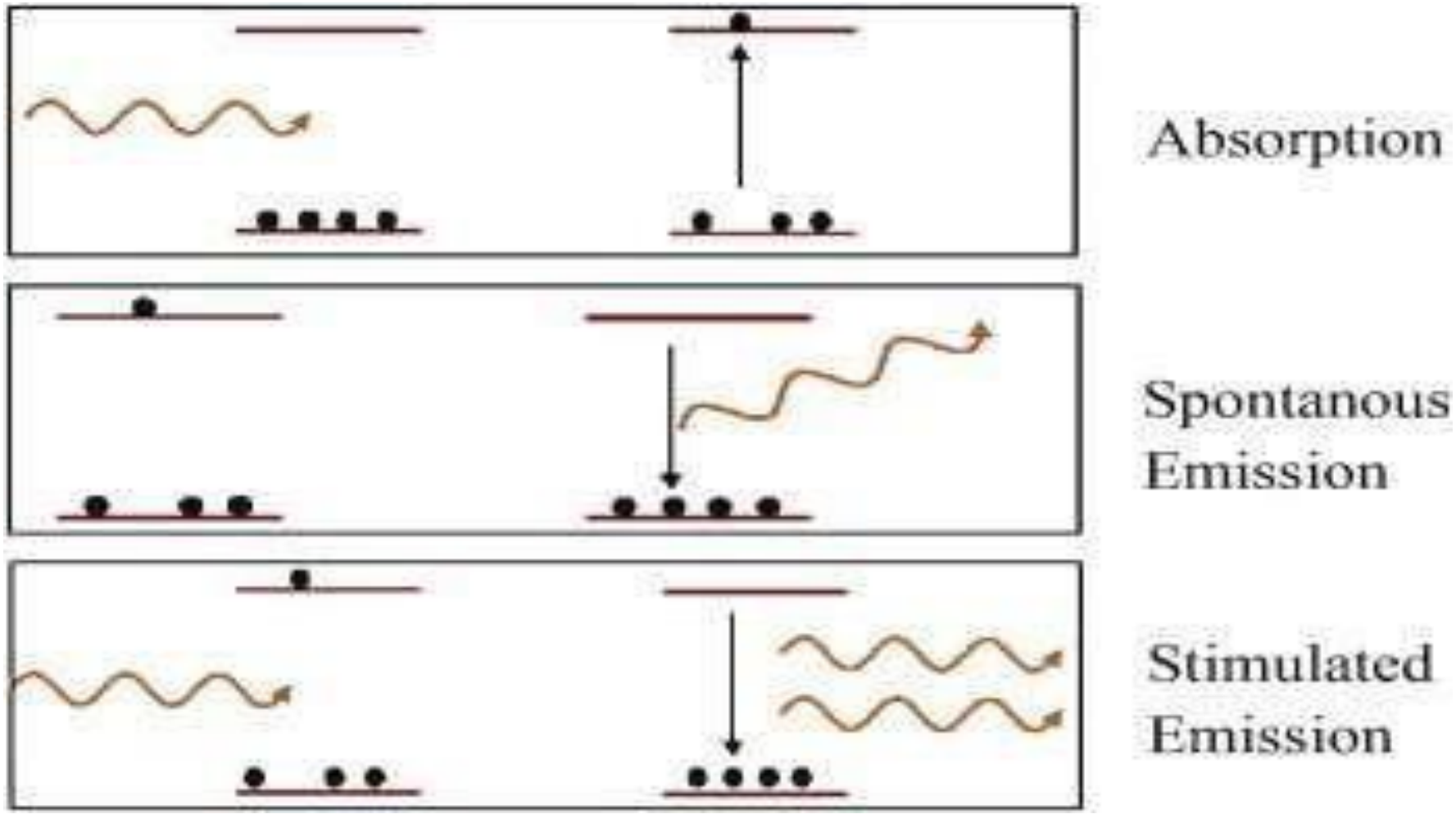
# LASERS AND ITS APPLICATIONS

# Introduction

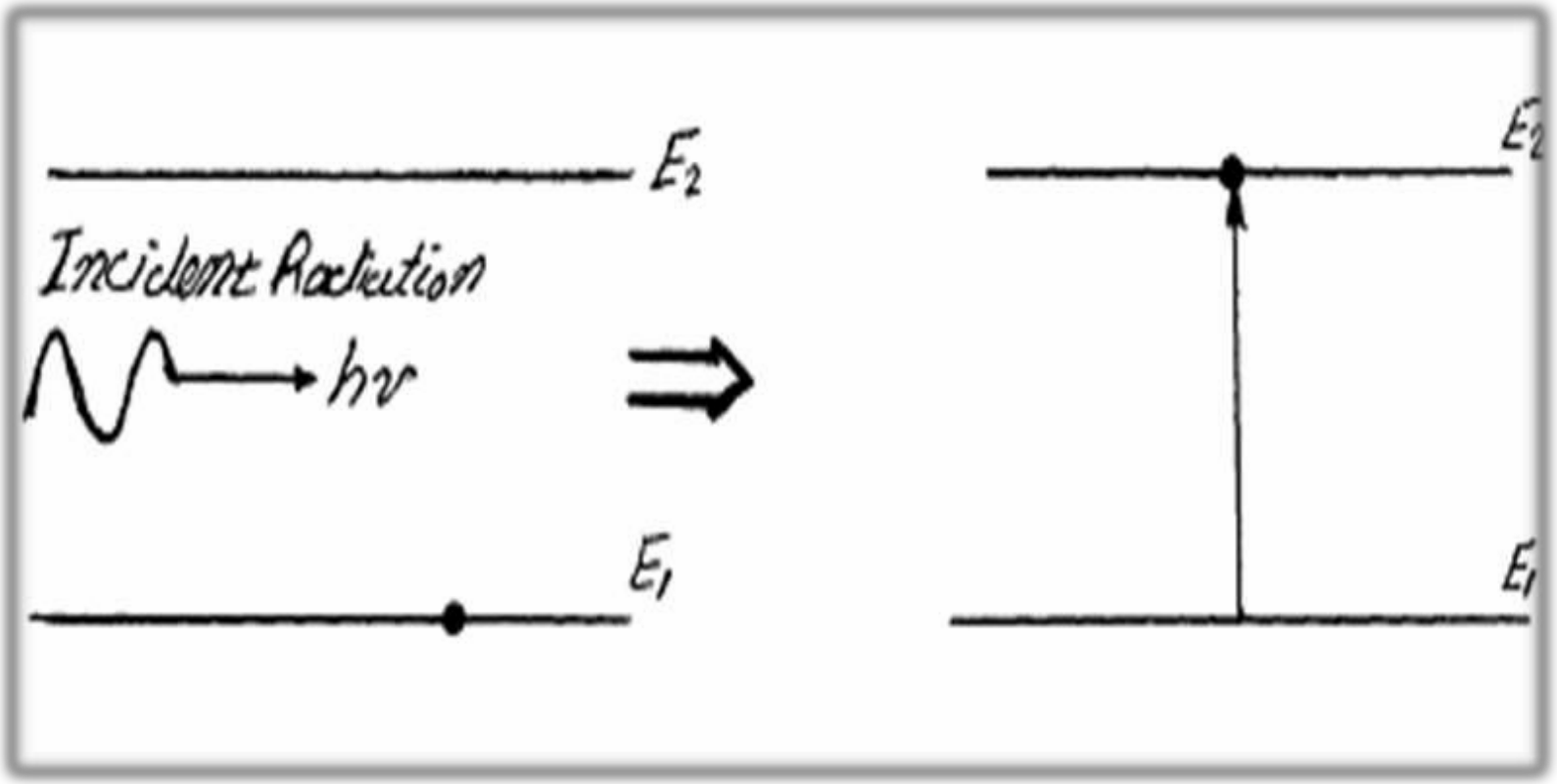
- The word laser is an acronym that stands for “light amplification by the stimulated emission of radiation”.
- Lasers are essentially highly directional, highly intense, highly monochromatic and highly coherent optical sources.
- Stimulated emission was postulated by einstein as early as in 1917.

