POLARIZATION

Interference and diffraction are the phenomenon which confirmed the wave nature of light. But the phenomenon could not establish whether light waves are longitudinal (or) transverse. When the phenomenon of polarization was discovered it was established that light waves are transverse in nature.

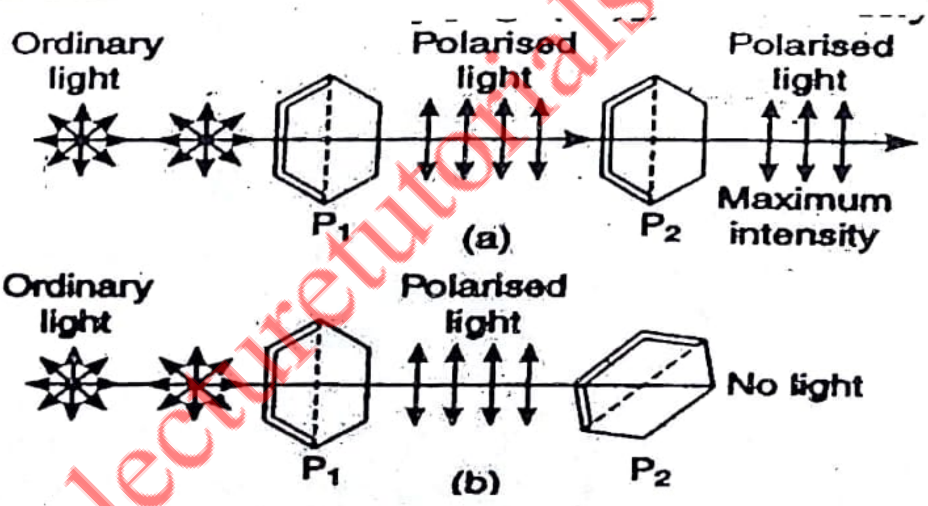
Polarization is a property of waves that describes the orientation of their oscillations. In a transverse wave if all the vibrations are confined in a single direction, it is said to be polarized.

Polarization: It is the process of converting ordinary light into polarized light.

Polarized wave: the wave which is unsymmetrical about the direction of propagation is called polarized wave.

Polarized light: The light which has acquired the property of one sidedness is called polarized light

POLARIZATION OF LIGHT WAVES



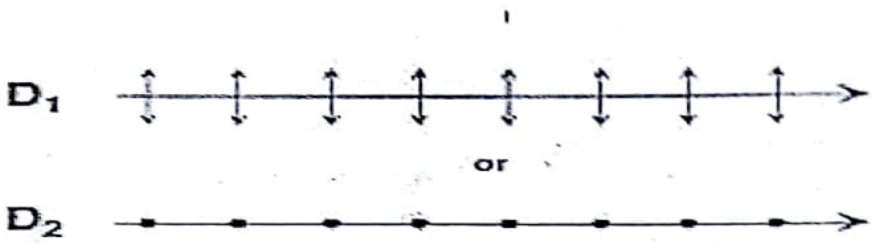
When a ordinary light is passed through a pair of tourmaline crystal plates with their planes parallel to each other, then the maximum intensity is obtained. When their planes perpendicular to each other, the intensity is zero. This shows that light is a transverse wave motion

TYPES OF POLARIZED LIGHT

There are three different types of polarized light.

1. Plane polarized light
2. Circularly polarized light.
3. Elliptically polarized light.

1. Plane polarized light: When the vibrations of light are confined along a single direction, the light is said to be plane polarized light. (Eighter in the direction along the plane of the paper (or) in the direction along the perpendicular to the plane of the paper)

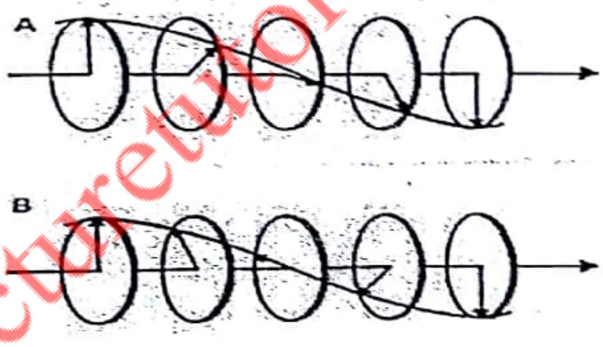


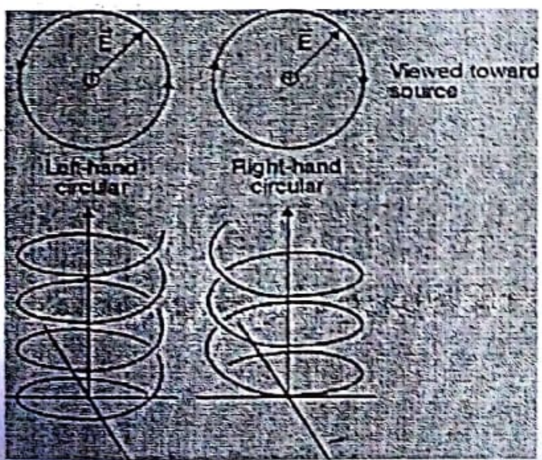
Plane Polarized

2. Circularly polarized light:

The projection of a wave on a plane intercepting the axis of propagating gives a circle with the amplitude vector remaining constant.

I.e. The vector rotates in the clock wise direction with respect to the direction of propagation; it results in right, circularly polarized light while the rotation anti-clock wise direction results in left circularly polarized light.

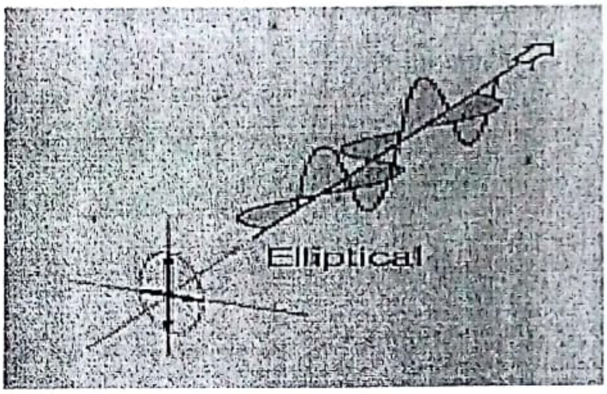




If the vibrations are along a circle, the light is said to be circularly polarized light.

3. Elliptically polarized light:

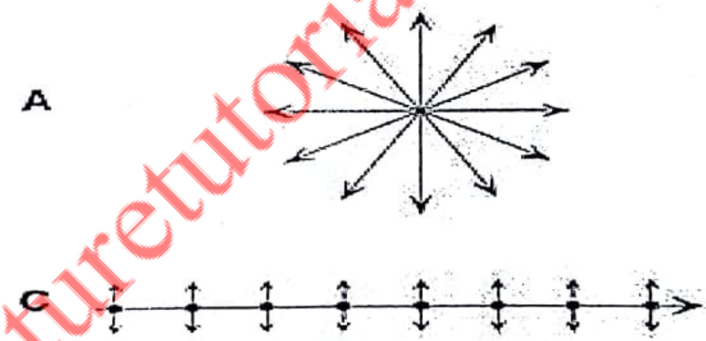
The projection of a wave on a plane intercepting the axis of propagating gives a ellipse and amplitude vector is not constant but various periodically.



If the vibrations are along an ellipse, the light is said to be elliptically polarized light.

