CMR
GROUP OF INSTITUTIONS
EXPLORE TO INVENT

COURSE MATERIAL FOR THE ACADEMIC YEAR 2016-17

COURSE: I YEAR B.TECH - IST SEM

SUBJECT: ENGINEERING PHYSICS

Vision of the institute

To be recognized as a premier institution in offering value based and futuristic quality technical education to meet the technological needs of the society.

Mission of the institute

1.To impart value based quality technical education through innovative teaching and learning methods.

2.To continuously produce employable technical graduates with advanced technical skills to meet the current and future technological needs of the society.

3.To prepare the graduates for higher learning with emphasis on academic and industrial research.

Course outcomes of Engineering Physics

CO1	**Distinguish** between the intensity distribution in the Phenomenon of Interference and Diffraction.
CO2	**Construct** the polarizer and separate the field components of light by different devices
CO3	**Examine** normal light and laser light and **categorize** various Laser systems
CO4	**Explain** the preparation of light through Optical fiber and **discusses** their losses.
CO5	**Distinguish** various crystal systems and **compare** atomic packing factors.
CO6	**Analyze** the structure of solids by X-ray diffraction and **list** the various defects in crystals.

ENGINEERING PHYSICS/ENGINEERING PHYSICS - I

B.Tech. I Year I Sem.
Course Code: **PH103BS**

L	T/P/D	C
3	0/0/0	3

Course Objectives:

- To understand interaction of light with matter through interference, diffraction and polarization.
- To able to distinguish ordinary light with a laser light and to realize propagation of light through optical fibers.
- To understand various crystal systems and there structures elaborately.
- To study various crystal imperfections and probing methods like X-RD.

Course outcomes: after completion of this course the student is able to

- Realize the importance of light phenomena in thin films and resolution.
- Learn principle, working of various laser systems and light propagation through optical fibers.
- Distinguish various crystal systems and understand atomic packing factor.
- Know the various defects in crystals.

UNIT-I

Interference: Coherence, division of amplitude and division of wave front, interference in thin films (transmitted and reflected light), Newton's rings experiment.

Diffraction: Distinction between Fresnel and Fraunhoffer diffraction, diffraction due to single slit, N-slits, Diffraction grating experiment.

UNIT-II

Polarization: Introduction, Malus's law, double refraction, Nicol prism, Quarter wave and half wave plates.

Lasers: Characteristics of lasers, spontaneous and stimulated emission of radiation, Einstein coefficients, population inversion, ruby laser, helium – neon laser, semi conductor laser, applications of lasers

UNIT-III

Fiber Optics: Principle of optical fiber, construction of fiber, acceptance angle and acceptance cone, numerical aperture, types of optical fibers: step index and graded index fibers, attenuation in optical fibers, applications of optical fibers in medicine and sensors.

UNIT-IV

Crystallography: Space lattice, unit cell and lattice parameters, crystal systems, Bravais lattices, atomic radius, co-ordination number and packing factor of SC, BCC, FCC, HCP and diamond, Miller indices, crystal planes and directions, inter planar spacing of orthogonal crystal systems.

UNIT-V

X-ray Diffraction and Defects in Crystals: Bragg's law, X-ray diffraction methods: Laue method, powder method; point defects: vacancies, substitutional, interstitial, Frenkel and

Schottky defects, line defects (qualitative) and Burger's vector, surface defects: stacking faults, twin, tilt and grain boundaries.

Text Books:

1. Physics Vol. 2, Halliday, Resnick and Kramer John wiley and Sons, Edition 4.
2. Modern Engineering Physics, K. Vijaya Kumar and S. Chandra Lingam, S. Chand and Co. Pvt. Ltd.
3. Introduction to Solid State Physics, Charles Kittel, Wiley Student edition.

Reference Books:

1. X-Ray Crystallography, Phillips, John Wiley publishers.
2. Waves, Frank S Crawford Jr, Berkeley Physics course, Volume 3.
3. Solid State Physics, AJ Dekker, MacMilan Publishers.
4. Introduction to Crystallography, Phillips, John Wiley publishers.

LECTURE PLAN: Subject: Engineering Physics

Year: B.Tech I year

	NAME OF THE TOPIC	NO.OF CLASSES	TEXT BOOKS
	UNIT-I		
	Interference: Introduction ,coherence	L1	T1
	Division of amplitude of amplitude and wave front	L2	T1
	Interference in thin films –reflected light	L3	T1
	Interference in thin films-transmitted light	L4	T1,T2,R1
	Newtons rings for reflected light	L5	T1,R1
	Newtons rings for transmited light	L6	T1,R1
	Newtons rings Experiment	L7	T1,R1
	Problems	L 8	T1,T2
	Diffraction: Introduction	L9	T1,T2
	D/w between fresenl &fraunhofer diffraction	L10	T1,T2,R1
	Diffraction due to single slit	L11	T1,T2,R3
	Diffraction due to N-slits	L12	T1,R3
	Diffraction grating experiment	L13	T1,T2,R2
	Problems	L14	T1,T2
	UNIT-II		
	Polarisation: Introduction	L15	T1,T3
	Types of polarisation	L16	
	Malus law	L17	T1,T2

	Double refraction	L18	T1
	Nicol prism	L19	T1
	Quarter and half wave plates	L20	T1,T2
	Problems	L21	T1,T2
	LASERS: Introduction	L22	T1,T3
	Characteristics of lasers	L23	T1,R3
	Spontaneous and stimulated emission of radiation	L24	T1,T3
	Einstein coeffients	L25, L26	T1,R3
	population inverstion	L27	T1,T3
	Ruby laser	L28	T1,T3
	helium neon laser	L29	T1,T2
	Semiconductor lasers	L30	T1,T2
	Applications of lasers	L31	T1,T2
	UNIT- III		
	Fibre optics: Introduction	L32	T1,R2
	Principal and construction of fibre optic	L33	T1,T3,R3
	Acceptance angle and acceptance cone	L34	T1,R3
	Numerical aperture	L35	T1,R3
	Types of fibre optics	L36, L37	T1,T3,R3
	losses in fibre optics	L38	T1,T2
	Applications of optical fibres	L39	T1,T2
	problems	L40	T1,T2
	UNIT-IV		
	Crytallography:space lattice,unit cell& lattice parameters	L41	T1,T2

	Crystal structures	L42	T1,T2
	Sc,bcc	L43	T1,T3,R3
	FCC	L44	T1,R3
	Hcp, diamond	L45, L46	T1,T2
	Miller indices ,crystal planes and directions	L47	T1,T3
	Miller indices problems	L48	T1,T2
	Inter planar spacing of orthogonal crystal systems	L49	T1,T2
	Problems	L50	T1,T3
	UNIT-V		
	X-ray diffraction &Defects in crystals Introduction	L51	T1,T3
	Braggs law	L52	T3,R1,T1
	Braggs law problems	L53	T3,R1,T1
	Laue method	L54	T1,R1
	Powder method	L55	T1,T3
	Points defects	L56	T1
	Line defects	L57	T1,T3
	Burgers vector	L58	T3,R1,T1
	Surface defects	L59	T1,T2
	problems	L60	T1,T2
	Total no of classes	60	

UNIT 1

INTERFERENCE

Definition: Interference is based on the principle of superposition of waves. When two or more waves superimpose, the resultant amplitude in the region of superposition is different than the amplitude of individual waves. This modification in the distribution of intensity in the region of superposition is called interference of light.

Def: Superimposing of two or more waves is interference.

Conditions for Interference of light:

(1) Conditions for sustained interference.
(2) Conditions for observation of fringes.
(3) Conditions for good contrast between maxima and minima.

Conditions for sustained interference: The two sources should be coherent, i.e they should vibrate in the same phase or there should be a constant phase difference between the two sources must emit continuous waves of same wavelength and time period.

