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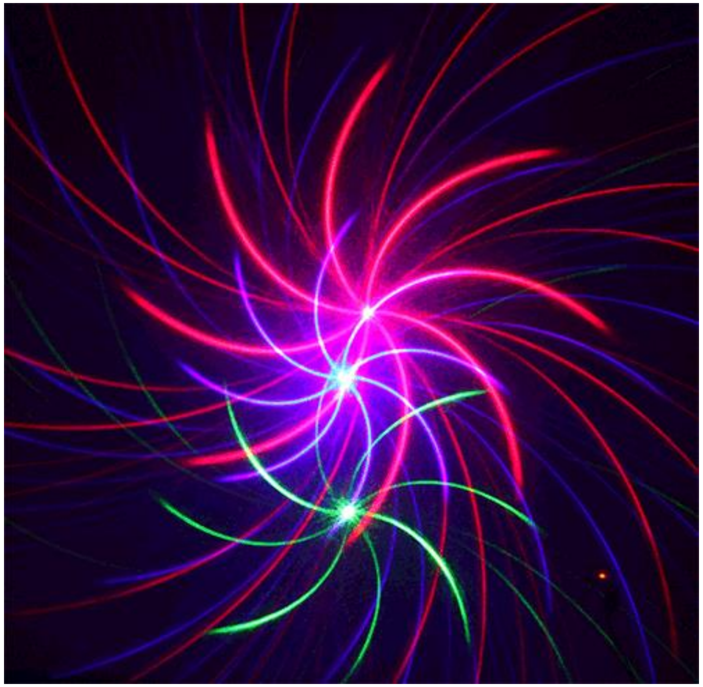
Module III:

LASERS and Optical Fibres



By Dr. Sathya Sheela S.

Assistant Professor

RV Institute of Technology and Managemnt, Bangalore

Module – III

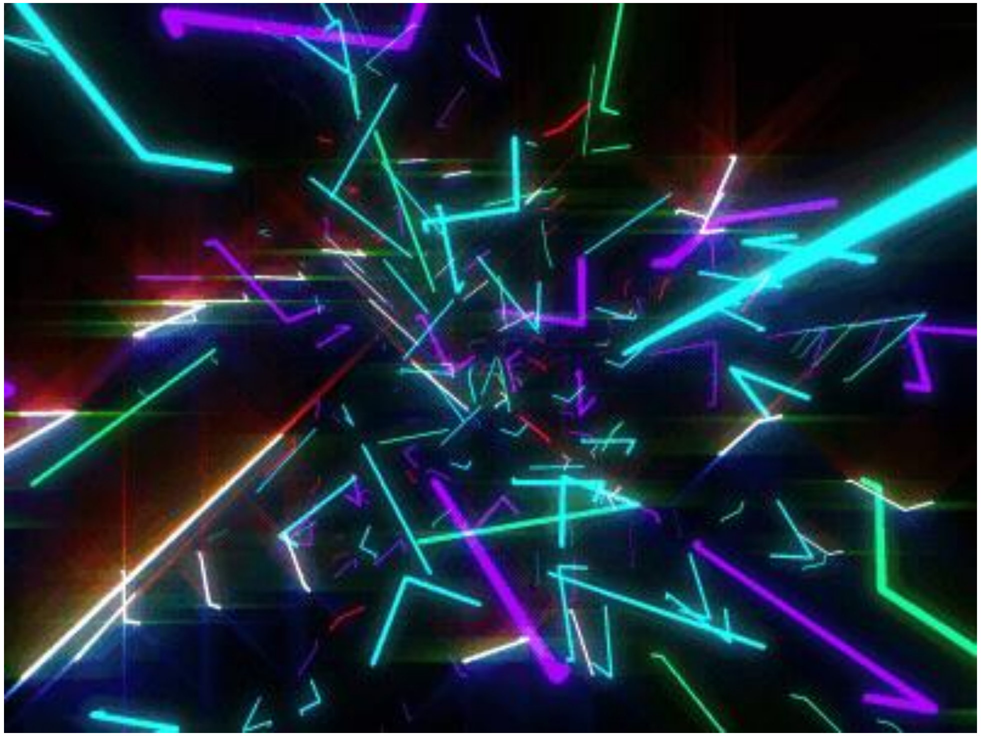
- **Lasers:**
- Interaction of radiation with matter
- Einstein's coefficients (derivation for expression for energy density).
- Requisites of a Laser system.
- Conditions for laser action.
- Principle, Construction and working of CO2 and semiconductor Lasers.
- Application of Lasers in Defense (Laser range finder) and medical applications- Eye surgery and skin treatment
- Numerical problems

Module – III

- **Optical fibers:**
- Propagation mechanism,
- Angle of acceptance.
- Numerical aperture.
- Modes of propagation and Types of optical fibers.
- Attenuation: Causes of attenuation and Mention of expression for attenuation coefficient.
- Discussion of block diagram of point to point communication.
- Optical fiber sensors-Intensity based displacement sensor and Temperature sensor based on phase modulation,
- Merits and demerits
- Numerical problems

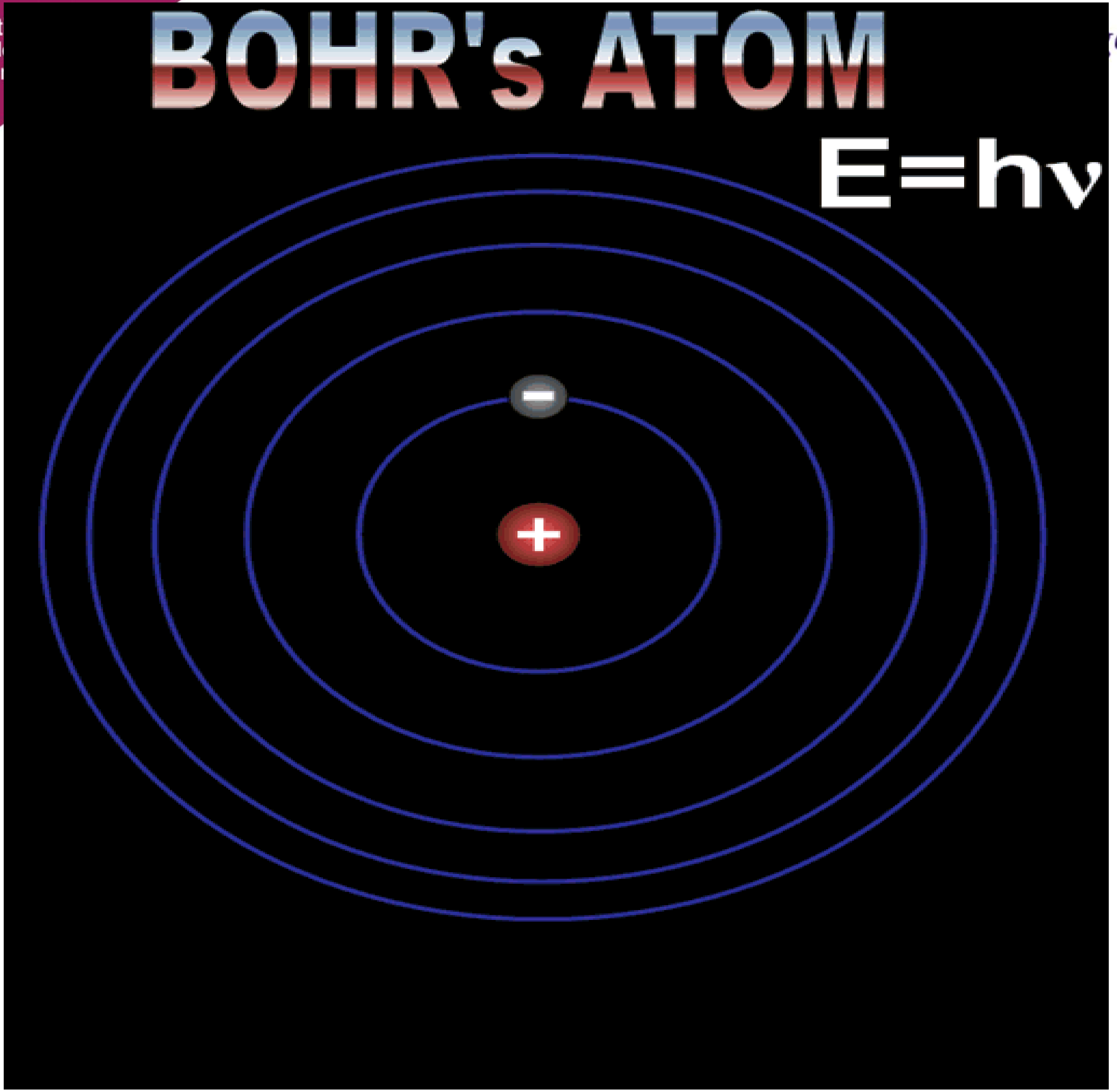
LASER

- **LASER** is an acronym for ***Light Amplification by Stimulated Emission of Radiation***.

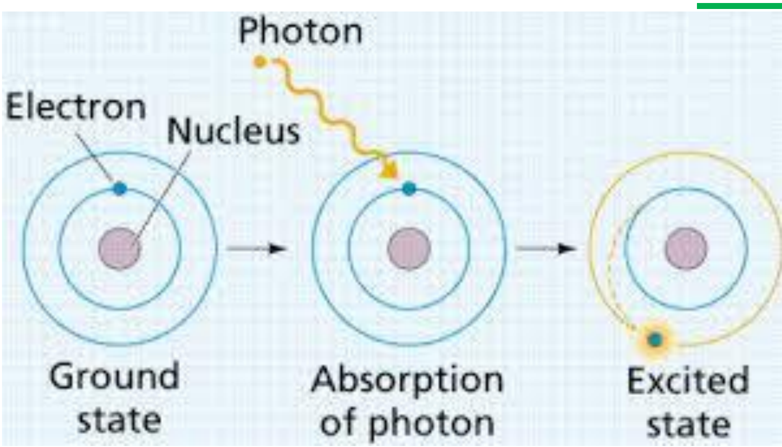


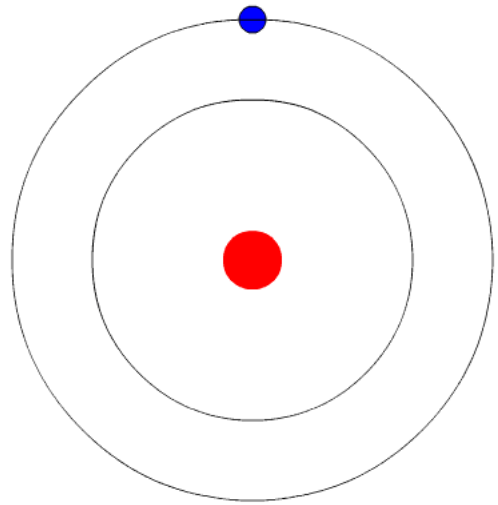
- Laser is a device that produces a very ***intense***, ***concentrated***, ***highly directional***, ***monochromatic*** and ***coherent*** beam of light with very little divergence.

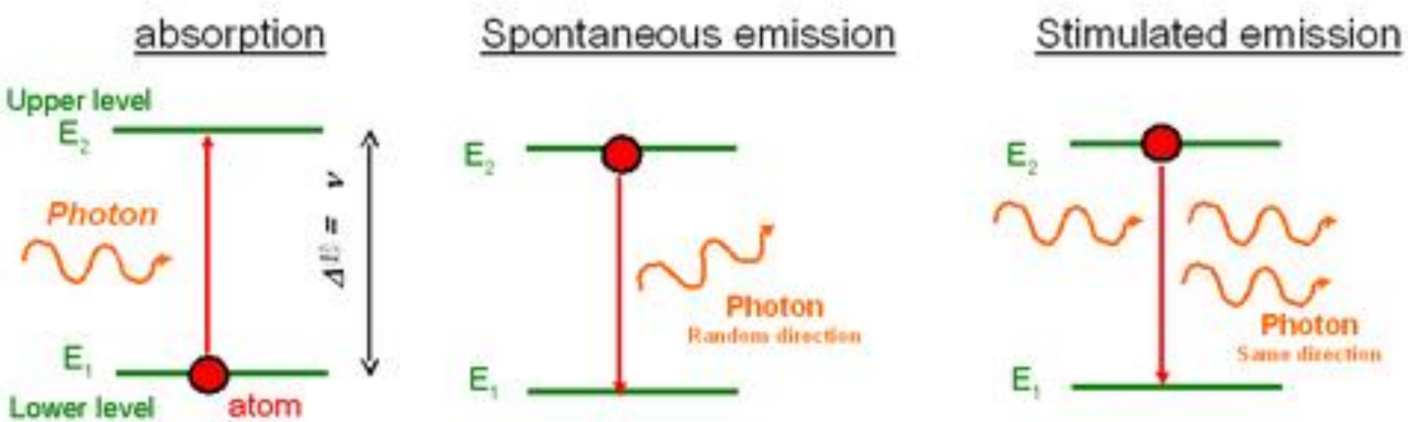

nick


BOHR's ATOM
E=hν
-
+

Interaction of radiation with matter

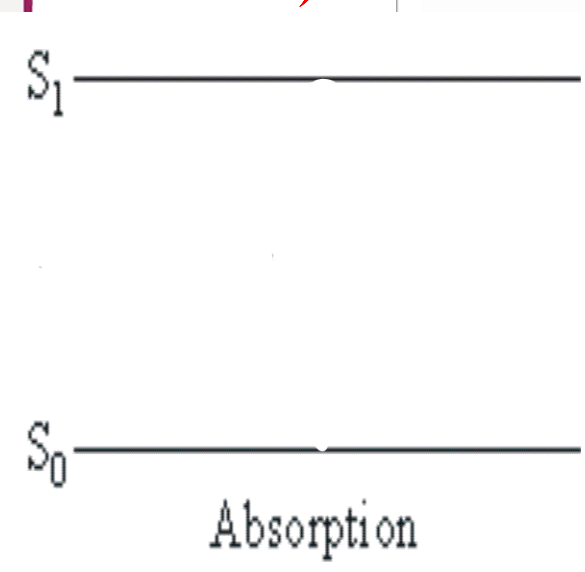


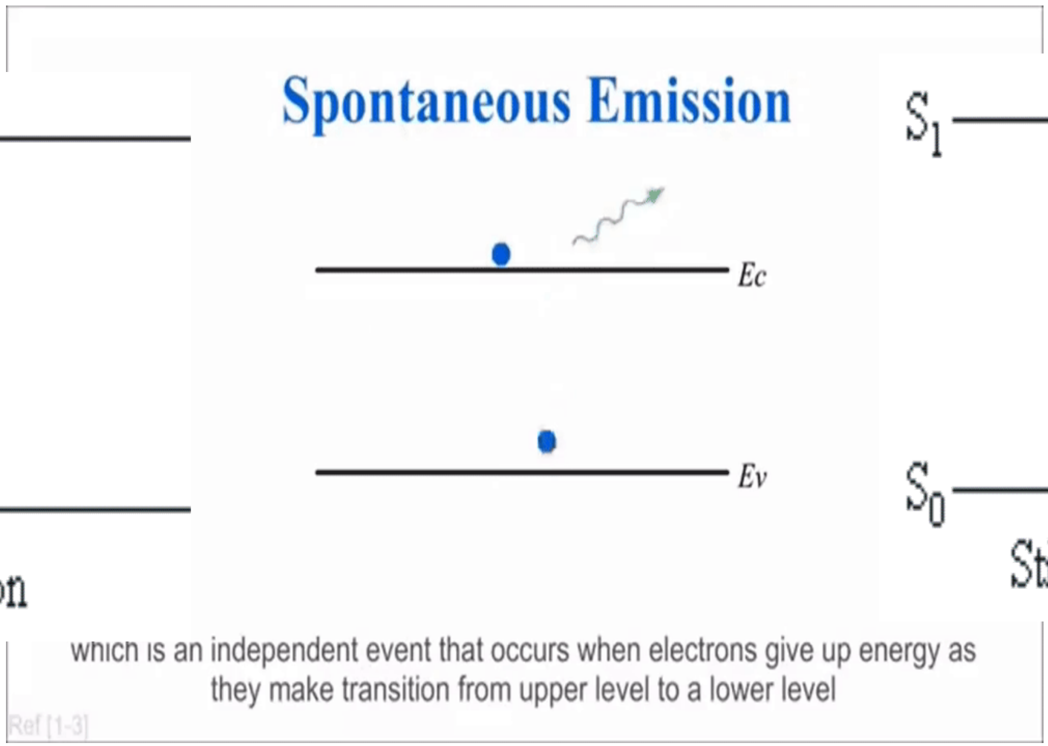


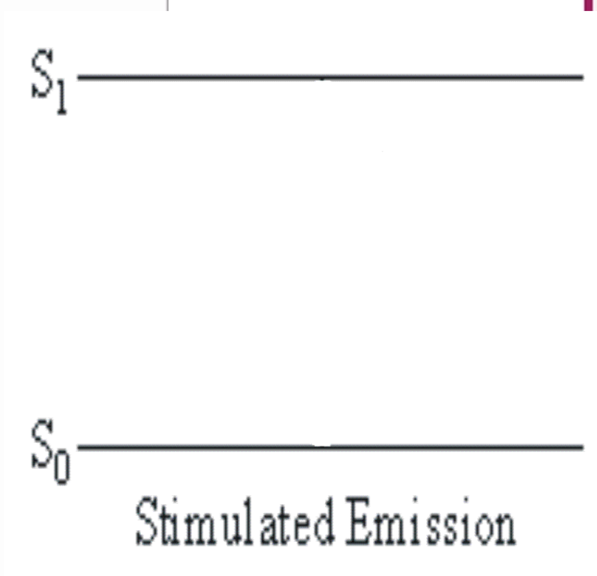


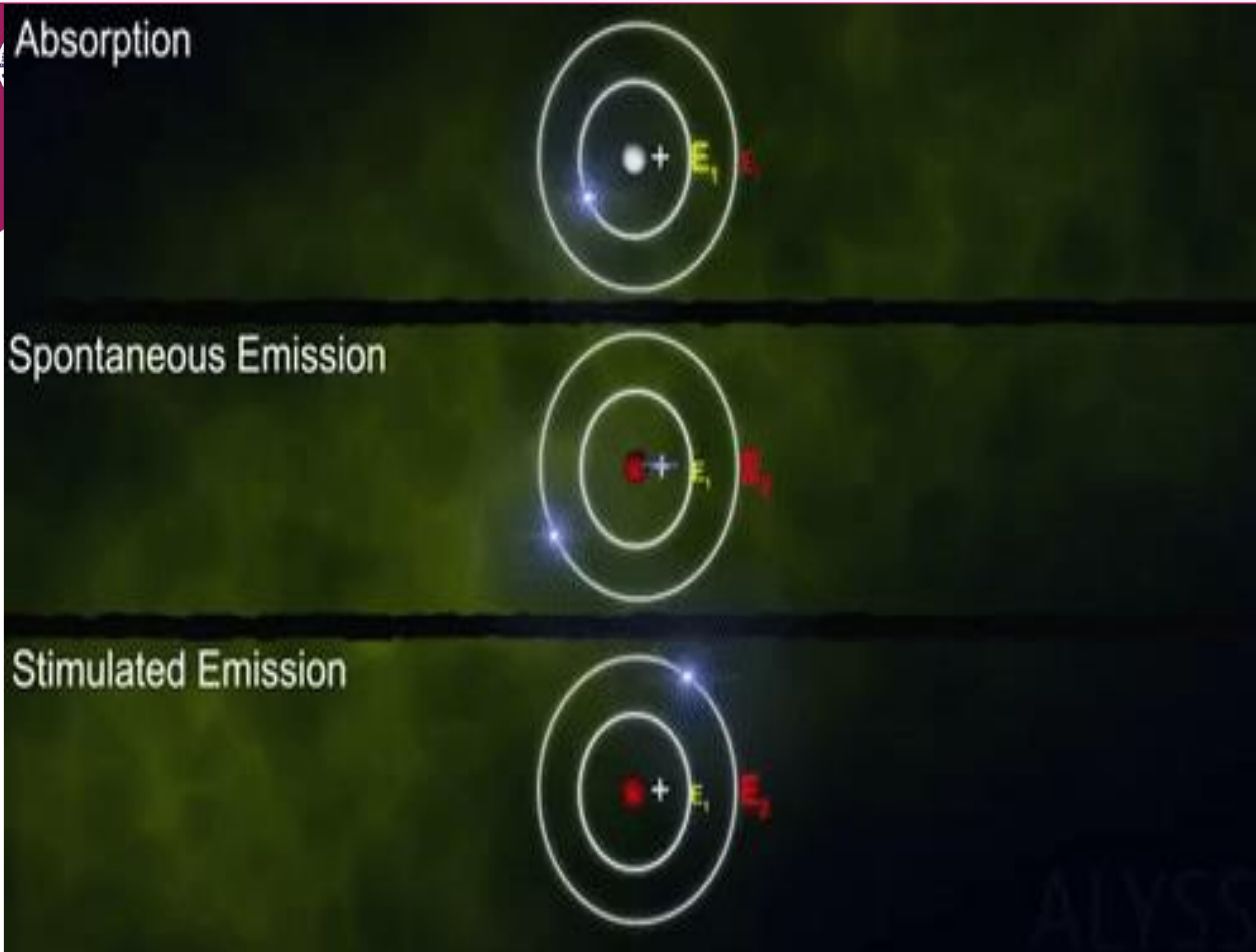
Interaction of radiation with matter

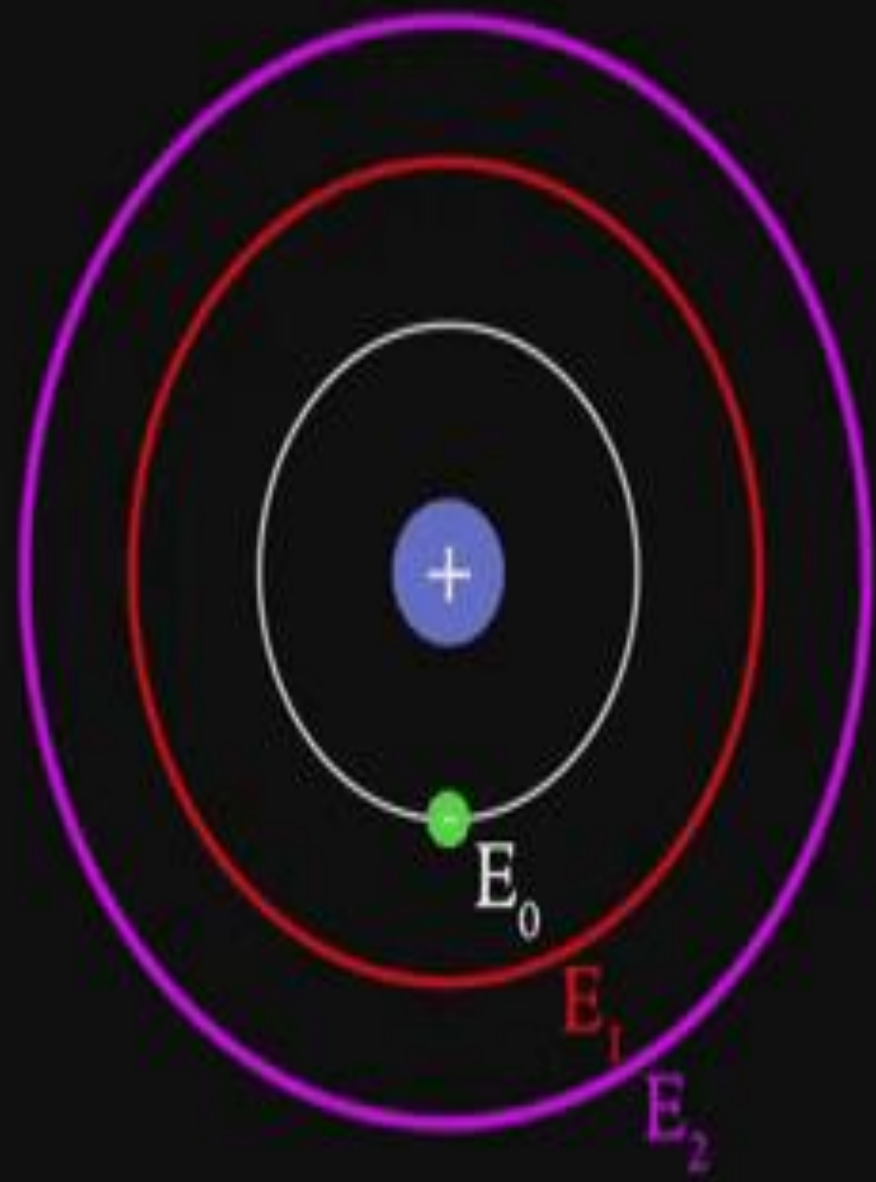
- Induced Absorption: Atom + Photon → Atom*
- Spontaneous Emission: Atom* → Atom + Photon
- Stimulated Emission: Atom* + Photon → Atom + (Photon + Photon)