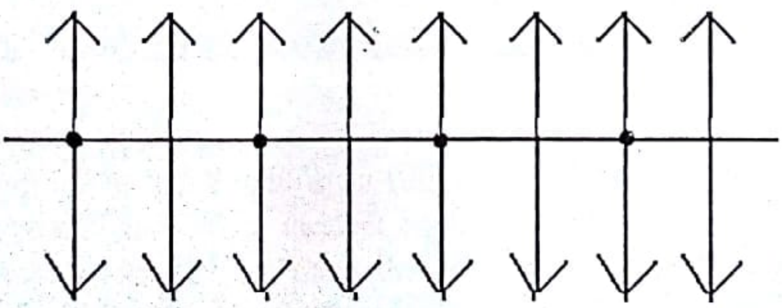
Unpolarized light:

Unpolarized light (or) ordinary light has vibrations both parallel and perpendicular to the plane of the paper.

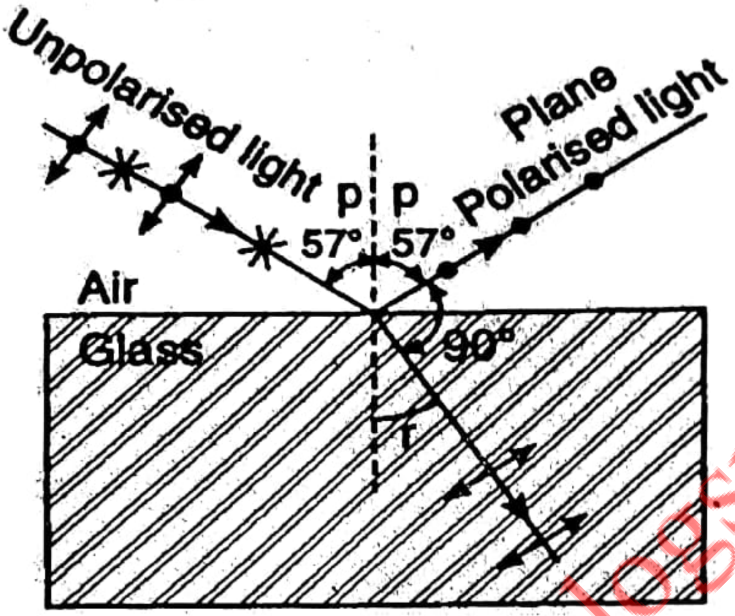


Partially polarized light:

If the linearly polarized light contains small additional component of unpolarised light it becomes partially plane polarized light.



1. POLARIZATION BY REFLECTION (BREWSTER'S LAW)



Brewster observed that for a particular angle of incidence is known as angle of polarization .The refracted light is completely plane polarized in the plane if incidence.

Brewster proved that the tangent of the angle of polarization (P) is numerically equal to refractive index of material.

$$\boxed{\mu = \tan P}$$

This is known as Brewster's law.

He also proved that the reflected and refracted rays are perpendicular to each other.

The angle between reflected and refracted rays

From Brewster's law

$$\mu = \tan p ....(1)$$

From Snell's law

$$\mu = \frac{\sin p}{\sin r} \quad \text{..........(2)}$$

$$from(1)and(2)$$

$$\frac{\sin p}{\cos p} = \frac{\sin p}{\sin r}$$

$$\cos p = \sin r$$

$$\cos p = \cos(90 - r)$$

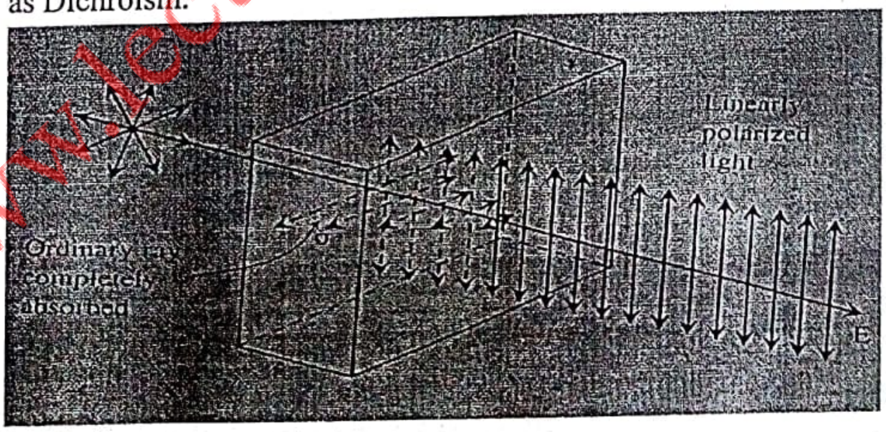
$$p = 90 - r$$

$$p + r = 90$$

The angle between reflected and, refracted ray is 90^o

2. POLARIZATION BY SELECTIVE ABSORPTION

There are certain crystals of doubly refracting class which have the property of absorbing one of the doubly refracting beams to a greater extent than the other the crystals showing this property are termed as Dichroic and the phenomenon is known as Dichroism.

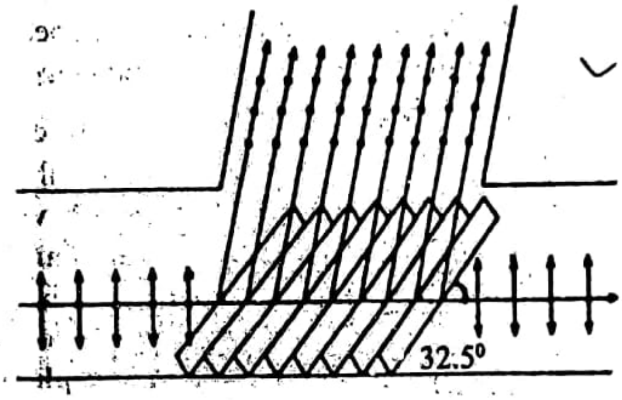


Ex: Tourmaline crystal.

Tourmaline absorbs ordinary ray much more strongly than the extraordinary ray. When a plate of Tourmaline crystal is cut with the face parallel to the optic axis and un polarized light is allowed to incident on it, the light spills into ordinary and extraordinary rays. The rays are travel through the crystal in the same direction.

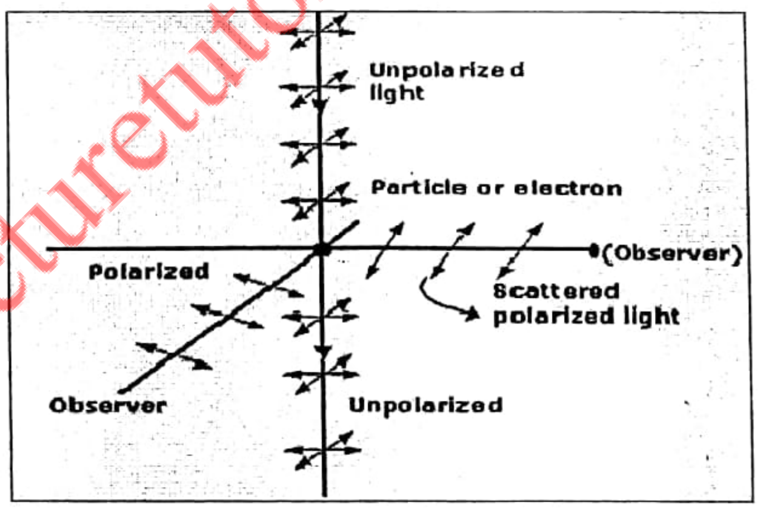
When the plate is sufficiently thick, the ordinary ray is almost completely absorbed and extraordinary is Tran missed.