- In 1960 , a solid state ruby laser is developed by maiman on this principle.
- In 1961, a gas state He-Ne laser is developed by Ali javan and others in Bell telephone laboratory.

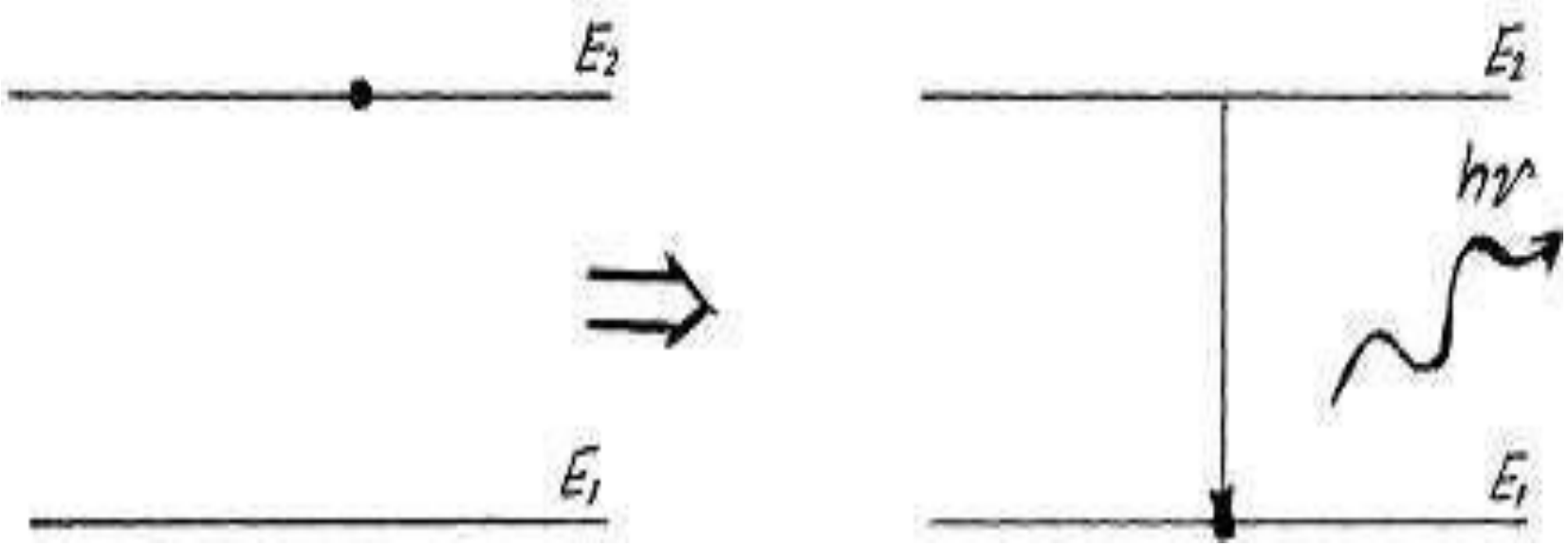
# Principle oflaser



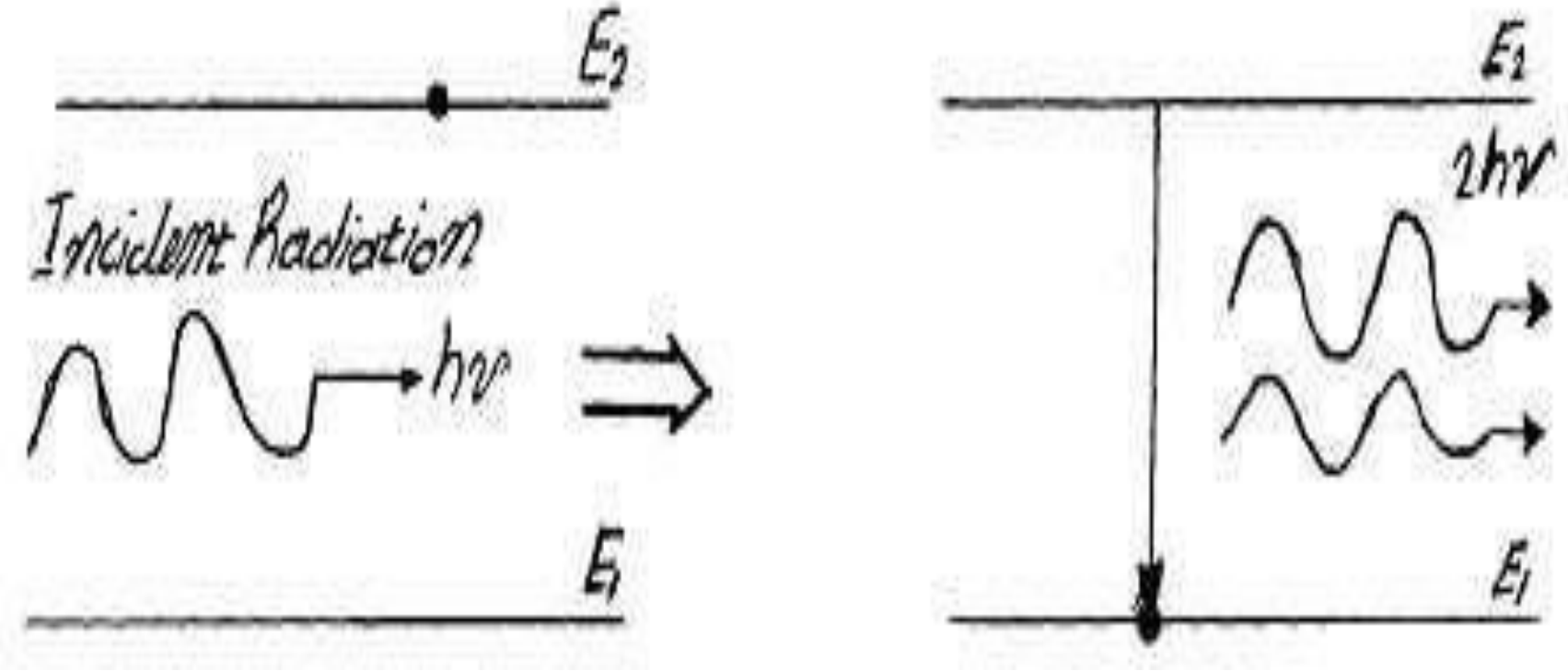
- The process of exciting the atom to higher energy level by absorbing the stimulating incident photon is known as stimulated absorption of radiation.



- The transition of an excited atom by itself to lower energy level is known as spontaneous emission of radiation.



- The excited atom after getting stimulated by the incident photon transits to lower energy level by emitting photons is known as stimulated emission of radiation.



| S. No. | Stimulated Emission | Spontaneous Emission |
|---|---|---|
| 1. | An atom in the excited state is induced to return to the ground state, thereby resulting in two photons of the same frequency and energy is called Stimulated emission. | The atom in the excited state returns to the ground state thereby emitting a photon, without any external inducement is called Spontaneous emission. |
| 2. | The emitted photons move in the same direction and are highly directional. | The emitted photons move in all directions and are random. |
| 3. | The radiation is highly intense, monochromatic and coherent. | The radiation is less intense and is Incoherent. |
| 4. | The photons are in phase, there is a constant phase difference. | The photons are not in phase (i.e.) there is no phase relationship between them. |