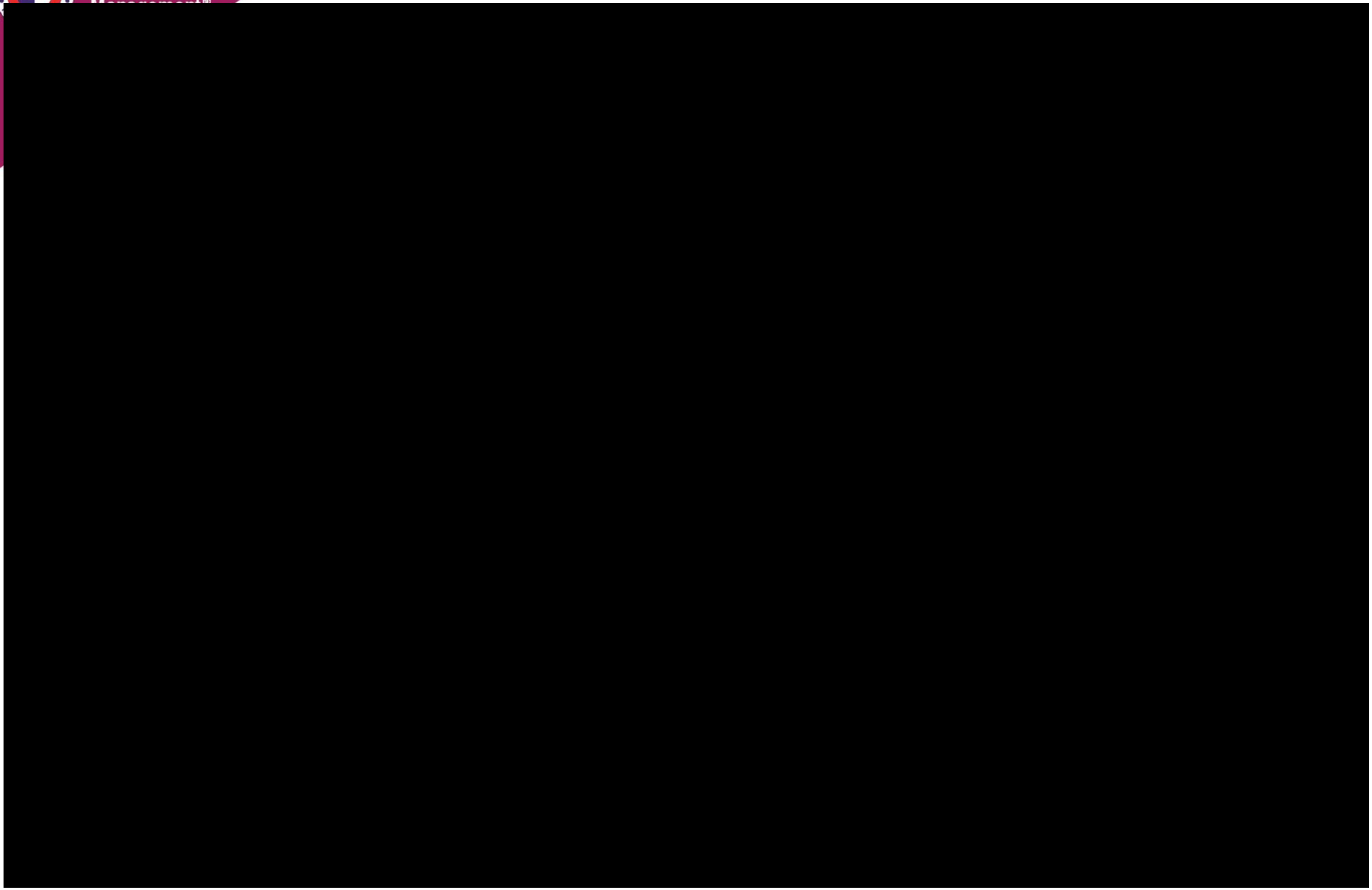







Absorption
Spontaneous Emission
Stimulated Emission


+
-
E0
E1
E2



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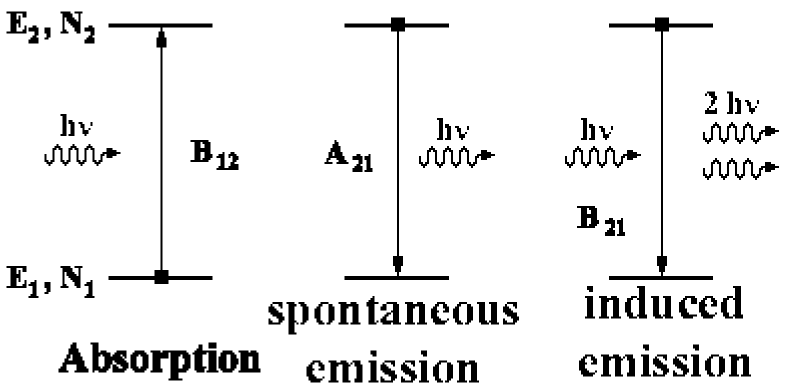
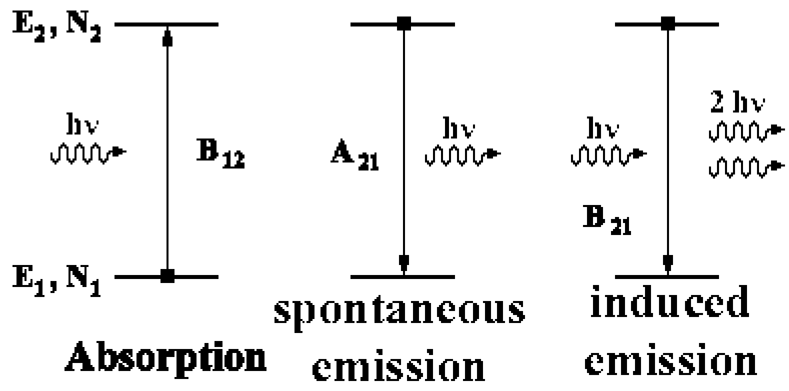
Expression for Energy Density in terms of Einstein's Coefficients:

- Consider two energy states E_1 and E_2 of a system of atoms ($E_2 > E_1$).

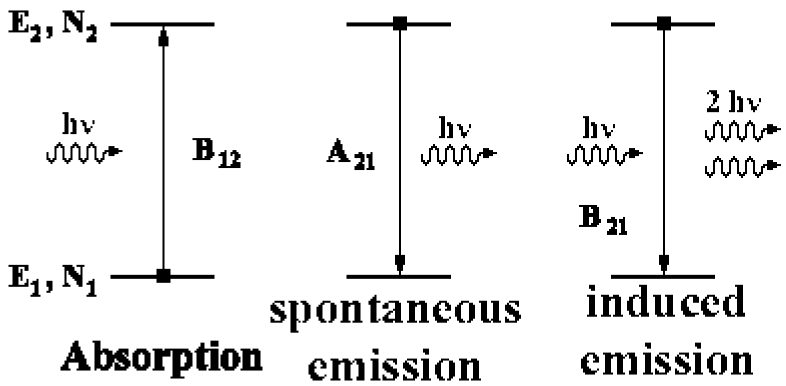


- Let there be N_1 atoms with energy E_1 and N_2 atoms with energy E_2, per unit volume of the system.
- N_1 and N_2 are called the number densities of atoms in the states 1 and 2 respectively.
- Let there be radiation of frequency $\nu = \dfrac{(E2 - E1)}{h}$ Hz ;
- And let U_υ be the energy density of radiations.



- The Rate of Induced absorption is proportional to N_1
- The Rate of Induced absorption is proportional to U_ν
- The Rate of Induced absorption is $= B_{12}N_1U_\nu$ ----------------- (1)
- where B_{12} is the Einstein's coefficient for stimulated absorption,

- The Rate of spontaneous emission is proportional to N_2
- The Rate of spontaneous emission is $= A_{21}N_2$ -------------------- (2)
- A_{21} is Einstein's coefficient for spontaneous emission.



- The Rate of stimulated emission is proportional to N_2
- The Rate of stimulated emission is proportional to U_ν

The Rate of stimulated emission is $= B_{21} N_2 U_\nu$ ------------ (3)

- B_{21} is the Einstein's coefficient for stimulated emission

- At thermal equilibrium,
- Rate of absorption = Rate of spontaneous emission + Rate of stimulated emission.
- From Eqs. (1), (2) & (3), we have,

- $B_{12}N_1U_\nu = A_{21}N_2 + B_{21}N_2U_\nu,$
- $B_{12}N_1U_\nu - B_{21}N_2U_\nu = A_{21}N_2$
- $U_\nu\,(B_{12}N_1 - B_{21}N_2\,) = A_{21}N_2$
- $U_\nu = \dfrac{A_{21}N_2}{(B_{12}N_1 - B_{21}N_2\,)}$
- $U_\nu = \dfrac{A_{21}N_2}{B_{21}N_2(\frac{B_{12}N_1}{B_{21}N_2} - 1)}$ ……………………… (4)
- By Boltzmann's law, The Boltzmann distribution law states that the probability of finding the molecule in a particular energy state varies exponentially as the energy divided by kT.
- $\dfrac{N_2}{N_1} = e^{-\frac{h\nu}{kT}}$
- $U_\nu = \dfrac{A_{21}N_2}{B_{21}N_2\,(\frac{B_{12}}{B_{21}}\,e^{\frac{h\nu}{kT}} - 1)}$ ……………… (5)

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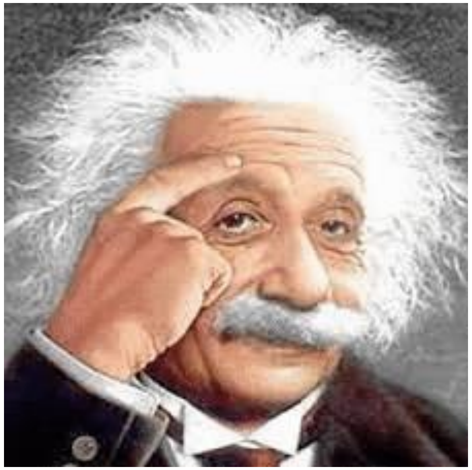
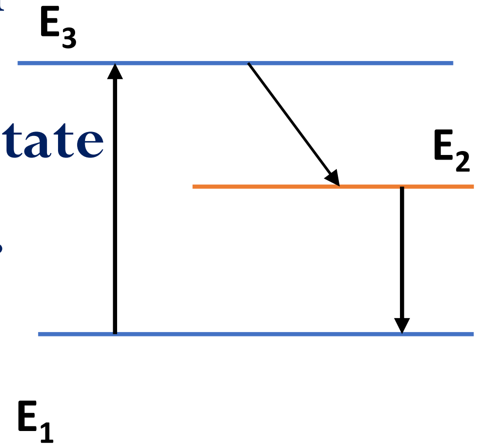
$$U_\nu = \frac{A_{21}}{B_{21}\left(\frac{B_{12}}{B_{21}} e^{\frac{h\nu}{kT}} - 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$



-
- By Planck's Law $U_\nu = \frac{8\pi h\nu^3}{c^3}\left[\frac{1}{e^{\left(\frac{h\nu}{kT}\right)}-1}\right] \ldots\ldots\ldots\ldots\ldots(6)$
- Now, comparing the equations (5) and (6) term by term,
- $\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$
- **It means that at thermal equilibrium, the probability of spontaneous emission increases rapidly with the energy difference between two states**
- $\frac{B_{12}}{B_{21}} = 1$; $B_{12} = B_{21}$
- **Which implies that the probability of induced absorption is equal to the probability of stimulated emission.**
- Eq (5) can be rewritten. At thermal equilibrium the equation for energy density is
- $U_\nu = \frac{A}{B}\left[\frac{1}{e^{\left(\frac{h\nu}{kT}\right)}-1}\right]$; This is the Einstein's expression for energy density of radiation.

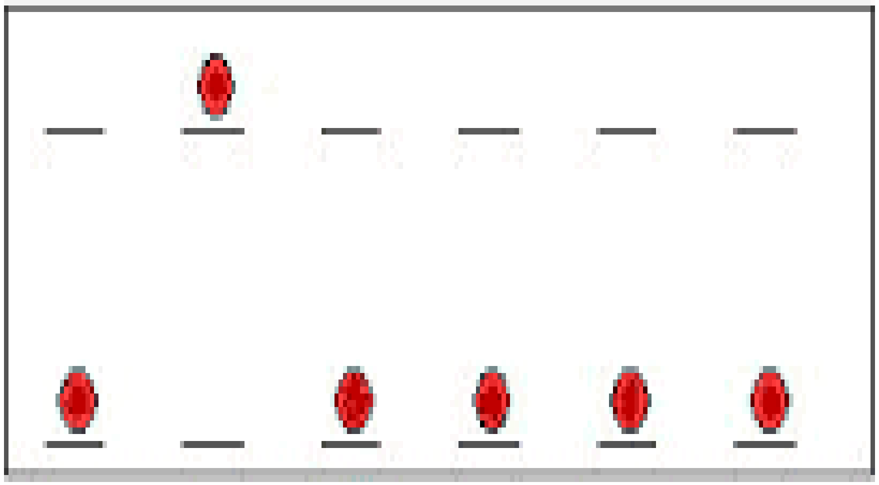
Population Inversion

- Under normal conditions of thermal equilibrium in an atomic system,
- the number of atoms in the lower energy state
- will be more than that in the excited state.
- In other words, if N_1 and N_2 are the

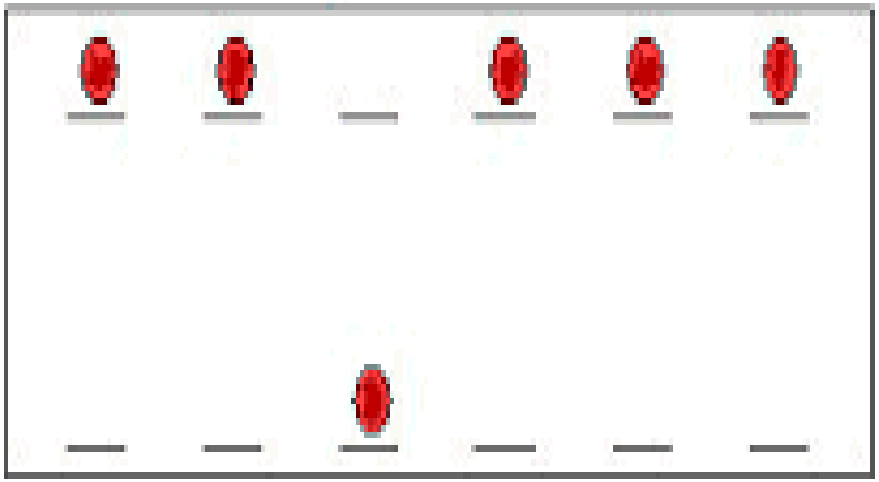


number densities of atoms in the lower and excited states respectively then

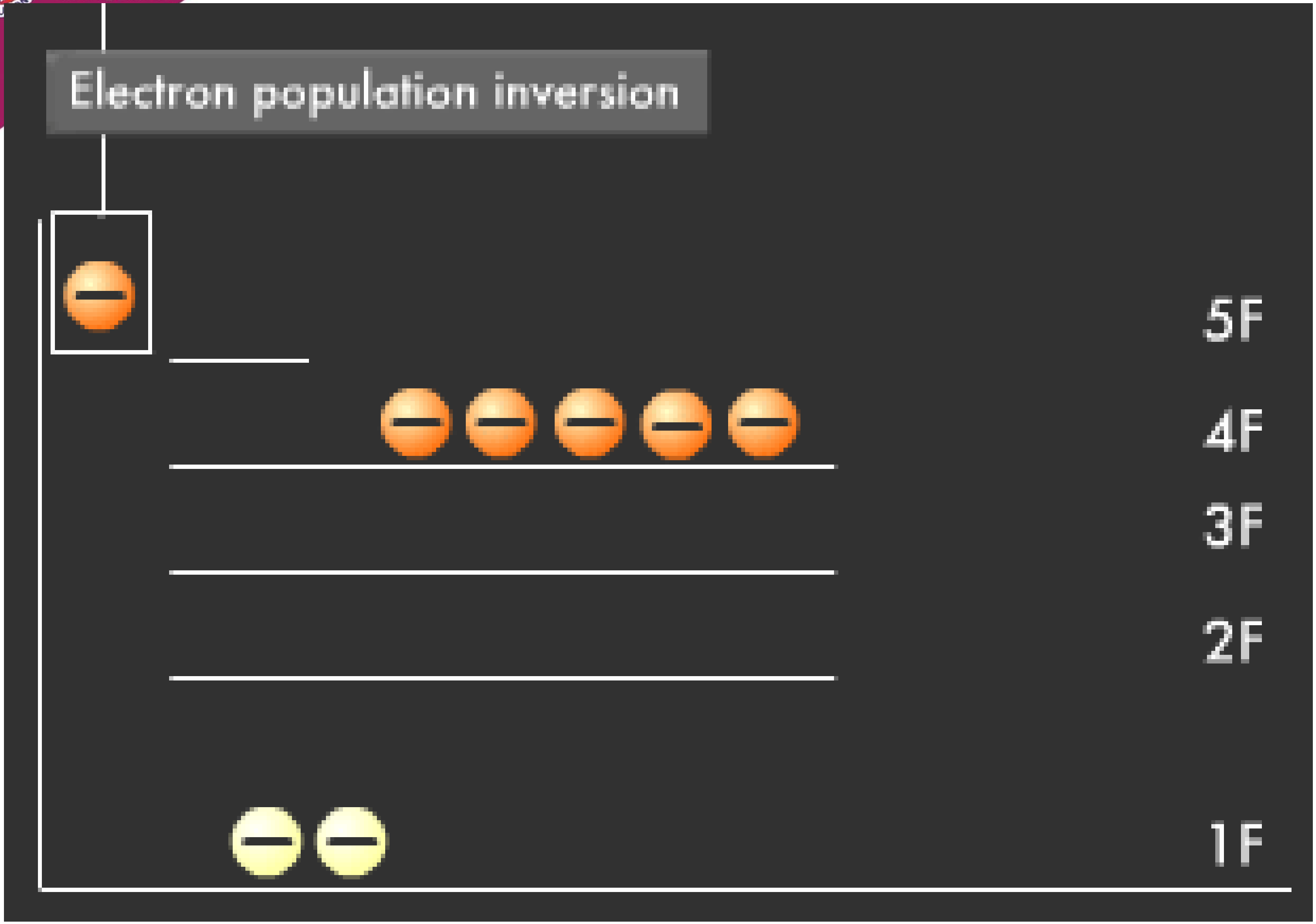
- $N_1 > N_2$ (Normal population)
- E_1 and E_2 (or E_3) are the energy of the atoms in the ground and excited states respectively