3. POLARIZATION BY TRANSMISSION (PILE OF PLATES)



We know that when unpolarized light is incident at polarizing angle the reflected light is completely plane polarized and transmitted light contains a greater proportion of light vibrating parallel to the plane of incidence. if the process of reflection at polarizing angle is repeated using no. of plates all inclined at polarizing angle, finally the transmitted light become s purely plane polarized. Such an arrangement is known as pile of plates.

4. POLARIZATION BY SCATTERING



According to Raleigh the intensity of scattered light depends upon the wave length and is proportional to $\frac{1}{\lambda^4}$

i.e. $\boxed{\text{the intensity of scattered light } \alpha \ \frac{1}{\lambda^4}}$

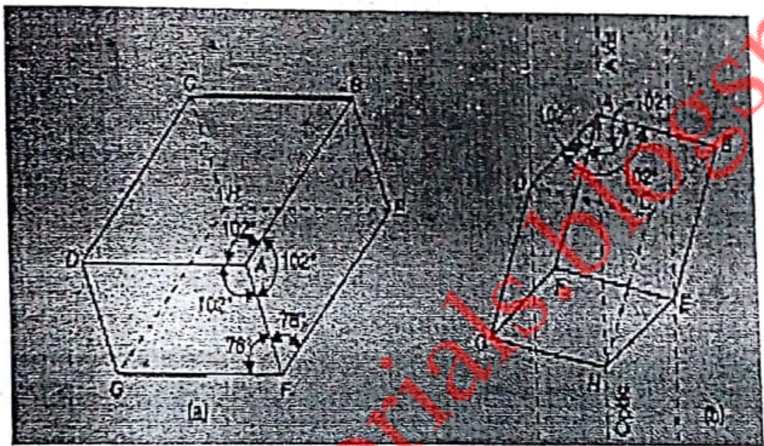
If the light is incident on the medium which contains floating particles such as dust, moisture or molecules of air, the transmitted light red, where as scattered light is blue because Violet and Blue are scattered more than red .this is the reason why the sky is appears blue and sky appears red.

The scattered blue light is examined by a Nicol prism, it found to be partially polarized. but in the direction perpendicular to the incident light ,the scattered light is completely polarized.

GEOMETRY OF CALCITE CRYSTAL

Calcite is a transparent color less crystal. Chemically it is hydrated calcium carbonate. It was at one time found in large quantities in ICELAND. Hence it is also known as ICELAND SPAR.

It consist six faces of parallegrams having angles of 102^0 and 78^0. The corners A and H are said to be blunt corners. The other corners of the crystal consist of two acute and one obtuse angle.



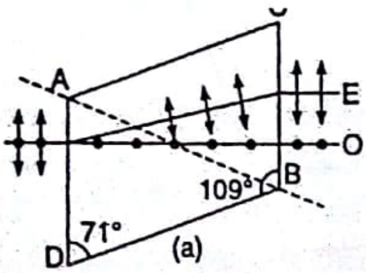
Blunt corner:

The corner where three obtuse angles meet .that corner is called Blunt corner

Principle axis:

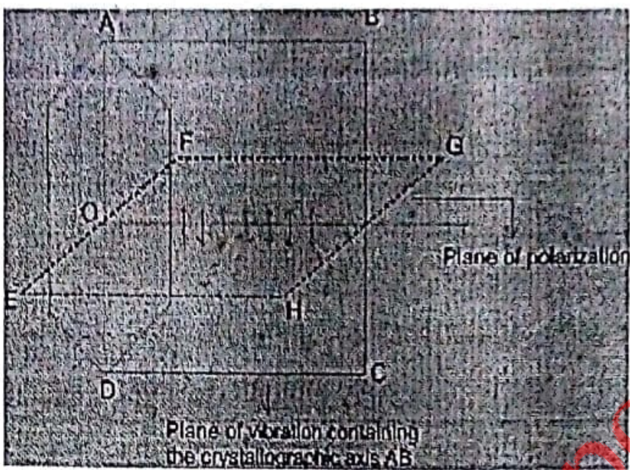
It is the line passing through the any one of the blunt corner and making equal angles with the three faces which meet at this corner.

Principle section:



Any plane which contains principle axes and is perpendicular to two opposite faces is called a principle section.

PLANE OF POLARIZATION & PLANE OF VIBRATION:



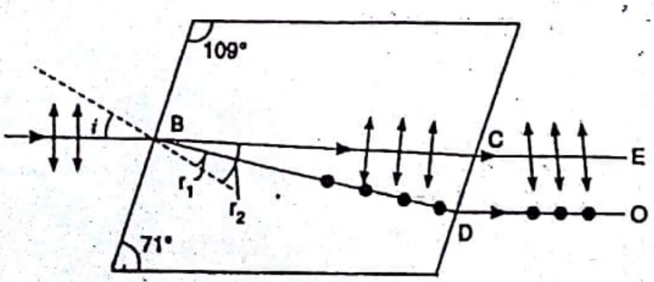
When ordinary light is passed through a tourmaline crystal, the light is polarized and the vibrations are confined only in one direction which is perpendicular to the direction of propagation of light

The plane in which the vibrations of polarized light are confined .this plane is known as plane of vibration. This plane contains the direction of vibration as well as direction of propagation

The plane which has no vibrations the plane is known as plane of polarization. Thus a plane passing through the direction of propagation and perpendicular to the plane of vibration is known as plane of polarization

2. DOUBLE REFRACTION (POLARIZATION BY REFRACTION):

When a beam of ordinary un polarized light is passed through a calcite crystal, the refracted light split into two refracted rays .this phenomenon is called double refraction



Among the two rays one which always obey the ordinary laws of refraction and having vibrations perpendicular to the principle section is known as ordinary ray and The other which do not obey general laws of refraction and having vibrations in the principle section is called extraordinary ray .

The crystals showing this phenomenon are known as doubly refracting crystals.

HUYGEN'S THEORY OF DOUBLE REFRACTION

1. When any wave front strikes a double refracting crystal, every point of the crystal becomes a source of two wave fronts

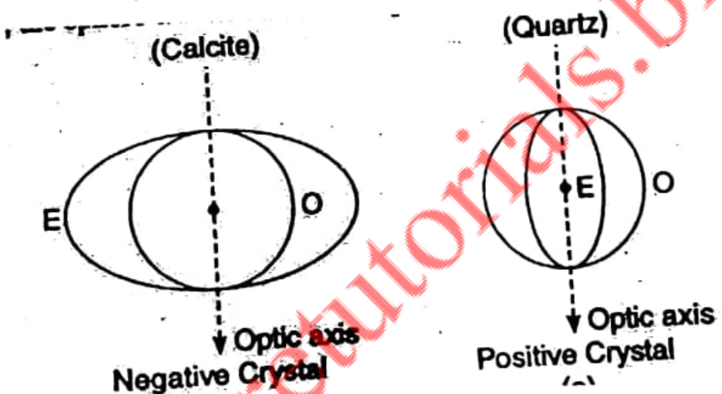
2. Ordinary wave front is spherical, because ordinary have same velocity in all directions

3. Extraordinary wave front is elliptical, because E-Ray has different velocities in different directions

4. The sphere and ellipsoid are touch each other along optic axis because the velocity of ordinary and extraordinary rays is same along optic axis

4. The crystal in which the velocity of ordinary is grater than extraordinary ray. That crystal are called Positive crystals

5. The crystals in which the velocity of extra ordinary is grater than ordinary ray .that crystals are called Negative crystal

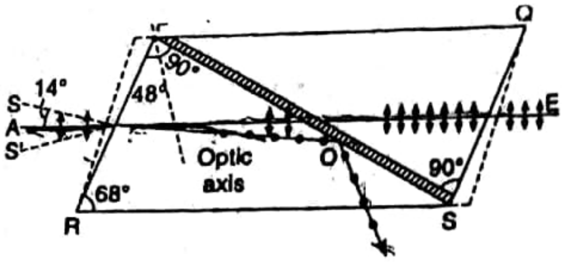


NICOL PRISM It is a device which is used to produce polarised light.