| 5. | The rate of transition is given by: $R_{ste} = B_{21}u(v)N_2$ | The rate of transition is given by: $R_{ste} = A_{21}N_2$ |

# 1.12 Laser Modes

A wave of frequency ν, that travel along the axis of cavity forms a series of standing waves within the cavity.

They are discrete resonant conditions determined by the physical dimensions of the cavity.

• Modes governed by the cross-sectional dimension of the optical cavity - Transverse modes

• modes governed by the axial dimension of the resonant cavity - Longitudinal or Axial modes

• In a cavity flanked by two plane parallel mirrors, the standing waves in the cavity satisfy the

condition. The axial modes contribute to a single spot of light in the laser spot.

## Pumping Schemes

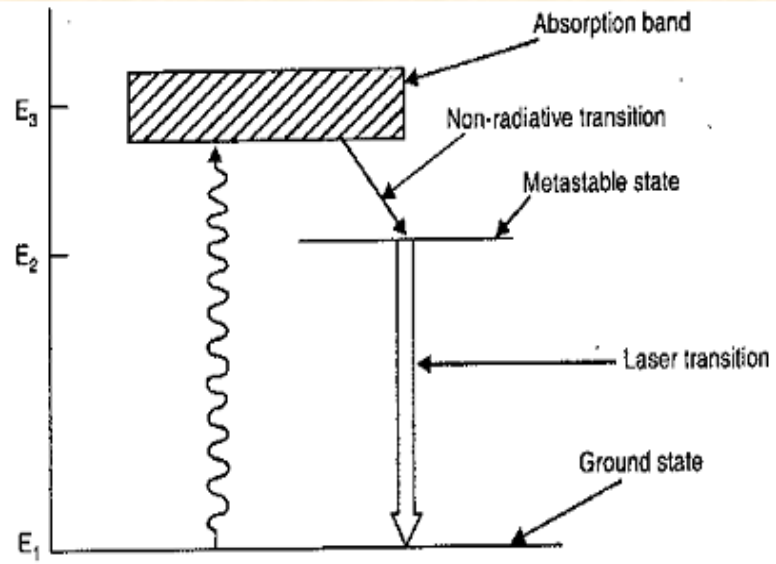
Atoms are characterized by a large number of energy levels. Only two, three or four levels are pertinent to the pumping process.

Types are

- Two-level,
- Three-level and
- Four –level schemes.

# Three Level Pumping Scheme

A three level scheme; Lower level is either the ground state or a level whose separation
from the ground state is small compared to kT as shown in figure below.




**$E_2$ – A metastable level**

- Atoms accumulate at level $E_2$
- Build-up of atoms at $E_2$ continues because of pumping process.
- Population $N_2$ at $E_2$ exceeds the population $N_1$ at $E_1$ and
  - ➢ **P.I. is attained.**

- A photon of hn(=E2-E1) can induce stimulated emission and laser action.

The major disadvantage of a three level scheme it requires very high pump powers.