Conditions for observation of fringes:

(1) The separation between the two sources should be small.
(2) The distance between the source and screen should be large.
(3) The background should be dark to observe interference pattern.

Conditions for good contrast between maxima and minima:

(1) The amplitudes of the interfering waves should be equal or nearly equal.
(2) The sources must be narrow i.e. they must be extremely small.
The source should be monochromatic

Coherence:

Two waves are said to be coherent if they have

1.Same wave wavelength

2.same amplitude

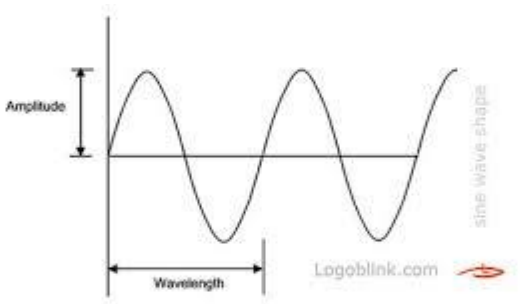
3.constant phase diffrerence

Coherence is a property of a wave. A predictable correlation of the amplitude and phase at any point with other point is called as coherence.

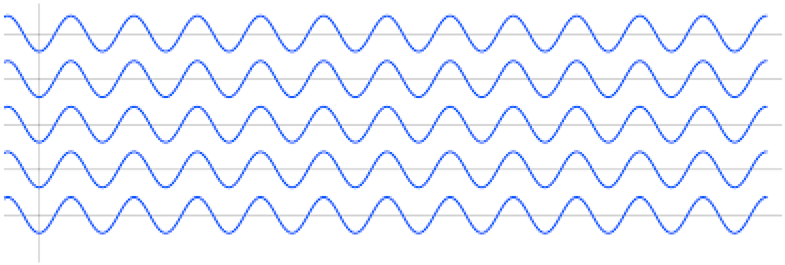
There are two types of coherence.they are

1) Temporal coherence
2) spatial coherence

Temporal coherence(longitudinal coherence):
It is possible to predict the amplitude and the phase at a one point on the wave with respect to another point on the same wave is called as Temporal coherence.
To understand this let us consider two points p1 & p2 on the same wave is shown in figure.suppose the amplitude and phase at any point is known then we can easily calculate the phase and amplitude for any other point the wave by using the formula y=asin($2\pi/\lambda(ct-x)$)



Spatial coherence: It is possible to predict the amplitude and the phase at a one point on the wave with respect to another point on the second wave then it is called as spatial coherence.



Division of amplitude anad division of wavefront:

Division of wavefront :the incident wavefront is divided into two parts by utilizing the phenomenon of reflection,refraction or diffraction .these two parts of the same wavefront travel unequal distances and reunite at some angle to produce interference bands

The fresnel biprism, Lloyd's mirror are the examples.

Division of amplitude:the amplitude of the incoming beam is divided into two parts either by parallel reflection or refraction.these divided parts reunite after traversing different parts and produce interference.

Newtons rings ,michelsons interferometer coimes under this class.

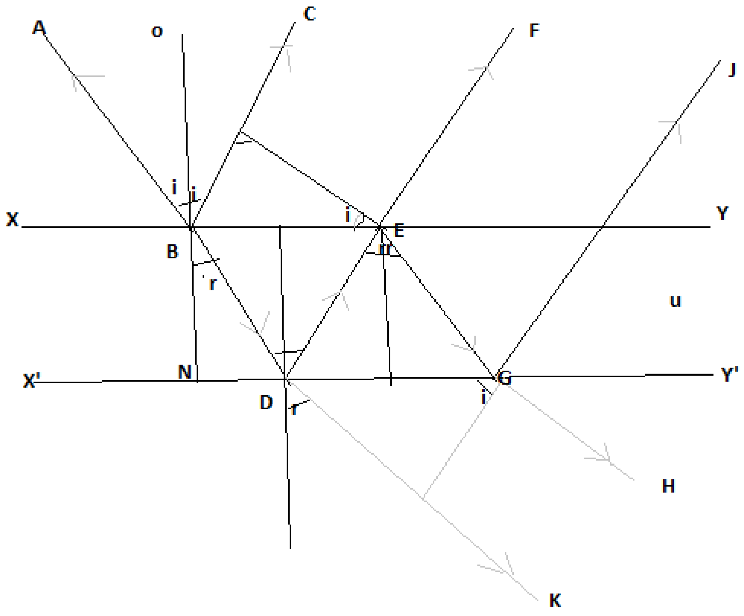
INTRRERFERENCE IN THIN FILMS:

In thin films interference is due to superposition of light deflected from the top and bottom surfaces of the film. In both reflected as well as transmitted light interference is observed.

Let a plane wavefront be allowed to incident normally on a thin film of uniform thickness‘t’. The plane wavefront is obtained with the help of a partially reflecting glass plate G inclined at an angle 45° with the parallel monochromatic beam of light. The plane wavefront is partly reflected at the upper surface of the film and partly transmitted into the film. The transmitted wavefront is reflected again from the bottom surface of the film and emerges through the first surface. The wavefront reflected from the upper surface and the lower surface interferes with each other and interference pattern can be observed.

INTERFERENCE IN THIN FILMS FOR REFLECTED LIGHT:

In interference thin films due to superposition of light reflected from top and bottom surfaces of the film.in both reflected and transmitted light one can observe interference.



Let us consider a thin film of thickness of t bounded by two plane surfaces XY AND $X'Y'$.andμ be the refractive index of the material of the film.A light ray AB incident on the surface atXY at an angle i is partly reflected along BC and partly refracted along BD.let the angle of refraction be r.on the surface $X'Y$, *the refracted ray is partly* reflected along DE and partly refracted along DK.similarl reflection and refraction occurs at E and G also.

The rays BC and EF constitute reflected system.to find the path difference between the reflected rays EP is drawn perpendicular to BC.

Path difference=(BD+DE)μ-BP

In ΔBDQ,cosr=DQ/BD=t/BD

Or BD=t/cosr=DE

Hence path difference =2μt/cosr-BP

IN ΔBPE, sini=BP/BE

Or BP=BEsini =(BQ+QE)sini

In ΔBDQ tanr= BQ/QD

OR BQ=ttanr= QE

Or BP=2t tanr sini

=2t (sini/sinr)μsinr $(since\ \mu = \text{sini}/\text{sinr})$

Substituting value in path difference we get

Path difference=$\frac{2\mu t}{cosr}$ - $2\mu t\frac{sinr^2}{cosr}$

= $2\mu t$**(1-**$sinr^2$**)/cosr =2μtcosr**

Since thje ray BC is reflected at the air medium(rarer –denser) interface,it undergoes a phase change ofπ or path increase of $\lambda/2$. Hence the path difference between the ray BC and EP is

=2μtcosr- $\lambda/2$

i)condition for bright band:

the film vwill appear bright iof the path difference

2μtcosr- $\lambda/2$**=nλ**

Where n=0,1,2,3,…….