When an ordinary light is transmitted through a calcite crystal, it splits into ordinary and extraordinary rays. Nicol eliminated the ordinary beam by utilizing the phenomenon of total internal reflection at Canada balsam separating the two pieces of calcite .this device is called NICOL PRISM

Construction:

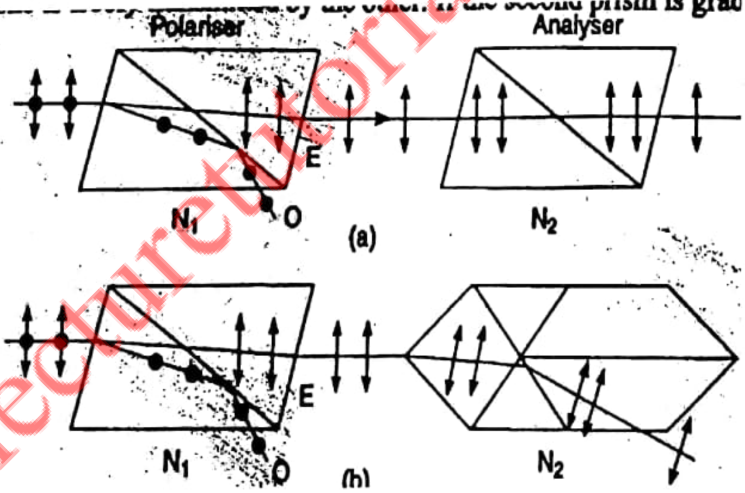
A calcite crystal whose length is three times as that of its width is taken .The end faces of this crystal are grounded in such a way that the angle in the principle section becomes 68^0 and 112^0 .Then calcite crystal cut into two pieces . The cut surfaces are grounded and polished optically flat and then cemented together by Canada balsam. The refractive index of Canada balsam lies between refractive indices of O-ray and E-ray. i.e



Working:

When an ordinary beam of light incident on the Nicol prism, it split into ordinary plane polarized light and extraordinary plane polarized light. From the values of refractive indices the Canada balsam acts as a rarer medium for ordinary ray and denser medium for extraordinary ray. Moreover the dimensions of the crystal are so chosen that the angle of incidence of ordinary ray at the calcite-Çanada balsam surface become grater than the corresponding critical angle .Under these conditions the ordinary ray under go total internal reflection and is eliminated. Only extraordinary transmitted

EXPLAIN HOW NICOL PRISM CAN BE USED BOTH AS POLARIZER AND ANALYZER



When two of Nicols placed co-axially then the first Nicol produces polarized light is known as polarizer while the second which analyzes the polarized light is known as analyzer.

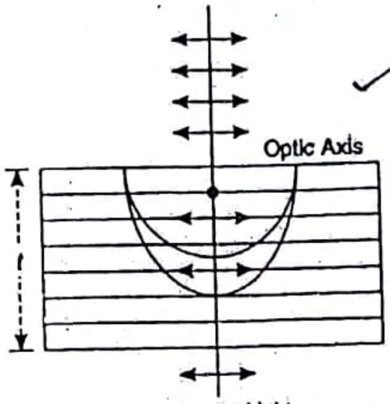
When two Nicols are placed with their planes parallel to each other. Then the extra ordinary Plane polarized transmitted by one is freely transmitted by the other. .if the second nicol is rotated gradually, then the intensity of E-ray gradually decreases and when the two nicols are at right angles to each other, no light comes from the second prism.

Thus first Nicol produces plane polarized light and second nicol detects it.

WAVE PLATES:

The wave plates are introduced specified path difference between o-ray and e-ray for particular wavelength.

HALF WAVE PLATE:



If the thickness of a crystal is taken such that it introduces a path difference of $\frac{\lambda}{2}$ or phase difference of π, then that crystal is called half wave plate.

Let μ_o, μ_e are the refractive indices of ordinary, extraordinary rays and t is the thickness of the calcite crystal

Then the path difference between ordinary and extraordinary ray $= \mu_e t - \mu_o t$

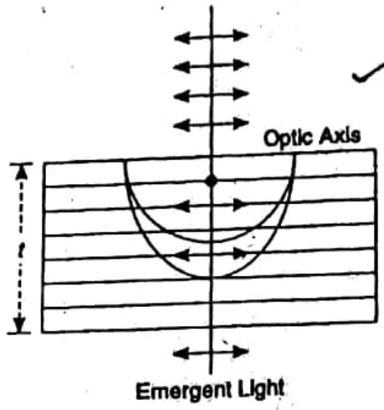
But for half wave plate $path.difference = \frac{\lambda}{2}$

$$\therefore \mu_e t - \mu_o t = \frac{\lambda}{2}$$

$$(\mu_e - \mu_o)t = \frac{\lambda}{2}$$

$$t = \frac{\lambda}{2(\mu_e - \mu_o)}$$

QUARTER WAVE PLATE



If the thickness of a crystal is taken such that it introduces a path difference of $\frac{\lambda}{4}$ or phase difference of $\frac{\pi}{2}$, then that crystal is called 'quarter wave plate.

Let μ_o, μ_e are the refractive indices of ordinary, extraordinary rays and t is the thickness of the calcite crystal

Then the path difference between ordinary and extraordinary ray $= \mu_e t - \mu_o t$

But for half wave plate $path.difference = \frac{\lambda}{4}$

$$\therefore \mu_e t - \mu_o t = \frac{\lambda}{4}$$

$$(\mu_e - \mu_o)t = \frac{\lambda}{4}$$

$$\boxed{t = \frac{\lambda}{4(\mu_e - \mu_o)}}$$

PREVIOUS QUESTIONS:

1. State Brewster's law. How can this law be used to produce plane polarized light.

(or)

State and explain Brewster slaw.

(or)

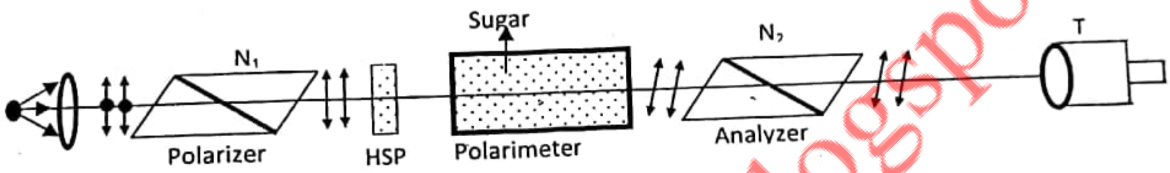
Prove that the angle between reflected and transmitted beams is 90^0.if the angle incidence is corresponding to Brewster's angle.

It is a device to which is used to check

Polarimeter: A polarimeter is an optical instrument used for the determination of the optical activity by measuring the angle of rotation of polarized light as it passes through them.

Sacharimeter: when the polarimeter is used to find the optical rotation of the sugar solution, then such a polarimeter is known as Sacharimeter.