- Terminal level of the laser transition is the ground state.
- As the ground state is heavily populated, large pumping power is to be used to depopulate the ground level to the required extent (N2 > N1)

- Three-level scheme can produce light only in Pulses.
- Once stimulated emission commences, the metastable state E2 gets depopulated very rapidly and the population of the ground state increases quickly.
- As a result the population inversion ends. One has to wait till the population inversion is again established.
- Three-level lasers operate in Pulsed Mode

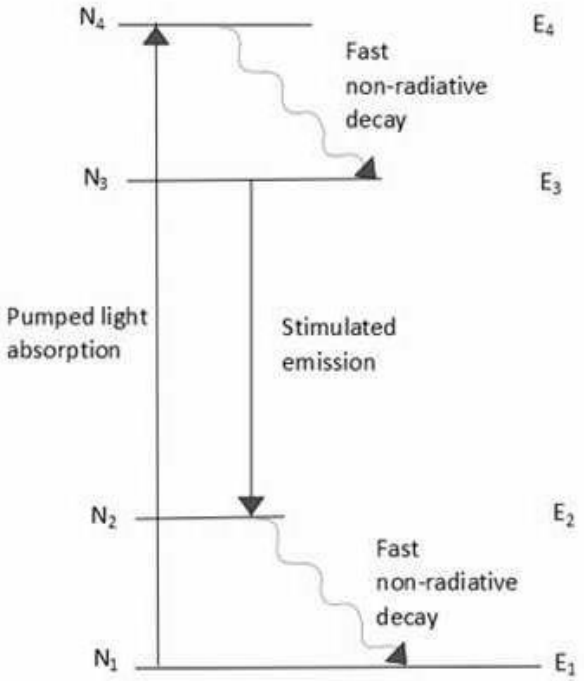
# Four level lasers

In a four level laser, there are fast, non-radiative transitions before and after the laser transition.

As in a three level laser, the initial fast decay causes population to build up at $E_3$.

After the laser transition to $E_2$, there is another fast decay to $E_1$. This keeps the population $N_2$ very low.

A population inversion between states 3 and 2 can be maintained with only a small fraction of atoms in excited states.

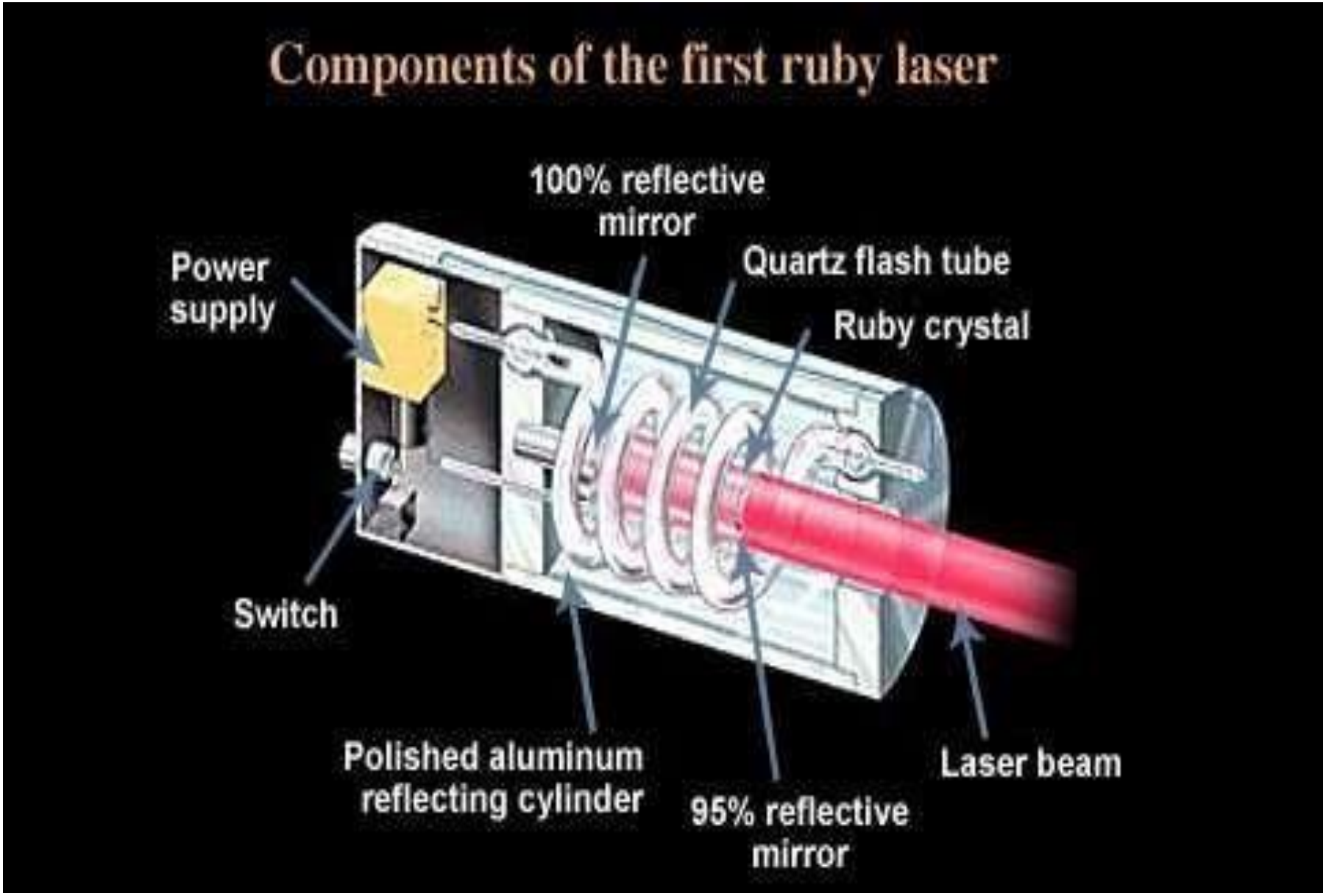


# Kinds of lasers

Among the various kinds of lasers some important types of lasers are listed below:

1) Solid state laser : Ruby laser
2) Gas laser : Co2 laser, He-Ne laser
3) Liquid laser : Europium chelate laser
4) Dye laser : Courmarin dye laser
5) Semiconductor laser : Inp laser