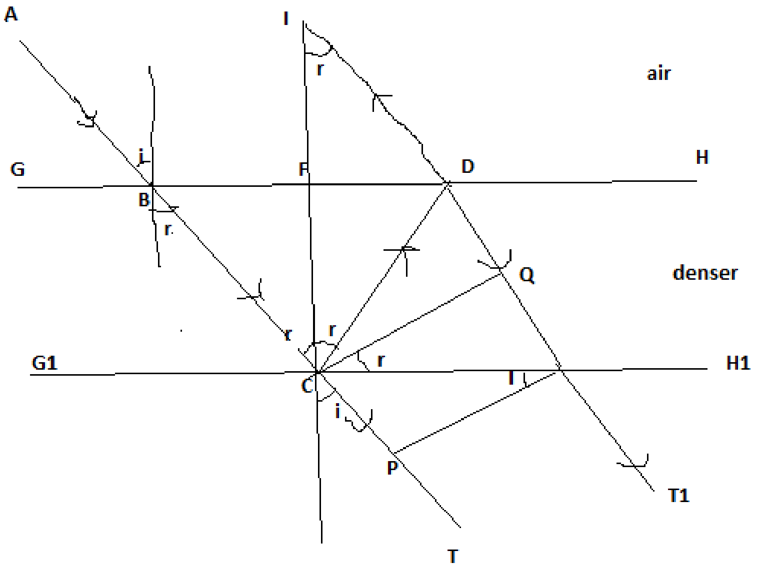
ii)condition for dark band:

the film will appear dark if the path difference

2μtcosr-$\frac{\lambda}{2}$ =(2n+1) $\lambda/2$

Where n=0,1,2,3…….

Interference in thin films due to transmitted light:



Due to simultaneous reflection and refraction we obtain two transmitted rays CT and ET1.these rays have been originat from the same point source,hence they have a constant phase difference and are in a position to produce sustained interference when combined.

In order to calculate the path difference between the two transmitted rays,we draw normal CQ and EP on DE and CT respectively.we also produce ED in the backward direction which meets produced CF at I.

THE effective path difference is given by

Δ =μ(CD+DE) – CP ……(1)

Also CP=sini/sinr=CP/QE

CP=μ(QE) ….(2)

From equations (1) &(2)

Δ =μ(CD+DQ+QE) – μ(QE)

Δ = μ(CD+DQ)

= μ(CI)

= 2μtcosr

It should be remembered that inside the film,reflection at different points takes place at the surface blocked by rarer medium(air) thus no abrupt chnge of π takes in this case.

The maxima occur when the effective path difference

$$\Delta = n\lambda$$

i.e., 2μtcosr=nλ

if this condition is fulfilled ,the film will appear bright in transmitted light.

The minima occur when the effective path difference is (2n$\pm 1)\lambda/2$.

Where n=0,1,2,3….etc

When this condition is fulfilled ,the film will appear dark.

Newtons rings experiment:

When a plano-convex lens with its convex surface is placed on a plane glass sheet, an air film of gradually increasing thickness outward is formed between the lens and the sheet. The thickness of film at the point of contact is zero. If monochromatic light is allowed to fall normally on the lens, and the film is viewed in reflected light, alternate bright and dark concentric rings are seen around the point of contact. These rings were first discovered by Newton, that's why they are called **NEWTON'S RINGS.**

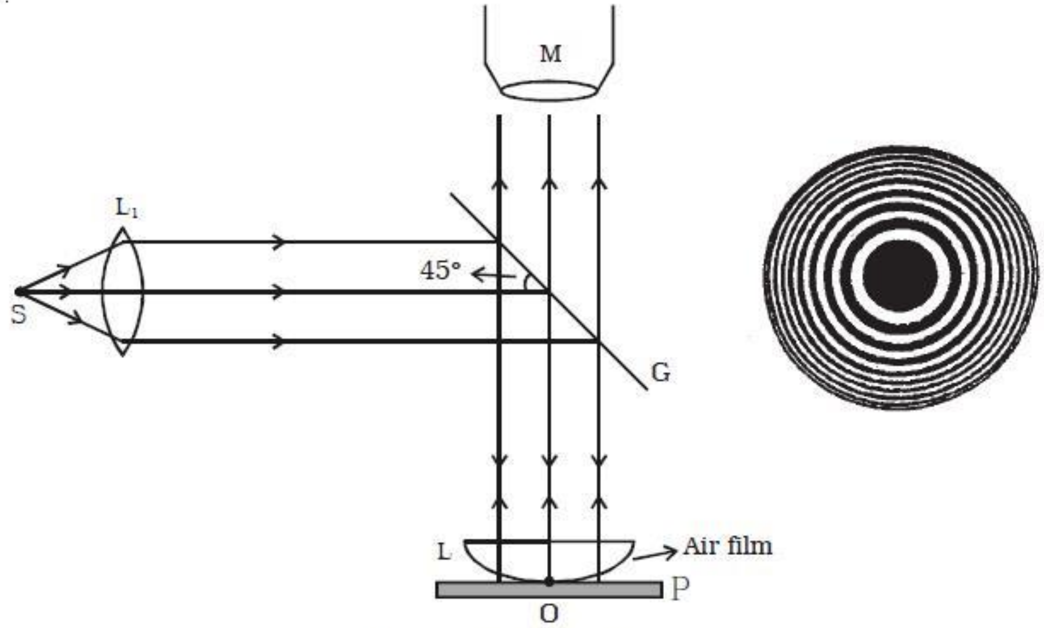


Fig 5.19 Newton's rings

Newton's rings are formed due to interference between the light waves reflected from the top and bottom surfaces of the air film formed between the lens and glass sheet.

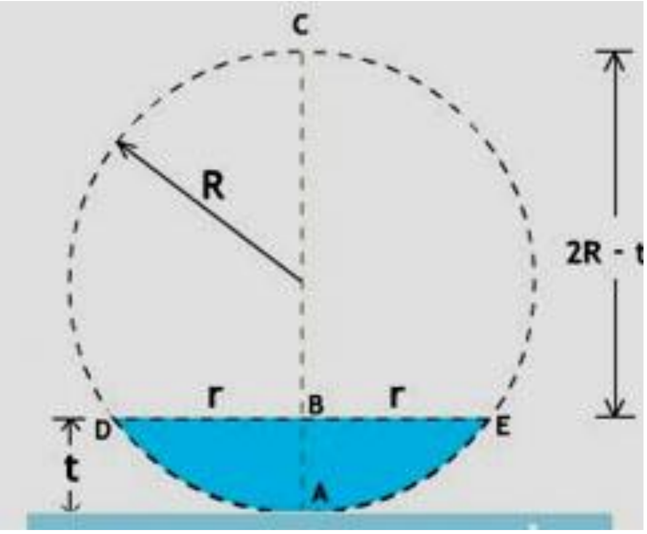
EXPLANATION:

- The phenomenon of formation of Newton’s ring can be explained on the basis of wave theory of light.

- An air film of varying thickness is formed between the lens and the glass sheet.
- When a light ray is incident on the upper surface of the lens, it is reflected as well as refracted.
- When the refracted ray strikes the glass sheet, it undergo a phase change of 180^{O} on reflection.
- Interference occurs between the two waves which interfere constructively if path difference between them is **(m+1/2)**and destructively ifpath difference between them is**m** producing alternate bright and dark rings.

NEWTON'S RINGS:

Let the radius of curvature of the convex lens is **R** and the radius of ring is '**r**'. Consider light of wave length '⍰' falls on the lens. After refraction and reflection two rays **1** and **2** are obtained. These rays interfere each other producing alternate bright and dark rings. At the point of contact the thickness of air filmis zero and the path difference is also zero and as 180^{o} path difference occurs, so they cancel each other and a dark ring is obtained at the centre.