Construction: A polarimeter set up as shown in figure. It consists of two Nicol prisms N_1 and N_2. Here N_1 acts as polarizer and N_2 acts as Analyzer. There is an Half shade plate having half wave plate of Quartz while the other half a glass plate is placed after N_1. An optically active substance, say sugar solution, is filled in the tube and closed with cover slips and introduce between N_1 and N_2. A telescope is placed after N_2.



Working: A monochromatic light is incident on the lens which renders into parallel beam. The unpolarized light after passing through the Nicol prism N_1 becomes plane polarized. The plane polarized light now passes through the half shade plate and then through polarimeter tube which contains sugar solution. The emergent light from tube on passing through the analyzer N_2 can be viewed through the telescope.

In order to determine specific rotation of polarized light, first fill the tube with water without bubbles and placed in its position. Now, focus the telescope on the half shade plate and the analyzer is rotated till the field of view of the telescope is bright. The position of the analyzer is noted on the circular scale S.

Now the tube is filled with sugar solution of known concentration(C) without bubbles and place it in the same position. The field of view of the telescope is not equally bright. The analyzer in now adjusted until the field of view of the telescope is again equally bright. The new position of the analyzer is noted on the circular scale. The difference of the two readings will give the angle of rotation θ.

Specific rotation $\theta_s = \frac{\theta}{l \times C}$ Here l is length of the light travelled in solution.

If θ' is the optical rotation due to the sugar solution of unknown concentration c' then $c' = \frac{\theta'}{\theta_s}$

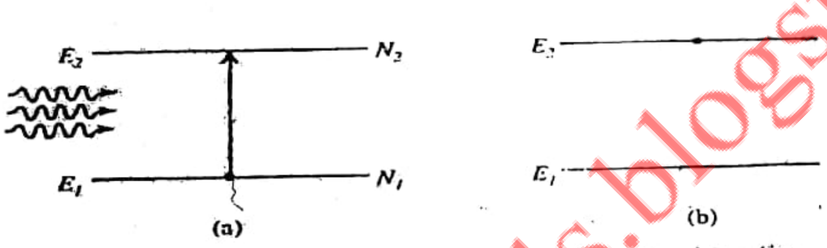
LASERS

The acronym for LASER is Light Application by Stimulated Emission of Radiation.

Transport phenomena: In lasers the interaction between matter and light is of three different types.

1. Stimulated absorption (or) induced absorption.
2. Spontaneous emission.
3. Stimulated emission

1.Stimulated absorption(or) Induced absorption:

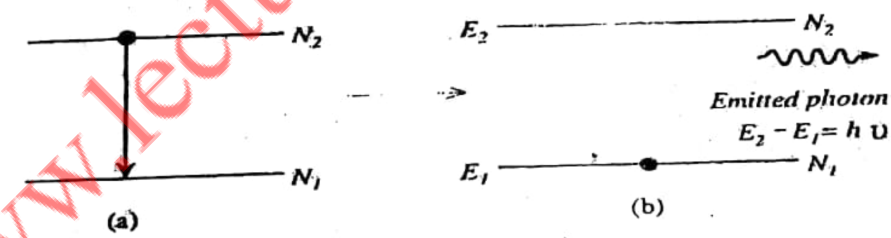


(a) Before absorption *(b) After absorption*

$$A + h\upsilon \rightarrow A^*$$

Initially the atom is in ground state. up on this ground state atom we incident some amount of energy $h\upsilon = E_2 - E_1$ then the atom is excited to higher energy level by absorbing incident energy .This is called stimulated absorption

Spontaneous emission:



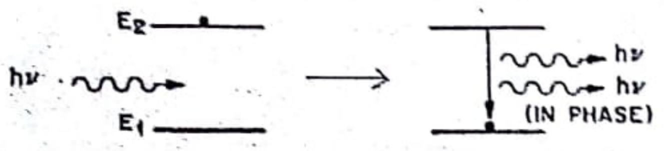
(a) Before emission *(b) After emission*

$$A^* \rightarrow A + h\upsilon$$

Initially the atom is in the excited state. This excited atom comes to ground state by emitting photon of Energy $h\upsilon = E_2 - E_1$ on its own after the lifetime of excited state (i.e. 10^{-8}sec).This type of emission without any external agency is called spontaneous emission . The emitted photons are out phase and travel in all directions so the intensity of light is very low

Ex: Light from Ordinary Source.

Stimulated emission:



$$A^{*} + h\upsilon \rightarrow A + 2h\upsilon$$

Initially the atom is in the excited state .Upon this excited atom we incident a photon of energy $h\upsilon = E_2 - E_1$, then this incident photon may force the atom to come down by emitting a photon .This type of forceful emission is called stimulated emission.

In this case the emitted photons are in phase and travel along the same direction so the intensity of light is very high

Ex: Laser

Relation between Einstein coefficients (B_{12}, A21 & B_{21})

Consider a system contain N_1 no of atoms per unit volume in lower energy level E_1, N_2 be the no of atoms per unit volume in higher Energy level in E_2. Let $\rho(\upsilon)$ is energy density which is supplied to system

1. Stimulated absorption rate $\alpha.\rho(\upsilon)$

$$\alpha.N_1$$

Stimulated absorption rate $= B_{12}\rho(\upsilon)N_1$..............(1)

Where B_{12} is the Einstein coefficient of stimulated absorption

2. Spontaneous emission rate $\alpha.N_2$

. **Spontaneous emission rate** $= A_{21}N_2$..................(2)

Where A_{21} Einstein coefficient of spontaneous emission

3. Stimulated emission rate αN_2

Stimulated emission rate $\alpha.\rho(\upsilon)$

Stimulated emission rate $= B_{21}\rho(\upsilon)N_2$..............(3)

Where B_{21} Einstein coefficient of stimulated emission

At thermal equilibrium

Up ward transition = Down ward transition

$\therefore$ *Stimulated absorption = spontaneous emission + stimulated emission*

$$B_{12}\rho(\upsilon)N_1 = A_{21}N_2 + B_{21}\rho(\upsilon)N_2$$

$$(B_{12}N_1 - B_{21}N_2)\rho(\upsilon) = A_{21}N_2$$

$$\rho(\upsilon) = \frac{A_{21}N_2}{B_{12}N_1 - B_{21}N_2}$$

$$\rho(\upsilon) = \frac{A_{21}N_2}{B_{21}N_2(\frac{B_{12}N_1}{B_{21}N_2} - 1)}$$

$$\rho(\upsilon) = \frac{A_{21}}{B_{21}(\frac{B_{12}N_1}{B_{21}N_2} - 1)}$$

According to Boltzman distribution law

$$N_1 = N_0 e^{-E_1/kT}$$

$$N_2 = N_0 e^{-E_2/kT}$$

$$\frac{N_1}{N_2} = e^{E_2 - E_1/KT} = e^{\frac{h\upsilon}{KT}}$$

$$\therefore \rho(\upsilon) = \frac{A_{21}}{B_{21}(\frac{B_{12}}{B_{21}} e^{\frac{h\upsilon}{KT}} - 1)} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

According to the plank energy distribution law

$$\rho(\upsilon) = \frac{8\pi h\upsilon^3}{c^3(e^{\frac{h\upsilon}{KT}} - 1)} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

On comparing Eq (4) and (5)

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\upsilon^3}{c^3} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$\frac{B_{12}}{B_{21}} = 1 \Rightarrow B_{12} = B_{21} \ldots\ldots\ldots\ldots(7)$$

The Eq (6) & (7) are called Einstein Relations

Conditions for light Amplifications:

At thermal equilibrium.