# Constructionandworking of rubylaser

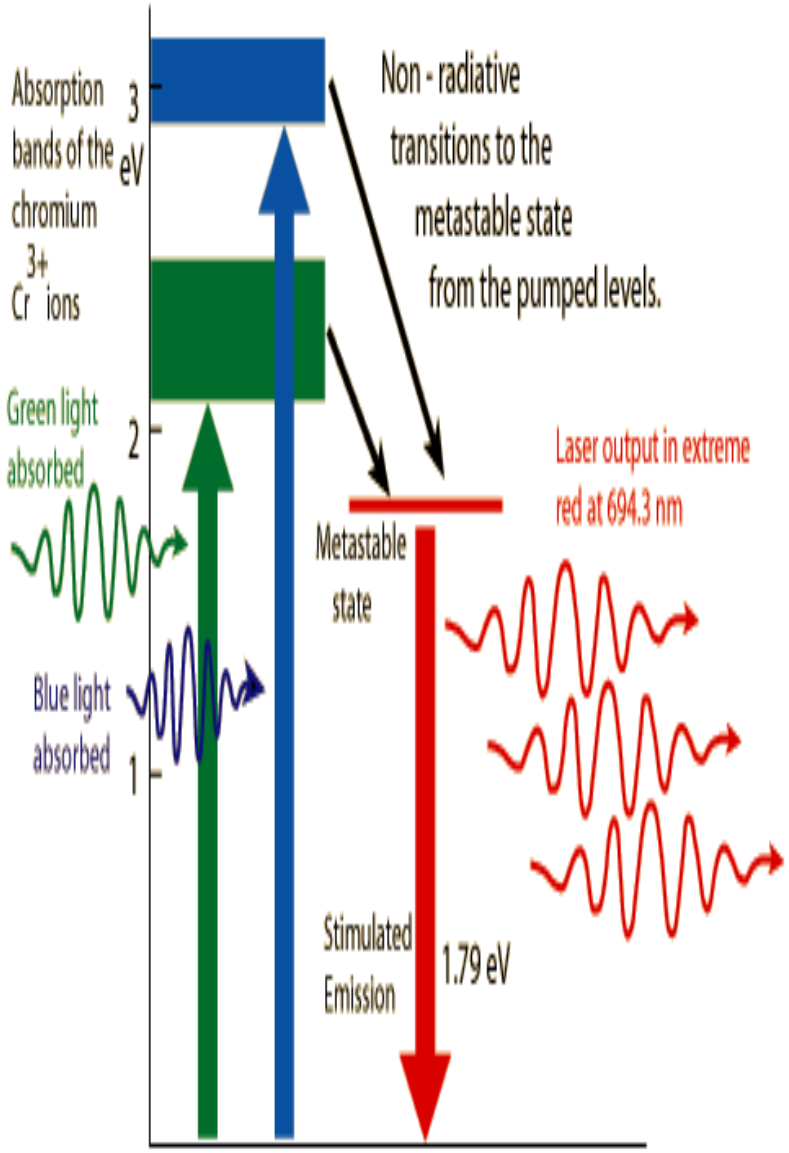


Construction :

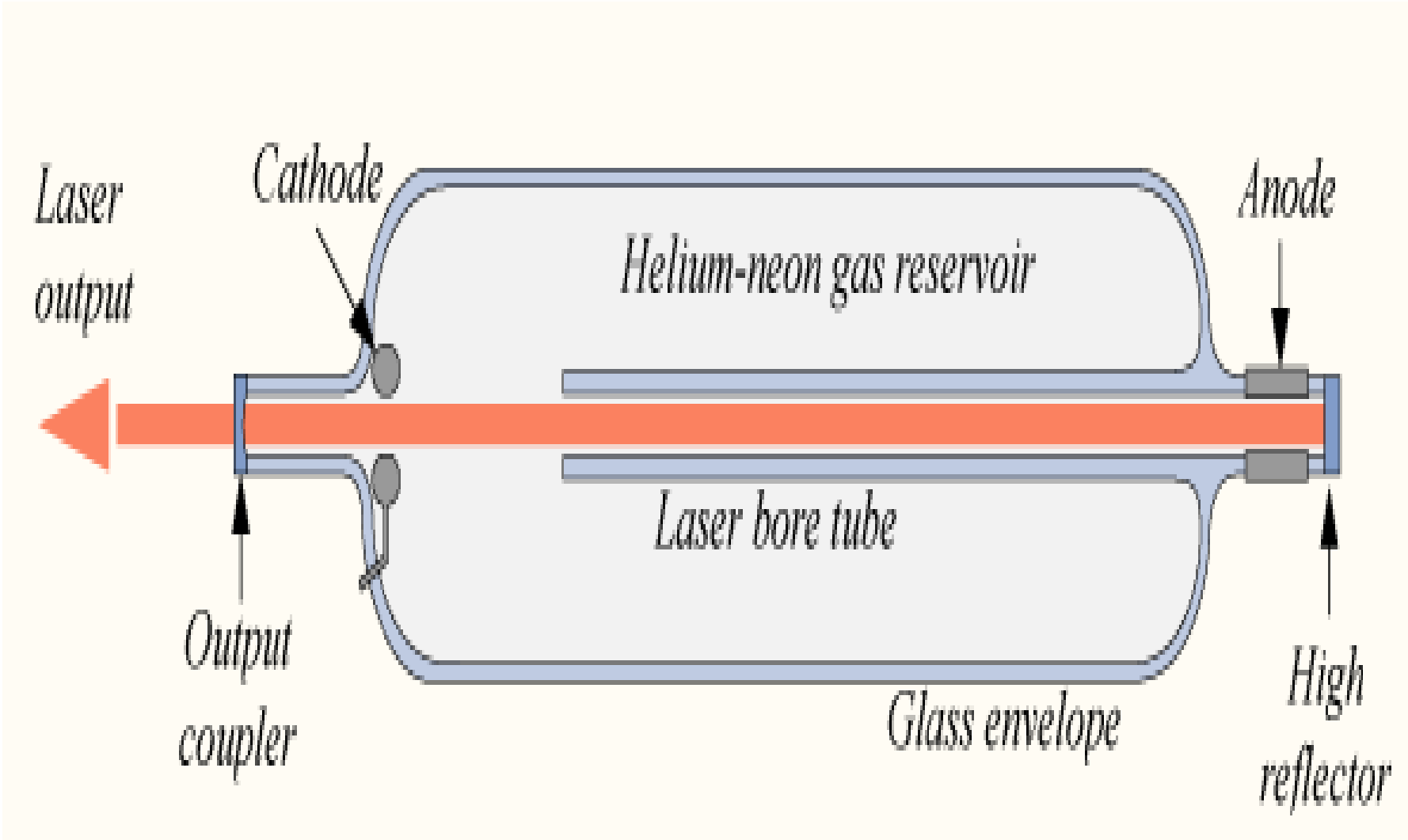
- In ruby laser a cylindrical ruby rod made up of aluminum oxide which is doped with 0.05% weight of chromium oxide.
- One end of rod is fully silvered and the other one partially silvered so it act as optical resonator.
- The rod is surrounded by a glass tube which in turn is surrounded by the helical flash lamp filled with xenon gas.