As we move away from the central point, path difference is also changed and alternate dark and bright rings are obtained. Let us suppose that the thickness of air film is'**t**'.By using the theorem of geometry,

$$BD * BE = AB * BC$$

$$= AB *(AC - AB)$$

$$r * r = t * (2R-t)$$

$$r^{2} = 2Rt - t^{2}$$

Since't' is very small compared to 'r',so we can neglect 't^{2}

$r^{2} = 2Rt$

In thin films, path difference for constructive interference is:

$$2nt = (m+1/2)\,\lambda$$

Where n= refractive index
for air n = 1
Therefore,

$$2t = (m+1/2)\,\lambda$$

For first bright ring **m = 0**
for second bright ring **m = 1**
for third bright ring **m = 2**
Similarly
For N^{th} bright ring **m = N-1** Putting the value of **m** in equation (2)

$$2t = (N-1+1/2)\,\lambda$$

$$2t = (N-1/2)\,\lambda$$
$$t = 1/2\,(N-1/2)\,\lambda$$

Putting the value of't' in equation (1)

$r^2 = 2Rt$
$r^2 = 2R.\ 1/2\,(N-1/2)\,\lambda$
$r^2 = R\,(N-1/2)\,\lambda$

DIFFRACTION

Differences between fresnel and fraunhoffer diffraction:

sno	Fresnel diffraction	Fraunhoffer diffraction
1	Either a point source or an illuminated narrow slit is used.	Extended source at infinite distance is used.
2	The wavefront undergoing diffraction is either spherical or cylindrical.	The wavefront undergoing diffraction is plane wavefront.
3	The source and the screen are finite distances from the obstacles producing diffraction	The source and the screen are infinite distances from the obstacles producing diffraction
4	No lens is used to focus the rays	Converging lens is used to focus the rays

Fraunhoffer diffraction due to single slit:

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Let us first consider a parallel beam of light incident normally on a slit AB of width 'a' which is of order of the wavelength of light as shown below in the figure

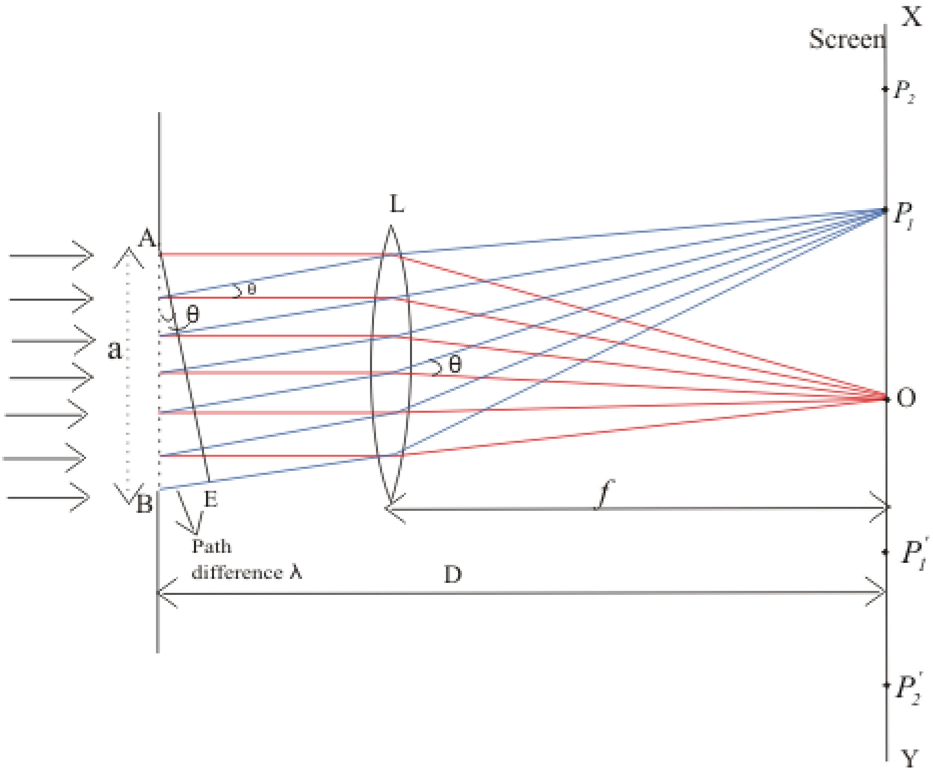


Figure 1. Fraunhofer diffraction of a plane wave at single slit

- A real image of diffraction pattern is formed on the screen with the help of converging lens placed in the path of the diffracted beam
- All the rays that starts from slit AB in the same phase reinforce each other and produce brightness at point O on the axis of slit as they arrive there in the same phase
- The intensity of diffracted beam will be different in different directions and there are some directories where there is no light
- Thus diffraction pattern on screen consists of a central bright band and alternate dark and bright bands of decreasing intensity on both sides

- Now consider a plane wave front PQ incident on the narrow slit AB. According to Huygens principle each point t on unblocked portion of wavefront PQ sends out secondary wavelets in all directions

- Their combined effect at any distant point can be found y summing the numerous waves arriving there from the principle of superposition

- Let C be the center of the slit AB.The secondary waves, from points equidistant from center C of the clit lying on portion CA and CB of wave front travel the same distance in reaching O and hence the path difference between them is zero

- These waves reinforce each other and give rise to the central maximum at point O

i) Condition for minima

- We now consider the intensity at point P_1 above O on the screen where another set of rays diffracted at a angle θ have been bought to focus by the lens and contributions from different elements of the slits do not arise in phase at P_1
- If we drop a perpendicular from point A to the diffracted ray from B,then AE as shown in figure constitutes the diffracted wavefront and BE is the path difference between the rays from the two edges A and B of the slit.

- Let us imagine this path difference to be equal to one wavelength.

- The wavelets from different parts of the slit do not reach point P_1 in the phase because they cover unequal distance in reaching P_1.Thus they would interfere and cancel out each other effect. For this to occur

  $BE=\lambda$
  Since $BE=AB\sin\theta$
  $a\sin\theta=\lambda$
  or $\sin\theta=\lambda/a$
  or $\theta=\lambda/a$ ---(1)
  As angle of diffraction is usually very small so that
  $\sin\theta=\theta$

- Such a point on screen as given by the equation (1) would be point of secondary minimum
- It is because we have assume the slit to be divided into two parts, then wavelets from the corresponding points of the two halves of the slit will have path difference of #955;/2 and wavelets from two halves will reach point P_1 on the screen in a opposite phase to produce minima

- Again consider the point P_2 in the figure 1 and if for this point path difference $BE=2\lambda$,then we can imagine slit to be divided into four equal parts

- The wavelets from the corresponding points of the two adjacent parts of the slit will have a path difference of $\lambda/2$ and will mutually interfere to cancel out each other

- Thus a second minimum occurs at P_2 in direction of θ given by
  $\theta=2\theta/a$
- Similarly n_{th} minimum at point P_n occurs in direction of θ given by
  $\theta_n=n\theta/a$ ---(2)

ii) Positions of maxima

- If there is any point on the screen for which path difference
  $BN=a\sin\theta=3\theta/2$
  Then point will be position of first secondary maxima

- Here we imagine unblocked wavefront to be divided into three equal parts where the wavelets from the first two parts reach point P in opposite phase thereby cancelling the e effects of each other

- The secondary waves from third part remain uncancelled and produce first maximum at the given point

- we will get second secondary maximum for $BN=5\theta/2$ and n_{th} secondary maxima for
  $BN=(2n+1)\theta/2=a\sin\theta_n$ ---(3)

  where n=1,2,3,4..