normal population

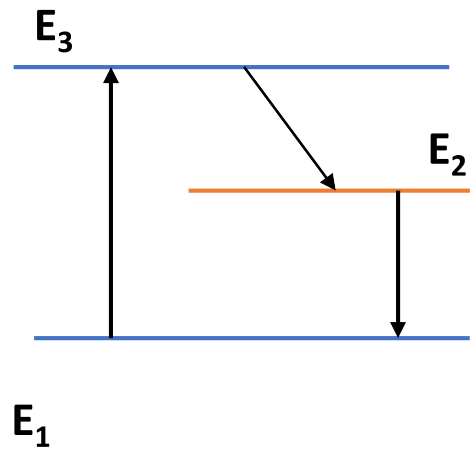


population inversion

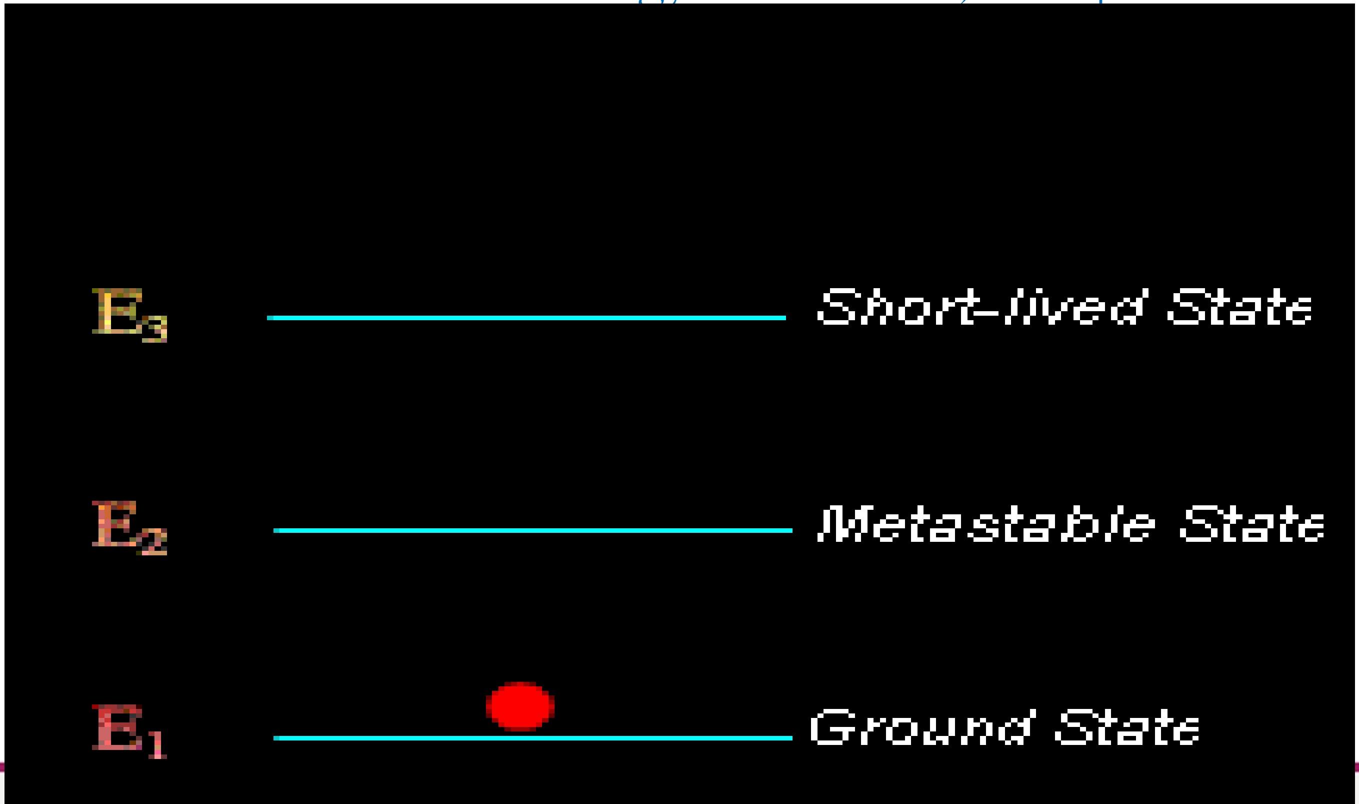

Electron population inversion
5F
4F
3F
2F
1F

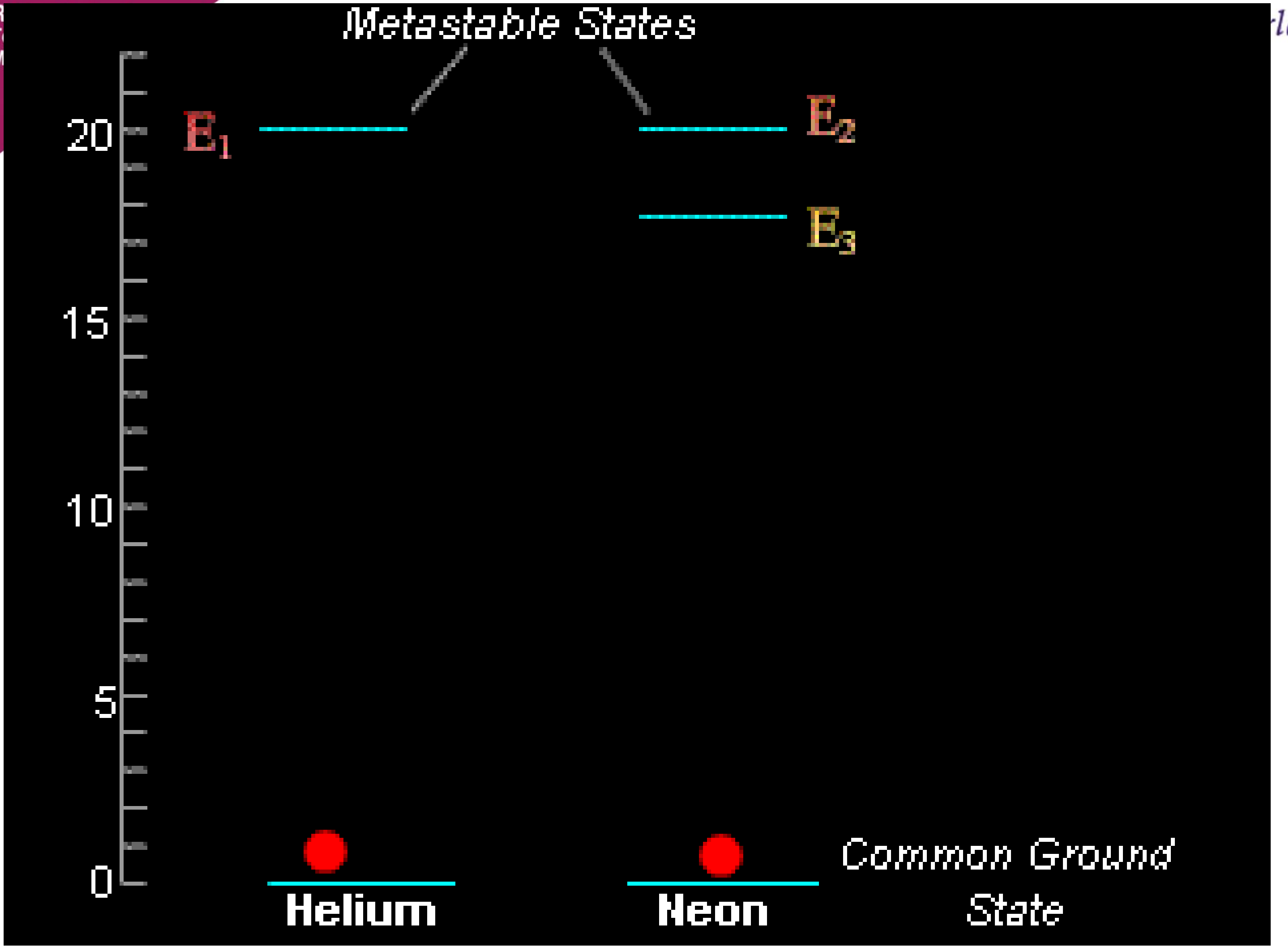
Population Inversion

- According to Boltzmann's distribution function,
- $\frac{N_2}{N_1} = e^{-\frac{h\nu}{kT}}$ (1)
- where k is Boltzmann's constant
- and T is temperature.
- As $E_2 > E_1$, ; $E_2 - E_1 = h\nu$
- RHS of equation (1) is always less than unity,
- hence $N_2 < N_1$.
- **For stimulated emission to dominate, population of atoms in the higher energy state must be greater than that in the lower energy state.**
- i.e. $N_2 > N_1$, Such a situation is known as population inversion.
- In some substances which contain meta-stable states, this may be achieved practically

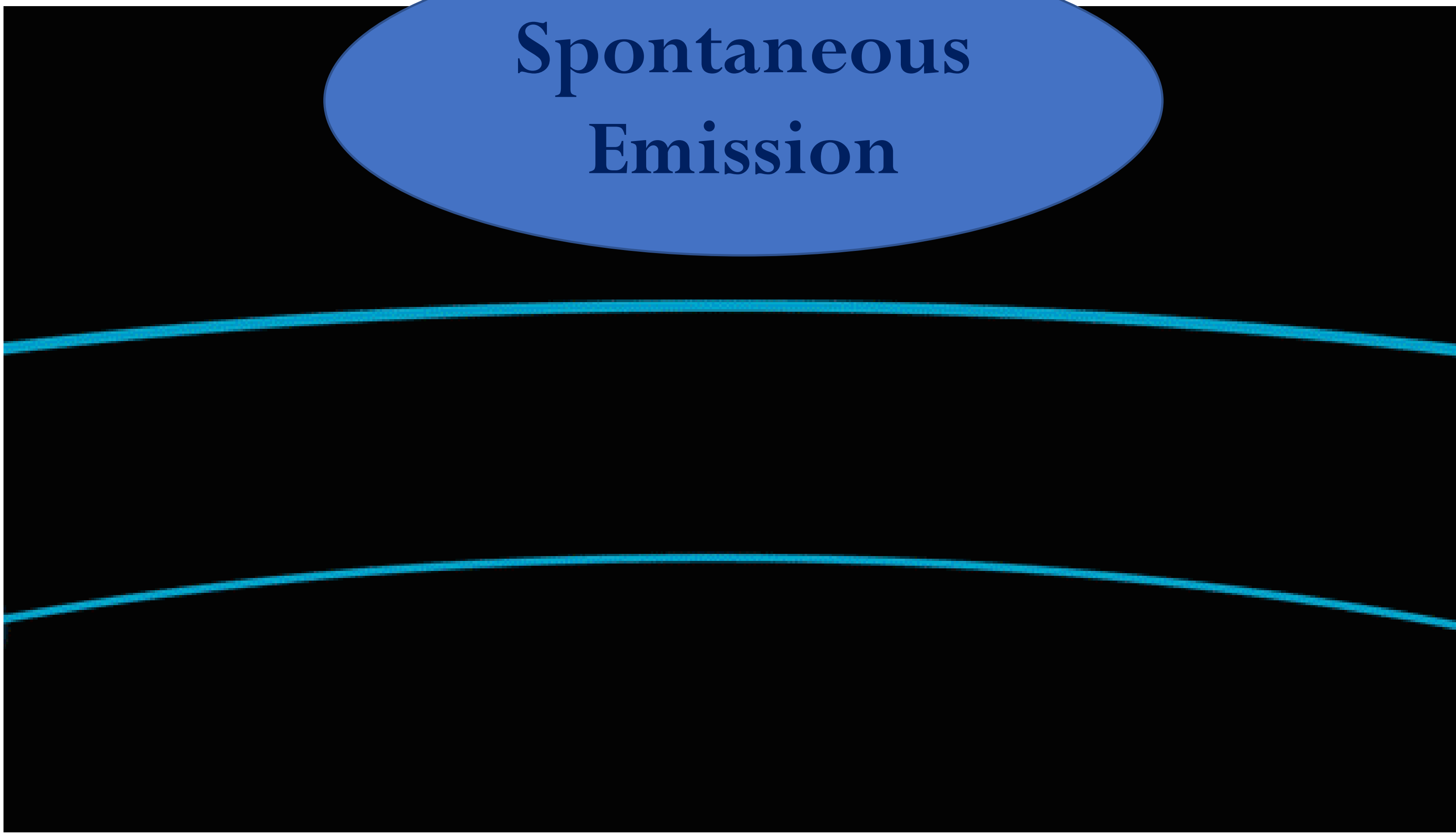


- Population Inversion:
- When the number of atoms in the lower energy state is less than that in the excited state
- For stimulated emission to dominate:
- population of atoms in the higher energy state must be greater than that in the lower energy state i.e. $N_2 > N_1$.

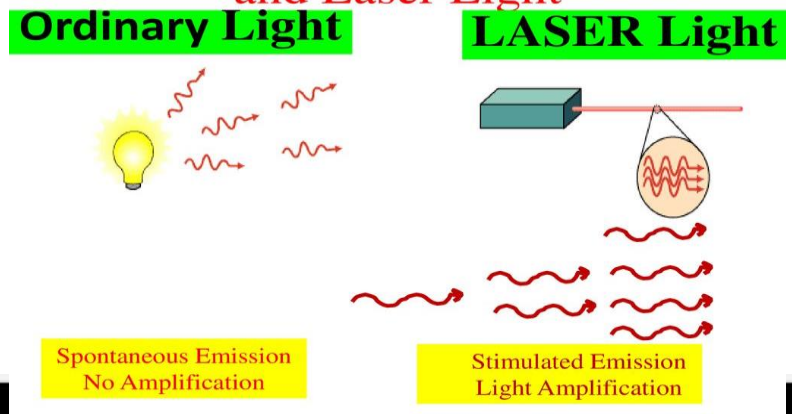


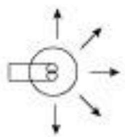
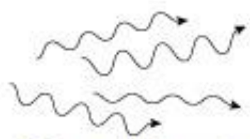
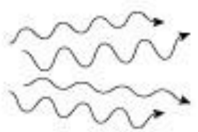
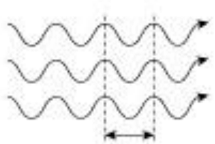
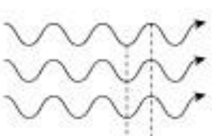

Metastable States
20
15
10
5
0
E1
E2
E3
Common Ground State
Helium
Neon

Spontaneous Emission



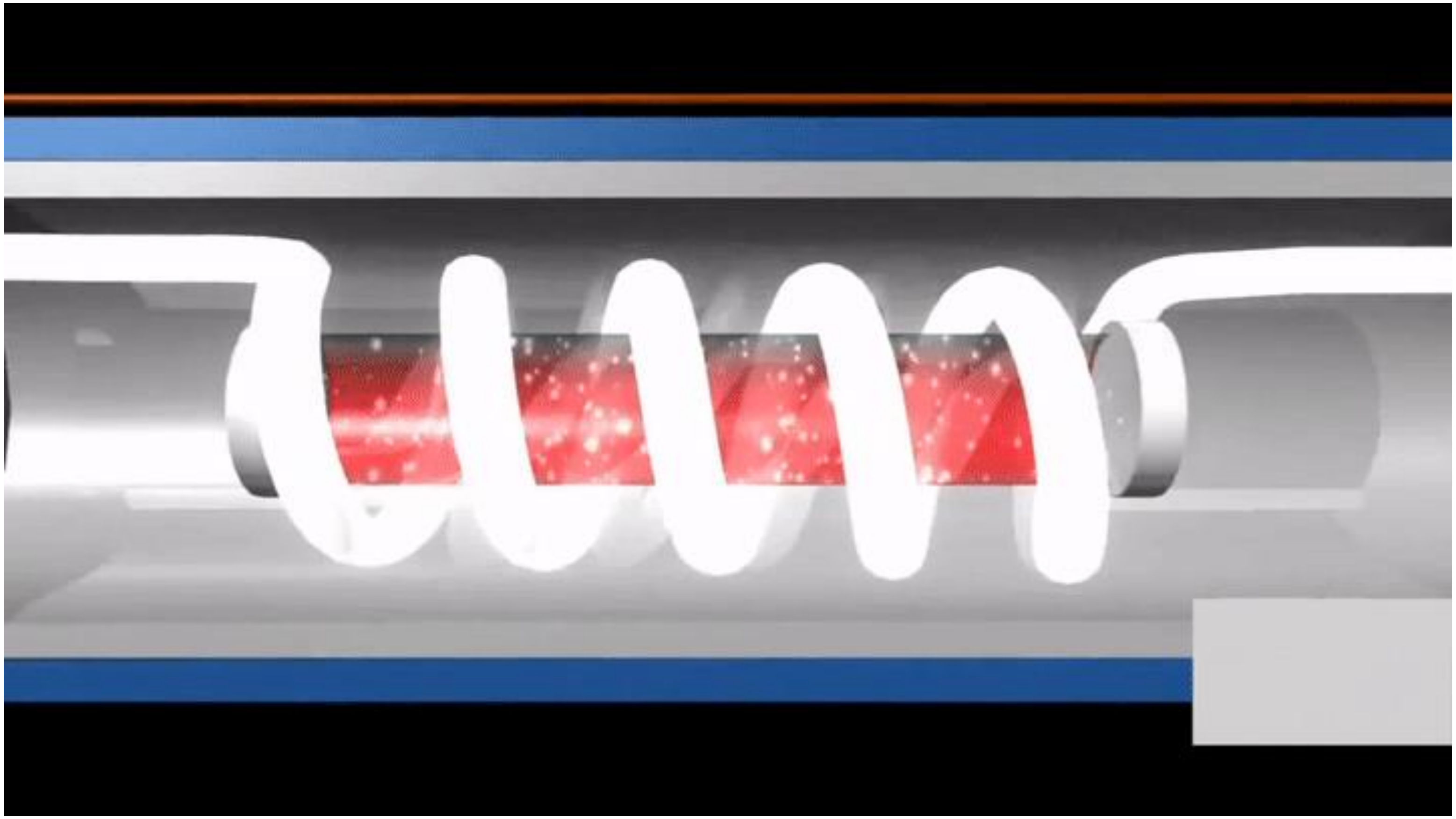
Difference Between Ordinary Light and Laser Light

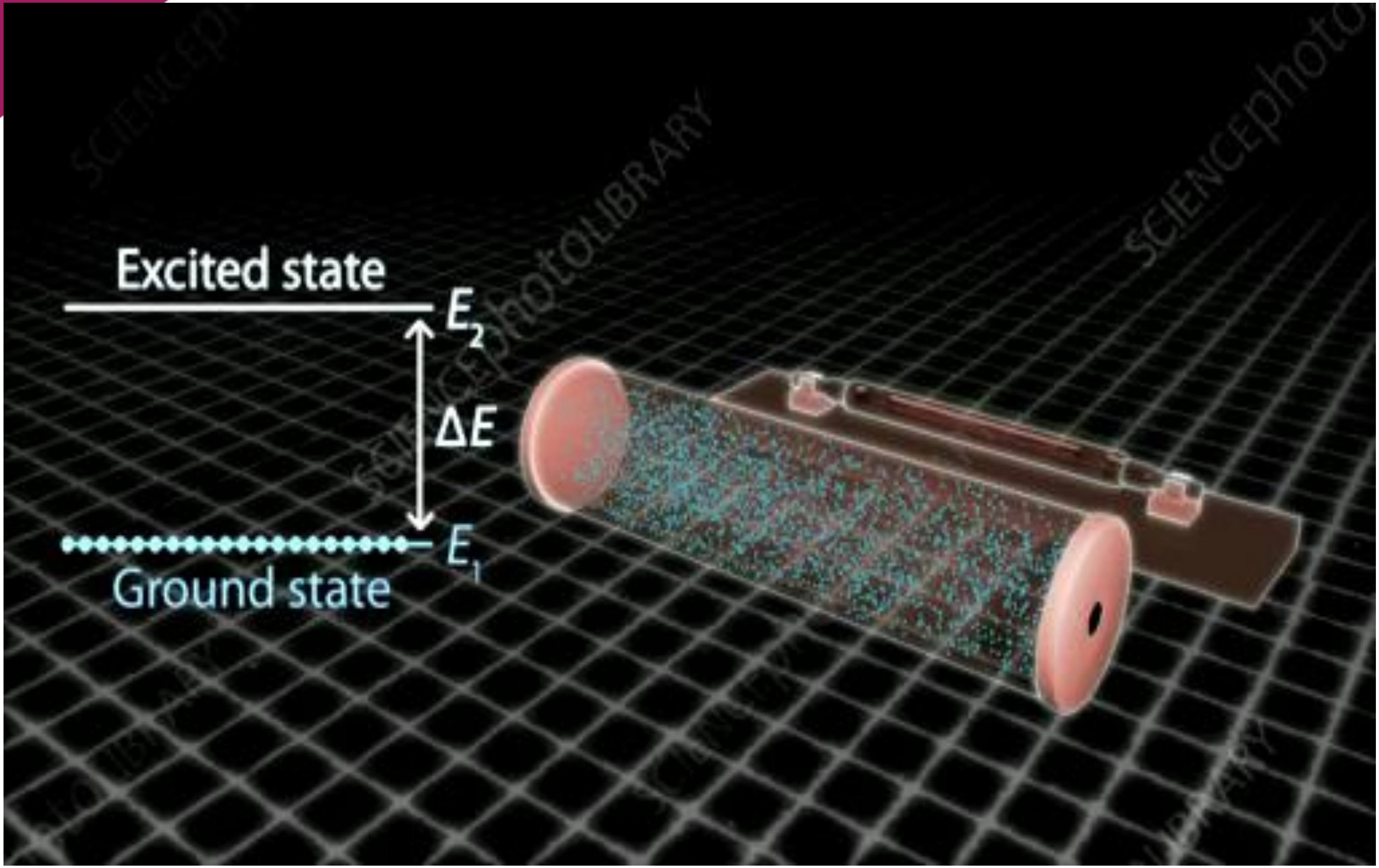


	Directivity (light waves travel in straight line)	Monochromaticity	Coherence
Ordinary light	 Light bulb	 Many different wavelengths	
Laser beam	 Laser	 Single wavelength	 Peaks and troughs align

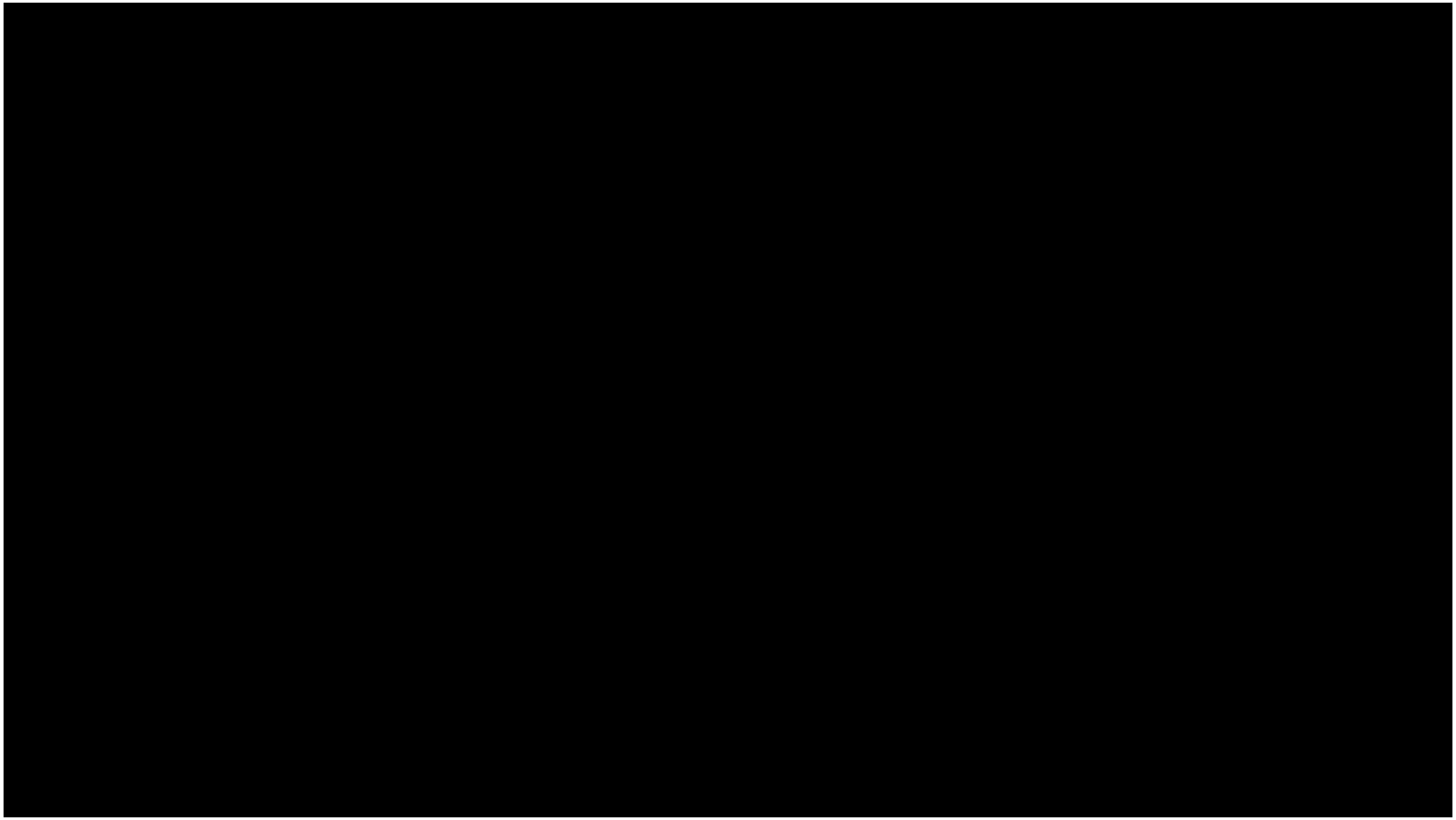
Pumping

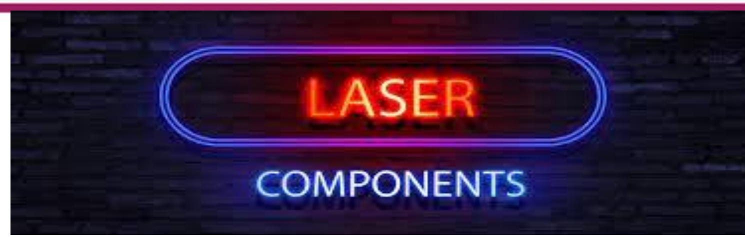
- Population inversion can be achieved by pumping action.
- The act of exciting atoms from lower energy state to a higher energy state by supplying energy from an external source is called pumping




Excited state
E_2
ΔE
E_1
Ground state

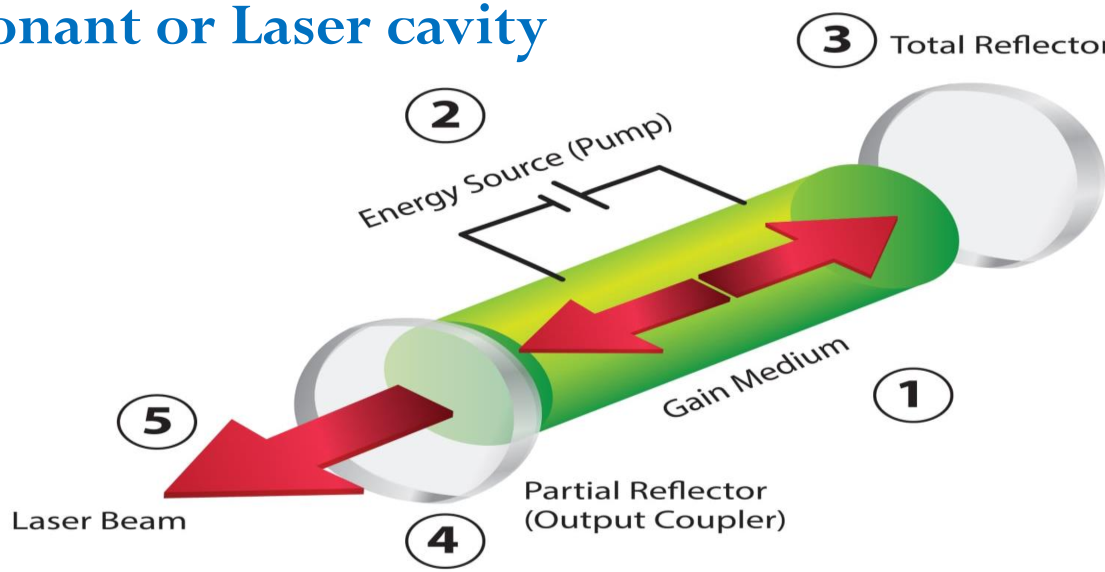
How does LASER work

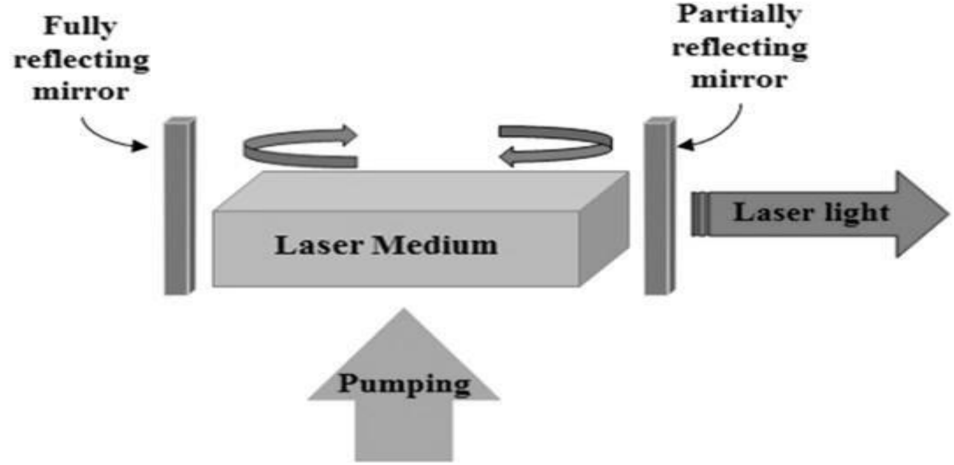




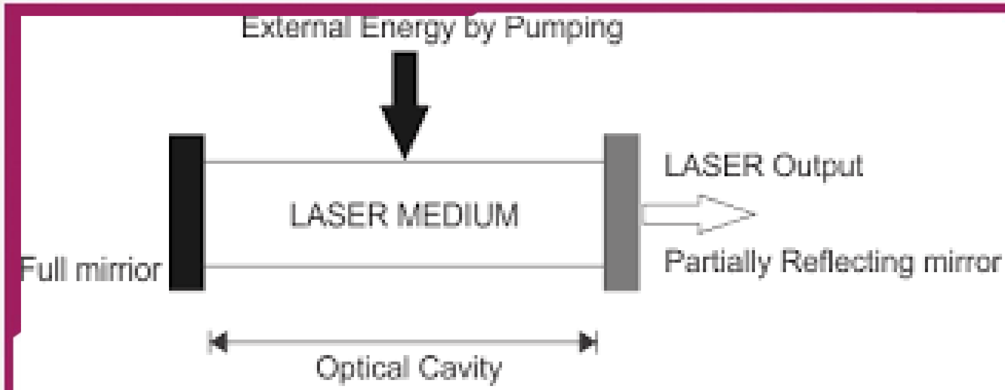
Requisites of a laser system:

