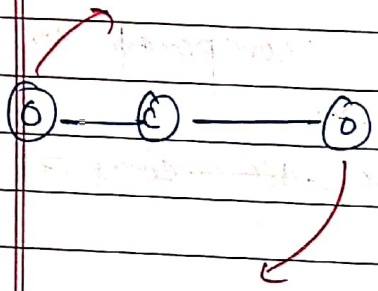
- Symmetric stretching mode
- Both O_2 Move towards or away from Carbon Atom.

- Asymmetric streching mode.
- one of the Oxygen atom move towards or away from Carbon atom.



- Bending mode.

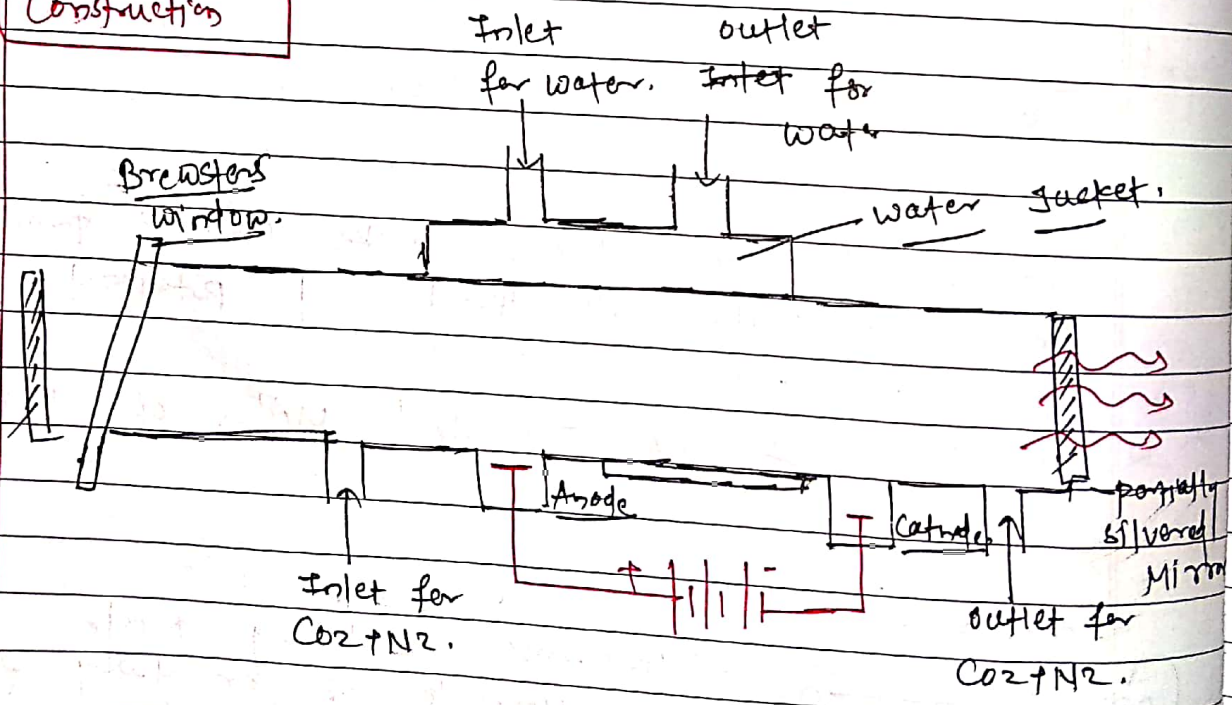
- 3 Atoms vibrate perpendicular to Axis of Molecule such that C- & O Atom move in opposite Direction.



Rotational Mode.

Co2 Molecule can Also Rotated.

Construction



Mixture of Co2, He & N2 is circulated in a glass tube which has two electrodes connected to a power supply.

One end of the tube has partially silvered Mirror and other completely silvered Mirror

is kept beyond the Brewsters window.