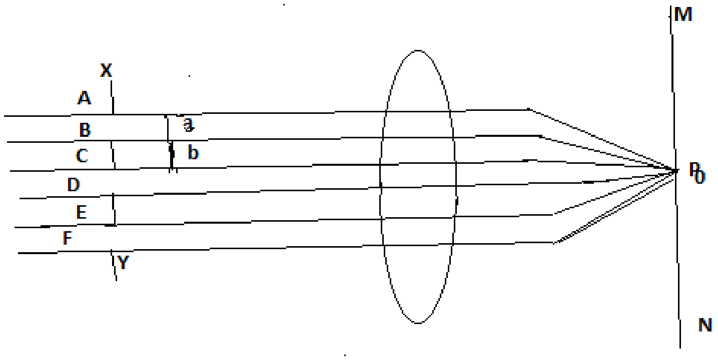
- Intensity of these secondary maxima is much less then central maxima and falls off rapidly as move outwards

- Figure below shows the variation of the intensity distribution with their distance from the center of the central maxima

Fraunhoffer diffraction due to N-slits(diffraction grating)

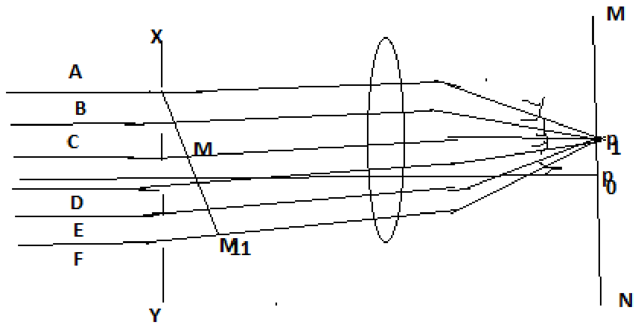
Diffraction grating is nothing but close placed multiple slits. It consists of very large number of multiple slits sise by side separated by opaque spaces. The incideny light is transmitted through the slits and blocked by opaque spaces. Such a grating is called transmission grating. When light passs through the grating ,each one of the slit diffracts the waves. All the diffracted waves reinforce one another producing sharper and intense maxima on the screen. A plane transmission grating is nothing but a plane sheet of transparent material on which opaque rulings are made. The spaces between the rulings are equal and transparent and constitute the parallel slits. The rulings and slits are of equal width.

The combined width of a ruling and a slit is called as grating element. Points on successive slits separated by distance equal to the grating element are called as corresponding points.



Theory of plane transmission grating:

_Let ABCDEF REPRESENT THE SECTION OF GRATING normal to the plane of paper . AB,CD,EF etc represent the slits of width a each while BC,DE,etc represent the opaque rulings of width b each. Now (a+b) which is the combined width of a ruling and a slit is called grating element. It is also the distance between two successiove slits. Let a wavefront incident normally on the grating. The points in the slits AB,CD,EF etc act as a secondary sources of light giving rise to secondary waves. These waves spread in all directions on the other side of the grating. The secondary waves travelling in the same direction as that of the incident wave are focused at P_o on the screen. Since all the secondary waves have travelled equal distance to reach P_o they reinforce constructively and the point P_o is the position of central bright maximum.



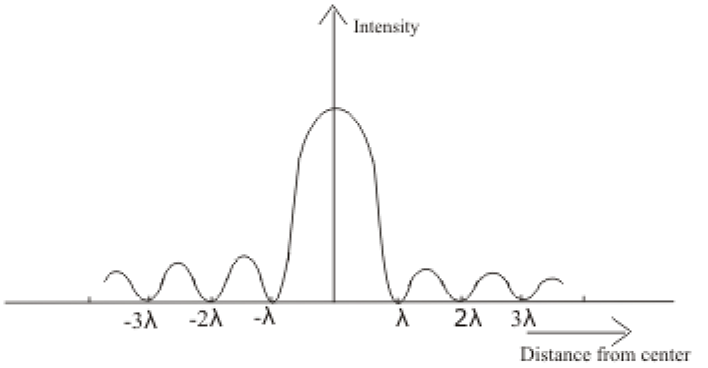


Figure 2. Intensity distribution in the diffraction due to single slit

Let us consider that the secondary diffracted waves proceeding in a direction which make an angle θ with respect to the normal. AMM_1 is drawn normal to the diffracted light. Let us consider the waves diffracted at the corresponding points A and C. The path difference between the waves on reaching P_1 is CM since they travel equal path beyond AM.

In ΔACM

Sinθ=CM/AC

=(a+b)sinθ

The super position of these waves at P_1 cause interference . P_1 *will be bright when*

$(a+b)\sin\theta_m = m\lambda$

Where m=0,,2,3,…..and angles θ_1, θ_2,….etc

Hence $\sin\theta_m = m\lambda/(a+b)$

$= mN\lambda$

Where 1/(a+b) N is the number of grating elements .

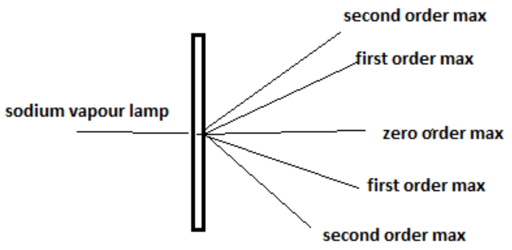
If m=1

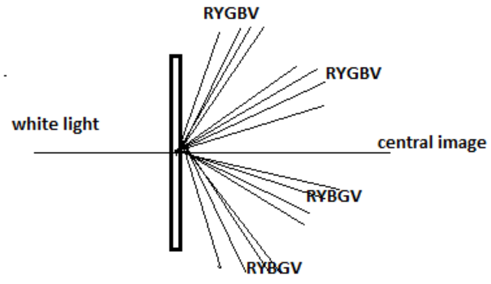
$(a+b)\sin\theta_{1=}\lambda$

If m=2

$(a+b)\sin\theta_2 = 2\lambda$

Thus different order bright images are obtained on the both sides of the direct ray as shown below





Maximum number of orders possible with a grating:

We know that $\sin\theta = mN\lambda$

Where θ is the angle of diffraction.the maximum value of θ can be 90^0. Hence the possible value of sinθ is 1.hence $mN\lambda \leq 1$ or $m \leq 1/N\lambda$

Unit 11

Polarization

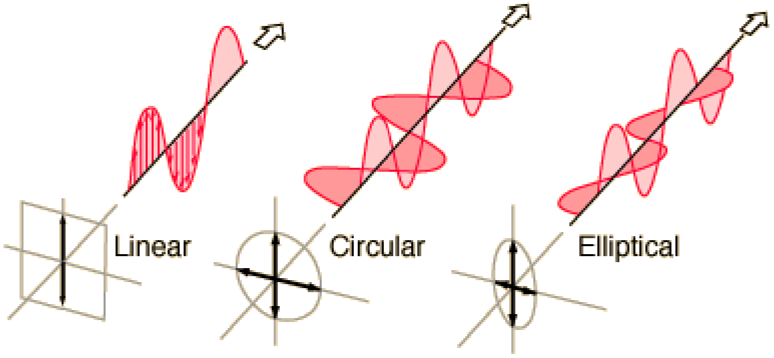
Introduction:

The process of converting unpolarized light to polarized light is called as polarization.

The transverse wave nature of light has been established by polarization phenomenon. Light is nothing but an electro magnetic wave.the light emitting atoms are oscillating independently emitting individual wave trains.as a result the oscillations are at random. Hence in nature most light as it is unpolarized. If the oscillations are confined to only one direction, then is called plane polarized light.

Classification of Polarization

Light in the form of a plane wave in space is said to be linearly polarized. Light is a transverse electromagnetic wave, but natural light is generally unpolarized, all planes of propagation being equally probable. If light is composed of two plane waves of equal amplitude by differing in phase by 90°, then the light is said to be circularly polarized. If two plane waves of differing amplitude are related in phase by 90°, or if the relative phase is other than 90° then the light is said to be elliptically polarized



A plane electromagnetic wave is said to be linearly polarized. The transverse electric field wave is accompanied by a magnetic field wave.

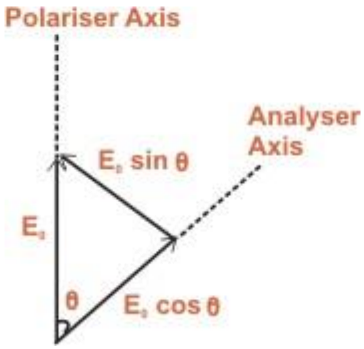
Circularly polarized light consists of two perpendicular electromagnetic plane waves of equal amplitude and 90° difference in phase. The light illustrated is right- circularly polarized.

Elliptically polarized light consists of two perpendicular waves of unequal amplitude which differ in phase by 90°. The illustration shows right- elliptically polarized light.