- **The main components of laser are**
- **1. An active medium having metastable state which supports Population Inversion.**
- **2. An excitation source for pumping action, by which population inversion can be achieved.**
- **3. Resonant or Laser cavity**



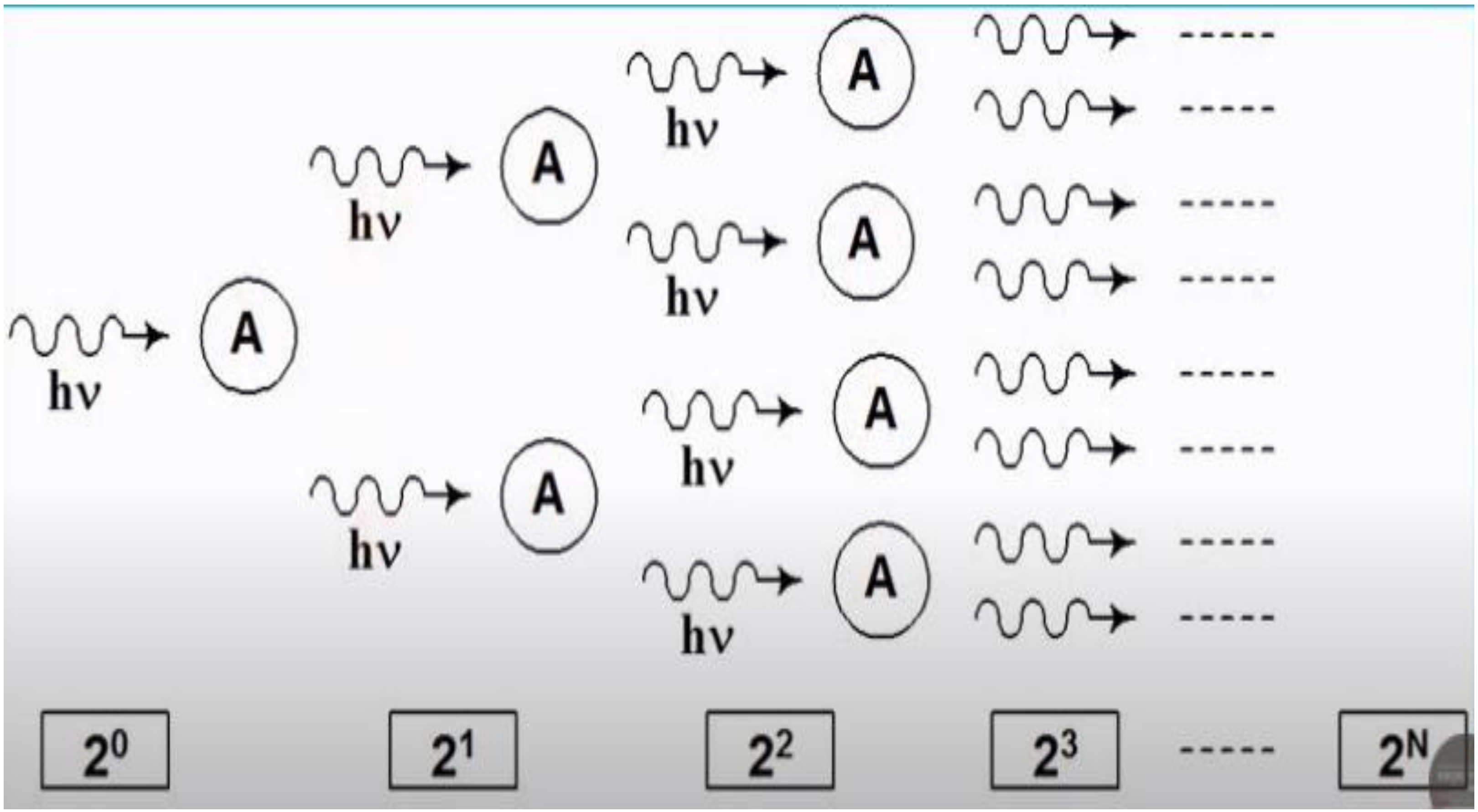


- **Active Medium:**
- The quantum system between whose energy levels, the pumping and lasing action occur is called an active medium.
- **Excitation source:**
- To achieve population inversion, atoms in the lower energy state have to be raised to the higher energy state by supplying energy. This process is called pumping.
- Pumping can be done in different ways such as
- ***optical*** *pumping*, ***electrical*** *pumping* and ***chemical*** *pumping*.



Components of LASER

- The system containing the active medium between two mirrors of high reflectivity is called laser cavity.
- The mirrors reflect the photons produced due to stimulated emission to and fro through the active medium.
- Thus the radiation inside the laser cavity builds up resulting in amplification of stimulated emission of radiation.
- Hence the output of the system is a laser coherent light.


hν
A
hν
A
hν
A
hν
A
hν
A
hν
A
hν
A
2^0
2^1
2^2
2^3

2^N

Stimulated Emission in a Mirrored Laser Cavity

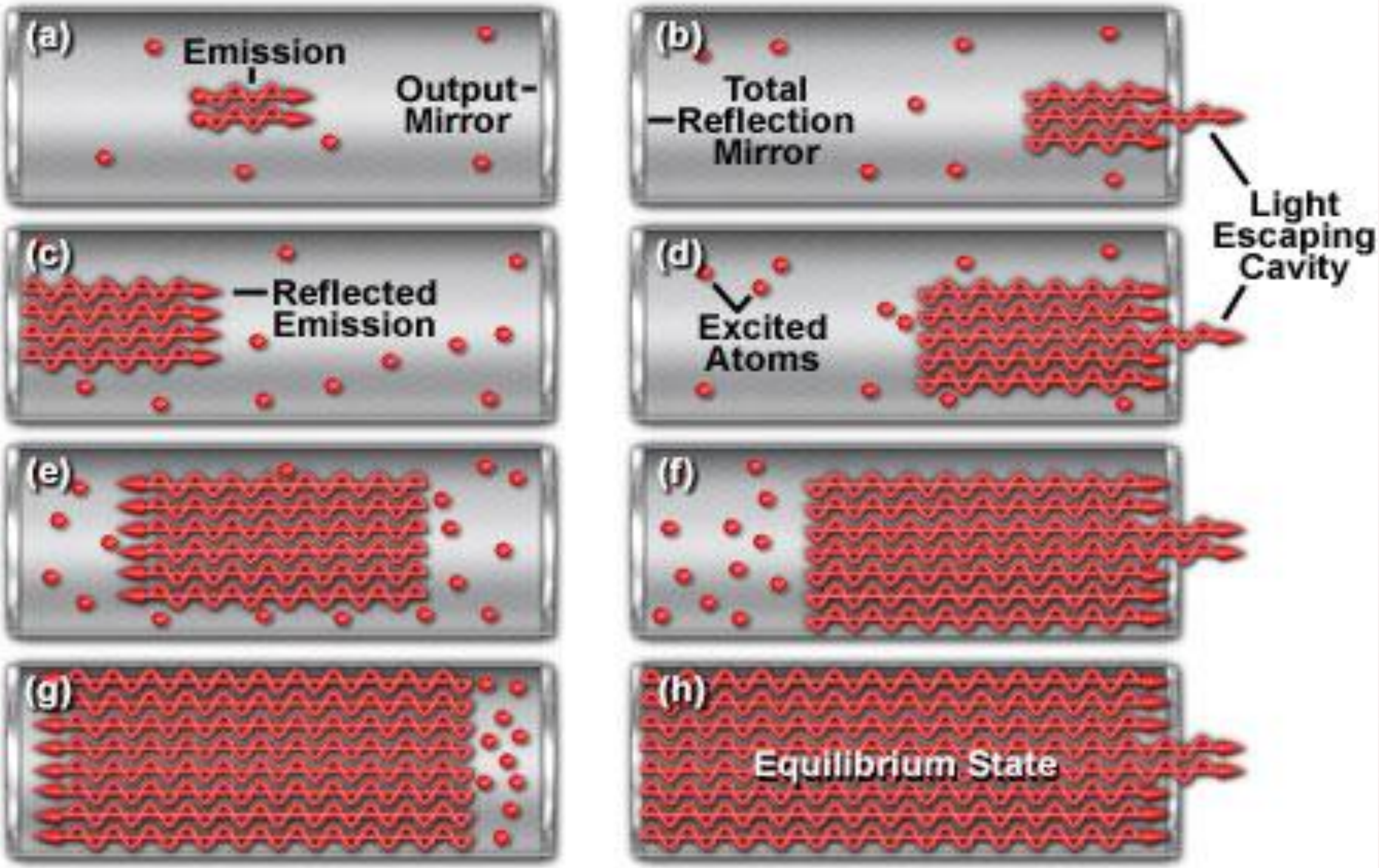


Figure 1

CO_2 laser

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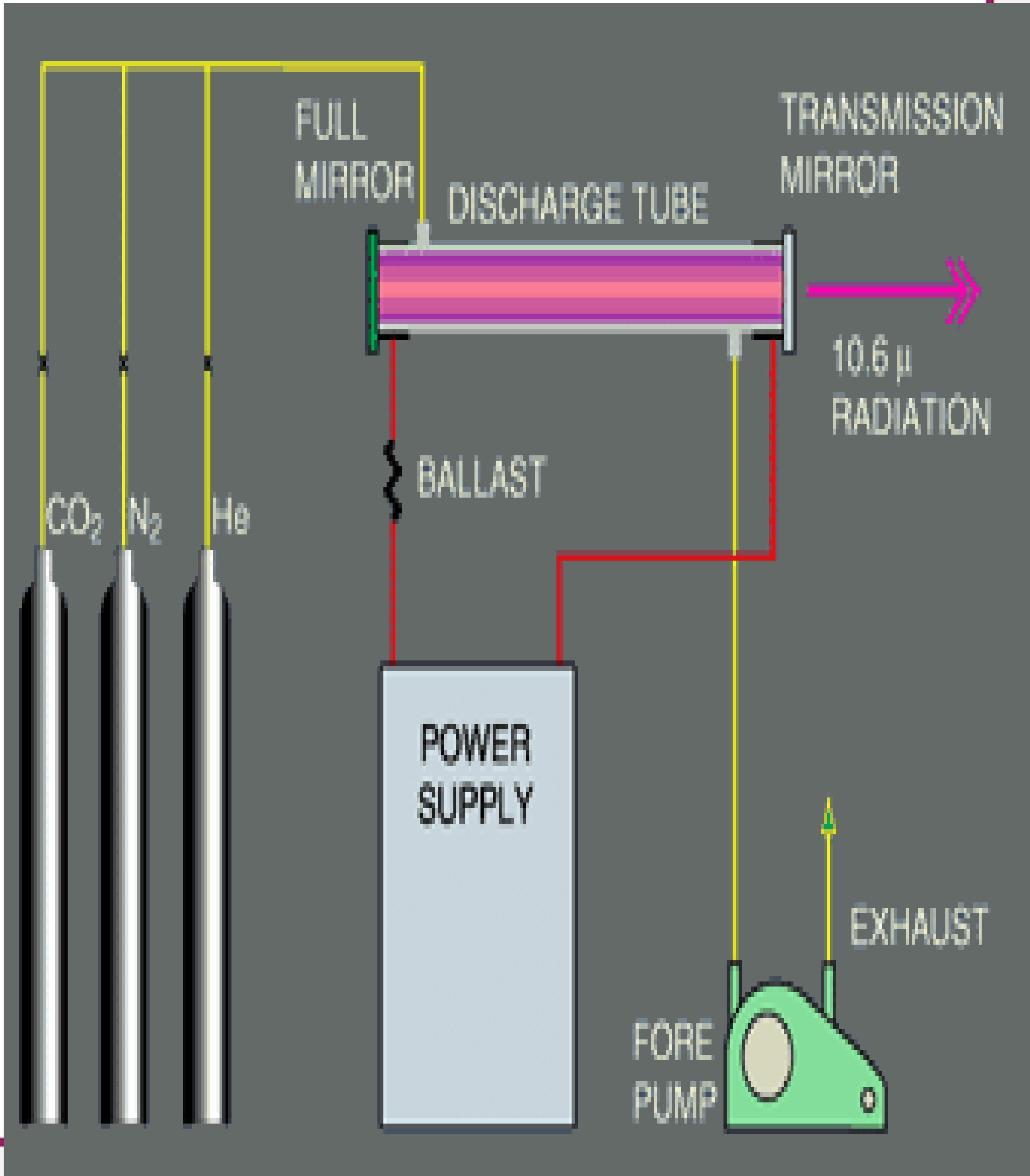
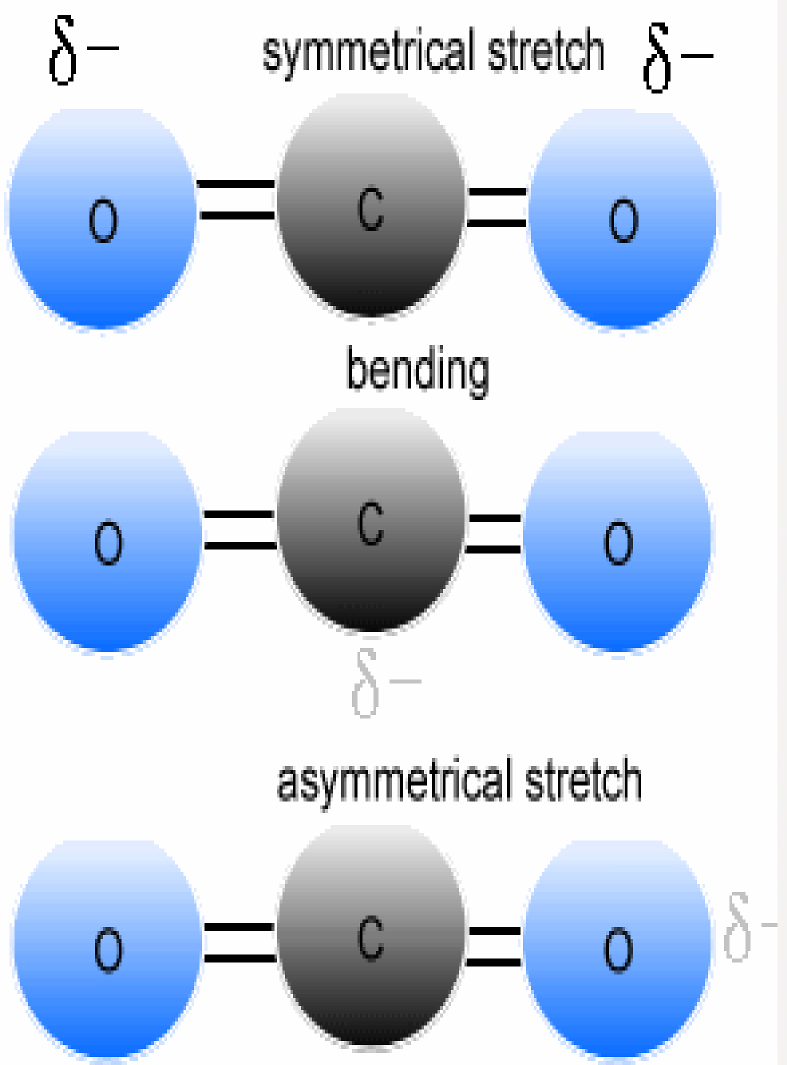
- One of the earliest gas lasers to be developed.
- It was invented by Kumar Patel of Bell Labs in 1964
- They are also quite efficient
- The CO_2 laser produces a beam of infrared light with the principal wavelength bands centering on 9.6 and10.6 µm.

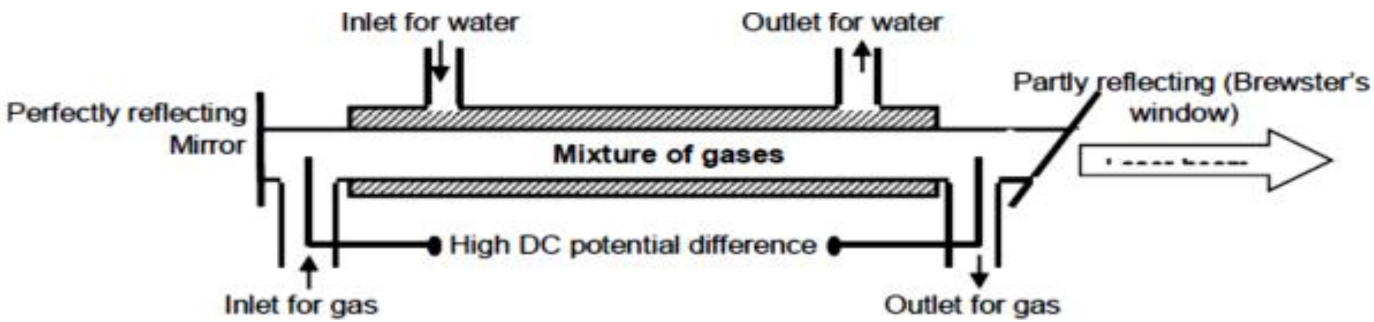


Carbon dioxide LASER (CO_2):

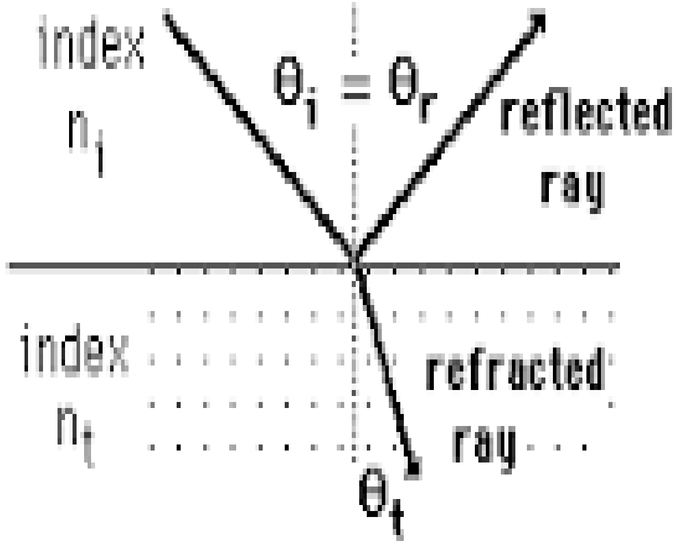
- 1. **Symmetric Stretching Mode**: Both of the oxygen atoms oscillate along the axis of the molecule simultaneously approaching and departing the carbon atom which is stationary.
- 2. **Bending Mode**: Atoms move perpendicular to the molecular Axis. The bending vibration is doubly degenerate it can occur in the plane of figure and the plane of perpendicular.
- 3. **Asymmetric Stretching Mode**: All the three atoms oscillate along the molecular axis, but while both oxygen atoms move in one direction, carbon atoms moves in the opposite direction.



Carbon dioxide LASER (CO2):



- The carbon dioxide laser consists of a tube of about 5m length and 2.5cm diameter
- The ends of the tube are closed with Brewster's windows.
- Brewster's windows: transparent plates which are oriented at Brewster's angle such that reflection losses are minimized.
- Outside the ends of the tube, two optically plane mirrors are fixed on either side of the tube normal to its axis out of which one is perfectly reflecting and the other is partly reflecting.
- This forms the resonant cavity.



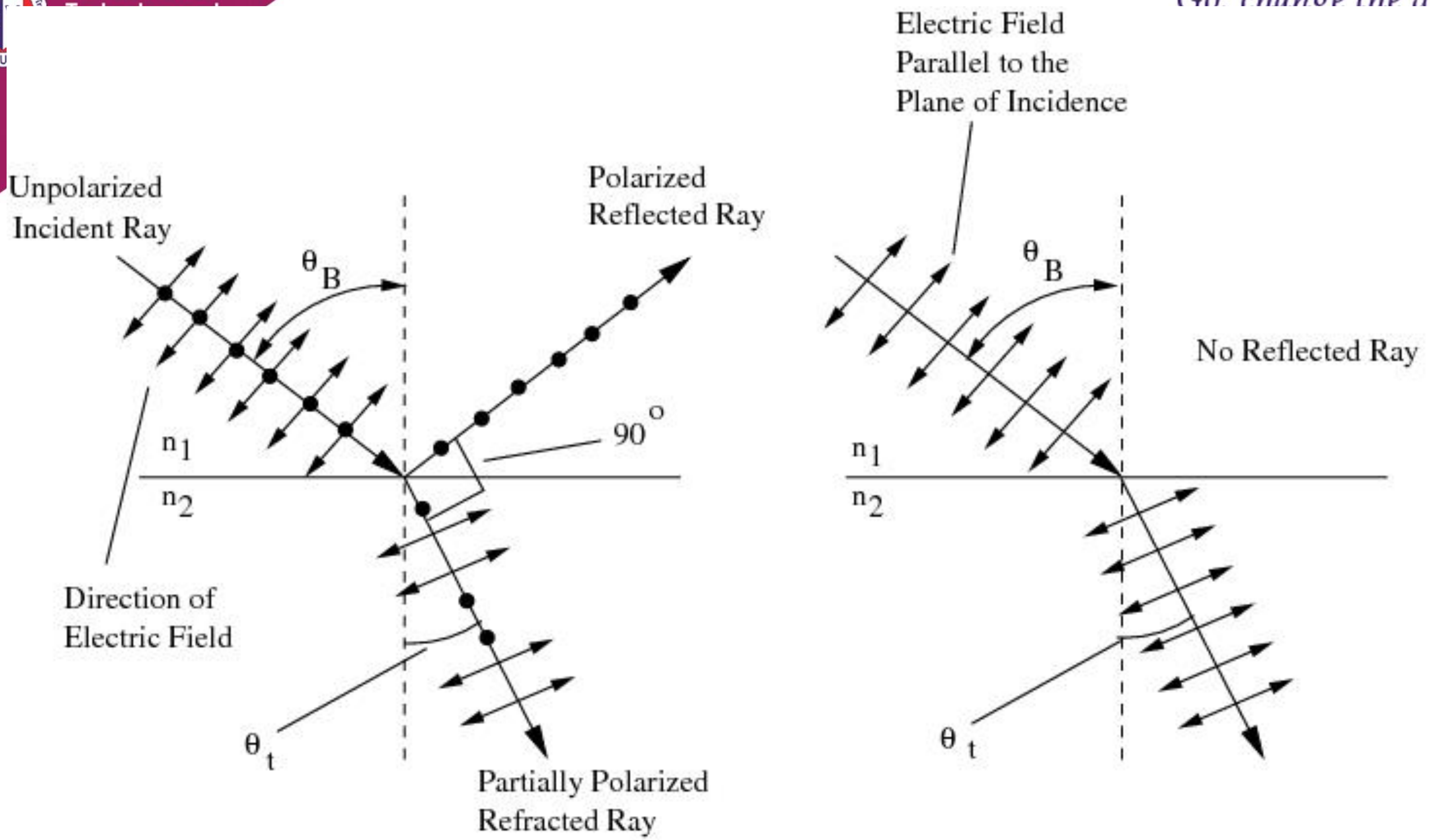
$$r_{\parallel} = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} = 0$$

when $\theta_i + \theta_t = 90°$.

$$n_i \sin\theta_i = n_t \sin(90° - \theta_i) \quad \text{by Snell's law}$$

$$\tan\theta_i = \frac{n_t}{n_i}$$

Brewster's angle (also known as the polarization **angle**) is an **angle** of incidence at which light with a particular polarization is perfectly transmitted through a transparent dielectric surface, with no reflection.