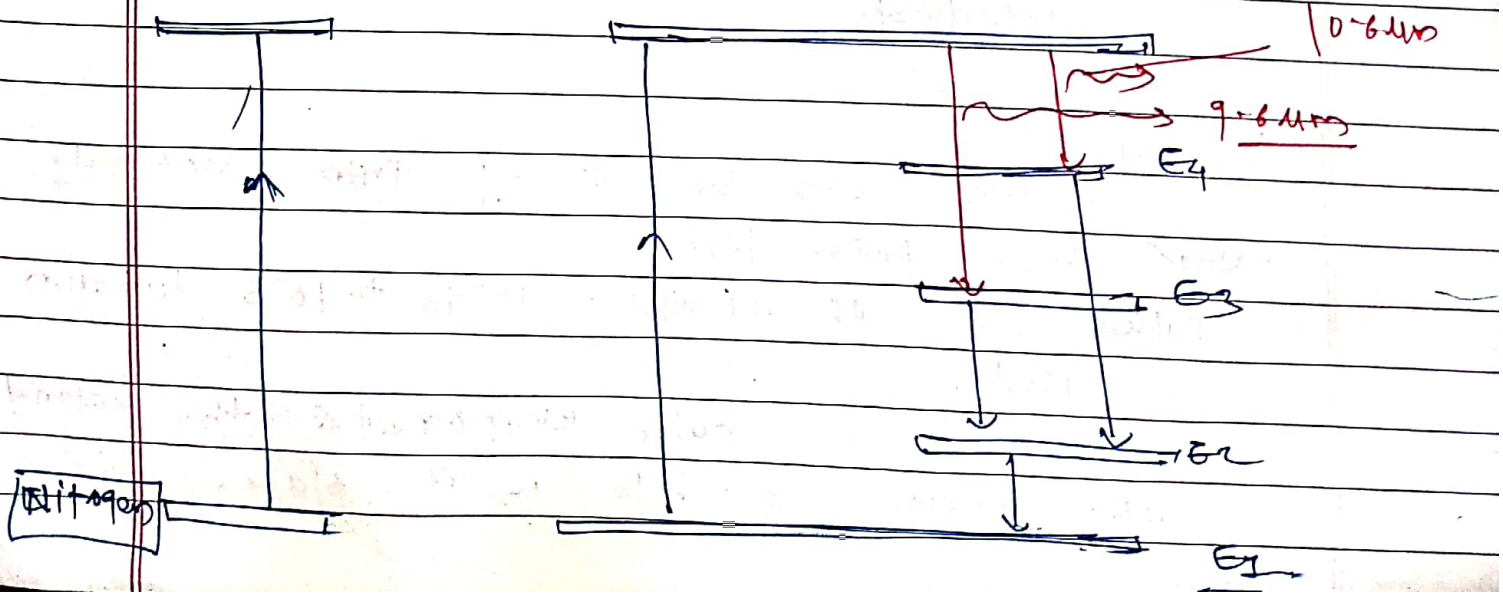
Working

High voltage - excite the gas Molecules.
N_2 - Molecule gets excited to higher level and transfer energy to CO_2 Molecules by collision.
The CO_2 Molecule then excited to the E_5 Meta-stable states. E_5 where population inversion takes place with respect to the lower lasing levels E_3 & E_4.

Thus, Transition $E_5 \rightarrow E_4$ - 10.6 μm - laser light.
$E_5 \rightarrow E_3$ - 9.6 μm - laser light.
both lies in IR Region.

Now role of Helium is to depopulate the lower energy levels in CO_2 which facilitates population inversion.

Advantages.
- High power o/p upto 10kw.
- High efficiency - 40%.



Characteristics of LASER

i) Mono-chromaticity.
ii) Coherence.
iii) Uni-directionality.
iv) Brightness.
v) Highly Energetic/ High energy.

Applications of LASER

A) **Welding**

Two Metal plates which are to be welded are held in contact at their edges. High power laser is focussed on the line of contact.

The Metal at the line of contacts Melt After cooling Metal gets solidifies which caus too Metal plates to stick together.

Advantages of LASER welding

⇒ Laser welding does not cause distortion of plates.

⇒ Contact-less procedure - No impurities ge introduced.

B) **Drilling.**

- Holes can be drilled into Materials using High power laser.

pulsed laser of duration 10^{-4}s to 10^{-3} durati is used.

The laser pulse evaporates the Mat which leaves a hole in its place.

Advantages of Laser Drilling.

- High degree of precision.
- Small holes of few microns can also be drilled.
- No vibrations will be generated.

Cutting.

Cutting of Metal sheets is provided using high power laser like Nd YAG or CO2 LASER.

A laser is focussed on the Metal sheet and a jet of oxygen is blown on the spot. A significant part of the energy required for cutting is supplied by burning of Metal in oxygen. The oxygen jet also blows away vapourized Metal.

Advantages

- High cutting speeds.
- High quality cut edges can be produced.