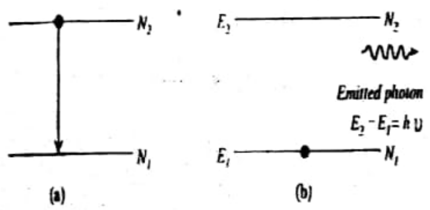
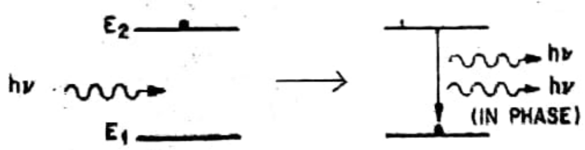
$$\frac{Stimulated\ emission}{Spontaneous\ emission} = \frac{B_{21}N_2\rho(\nu)}{A_{21}N_2} = \frac{B_{21}}{A_{21}}\rho(\nu)........(8) \qquad \text{And}$$

$$\frac{Stimulated.emision}{Stimulated.absorption} = \frac{B_{21}N_2\rho(\nu)}{B_{12}N_1\rho(\nu)} = \frac{N_2}{N_1}........(9)$$

From Eq(8) & (9) *we concluded that for* getting *light amplification(getting Laser)*

1. *The radiation density* $\rho(\nu)$ *is to be made larger.*
2. $N_2 > N_1$ *(Population inversion)*

DIFFERNCE BETWEEN SPONTANEOUS AND STIMULATED EMISSION

SPONTANEOUS EMISSION	STIMULATED EMISSION
1. Transition occurs from a higher energy level to lower energy level.	1.Transition occurs from a higher energy level to lower energy
2.NO incident photon is required	2. Photon whose energy is equal to the difference of two energy levels is required.
3. Single photon is emitted.	3. Two photons with same energy are emitted.
4. The energy of emitted photon is equal to the energy difference of two energy levels.	4. The energy of the emitted photons is double the energy of stimulated photons.
5. This was postulated by Bohr.	5. This was postulated by Einstein.
6.  (a) Before emission (b) After emission	6. 

POPULATION INVERSION

Making the number of particles N_2 more in higher energy level ~~is~~ less than the number of particles N_1 in lower energy level ($N_2 > N_1$) is called as population inversion or inverted population.

Pumping :

The method of raising the particles from lower energy state to higher energy state is called as **pumping.**

METHODS OF ACHIEVING POPULATION INVERSION

There are several methods for achieving the condition of population inversion necessary for laser action to takes place. Some of the most commonly used methods are

1. **Optical pumping:-** In case of optical pumping, an external light source like a Xenon flash lamp is employed to supply luminous energy and to produce a high population in the higher energy level of the laser medium.

   This method of excitation is used in solid-state lasers like RUBY laser.

2. **Electric discharge: -** This method is used in some of the gaseous ion lasers, such as an argon laser. In this type of excitation, the laser medium itself carries the discharge current under suitable conditions of pressure and temperature.

   In this method, the electrons directly excited the active atoms to achieve higher population in certain higher energy levels compared to lower energy level.

3. **Inelastic atom-atom collision:-** Here the electric discharge is employed to cause collision and excitation of the atom. In this method the combination of two types of gases is used, say A and B both having the same excited states A*and B* that coincide (or) nearly coincide.

   In the first step, during electric discharge, A gets excited to A* due to collision with electron is

$$A + e \rightarrow A^* + e,$$

$$A^* + e \rightarrow A + B^*.$$

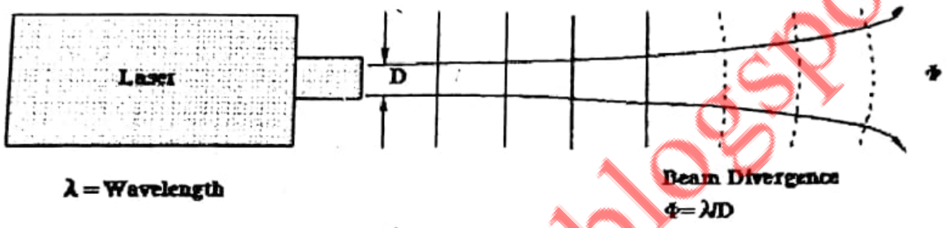
   The excited A atom now collide with B atoms so that the later atom gets excited to higher energy B*.this type of transition is used in He- Ne laser.

4. **Chemical reaction:-** In this method the molecules undergo chemical changes in which one of the products of the reaction excites a molecule or an atom to excited state under appropriate conditions. Under such conditions population inversion occurs. An example this type of lasers is the hydrogen fluoride chemical laser, in which hydrogen fluoride molecules can be excited to a higher energy state with help of heat energy released due to the following chemical reaction.

$$H_2 + F_2 \rightarrow 2HF + \text{heat}.$$

Characteristics of laser

1. **Directionality**: the light beam can travel as a parallel beam up to a distance of $\frac{d^2}{\lambda}$. where d is the diameter of the aperture and λ is wave length of light used. After traveling the distance $\frac{d^2}{\lambda}$ the light beam spreads radially. In ordinary light, the angular spread is 1m per 1m travel. But in Laser the angular spread is only 1mm per 1m travel .this indicates Lasers are highly directional.



2. **Intensity:** the intensity of the laser beam is very high. If a person is allowed to observe an ordinary light emitted by 1000W bulb at distance of 1foot from the source, he can receive only $\frac{1}{1000}W$ of light .if the person is allowed to observe the laser beam from the same distance; the entire laser beam penetrates through his eye. It will damage the eye of the observer.

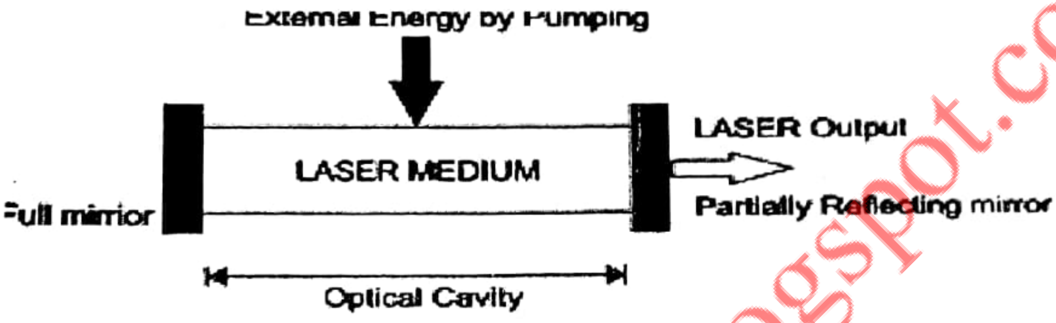
3. **Monochromaticity**: the laser beam is strictly monochromatic than any other conventional monochromatic source. the band width($(\Delta\upsilon = 0)$ of laser beam is narrow, while ordinary light spreads over a wide range of frequency .the line width $\Delta\lambda$ emitted by laser is very small.

4. **Coherence**: the degree of coherence of laser beam is very high than the other sources. The laser beam consists of wave trains that are identical in phase and direction of propagation.

sCONSTRUCTION AND COMPONENTS OF LASER

Any laser system consists of three important components.