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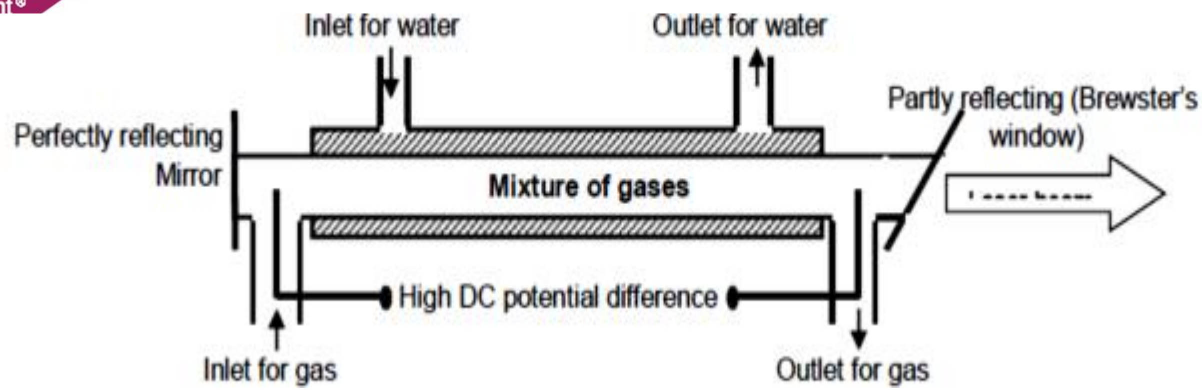
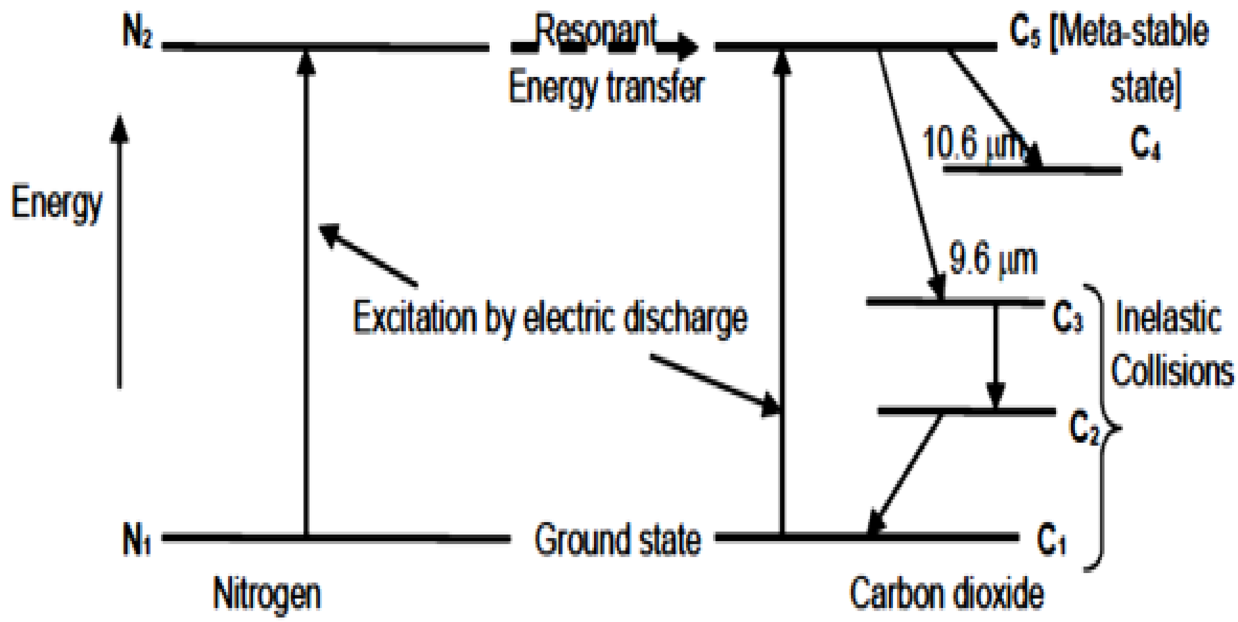
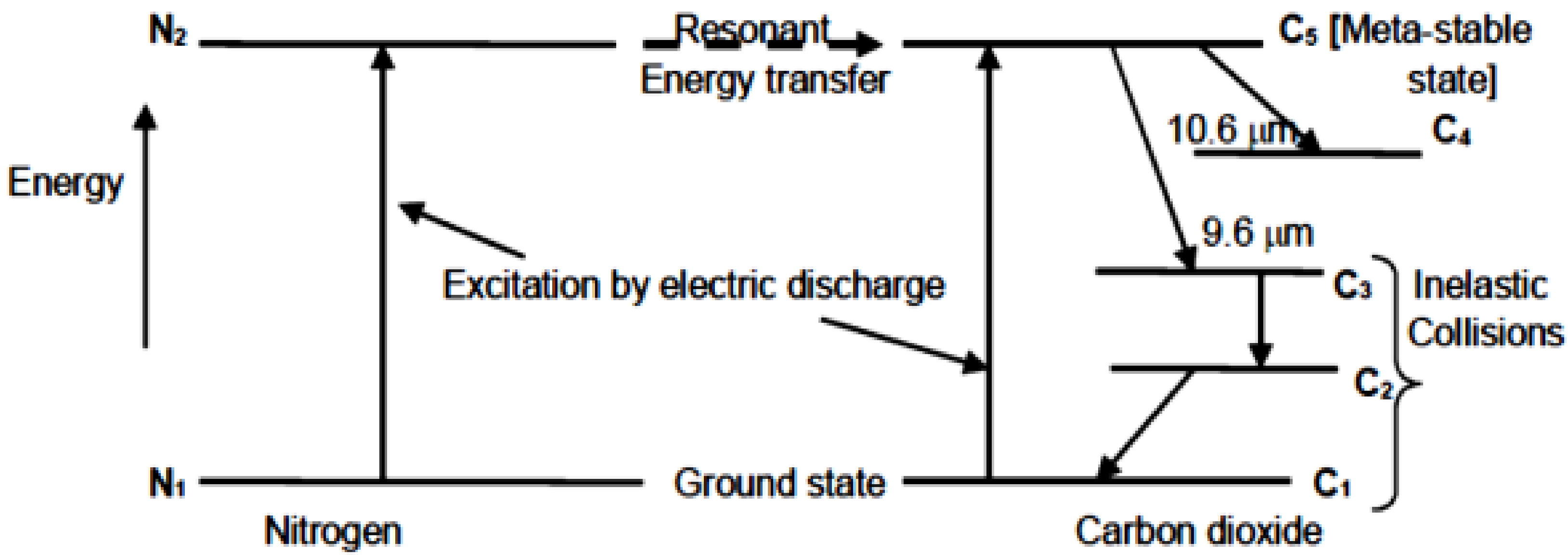


- The active medium in this laser is a mixture of CO_2, N_2 and He gases in the ratio 1:2:3.
- The pressure inside the tube is about 6-17 torr.
- The discharge tube containing the mixture of gases is continuously cooled by circulating water.
- Pumping mechanism employed here is electric discharge.
- When a high voltage is applied to the gas, electric discharge takes place through the gas mixture and N_2 and CO_2 atoms collide with the electrons and get excited to higher energy levels.



Energy level diagram

- For CO_2 gas, it so happens that there is a close coincidence in energy of its C5 state with the N_2 state of nitrogen gas.
- Therefore when a N2 molecule in the metastable state collides with a CO2 molecule in the ground state,
- Because of the matching of the energy levels, resonant transfer of energy takes place form N2 molecule to a CO2 molecule.
- As a result the CO2 molecules get elevated to C5 state whereas,
- the N2 molecules return to the ground state.



Energy level diagram

- Thus the population of C5 level of CO2 increases rapidly which leads to population inversion with respect to the two lower lasing levels C3 and C4.
- Transition from the level C5 to C4 produces laser of wavelength 10.6 μm and that from C5 to C3 results in a laser beam of wavelength 9.6 μm.
- Both these radiations lie in the IR region.
- The CO2 molecules present in C4,C3 and C2 levels may make non-radiative transition to the ground state quickly by colliding with the helium atoms.

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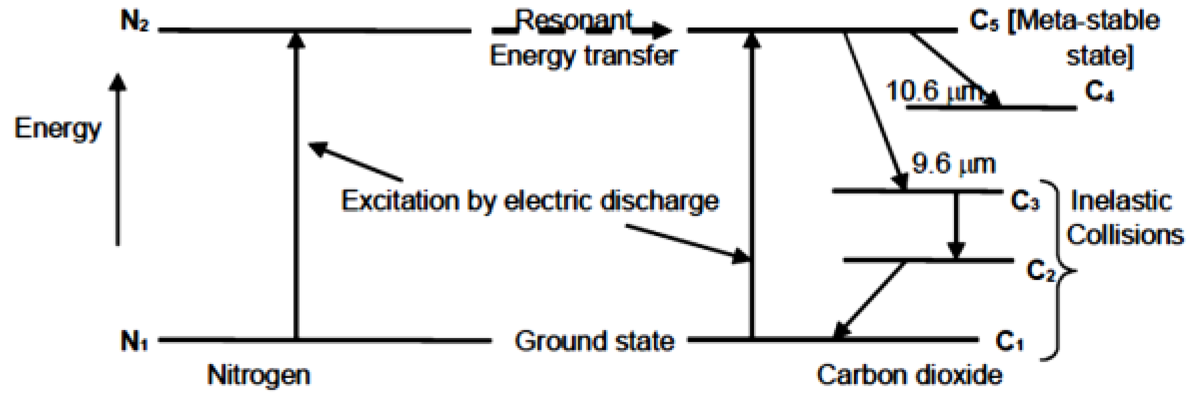
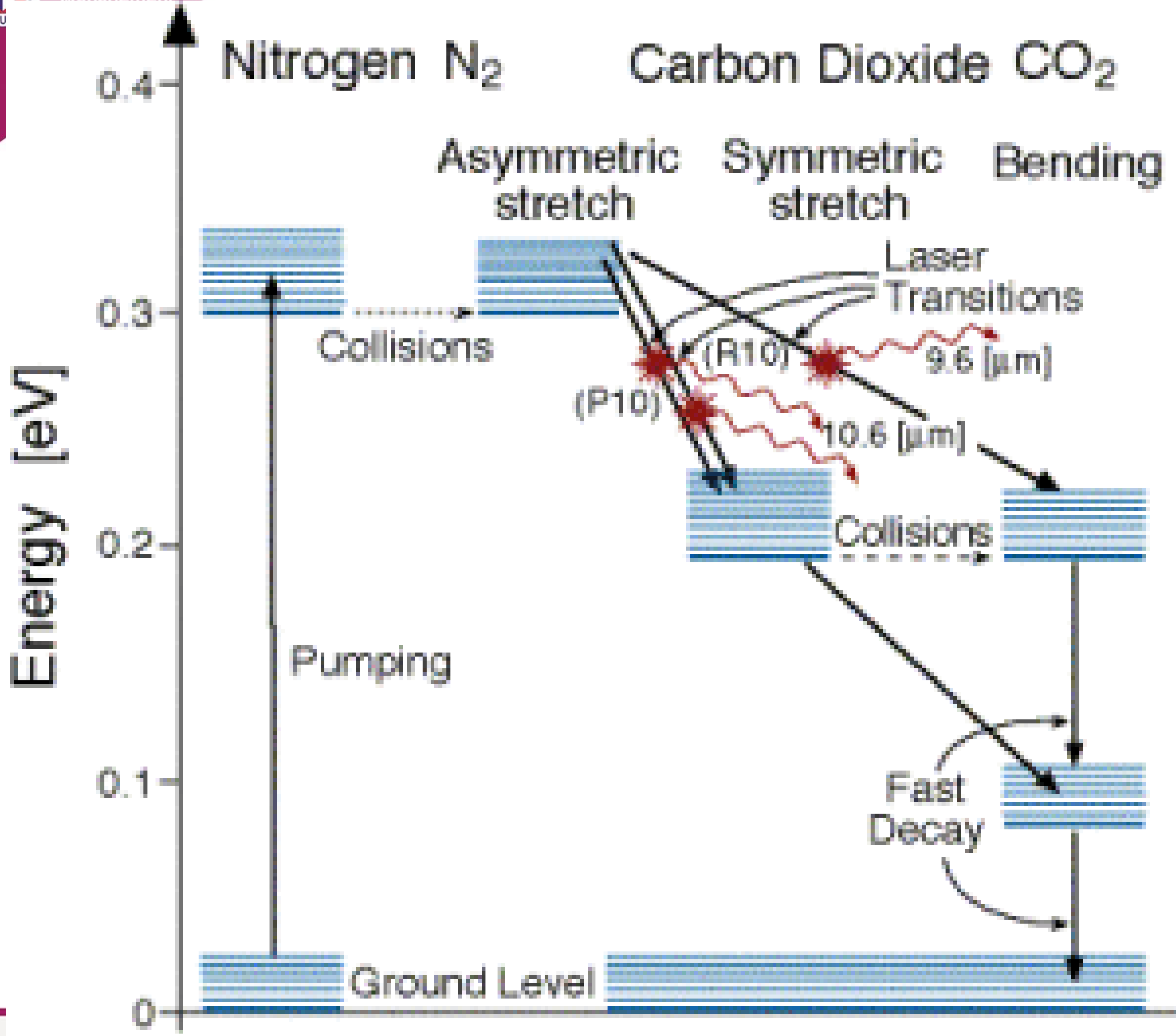
world



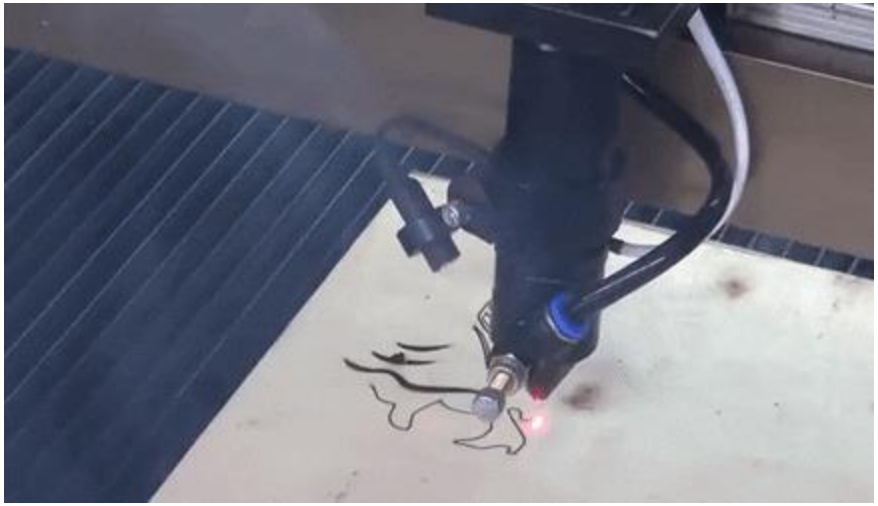
Energy level diagram

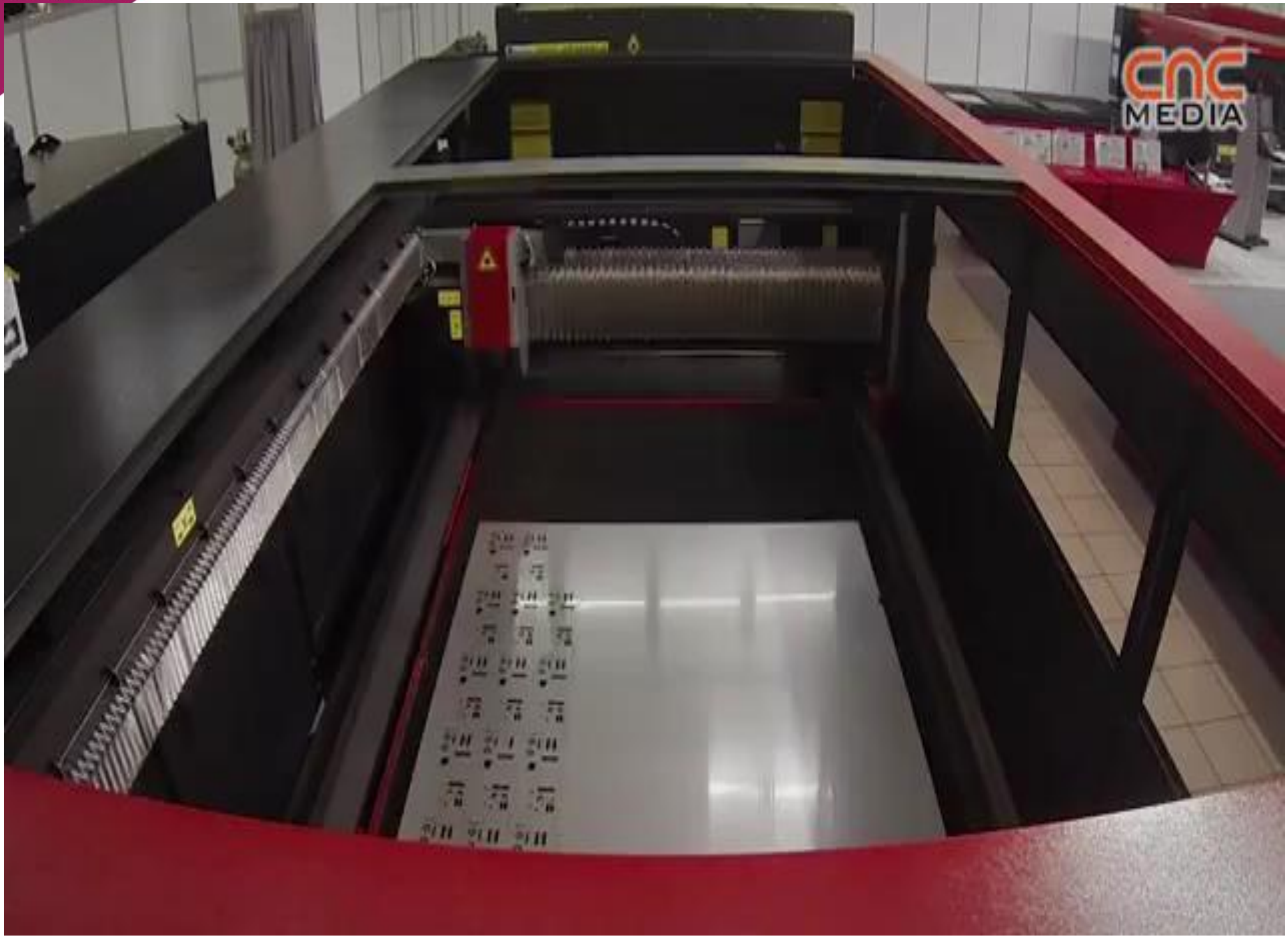
- Carbon dioxide molecules are the active molecules in which lasing action takes place.
- The purpose of nitrogen gas in the tube is to create the condition of population inversion in CO2
- whereas helium gas is passed through the tube in order to avoid population in the lower levels by thermal excitation
- as helium gas possesses high thermal conductivity, it helps to conduct heat away to the walls, keeping the CO2 temperature low.
- Thus nitrogen helps to increase the population of upper levels and helium helps to depopulate the lower levels
- The laser output is about few kilowatts and operates with an efficiency of up to 30%.


Nitrogen N_2
Carbon Dioxide CO_2
Asymmetric stretch
Symmetric stretch
Bending
Energy [eV]
0.4
0.3
0.2
0.1
0
Collisions
Laser Transitions
(R10)
(P10)
9.6 [μm]
10.6 [μm]
Collisions
Pumping
Fast Decay
Ground Level

Application of CO_2 laser

- • It is used in material processing (welding, cutting and drilling).
- It is used in open air communication systems.
- • It is used in micro surgery and bloodless operation.
- • It is used in laser remote sensor




CNC
MEDIA

Characteristics of laser beams:

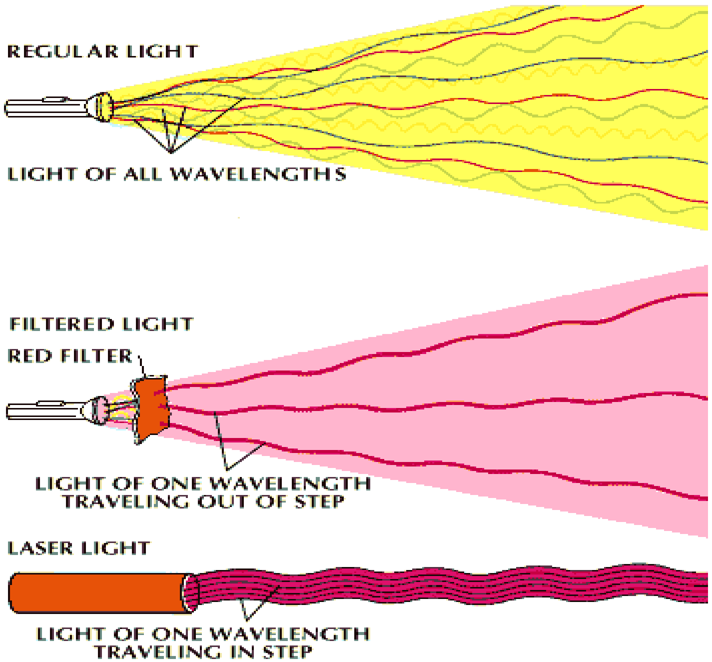
- 1. **Intensity:** **Since a large number of photons are emitted by stimulated emission continually, the laser beam is highly intense.**

Characteristics of laser beams:

- **2. Monochromaticity: Since laser results from stimulated emission, all the photons in the beam are of the same frequency and the line width of radiation is negligible.**

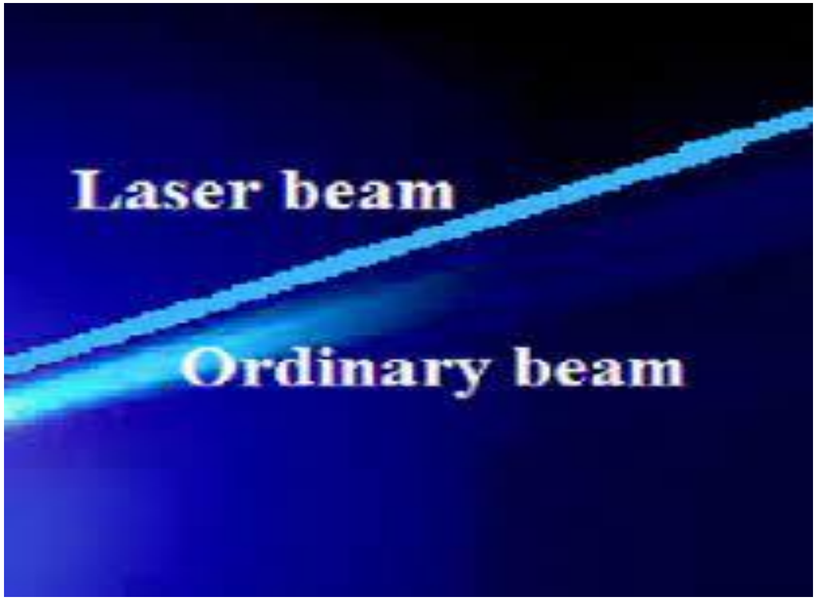
Characteristics of laser beams:

- 3. Coherence: Coherence is another important characteristic that distinguishes laser from other types of monochromatic light. Coherence means constancy in phase difference between any two points in a wave separated by the same distance, in any of the waves emitted by the source.