Malus's Law

According to malus, when completely plane polarized light is incident on the analyzer, the intensity I of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer.

i.e $I \infty \cos^2\theta$



Suppose the angle between the transmission axes of the analyzer and the polarizer is θ. The completely plane polarized light form the polarizer is incident on the analyzer. If E_0 is the amplitude of the electric vector transmitted by the polarizer, then intensity I_0 of the light incident on the analyzer is

$I \infty E_0^2$

The electric field vector E_0 can be resolved into two rectangular components i.e $E_0 \cos\theta$ and $E_0 \sin\theta$. The analyzer will transmit only the component (i.e $E_0 \cos\theta$) which is parallel to its transmission axis. However, the component $E_0 \sin\theta$ will be absorbed by the analyser. Therefore, the intensity I of light transmitted by the analyzer is,

$I \infty (E_0 \times \cos\theta)^2$

$I / I_0 = (E_0 \times \cos\theta)^2 / E_0^2 = \cos^2\theta$

$I = I_0 \times \cos^2\theta$

Therefore, $I \infty \cos^2\theta$. This proves law of malus.

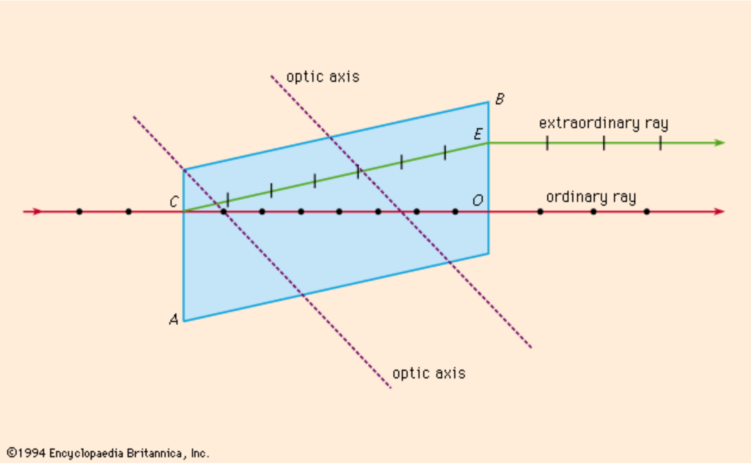
When $\theta = 0°$ (or 180°), $I = I_0 \cos^2 0° = I_0$ That is the intensity of light transmitted by the analyzer is maximum when the transmission axes of the analyzer and the polarizer are parallel.

When $\theta = 90°$, $I = I_0 \cos^2 90° = 0$ That is the intensity of light transmitted by the analyzer is minimum when the transmission axes of the analyzer and polarizer are perpendicular to each other.

Double Refraction: Unpolarized light has two components –one vertical and another horizontal. When unpolarized light passes through certain anisotropic crystals such as calcite or quartz, velocity of propagation of these two components vary. This means that the material exhibits two different refractive indices.

Since $\mu = \sin I / \sin r$, though both the components have the same angle of incidence, they have different angles of refraction. Hence when unpolarized light passes through such crystals, we get two refracted beams and this phenomenon is called double refraction or birefringence.

Calcite is a good example of a system of anisotropic crystals. It is rhombic in shape and the line **AC** joining the blunt corner **A** and **C** is called crystal axis.



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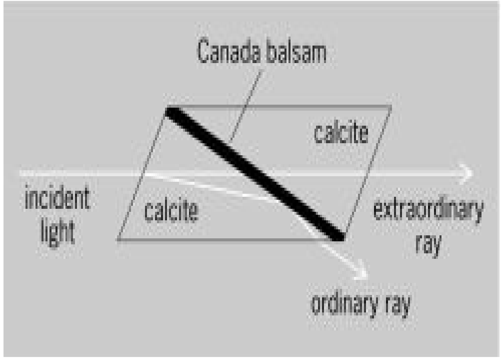
A line through **A** which makes equal angles with the three edges gives the direction of optic axis since optic axis is not a line but direction. When unpolarized light passes through the crystal, in a direction different from optic axis, it is split into **ordinary or O-ray** and **extra-ordinary or e-ray**.

The ordinary ray travels with the same velocity in all directions. The corresponding refractive index is called ordinary refractive index (μ_0). The extraordinary ray travels with the same velocity as that of ordinary ray along optic axis direction. In other directions, the velocity gradually changes and in a direction perpendicular to optic axis, the change is maximum. The refractive index of extraordinary ray corresponding to this direction (which is perpendicular to optic axis) is called extraordinary refractive index (μ_e).

Both o-ray and e-ray are plane polarized but with their planes of polarization mutually perpendicular to each other.

Nicol Prism:



Principle: It is a device for producing and analyzing a plane polarized light. When an ordinary light is transmitted through a calcite crystal, it splits in o-ray and e-ray which is completely plane polarized with vibrations in two mutually perpendicular planes. If one beam is eliminated then the emergent beam from the crystal will be plane polarized light. Nicol eliminated the o-ray by utilizing the phenomenon of total reflection at thin film of Canada balsam separating the two pieces of calcite. The device is known as Nicol prism.

Construction: A calcite crystal whose length is 3 times as its width is taken. The end faces of this crystal are grounded in such a way that the angles in the principal section become 68 ˚and 112 ˚ instead of 71˚ and 109˚. This is done to increase the field of view.

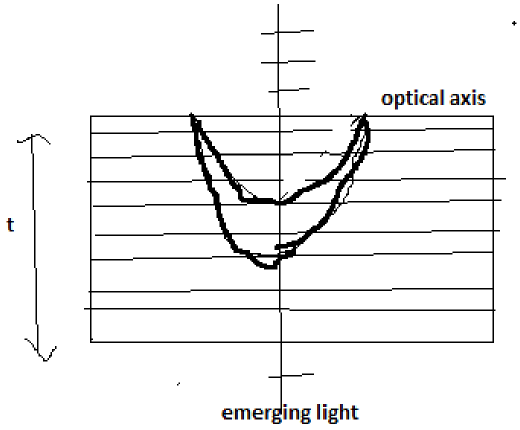
The crystal is cut in two pieces by a plane perpendicular to principal section as well as the end faces PR and QS. The two cut surfaces are grounded and polished optically flat and then cemented together by Canada balsam. The refractive index of Canada balsam lies between the refractive indices for the o-ray and e-ray for calcite.

Working: When a beam of light AB enters the faces PR in direction parallel to the long side, it is doubly refracted into ordinary plane polarized beam BO and extraordinary plane polarized beam BE. From the values of refractive indices, it is clear that Canada balsam acts as a rarer medium for an ordinary ray and denser medium for e-ray. Moreover the dimensions of the crystal are chosen in such a way that the angle of incidence of o-ray at the calcite-balsam surface becomes greater than the corresponding critical angle 69 ˚. Under these conditions, the o-ray is completely reflected at calcite-balsam surface. The e-ray is not totally reflected because it is travelling from a rarer to a denser medium and is thus transmitted with no appreciable loss in intensity. It is slightly displaced laterally but emerges out of the prism parallel to its original direction. Thus only the e-ray is transmitted since e-ray is plane polarized having vibrations parallel to principal plane, the light emerging from the Nicol prism is plane polarized.Nicol prism can be used both as polarizer and an analyzer

Wave plate

A **waveplate** or **retarder** is an optical device that alters the polarization state of a light wave travelling through it. Two common types of waveplates are the *half-wave plate*, which shifts the polarization direction of linearly polarized light, and the*quarter-wave plate*, which converts linearly polarized light into circularly polarized light and vice versa.[1] A quarter wave plate can be used to produce elliptical polarization as well.