1. Source of energy.
2. Active medium.
3. Optical resonant cavity.



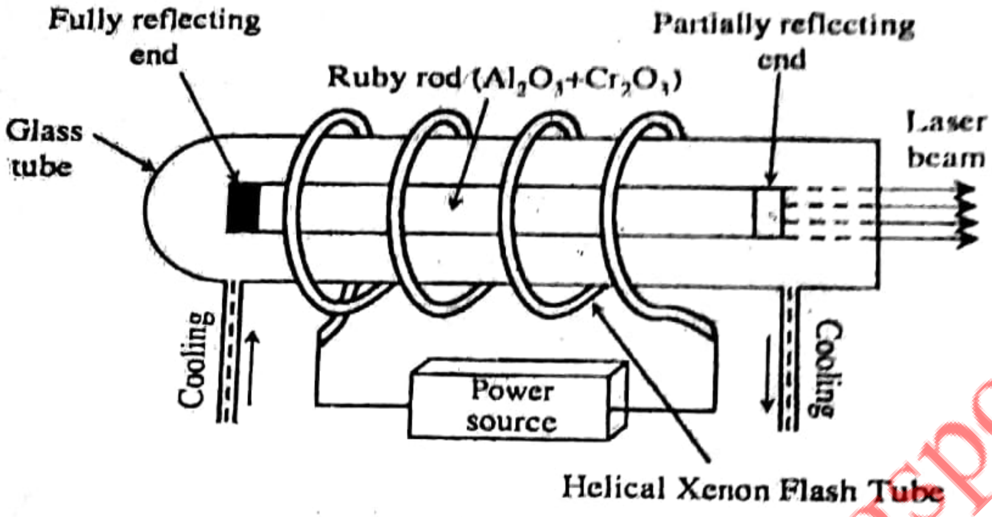
Components of LASER

Source of energy: - To get laser emission, first we must have population inversion in the system. the source of energy supplies sufficient amount of energy to the active medium by which the atoms (or) molecules in it can be excited to the higher energy level. As a result we get population inversion in an active medium. That means the source of energy supply energies and pumps the atoms (or) molecules in the active medium to excited states.

Active Medium(or) Laser Medium:-This is the medium where stimulated emission of radiation takes place. After receiving energy from the source, the atoms or molecules get excited to higher energy levels. While transiting to a lower energy level, the emitted photons start the stimulated emission process which result in laser emission. Depending upon the type of active medium, we have solid state, liquid state, gaseous state and semiconductor laser.

Optical cavity (or) Resonator: - The active medium is enclosed between after reflective mirror and a partially reflective mirror. These mirrors constitute an optical cavity (or) resonator. The reflective portion of the mirrors reflects the incident radiation back into the active medium. These reflected radiations enhance the stimulated emission process with in the active medium. As a result we get high- intensity mono chromatic and coherent laser light through the non-reflecting portion of the mirror.

Ruby Laser



A schematic diagram of Ruby laser

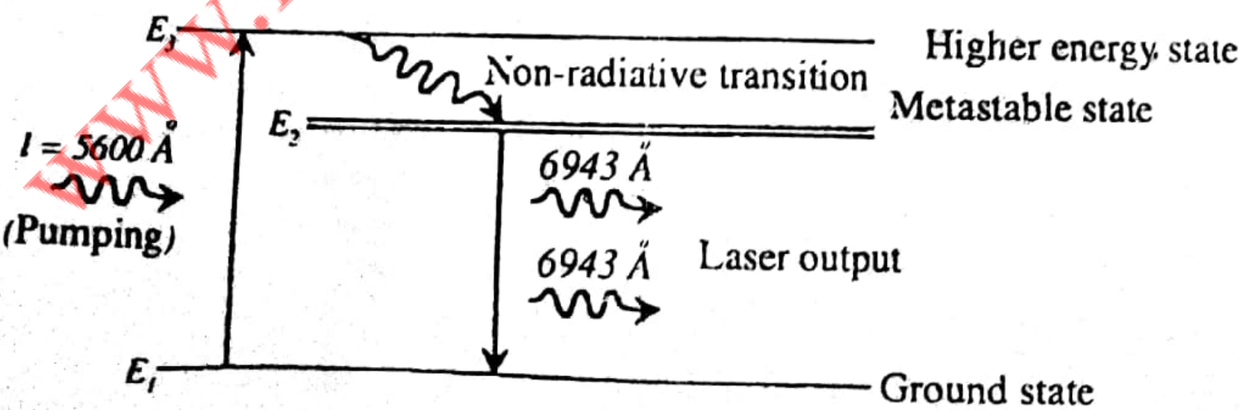
Basically Ruby is a Al_2O_3 crystal congaing 0.05% of chromium atoms

1. **Active medium: Ruby rod.**
2. **Active centers: chromium atoms**
3. **Exciting source: Xenon flash tube**
4. **Cavity Resonator: The partially silvered face and fully silvered face of ruby rod acts as Resonating cavity**

Construction:

Ruby is taken in the form of rod. then end face are grounded and polished such that the end faces Are exactly parallel to each other .one of the face is silvered fully to get fully reflection and other partially silver to get partially reflection .These two silver faces acts as resonating cavity .The Ruby rod is surrounded by helical xenon glass tube which act as exciting source

Working:



Energy level diagram of Chromium ion

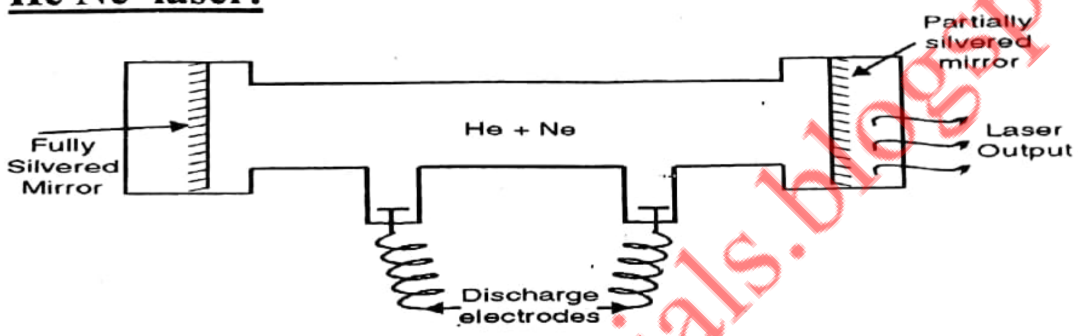
The energy levels of Cr^{3+} ions in the crystal lattice are shown in the fig.

In normal state, the chromium ions are in the lower levels, when the ruby crystal is irradiated with light of xenon flash, the chromium atoms are excited and pass to E2 and E3. The excited levels are highly unstable. So the excited atoms return to grand level E1 directly or via. E2. The transition E3→E2 and E3→E1 are non-irradiative. i.e. Cr atoms gives part of energy to the crystal lattice in the form of heat. Here E2 is the Meta stable state. Therefore Cr atoms accumulate there, after a few mille sec. The population at level E2 exceeds E1. So, there is a population inversion established between E2 and E1 levels, then stimulated emission takes plate. This leads to the production of laser beam.