Characteristics of laser beams:

- 4. Directionality: The laser cavity mirrors can reflect only those photons incident normal to their planes. Due to this, photons moving even at slightly different angles fail to return to the lasing medium and form standing waves. Such beams are therefore suppressed and hence the laser beam is highly directional.



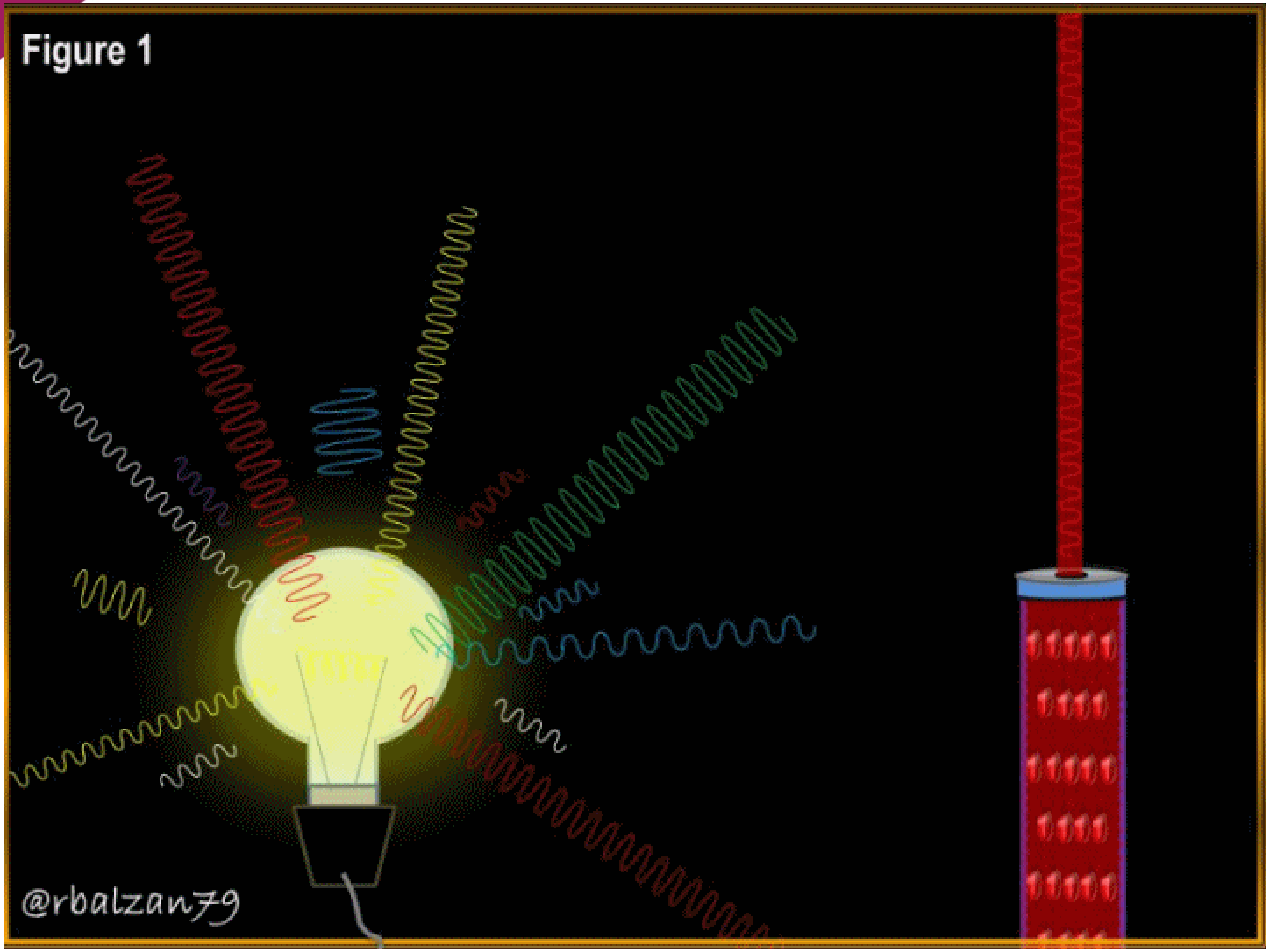
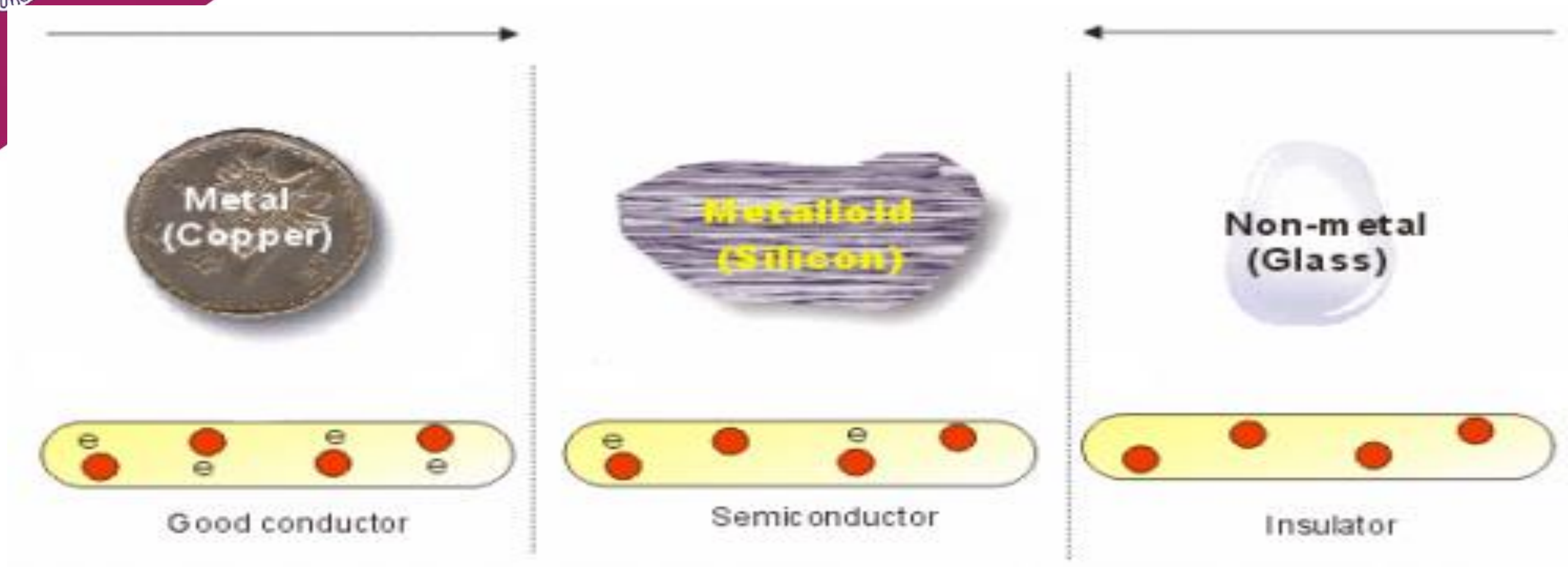
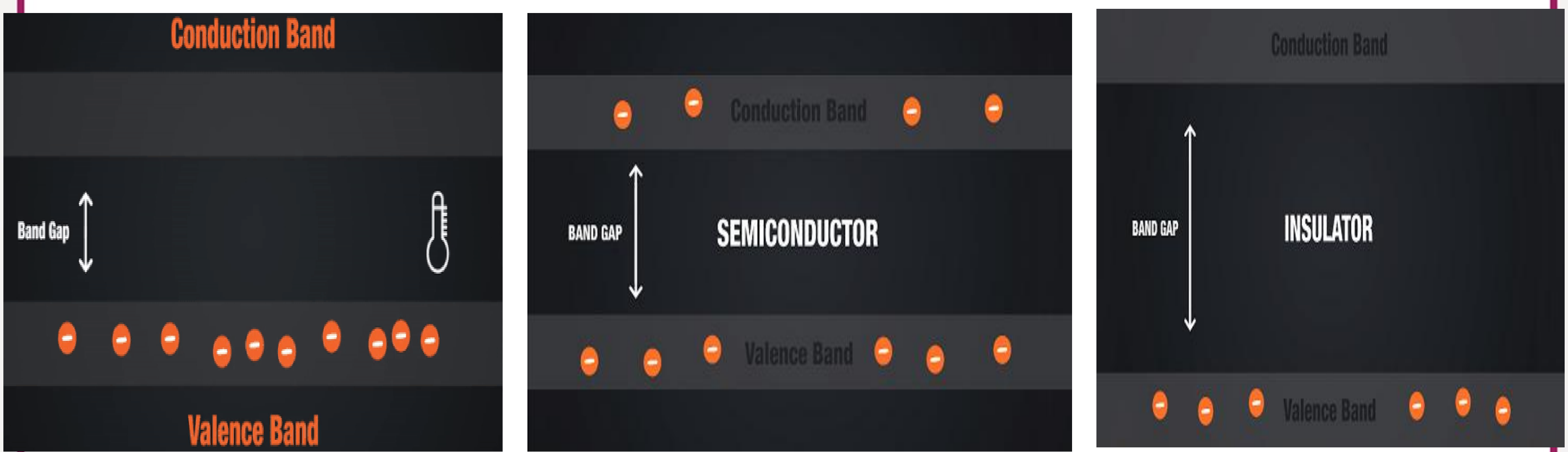


Figure 1
@rbalzan79

Characteristics of laser beams:

- 5. Focussability: Since laser beam is highly monochromatic and collimated, it can


Metal
(Copper)
Metalloid
(Silicon)
Non-metal
(Glass)
Good conductor
Semiconductor
Insulator


Conduction Band
Band Gap
Valence Band
Conduction Band
BAND GAP
SEMICONDUCTOR
Valence Band
Conduction Band
BAND GAP
INSULATOR
Valence Band

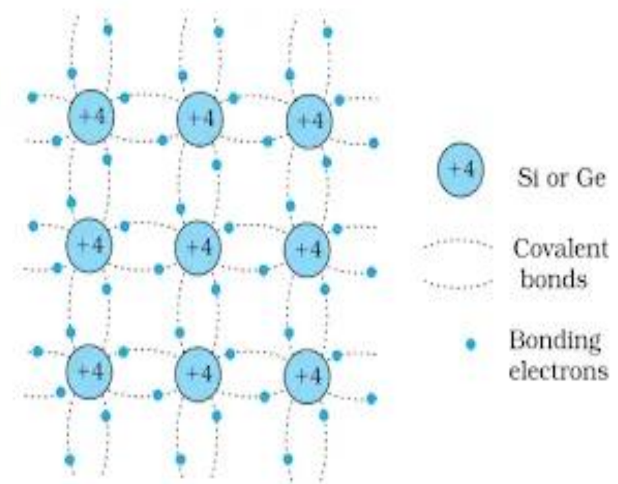
Semiconductors

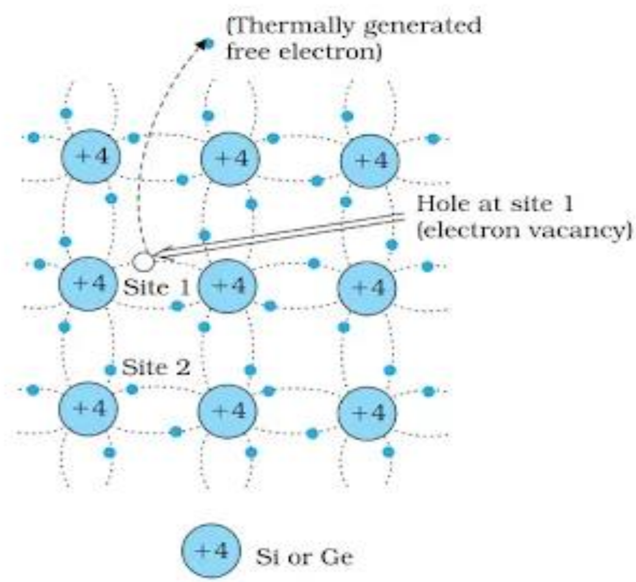
- Semiconductors are the materials which have a **conductivity between conductors** and **insulators.**
- Semiconductors can be compounds such as gallium arsenide or pure elements, such as germanium or silicon.
- ***Intrinsic Semiconductors:***

Pure semiconductors, conductivity low

- ***Extrinsic Semiconductors:***

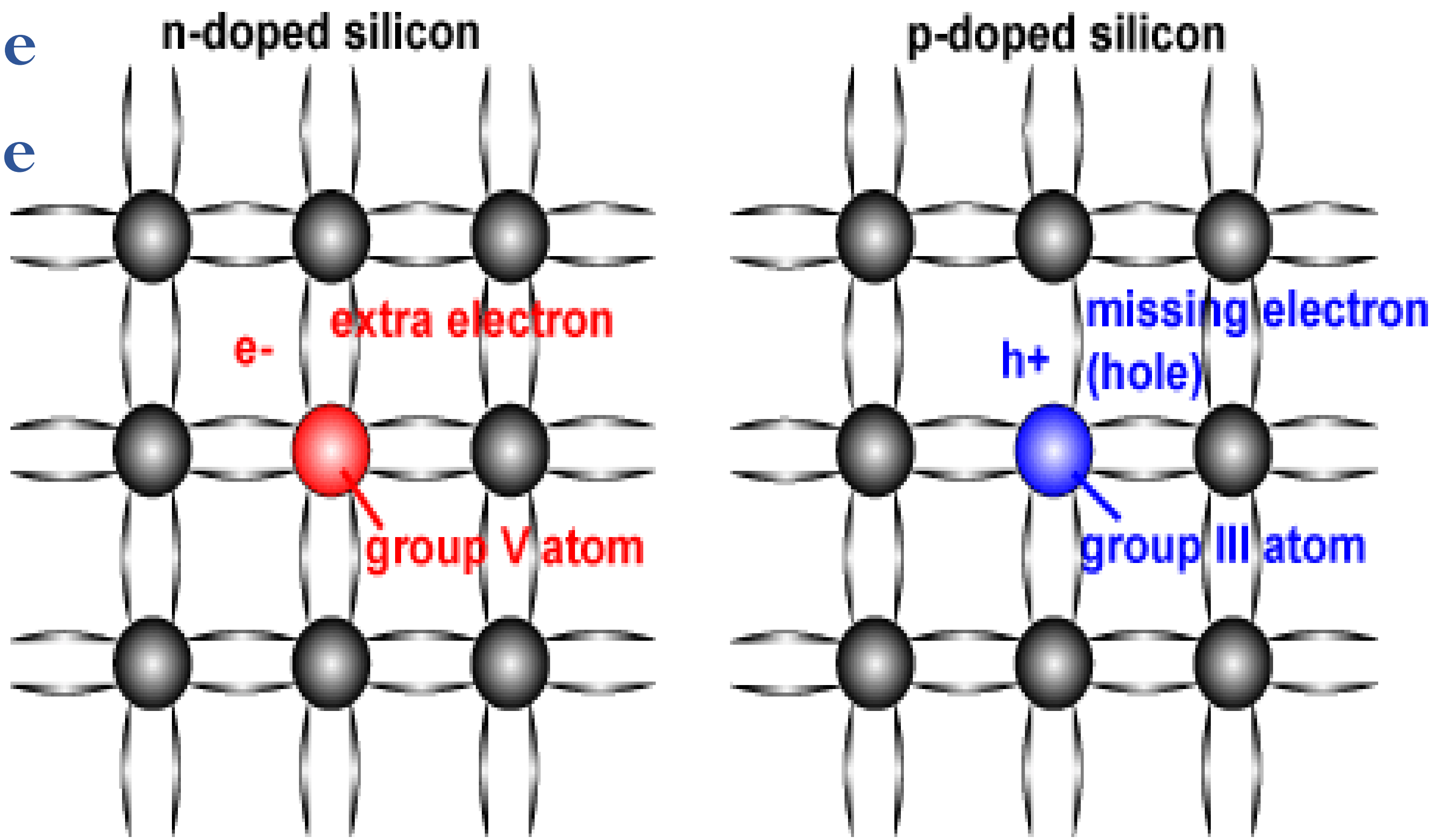
semiconductors made from adding impurity into an intrinsic semiconductor to increase conductivity at room temperature are called extrinsic semiconductors





Extrinsic Semiconductors

- p-type
- n-type



p Type Semiconductor

Easy PhyZee

LET'S UNCOMPLICATE.....

- The extrinsic **p-Type Semiconductor** is formed when a **trivalent impurity** is added to a pure semiconductor in a small amount, and as a result, a large number of holes are created in it.
- A large number of holes are provided in the semiconductor material by the addition of trivalent impurities like **Gallium** and **Indium.**
- A trivalent impurity like Al, having three valence electrons is added to Si crystal in a small amount.
- Each atom of the impurity fits in the Si crystal in such a way that its three valence electrons form covalent bonds with the three surrounding Si atoms and the fourth covalent bonds, only the Si atom contributes one valence electron, while Al atom has no valence bonds.

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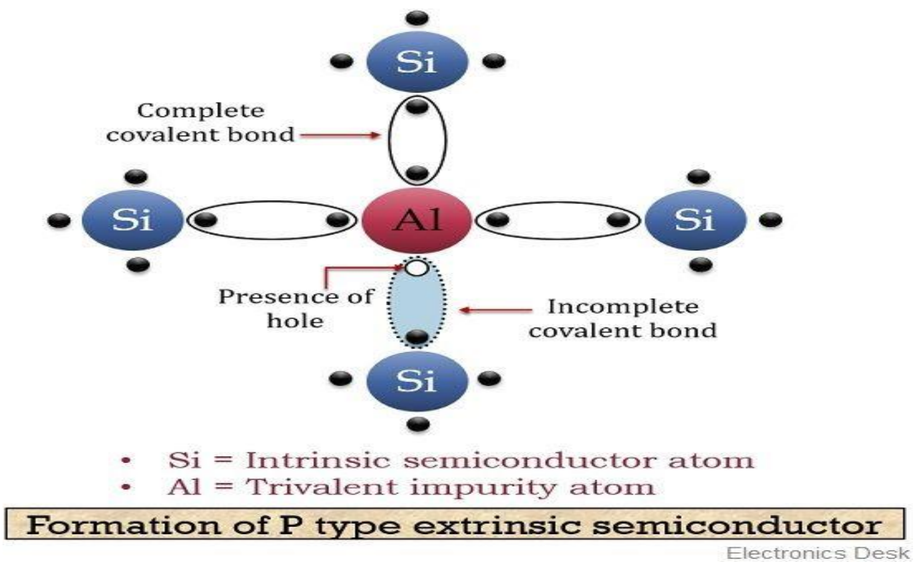
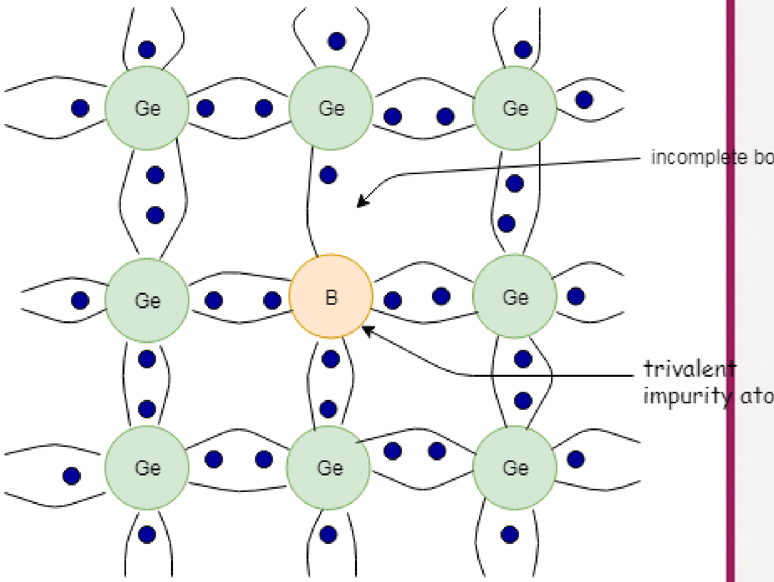
p Type Semiconductor

- Hence, the fourth covalent bond is incomplete, having one electron short.
- This **missing electron is known as a Hole**. Thus, each Al atom provides one hole in the Si crystal.
- As an extremely small amount of Gallium impurity has a large number of atoms, therefore, it provides millions of holes in the semiconductor

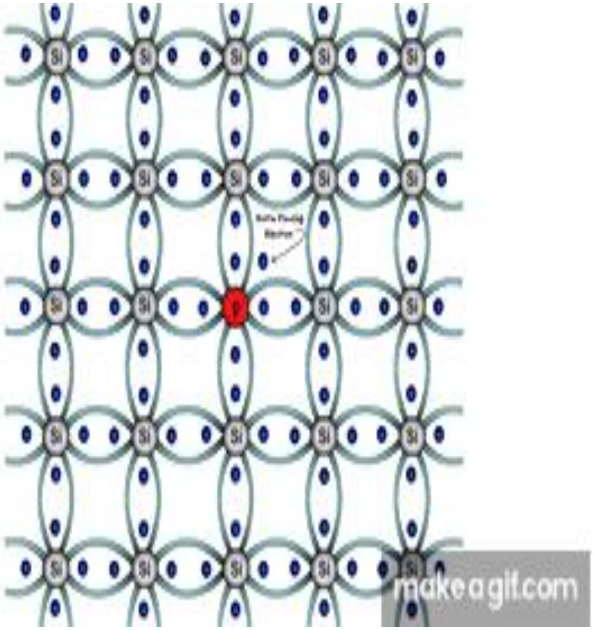


Formation of P type extrinsic semiconductor

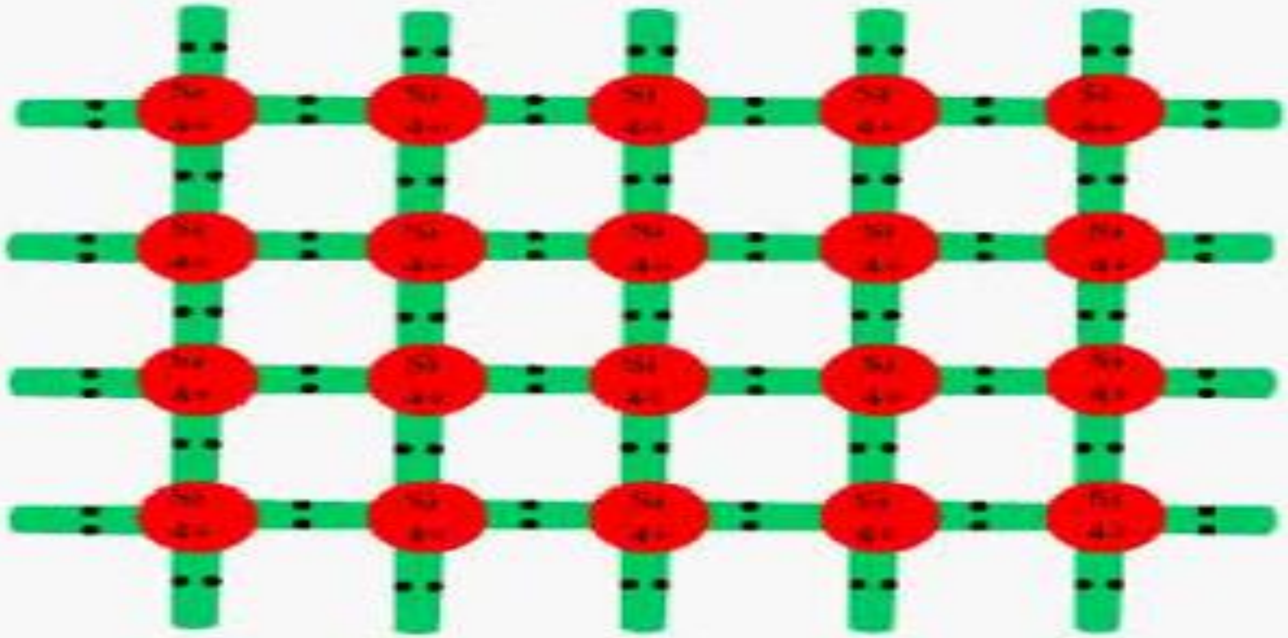


n Type Semiconductor

- When a small amount of **Pentavalent impurity** is added to a pure semiconductor providing a large number of free electrons in it, the extrinsic semiconductor thus formed is known as **n-Type Semiconductor.** The conduction in the n-type semiconductor is because of the free electrons denoted by the pentavalent impurity atoms.
- These electrons are the excess free electrons with regards to the number of free electrons required to fill the covalent bonds in the semiconductors.
- The addition of Pentavalent impurities such as arsenic and antimony provides a large number of free electrons in the semiconductor crystal. Such impurities which produce n-type semiconductors are known as Donor Impurities.