Quarter wave plate:



Let us consider a calcite plate cut with optical axis parallel to the surface.when a plane polarized light falls normally on a thin plate of uniaxial crystal(here calcite plate) cut parallel to its optic axis,the light splits into ordinary and extraordinary plane polarized lights.they travel along the same path but with different velocities.the velocity of extra ordinary ray is greater than the velocity of ordinary ray. As a result a phase difference is introduced between them.

If the thickness of the crystal plate is such that it introduces a phase difference of $\pi/2$ radians or a path difference of $\lambda/4$ then it is called a quarter wave plate.

Let t be the thickness required for such a plate.if μ_o and μ_e be the refractive indices of the crystal for ordinary and extra ordinary waves,then the path difference between these waves is given as

$\mu_o t+\mu_e t = (\mu_o-\mu_{e)} t$

For a quarter plate this distance should be $\lambda/4$ or $t=\lambda/4(\mu_o-\mu_{e)}$

HALF WAVE PLATE:

IF the thickness of the calcite crystal plate,cut with its faces parallel to optical axis,is such that it introduces a phase difference of π or a path difference of $\lambda/2$ between ordinary and extra ordinary wave then it is called as half wave plate. For a half wave plate

$= (\mu_o-\mu_{e)} t=\lambda/2$

Then $t=\lambda/2(\mu_o-\mu_{e)})$

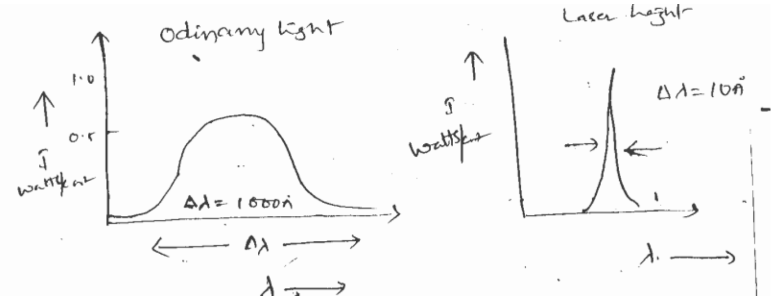
LASERS

LASER means light amplification of stimulated emission of radiation

Laser is an acronym for light amplification by stimulated emission of radiation.
Maser is an acronym of microwave amplification by stimulated emission of radiation.
The light emitted from the conventional light source(eg:sodium lamp,candle) is said to be incoherent.Because the radiation emitted from different atom donot have any definite phase relationship with each other. Lasers are much important because the light sources having high monochromaticity, high intensity, high directionality and high coherence.
In the laser the principal of maser is employed in the frequency range of 1014- 1015 Hz and it is termed as optical maser.Laser principle now a days extended upto ϒ-rays hence Gamma ray lasers are called Grazers.The first two success full lasers developed during 1960 were Ruby laser and He-Ne lasers.

Characteristics of laser radiation:
(1)Laser is highly monochromatic
(2)Laser is highly directional
(3)Laser is highly coherent
(4)The intensity of laser is very high

HIGHLYMONOCHROMATIC:



Thebandwidthofordinarylightisabout1000 A^{o}.Thebandwidthoflaserlightisabout 10 A^{o}.The narrow band width of a laser light is called on high monochromacity.

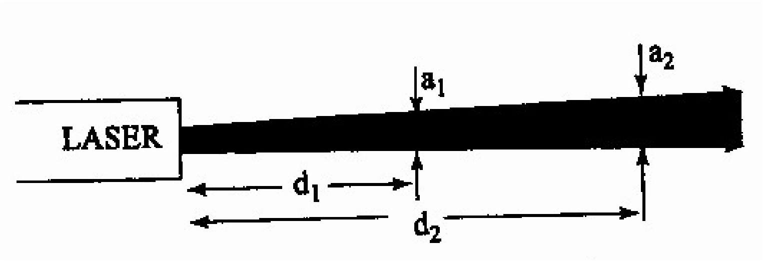
BANDWIDTH: -The spread of the wavelength(frequency) about the wavelength of maximum intensity is band width.
Laserlightismoremonochromaticthanthatofaconventionallightsource.Becauseofthis monochromaticity large energycanbe concentrated in to an extremely small band width.

For good laser $dv = 50Hz$, $v = 5\times10^{14}Hz$. The degree of non-monochromaticity for conventional sodiumlight.

HIGH DIREATIONALITY:

The conventional light sources like lamp, torch light, sodium lamp emits light in all directions.Thisiscalleddivergence.Laserin theother hand emits lightonly in one direction. This is called directionality of laser light.

Light fromordinary light spreads in about few kilometers.



Light from laser spreads to a diameter less than 1 cmfor many kilometers.

The directionality of laser beam is given by (or) expressed in divergence.

The divergence $\Delta\theta = (r2 - r1) / d2 - d1$

Wherer_2, r_1 are the radius of laser beamspots $d_2, d_1$are distances respectively from the laser source.Hence forgetting a high directionality there should be low divergence.

HIGHLY COHERENT:

When two light rays are having same phase difference then they are said to be coherent. It is expressed in terms of ordering of light field.

Laser has high degree of ordering than other common sources. Due to its coherence only it is possible to create high power (10^{12}watts) in space with laser beam of 1μm diameter.

There are two independent concepts of coherence.

1) Spatial coherence (2) Temporal coherence

SPATIALCOHERENCE: The two light fields at different point in space maintain a constant phase difference over any time (t)they are said to be spatial coherence.

In He- Ne gas laser the coherence length (lc) is about 600km.It means over the distance the phase difference is maintained over anytime .For sodiumlight it is about 3cm.

TEMPORAL COHERENCE: The correlation of phase between the light fields at a point over a period of time. ForHe- Ne laser it is a about 10^{-3}second, for sodiumit is about 10^{-10}sec only.

Higher is the Tchigher is the monochromacity.

HIGHINTENSITY:

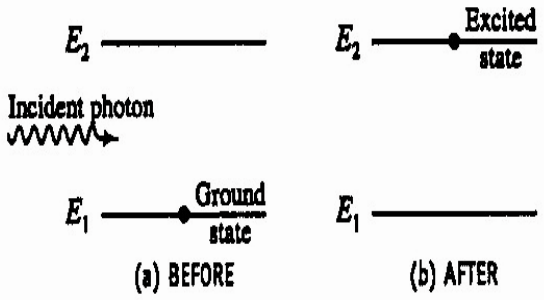
Intensity of a wave is the energy per unit time flowing through a unit area.

The light from an ordinary source spreads out uniformly in all directions and fromspherical wave fronts around it.

Ex: - If you look a 100W bulb from a distance of 30cm the power entering the eye is 1 / 1000 of

watt.
But in case of a laser light, energy isin small region of space and in a small wavelength and hence is said to be of great intensity.
The power range of laser about 10^{-3} W for gas laser and 10^{9} W for solid state laser.

SPONTANEOUS AND STIMULATED(INDUCED) EMISSION:

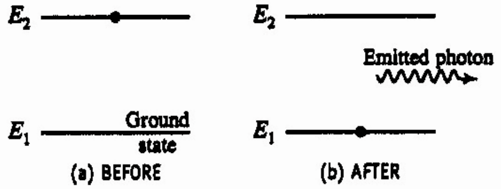


(a) BEFORE (b) AFTER

INDUCED ABSORPTION

Light is emitted or absorbed by particles during their transitions fromone energy state to another .the process of transferring a particle from ground state to higher energy state is called excitation. Then the particle is said to be excited.