Drawbacks of ruby laser:

1. In this case the laser beam is not continuous and contains pluses
2. Intensity of laser beam is very poor

He Ne laser:

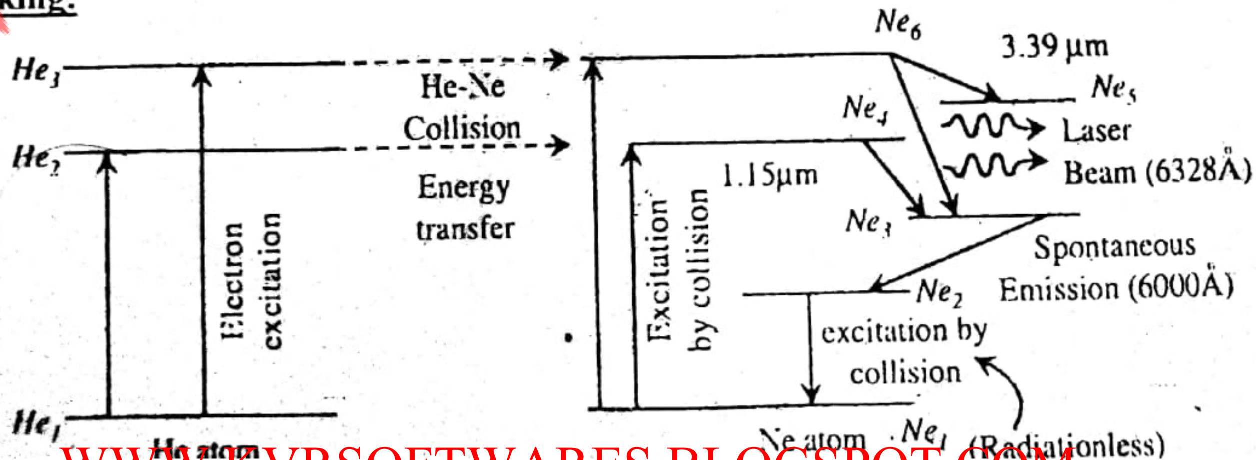


Active medium : **mixture of He and Ne in the ratio 10:1**
Active centers : **Ne atoms**
Exciting Source : **Electric discharge**
Resonating Cavity : **Partially & fully reflecting Mirrors.**

Construction:

The schematic of a typical He-Ne laser is as shown in the fig. It consists of long discharge tube containing a mixture of He and Ne gases in the ration 10:1. Electrodes are provided to produce a discharge in the gas and they are connected high voltage power supply. The tube is sealed by two windows. Two mirrors are fixed in both sides of the tube, which acts as a resonating cavity.

Working:

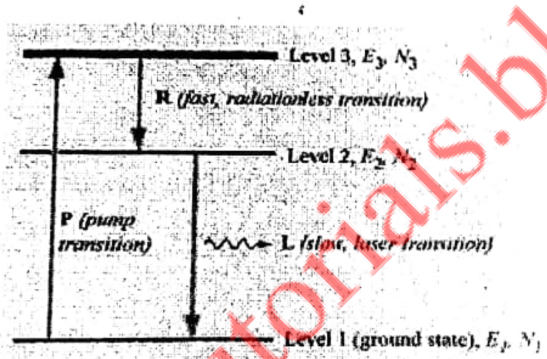


When a discharge is passed through the gas, the electrons are accelerated towards the positive electrode. During their passage, they collide with He atoms and excite them into the upper states. i.e. from He_1 to He_2 and He_3. He_2 and He_3 are Meta stable states. So excised He atoms accumulate in He_2 and He_3 levels. The excited He atoms can return to the ground state by transferring their energy to neon atoms through collisions. Here the Ne_6 and Ne_4 levels of Ne atom nearly coincide in energy with He_3 and He_2 levels of Helium atom. So the Ne atoms directly go to Ne_4 & Ne_6 levels. In case of Ne, Ne_4 & Ne_6 are Meta stable states. So Ne atoms accumulate more & more at these levels. After some time population inversion is achieved between Ne_6 & Ne_5, Ne_6 & Ne_3 and Ne_4 & Ne_3 levels. Consequently three laser transitions can occur.

1. $Ne_6 \rightarrow Ne_3$ transition : This transition generated a beam of Red Laser
2. $Ne_4 \rightarrow Ne_3$ transition : Gives a laser beam in infrared region.
3. $Ne_6 \rightarrow Ne_5$ transition : Gives a laser beam in far infrared region.

THREE LEVEL PUMPING SCHEM

In three level pumping schem, three energy levels involved in lasing action. They are the ground state energy (E_1), excited state energy (E_3) and metastable state energy (E_2) as shown in fig.

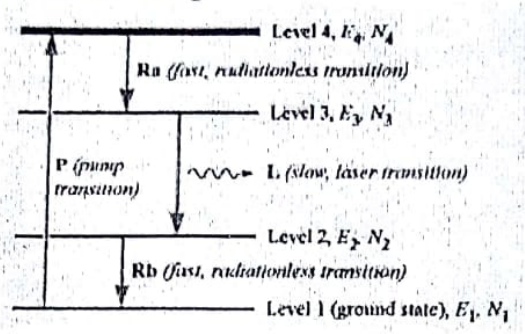


In the laser, initially all the lasing atoms are present in the ground state energy level,(E_1).light photons of energy E_3-E_1 is made to incident on the ground state lasing atoms. The atoms in the ground state energy level will absorb the energy of photons and make transition to excited state energy (E_3).the atoms in the excited energy level (E_3), will remain for very short duration of the order of 10^{-9} sec and make non radiative transaction to metastable state E_2. The atoms will remain for longer duration in metastable state. If photons are continuously supplied to ground to ground state atoms then more number of atoms makes transitions to excited state and then to metastable state fastly, so that more number of atoms will accumulate in metastable than in ground state. This is known as population inversion. Now a chance photon of transition from E_2-E_1= hv can trigger stimulated emission as shown in fig. The atoms present in E_2 energy level will make stimulated transition to E_1 energy level.

This scheme requires very high pumping power. In this three level scheme, once the stimulated emission starts then quickly the metastable state becomes empty, hence population inversion ends. The system has to wait till the population inversion is to be reestablished. Because of this three level laser produces pulses of laser light.

FOUR LEVEL PUMPING SCHEM

In four level pumping scheme, four energy levels involved in lasing action. They are the ground state energy (E_1), excited state energy (E_4) and metastable state energy (E_3) and lower lasing level (E_2).as shown in fig.



In the laser, initially all the lasing atoms are present in the ground state energy level,(E_1).light photons of energy E_4-E_1 is made to incident on the ground state lasing atoms. The atoms in the ground state energy level will absorb the energy of photons and make transition to excited state energy (E_4).the atoms in the excited energy level (E_4), will remain for very short duration of the order of 10^{-9} sec and quickly drop down to the metastable state (E_3).after some time population inversion between the states E_3 and E_2.A spontaneous emitted photon of energy E_3-E2= hν can initiates stimulated emissions. This makes transition of atoms from E_3 to E_2 level. The atoms in the E_2 level will undergo non radiative transition to ground state E_1 level. This atom once again available for excitation to E_4 level. **In this scheme the lower lasing level is nearly vacant, hence less pumping power is sufficient to get population inversion. This four level laser operated continuously.**

APPLICATIONS OF LASER

1. **In consumer electronics:** Telecommunications, and data communications, lasers are used as the transmitters. They are used to store data in compact discs and DVD's as well as magneto optical discs.
2. **In science**: Lasers are employed in wide variety of interferometric techniques, atmospheric remote sensing and investigation of non-linear optics phenomena and Holographic techniques.
3. **In industry:** laser cutting is used to cut steel and other metals. Laser lines are used in surveying and constructions. Lasers are used for guidance for aircraft.
4. **In medicine:** laser is used for laser vision correction and surgical techniques. Laser also used for dermatological procedures including removal of tattoos, birth marks and hair.
5. **In law of enforcement**: lasers are used for detect the speed of vehicles. In military used as target destinations for other weapons