# Working:

- When the flash lamp light will be flashed on ruby rod the chromium ions excited to higher energy states.
- After staying for up to $10^{-8}$ second ions get transmitted to the metastable state.
- The laser radiation of a wavelength of $6943A^0$ and laser emission is pulsed one.



# Construction and working of He-Ne laser

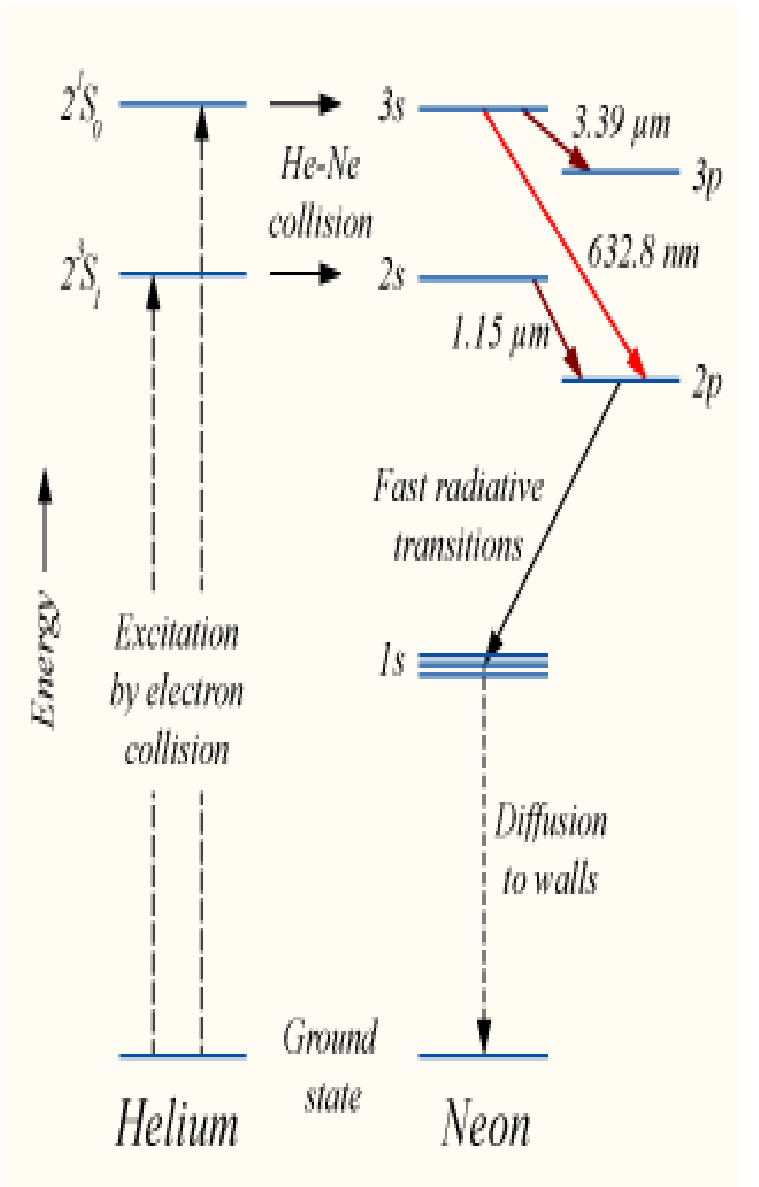


# Construction:

- A He-Ne laser consists of large and narrow discharge tube filled with helium a and neon gases in the ratio 10:1.
- The tube is enclosed between fully and partially reflective mirrors which serve as optical cavity.
- The two end windows are set at Brewster's angle, so reflected radiations enter into the tube become polarized.

# Working

- Helium atoms after transferring their energies to neon atoms are excited to 2s and 3s.
- The population in theses levels is more than those in lower levels 2p and 3p.
- The emission of radiation having wavelength $6328A^0$ is red in colour and it gives continuous emission of radiation.