Neutral Silicon



All electrons locked in covalent bonds

n-type

p-type

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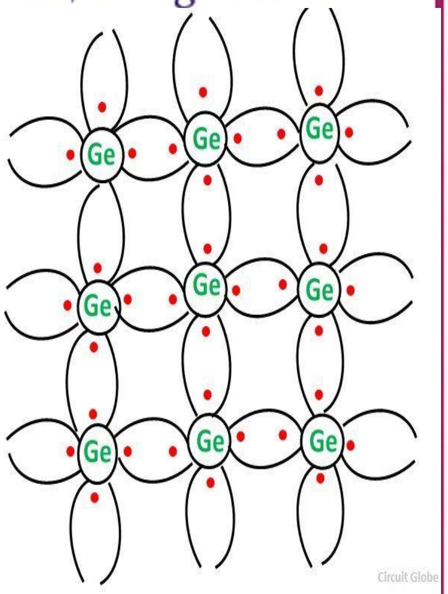
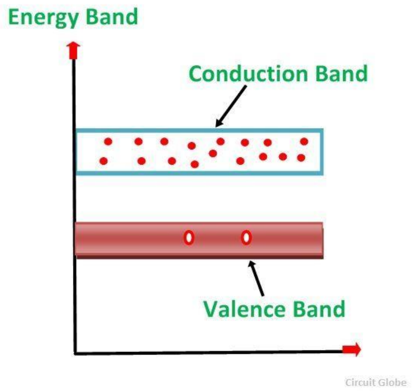
n Type Semiconductor

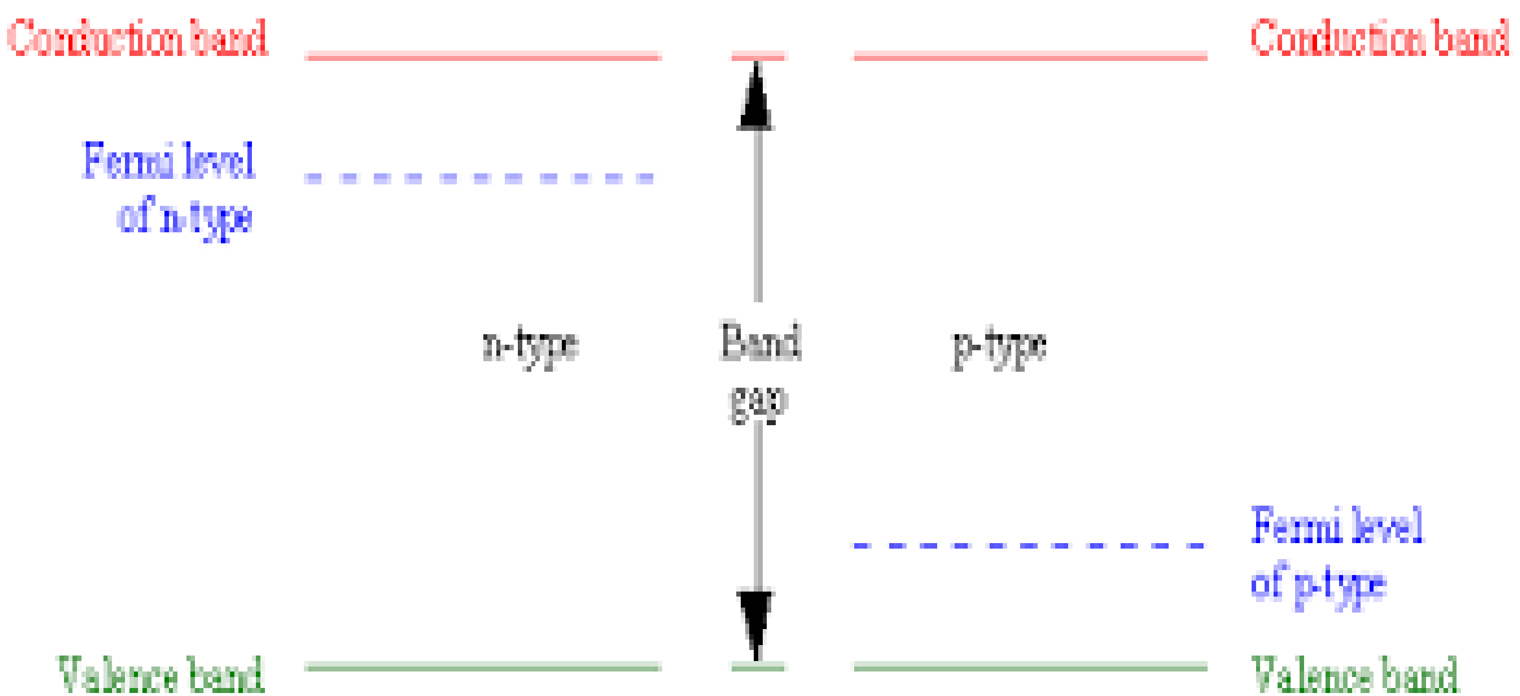
Go, change the world

- They are called a **donor impurity** because each atom of them donates one free electron crystal.
- When a few Pentavalent impurities such as **Arsenic** whose atomic number is 33, which is categorized as **2, 8, 15 and 5**.
- It has five valence electrons, which is added to germanium crystal. Each atom of the impurity fits in four germanium atoms as shown in the figure above.
- Hence, each Arsenic atom provides one free electron in the Germanium crystal. Since an extremely small amount of arsenic impurity has a large number of atoms; it provides millions of **free electrons for conduction.**



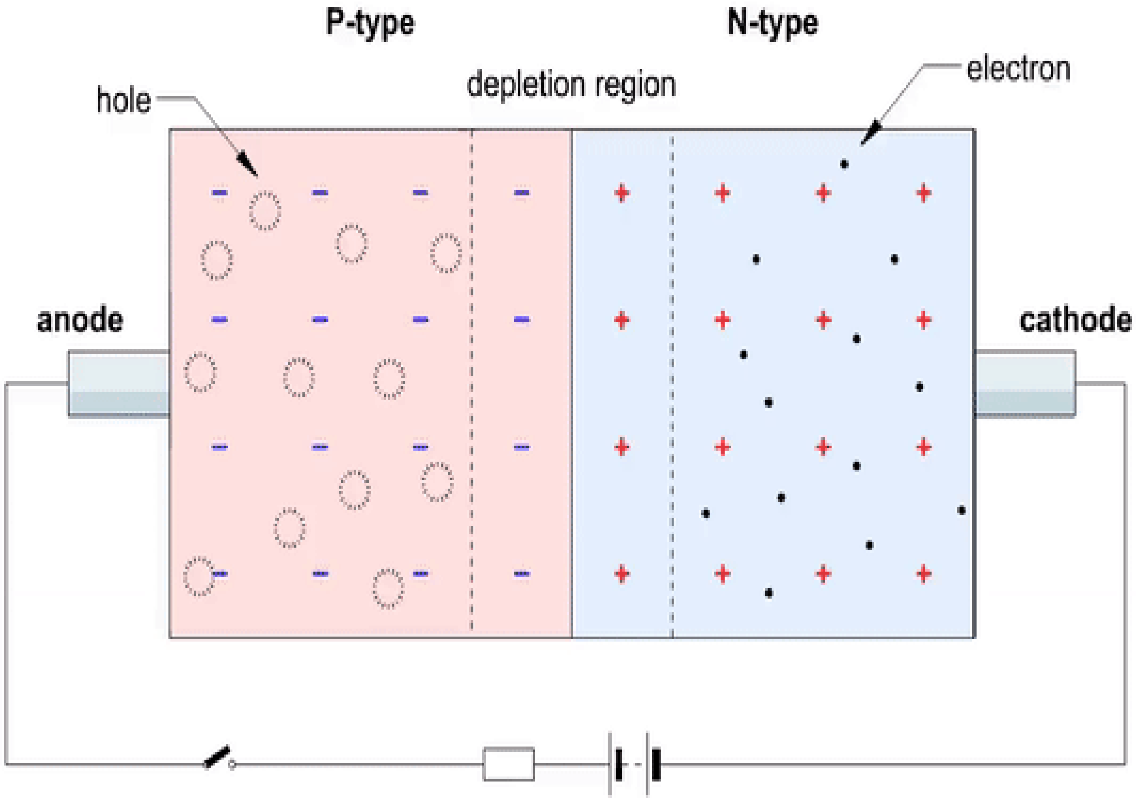


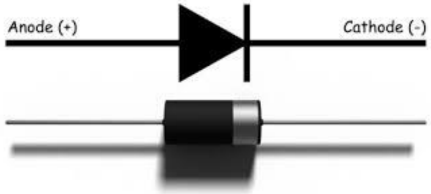
Fermi level of n-type and p-type semiconductors



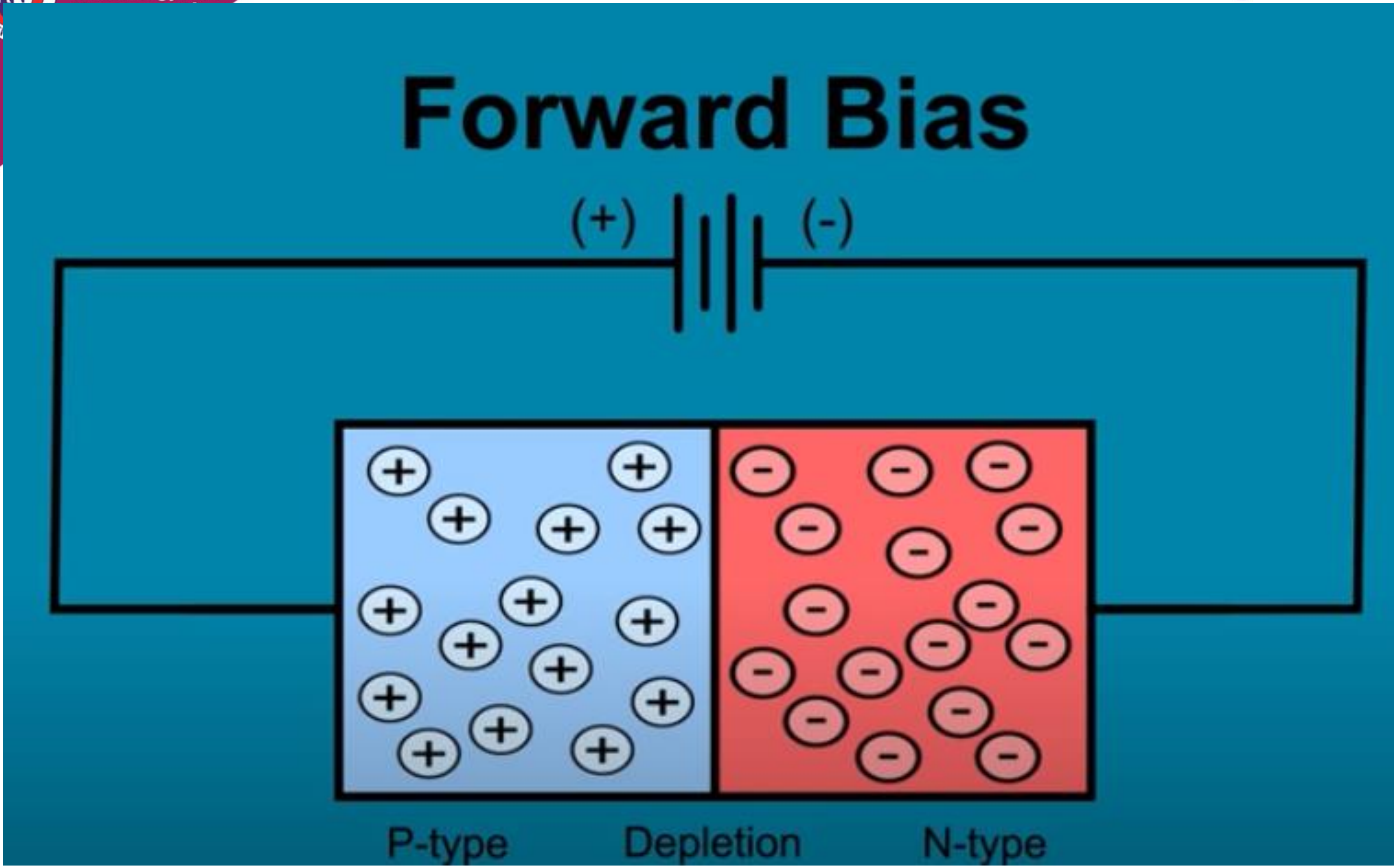
Principle of a Laser Diode

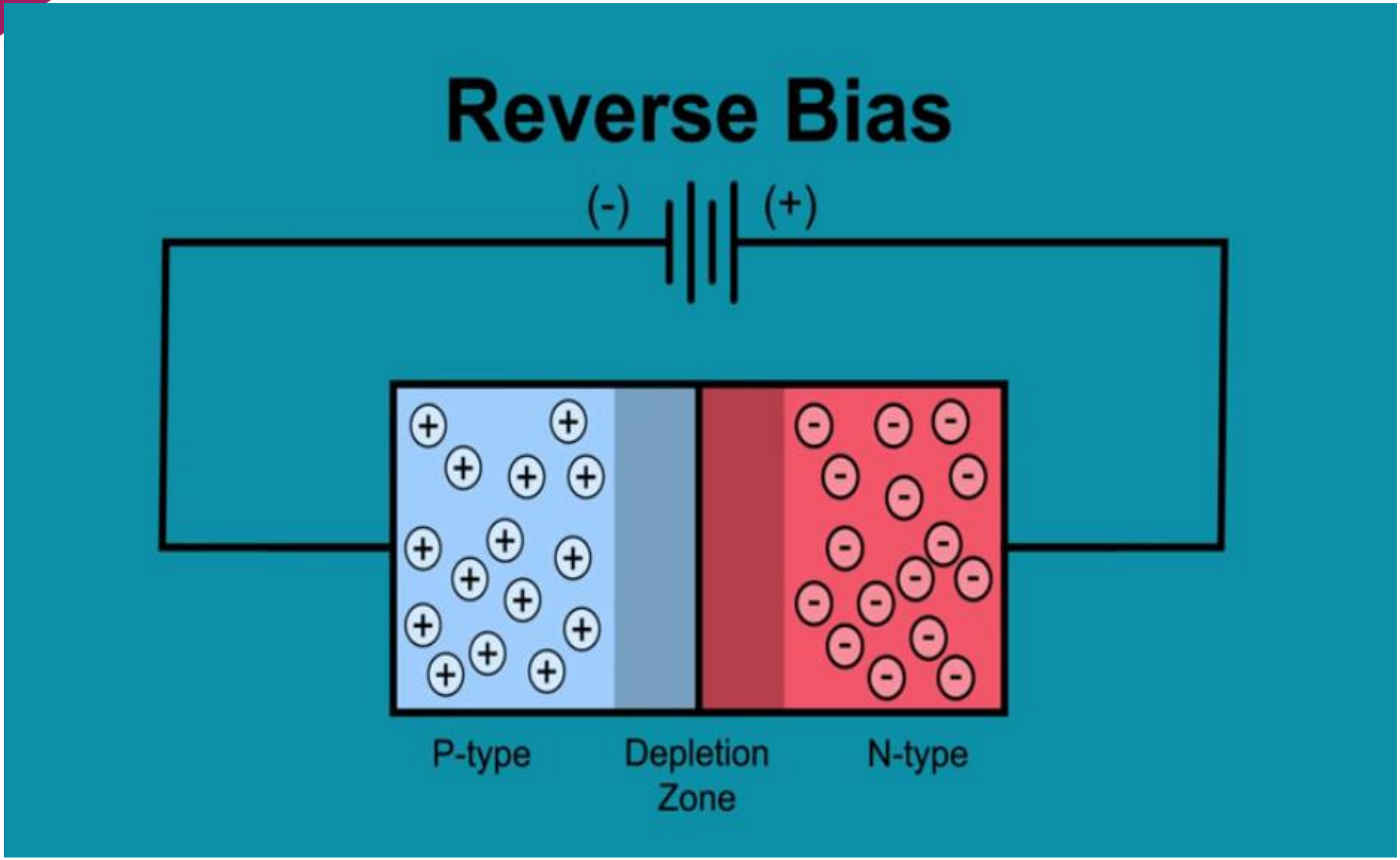
Diode





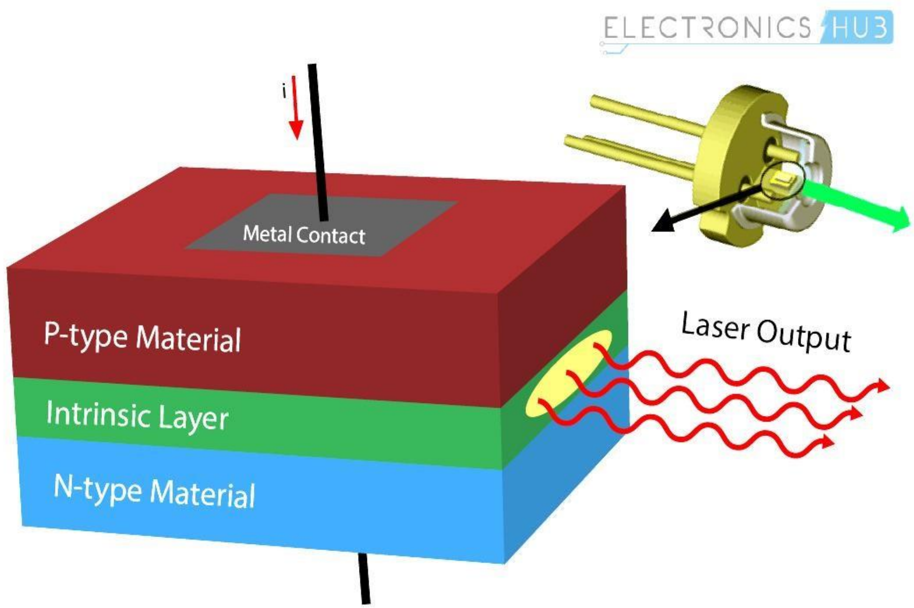
- A **diode** is a two-terminal electronic component that conducts current primarily in one direction
- A **semiconductor diode** is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals.
- Diodes are made of silicon, gallium arsenide and germanium


Forward Bias
(+)
(-)
P-type
Depletion
N-type

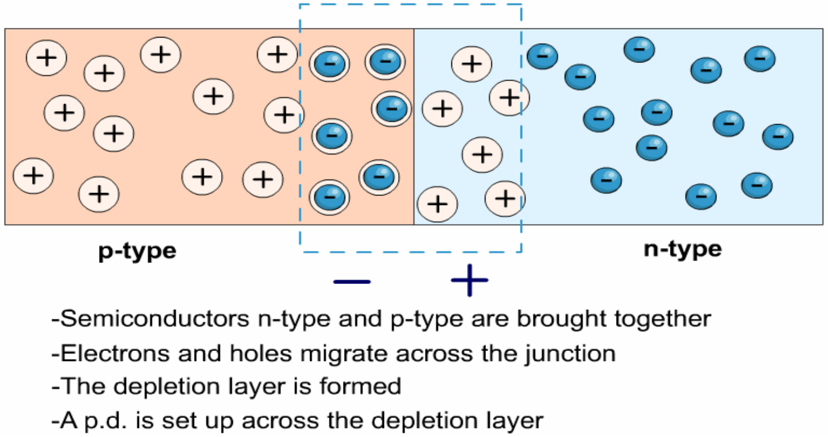

Reverse Bias
(-)
(+)
P-type
Depletion Zone
N-type

Semiconductor Diode Laser

- A semiconductor diode laser is a specially fabricated p-n junction device that emits coherent light when it is forward biased



LASER DIODE CONSTRUCTION



Principle

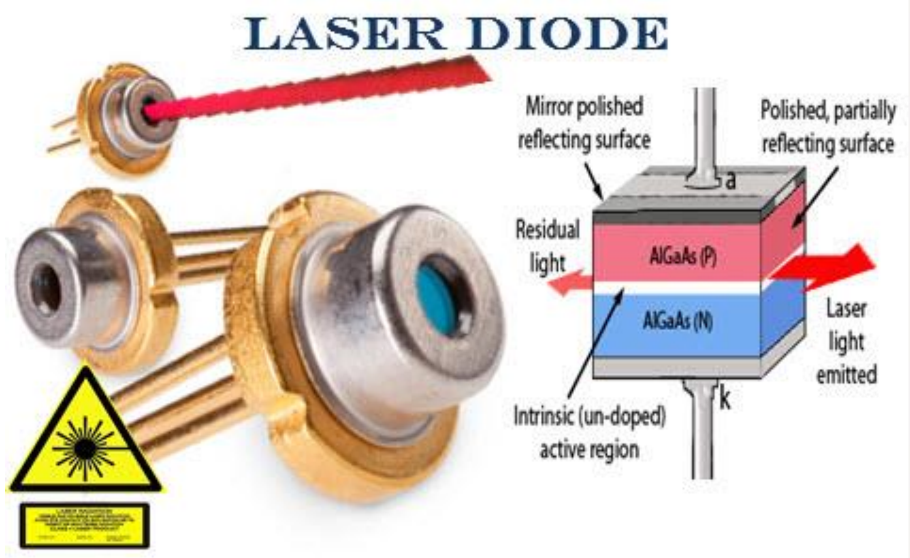
- When a p-n junction diode is forward biased, the electrons from n – region and the holes from the p region cross the junction and recombine with each other.

- During the recombination process, the light radiation (photons) is released from a certain specified direct band gap semiconductors like Ga-As. This light radiation is known as recombination radiation.

- The photon emitted during recombination stimulates other electrons and holes to recombine. As a result, stimulated emission takes place which produces laser.

- It is made from Gallium Arsenide (GaAs) which operated at low temperature and emits light in near IR region.
- Now the semiconductor lasers are also made to emit light almost in the spectrum from UV to IR using different semiconductor materials.
- They are of very small size (0.1 mm long), efficient, portable and operate at low power.
- These are widely used in Optical fibre communications, in CD players, CD-ROM Drives, optical reading, laser printing etc.

Construction



- single crystal consisting of a heavily doped n & p sections.
- Doping concentration is very high: 10^{17} to 10^{19} dopant atoms/cm^3 .
- The diode is extremely small

in size, The diode chip is about 500 micrometer long and 100 micrometer wide and thick.

- The depletion layer has a width varying from 1µm to 100µm
- The end surfaces of the p & n sections are provided with electrodes
- The front and rear faces are polished. The polished faces play the role of reflecting mirrors.
- The other two opposite faces are roughened to prevent lasing action in that direction.