Holography

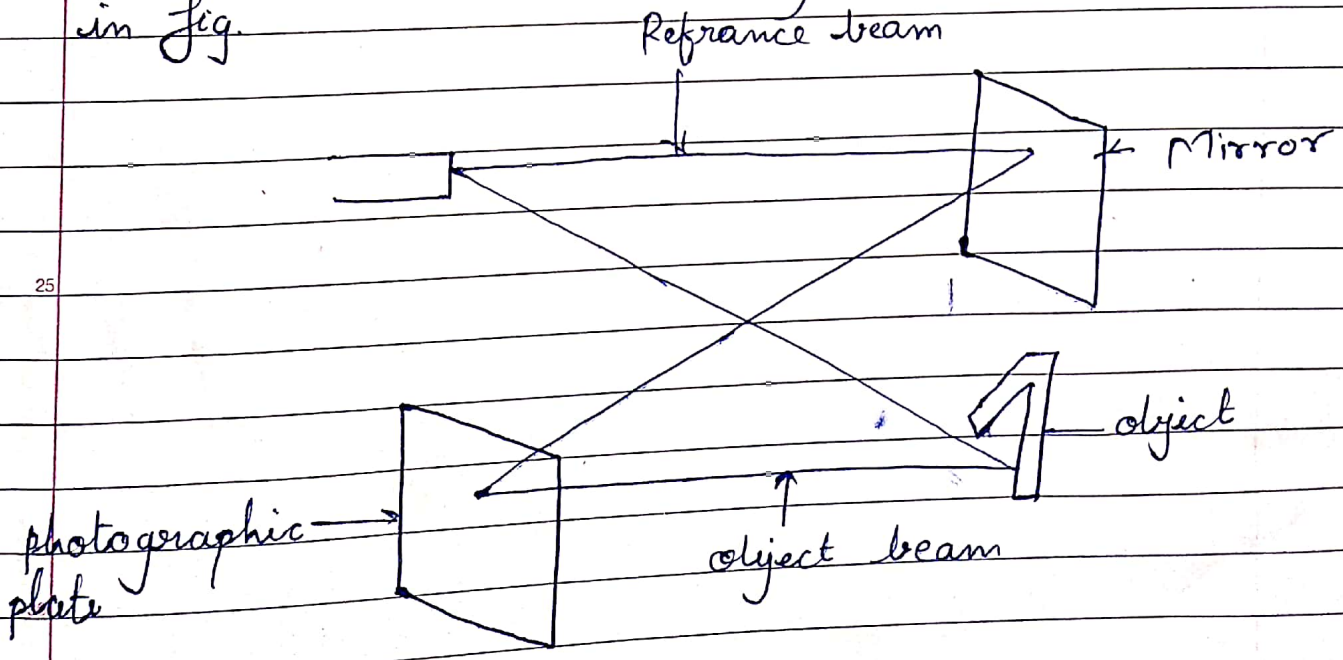
Holography	photography
3D Image is obtained	2D image is obtained.
Amplitude & phase both are recorded.	Amplitude is recorded only.
Highly Monochromatic light is required	Monochromatic light do not required.

Recording of Hologram

* Recording involves formation of complicated interference pattern.

, coherent light from laser incident on mirror and gets reflected known as refrence beam.
, coherent light from laser partly reflect from object know as object beam.

Interferance pattern of refrence beam and object beam is recorded on photographic plate as shown in fig.



Real image is inverted.

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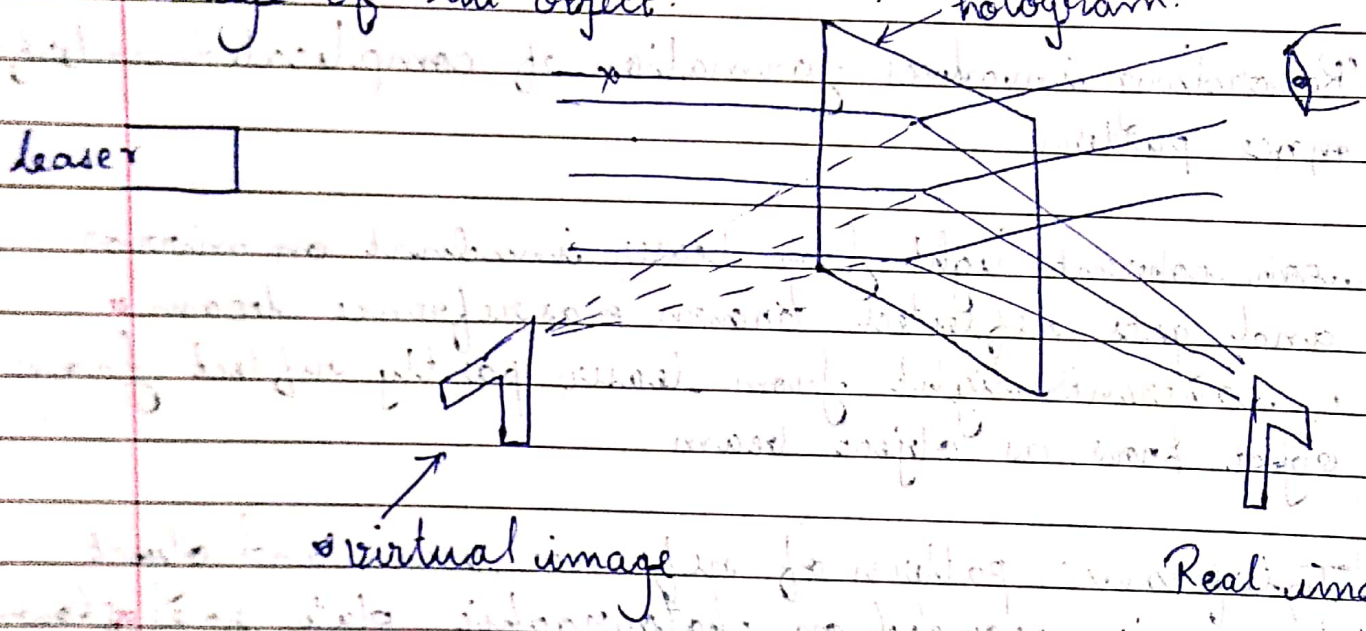
* Reconstruction of image -

To reconstruct image of object hologram is illuminated by reference beam. The hologram will act as refracting gratting.

one of the first order diffracted ray produces real and inverted image of object and other diffracted beam produces 3D virtual image of the object.



Real image of object is inverted, and virtual image is non-inverted.