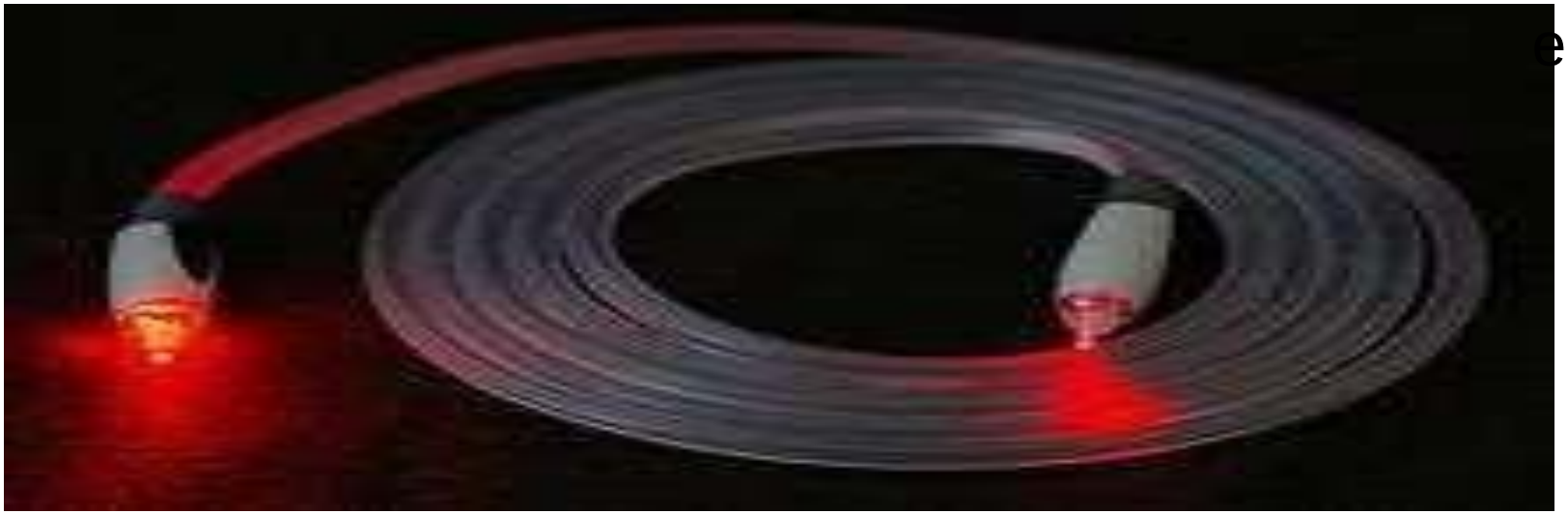


# Applications of lasers

## Lasers in communication:

In optical fiber communication laser bandwidth is very high compared to the radio and microwave communications.

- As it has large bandwidth,more amount of data can be sent.
- More channels can be simultaneously transmitted.
- lasers are also used in other communication



ers.

## Lasers in industry:

- Lasers can be used to blast holes in diamonds and hard steel.
- Lasers can cut,drill,weld, remove metal from surfaces and perform these operations even at surfaces inaccessible by mechanical methods.
- Lasers range finder is used to measure distance to making maps by surveyors.


- Argon and Co2 lasers are used in treatment of liver and lungs .
- New kind of laser surgery that uses molecules to stitch together wounds .
- Co2 laser is particularly used in spinal and brain tumour  excision and kidney stone extrusion.
- Lasers are used in the treatment of Glaucoma.

# Advantages of lasers

- Lasers are used to cut glass and drill holes in ceramics.
- Lasers are used for bloodless surgery and in destroying kidney stones and gallstones.
- Lasers are used to study the internal structure of microorganisms and cells.
- Lasers are used in air pollution, to estimate the size of dust particles.

# Disadvantages of lasers

- Lasers are known to be dangerous to the atmosphere and health.
- Laser printers are very costly when compared to other printers.
- When running the laser machine small amount of ozone are generated, which can damage the ozone layer.
- Some laser particles are also known to emit particles that may cause respiratory disease.

# CONCLUSION

- Finally I conclude that laserplays a crucial role in the modern world.

- Therefore laser play an pivotal role in the present technical world.

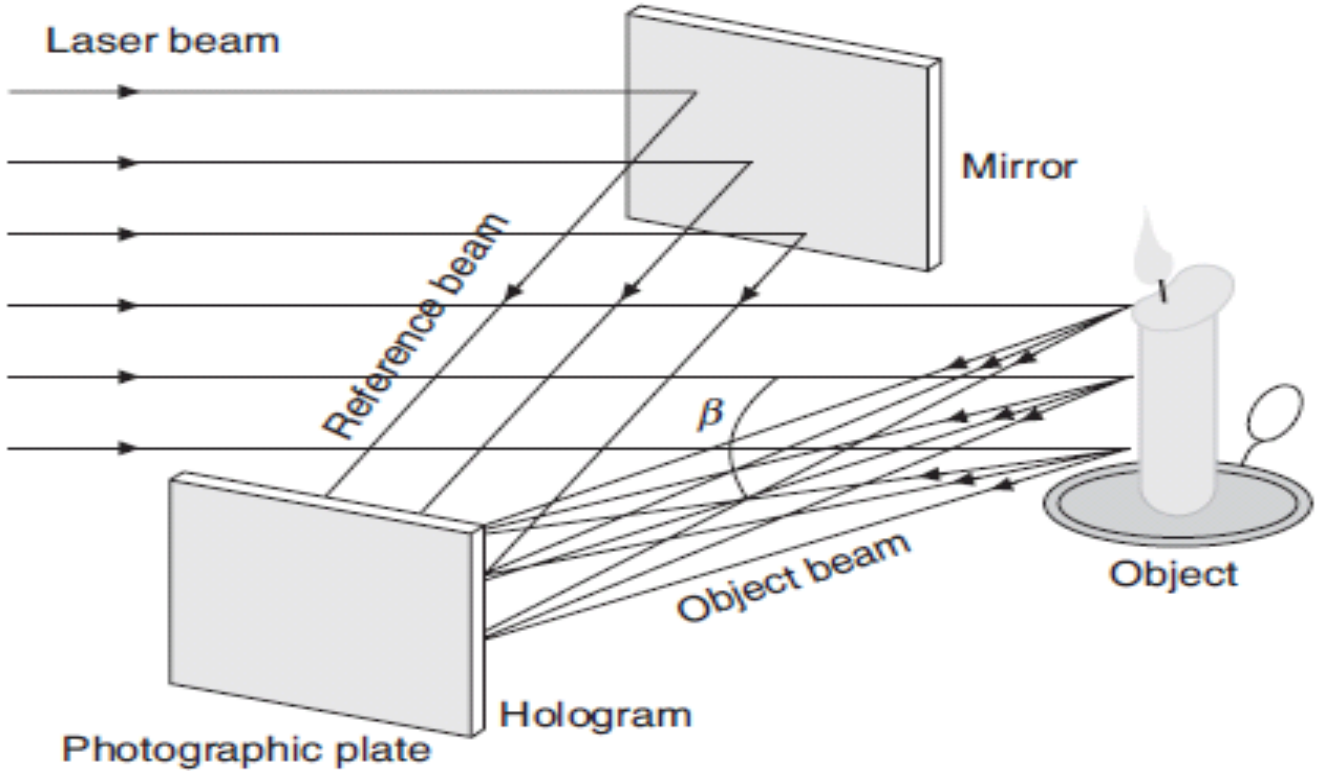
# HOLOGRAPHY

- In the photographic methods for images of objects the information about the phase of the wave (reflected from the object) is not recorded.
- During 1948,Dennis Gobor invented a two- step lens less imaging process.
- The word **holography** is the combination of two Greek words: **holos** and **graphein. Holos** stands for **whole** and **graphein** stands for to **write**. Hence, holography means writing the complete image.
- Holography is actually a recording of interference pattern formed between two beams of coherent light coming from the same source. In holography, intense coherent light is required.
- In this process, both the amplitude and the phase components of the light wave are recorded on a light sensitive medium such as a photographic plate. This recording is known as a **hologram.**