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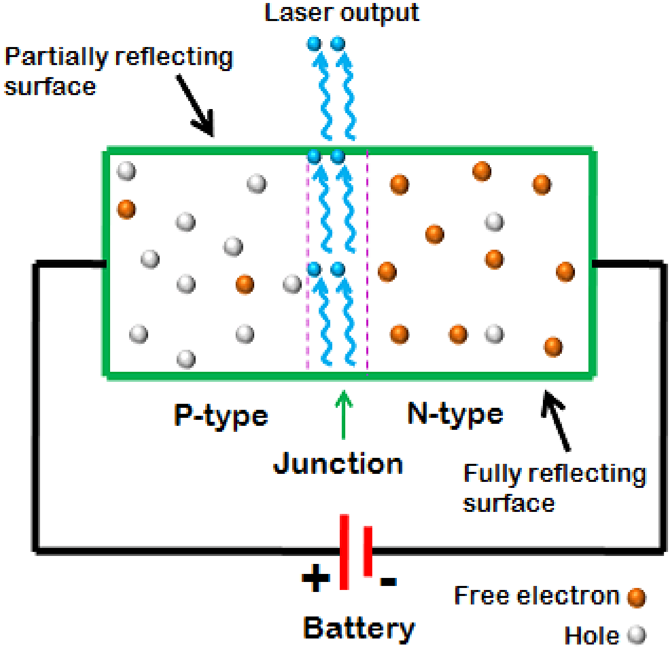
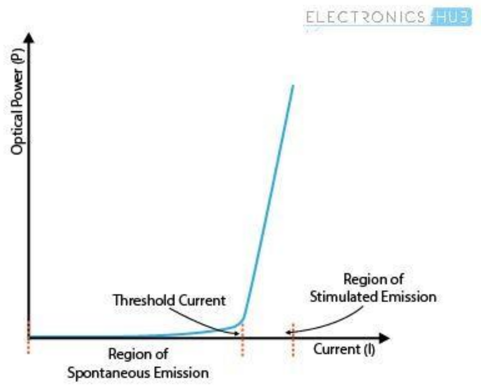
Working:

- For achieving population inversion in a semiconductor laser
- the p & n sections are heavily doped
- forward bias the junction.
- At low forward currents, the electron-hole recombination causes spontaneous emission of radiation and the diode acts as a LED.
- When current is increased and reaches a threshold value,
- population inversion is achieved in the depletion region due to large concentration of electrons in conduction band and holes in valence band.



Laser diode

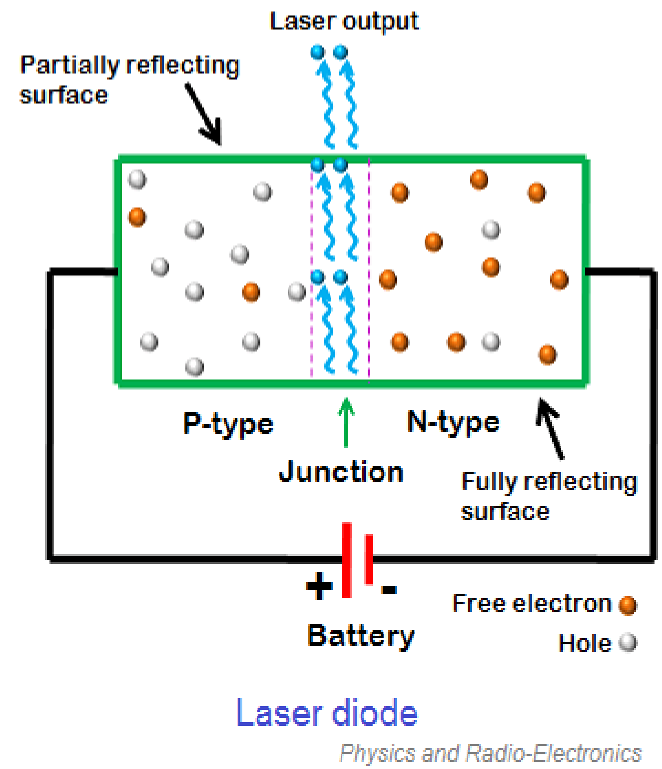
Physics and Radio-Electronics



LASER DIODE P-I GRAPH

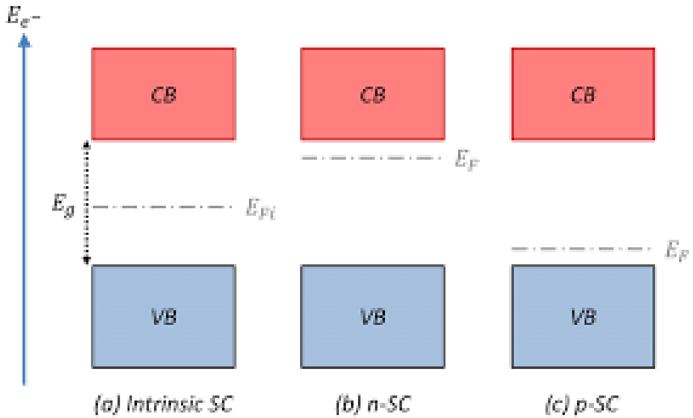
Working:

- The narrow region where population inversion is achieved becomes the active region where lasing action takes place.
- The forward bias applied to the junction is thus the pumping mechanism which produces population inversion.
- The photons traveling in the junction along the resonant cavity stimulate
- recombination of electron-hole pairs due to which the intensity of coherent light builds up along the axis of the cavity.



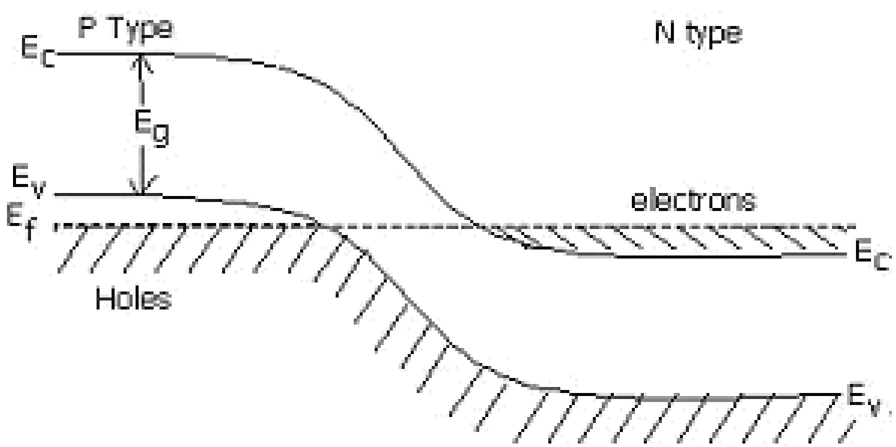
- The semiconductor lasers have low power consumption, are compact and highly efficient. But the laser output is less monochromatic and more divergent compared to other lasers.

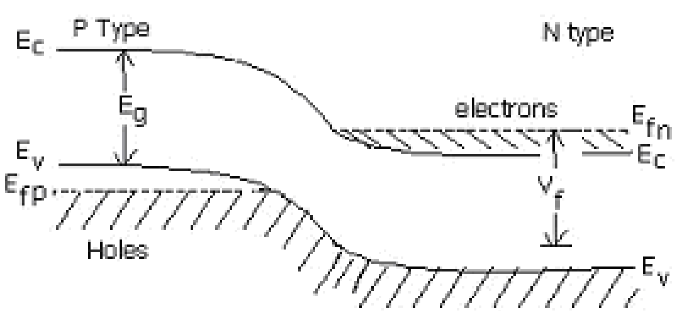
- When an electron and a hole are present in the same region, they may recombine producing a spontaneous emission
- The electron may re-occupy the energy state of the hole, emitting a photon with energy equal to the difference between the electron's original state and hole's state.
- In a conventional semiconductor junction diode, the energy released from the recombination of electrons and holes is carried away as phonons, i.e., lattice vibrations, rather than as photons.
- Spontaneous emission below the lasing threshold produces similar properties to an LED.
- Spontaneous emission is necessary to initiate laser oscillation, but it is one among several sources of inefficiency once the laser is oscillating.

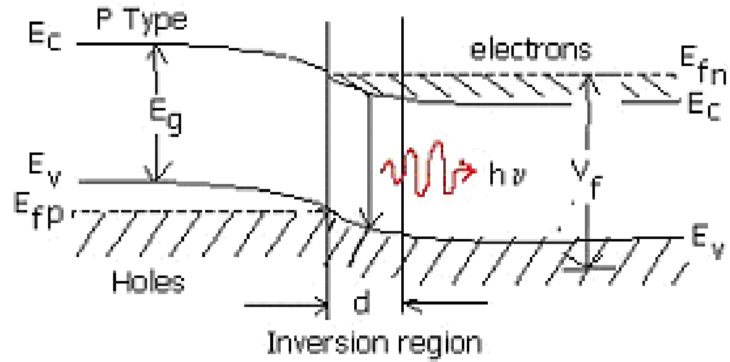


The highest energy level that an electron can occupy at the absolute zero temperature is known as the **Fermi Level**.

- When highly doped p and n regions are joined at the atomic level to form pn-junction, the equilibrium is attained only when the equalization of fermi level takes place
- ie the fermi level is pushed inside the conduction band in n type and the level pushed inside the valence band in the p type







·ld

- When the junction is forward biased, at low voltage the electron and hole recombine and cause spontaneous emission.
- But when the forward voltage reaches a threshold value the carrier concentration rises to very high value.
- As a result the region "d" contains large number of electrons in the conduction band and at the same time large number of holes in the valence band.
- Thus the upper energy level has large number of electrons and the lower energy level has large number of vacancy, thus population inversion is achieved.
- The recombination of electron and hole leads to emission and it stimulate the others to emit radiation.
- Ga As produces laser light of 9000 Å in IR region.

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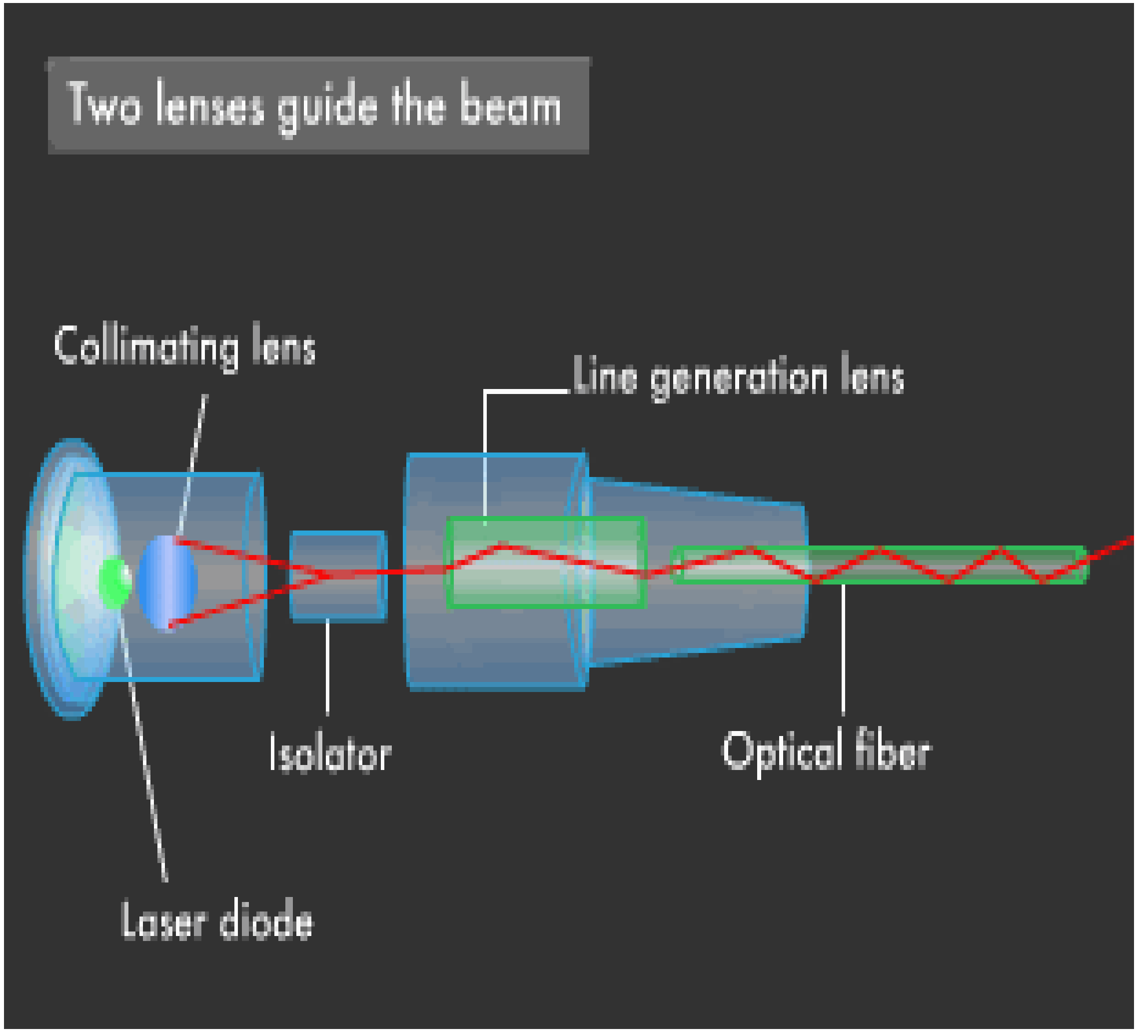
Application of Semiconductor laser

- Fiber Optical Communications.
- Produce Laser Diodes which are more powerful & coherent than LED.
- Printers for Computers, printouts, writing, Reading & CD'S.



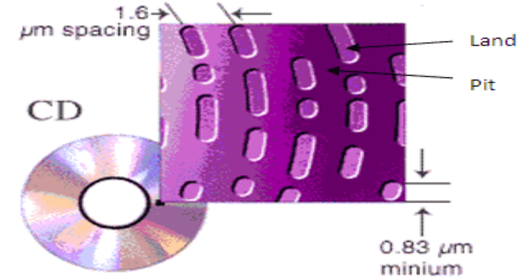
Applications of LASER:

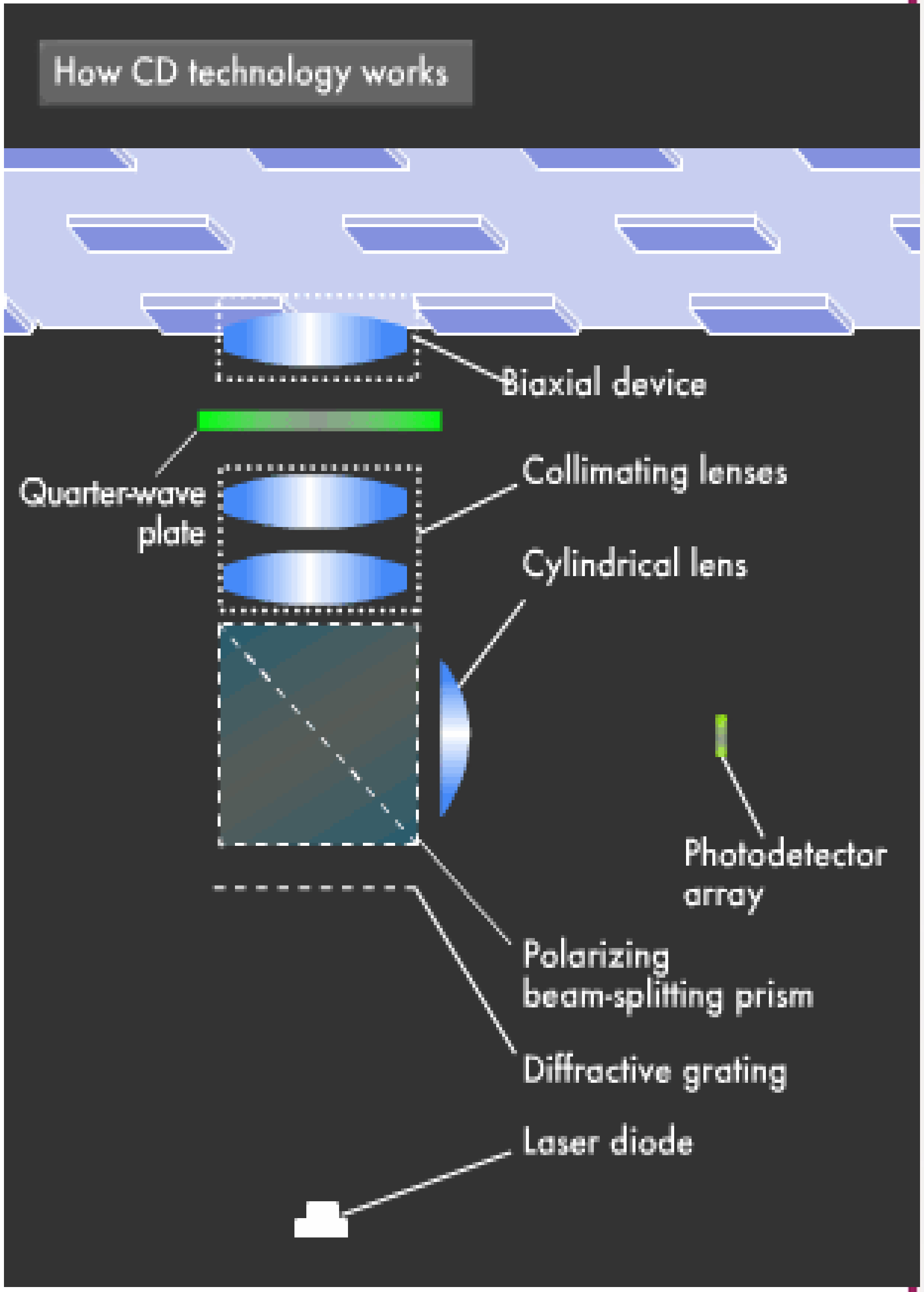
Applications of LASER:

- 1. Storage device (In compact disc):
- A compact disc is a thin circular disc of about 12cm diameter
- Its shining side is made of metal.
- Bottom is made of poly carbonate which is brittle and above that is aluminum coated with plastic and lacquer.

Applications of LASER:

- Working: The information is created in digital form in the CD by using laser beam.
- The laser burns and etches bumps on the surface at some specified intervals.
- These (Bumps) are called "Pits".
- Presence of a bump in a fixed length in the track indicates a zero.
- An unburnt space in a specific length of the track remains flat on that length, and is called 'land' and represents the number 'one'.





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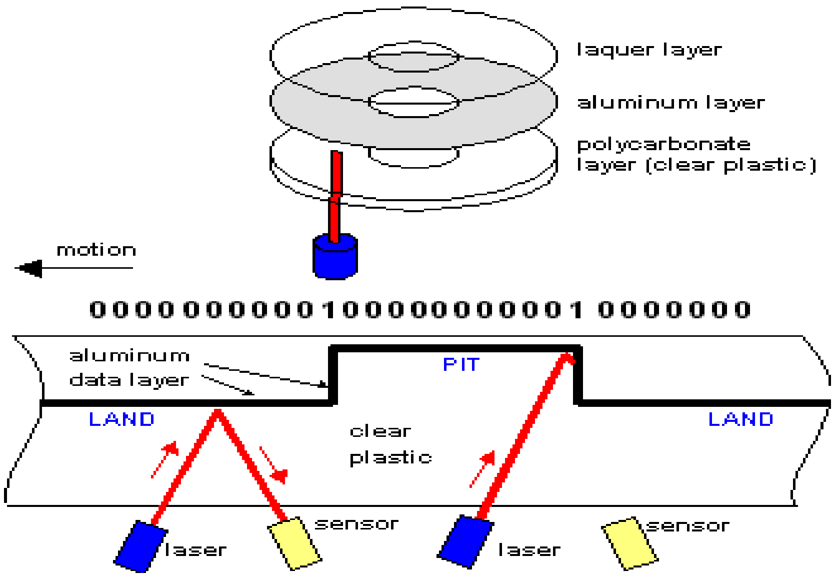


- Thus the laser beam can store information by burning some lengths [for zeroes] and leaving some lengths unburned [for ones] in the binary language.
- While reading the CD, a laser beam scans the tracks. As it is bounced, it follows the pattern of pits and lands.
- A photocell converts these into electric pulses in the same order.
- In turn, an electronic circuit generates zeroes and ones.
- A decoder converts these binary numbers into a changing pattern of electric currents in the analog form which is made use of for the required application.

- The compact disc technology was extended to DVD [digital versatile disc] and further advanced to Blu-ray or Blue-ray disc [BD].
- Both the DVD and the Blu-ray discs having same dimensions as that of a CD.
- A CD can store data of roughly about 700 MB, DVD about 4.7 GB and a Blu-ray about 5 times that of a DVD. CDs are already at the verge of extinction.
- Now a days BDXL [Blu-ray Disc Extra Large] devices have crossed 50 GB of data storage for a dual-layer disc.
- In theory, a fourth storage layer in BDXL format offers a large storage capacity of 128 GB in a single disc

Military applications

- (Laser range finder in Defense) Operational principle of a laser range finder is same as a radar.
- Excellent directionality of laser is used in this devise.
- In defense knowing accurate data of the enemy target distance is very important for first hit chance.
- The hand held laser range finders are best suitable for this.
- They are interfaced with computers to know information in digital readout form.

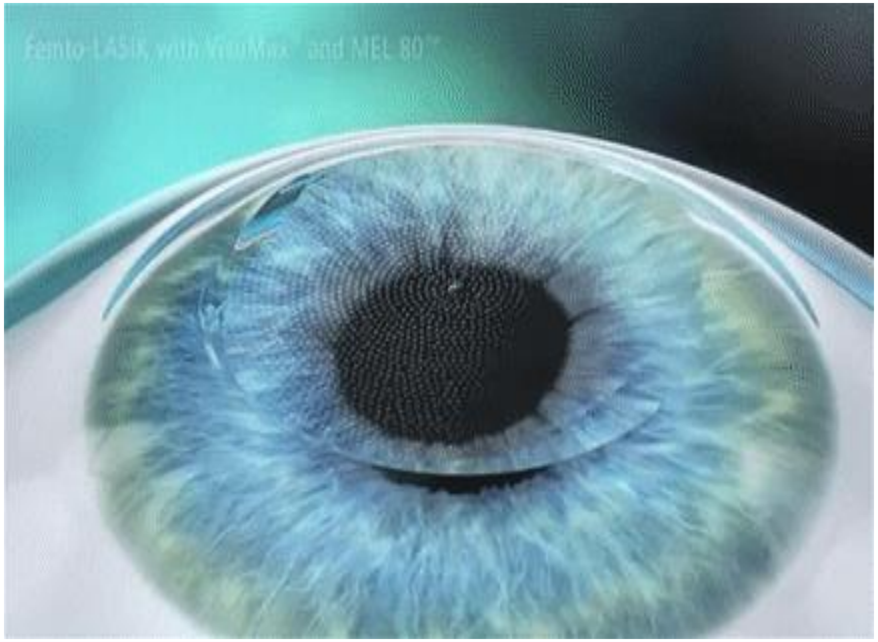
Military applications

- **Working:** A high powered pulsed laser like **Nd-Yag laser** is directed to the enemy target using a transmitter .
- The pulses are narrow with high power.
- The beam reflects back from the target like an **echo** and collected in a receiver.
- Inside the receiver there is an **interference filter.**
- It is a narrow band optical filter tuned to the frequency of laser.
- Unwanted signals are removed and the original signal is amplified by using a **photo multiplier.**
- The range finders **high speed clock** measures the exact time from time of emission of laser to time of receiving the echo.
- From these **data distance** can be calculated accurately.

US Navy's Laser Weapon

Medical applications:

- <u>Laser eye surgery:</u>
- **Lasik (laser-assisted in situ keratomileusis), commonly referred to as laser eye surgery or laser vision correction, is a type of *refractive surgery* for the correction of myopia, hyperopia, and astigmatism.**



Medical applications:

- <u>Laser eye surgery:</u>
- Lasik (laser-assisted in situ keratomileusis), commonly referred to as laser eye surgery or laser vision correction, is a type of *refractive surgery* for the correction of myopia, hyperopia, and astigmatism.
- LASIK surgery is performed by an ophthalmologist who uses a laser or microkeratome to reshape the eye's cornea in order to improve visual acuity.
- For most people, LASIK provides a long-lasting alternative to eyeglasses or contact lenses.

How does Eye surgery work

TED Ed
LESSONS WORTH SHARING

Laser skin treatment

- Laser resurfacing is a treatment to reduce facial wrinkles and skin irregularities, such as blemishes or acne scars.
- The technique directs short, concentrated pulsating beams of light at irregular skin, precisely removing skin layer by layer.
- The two types of lasers most commonly used in laser resurfacing are carbon dioxide (CO_2) and erbium.
- Each laser vaporizes skin cells damaged at the surface-level.

Laser skin treatment

- The newest version of CO_2 laser resurfacing uses very short pulsed light energy (known as ultrapulse) or continuous light beams that are delivered in a scanning pattern to remove thin layers of skin with minimal heat damage.
- Erbium laser resurfacing is designed to remove surface-level and moderately deep lines and wrinkles on the face, hands, neck, or chest.
- One of the benefits of erbium laser resurfacing is minimal burning of surrounding tissue. This laser causes fewer side effects -- such as swelling, bruising, and redness.