# BASIC PRINCIPLE OF HOLOGRAPHY

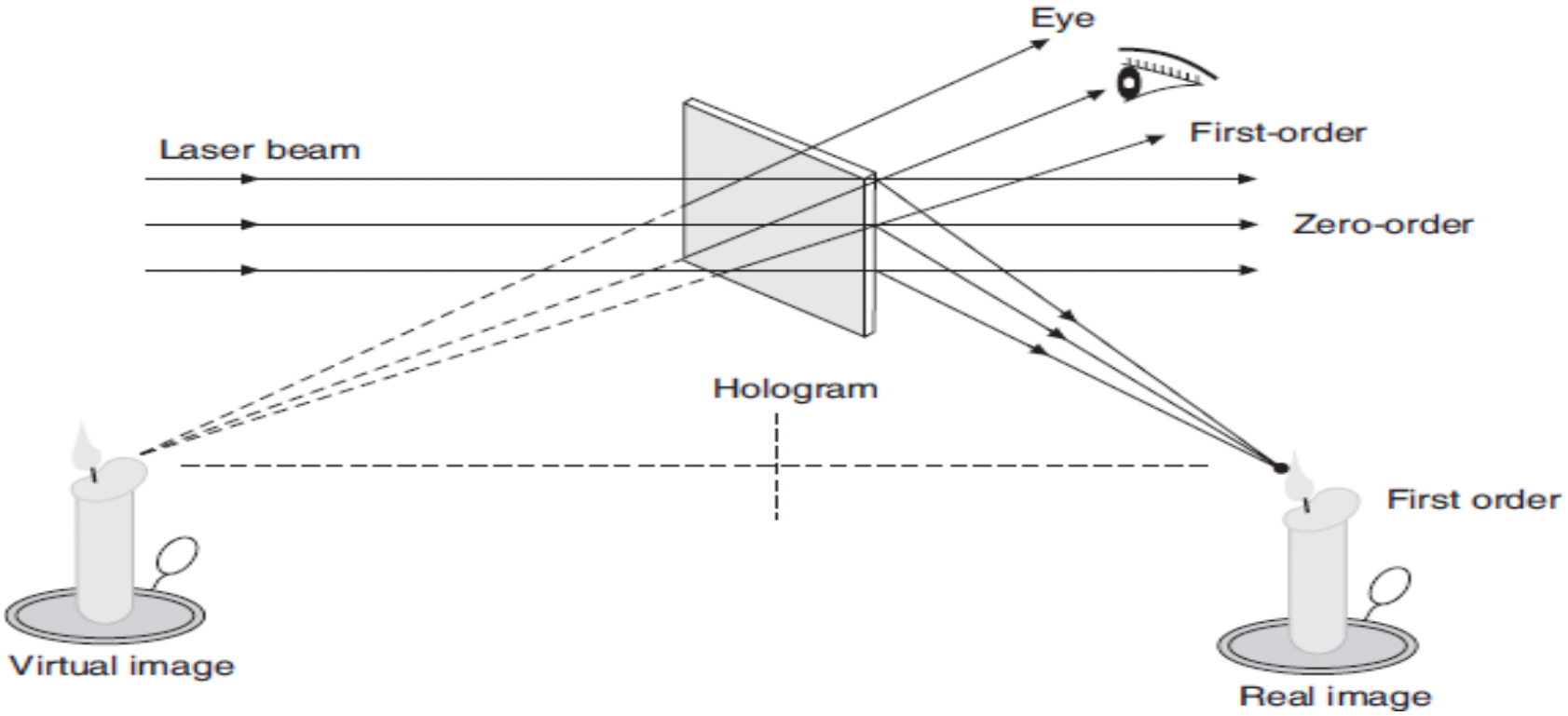
- Holography is a method in which one not only records the the amplitude of the light wave (reflected from the object), but also the phase of it which produces a three dimensional image of an object.
- Holography is a two-step process. First step is the recording of hologram where the object is transformed into a photographic record.
- The second step is the reconstruction in which the hologram is transformed into the image.
- The image will change its appearance if you look at it from a different angle.
- Holography is the lensless photography in which hologram is a result of the interference occurring between the coherent light (from laser), reflected from the object and the light from a coherent reference beam, obtained by splitting the light from the same laser source.

- To construct the hologram, a broad laser beam is divided into two beams, namely, a reference beam and an object beam, by the beam splitter in the form of the mirror as shown in Figure.
- The object beam directly illuminates the object, while the reference beam, after being reflected from the mirror, is collected on the the photographic plate. Thus, the film is exposed simultaneously by both the reference beam and the object beam.



## RECONSTRUCTION OF THE IMAGE

- The reconstruction of the object is schematically shown in Figure.
- In this process, the hologram is illuminated by a parallel beam of light, called the reconstruction beam, from the laser source. Most of the light passes straight through, but the complex of fine fringes acts as an elaborated diffraction grating.



# Comparison between

**photography**

- 2D image of 3D object
- Intensity variation only recorded
- Recorded film is called photograph
- Point to point recording of the intensity of light
- When cut into pieces, each piece gives partial information only

**holography**

- 3D image of 3D object
- Intensity and phase variation recorded
- Recorded film is called hologram
- Each point of the film receives light from all parts of the object
- Each piece gives full information of object

# APPLICATIONS OF HOLOGRAPHY

- Mostly the holographic techniques have been used for biomedical applications.
- X-ray holography
- Endoscopic holography
- Three dimensional images of biological specimens
- Holography is useful for measurements for biomedical specimen.