The particle in the excited state can remain for a short intervaloftime known as life time. The life time is of the order of 10^{-8}sec, in the excited states in which the life time is much greater than 10^{-8}sec are called Meta stable states.The life time ofthe particle in the Meta stable state is of the order 10^{-3}sec



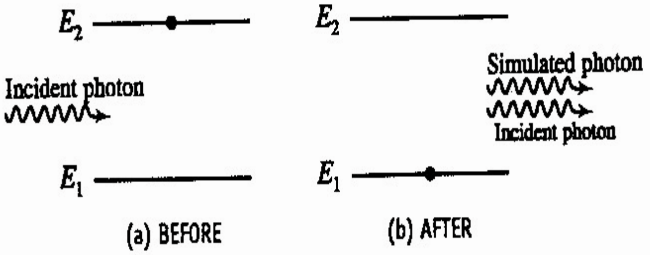
(a) BEFORE (b) AFTER

SPONTATNEOUS EMISSION

The probability of transition to theground state with emission of radiation is made up of two factors one is constant and the other variable.

The constant factor of probability is known as spontaneous emission and the variable factor is known as stimulated emission.

SPONTANEOUS EMISSION: The emission of particles fromhigher energy state to lower energy state spontaneously by emitting a photon ofenergy $h\upsilon$ is known as “spontaneous emission”



(a) BEFORE (b) AFTER

STIMULATED EMISSION

STIMULATED EMISSION: The emission of aparticle from higher state to lower state by stimulating it with another photon having energy equal to the energy difference between transition energy levels called stimulated emission.

SPONTANEOUS EMISSION	**STIMULATED EMISSION**
1) Incoherent radiation	1) coherent radiation
2) Less Intensity	2) high intensity
3) Poly chromatic	3) mono chromatic
4) One photon released	4) two photons released
5) Less directionality	5) high directionality
6) More angular spread during propagation	6) less angular spread during Propagation
Ex:-Light fromsodium Mercury vapour lamp	ex: - light froma laser source ruby laser, He-He gas laser gas Laser

POPULATIONINVERSION:

Thenoofatomsinhigherenergylevelislessthanthenoof atomsinlowestenergy level.Theprocessofmakingofhigherpopulationinhigherenergylevelthanthepopulation in lower energy level is known as population inversion.

Population inversionisachieved by pumping the atoms fromthe ground level to thehigher energy level through optical (or) electrical pumping. It is easily achieved at the matastablestate, wherethelifetimeoftheatomsishigherthanthatinotherhigherenergy levels.

Thestatesofsystem,inwhichthepopulationofhigherenergystateismoreincomparision with the population of lower energy state,are called “Negative temperature state”.

Asysteminwhichpopulationinversionisachievediscalledasanactivesystem.The methodofraisingtheparticlesfromlowerenergystatetohigherenergystateiscalled ”Pumping”.

EINSTEINSCO-EFFICIENTS:

Based on Einstein’s theory ofradiation one can get the expression for probability for stimulated emission of radiation to the probability for spontaneous emission of radiation under thermal equilibrium.

E_1,E_2be the energy states

N_1,N_2be the no of atoms per unit volume

ABSORPTION: If $\rho(\upsilon)d\upsilon$ is the radiation energy per unit volume between the frequency range of ν and$\nu + d\nu$

The number of atoms undergoing absorption per unit volume per second fromlevel

$E_1$to E_2= $N_1\rho(\upsilon)B_{12}$------ 1

B_{12}represents probability of absorption per unit time

STIMILATED EMISSION: When an atommakes transitionE_2toE_1in the presence of external photon whose energy equal to (E_2-E_1)stimulated emission takes place thusthe number of stimulated emission per unit volume per second from levels.

$E_2$to E_1= N2 $\rho(\nu)$ B_{21}------ 2

$B_{21}$is represents probability ofstimulated emission per unit time.

SPONSTANEOUS EMISSION: An atomin the level E_2can also make a spontaneous emission by jumping in to lower energy level E_1.

$E_2$to E_1=N_2A_{21}--- 3

A_{21}represents probability of spontaneous emission per unit time.

Under steady state (dN/dt) =0

No of atomsundergoing absorption per second = no of atomsundergoing emission per second

(1)= (2) + (3)

$N_1\rho(\upsilon) B_{12} = N_2\rho(\upsilon) B_{21} + N_2A_{21}$

$N_2A_{21} = N_1\rho(\upsilon) B_{12} - N_2\rho(\upsilon) B_{21} == \rho(\upsilon)(N_1B_{12} - N2B_{21})$

$\rho(\upsilon) = N_2A_{21} / (N_1B_{12} - N_2B_{21})$

$= A_{21} / [(N_1/ N_2) B12 - B21)]$-------- 4

Fromdistribution law we know that

$N_1 / N_2 = e^{(E_2 - E_1) / k_B T}$

$= e^{h\upsilon / k_B T}$ ------------5

Substituting N 1 / N_2 in eqn (4) we get

$\rho(\nu) = A_{21} / B_{21}(e^{h\upsilon/k_BT} - 1)$--- 6

From Planck'sradiation

$\rho(\nu) = 8\Pi hc^3/\lambda^3 \times [1 / (e^{h\upsilon/k_BT} - 1)]$ -------7

n – refractive index of the medium

λ - Wave length of the light in air.

$\lambda_m = \lambda / n$ wavelength of light in medium - - - - - - 8

$\rho(\upsilon) = 8\Pi h / \lambda_m^3 \times [1 / (e^{h\upsilon/k_BT} - 1)]$ --9

Comparing eqn 6 and 9

$\mathbf{A_{21}/B_{21} = 8\Pi h/ \lambda_m^3}$

Where $\mathbf{A_{21}}$**,** $\mathbf{B_{21}}$are Einstein's co-efficient of spontaneous emission probability per unit time and stimulated emission probability per unit time respectively.

For stimulated emission to be predominant, we have

$\mathbf{A_{21}/B_{21} << 1}$

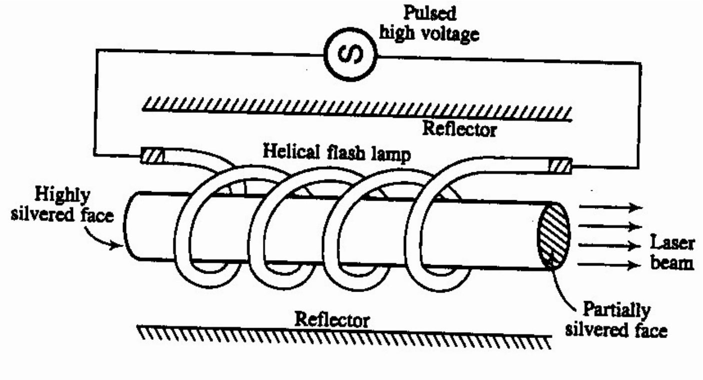
RUBYLASER:

Ruby laser is a three level solid state laser having very high power of hundreds of mega watt in a single pulse it is a pulsed laser. The systemconsists of mainly two parts

1) ***ACTIVEMATERIAL:*** Ruby crystal in the formof rod.

2) ***RESONANTCAVITY:*** A fully reflecting plate at the left end of the ruby crystal and partially reflecting end at the right sideof the rubycrystal boththe surfacesare optically flatand exactly parallel to each other.
3) ***EXCITINGSYSTEM:*** A helical xenon flash tube with power supply source.

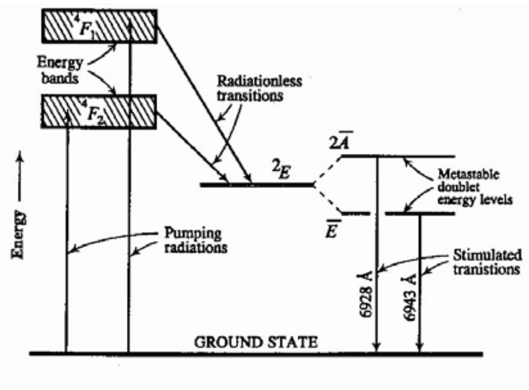
CONSTRUCTION: In ruby laser, ruby rod is a mixture of Al_2O_3 $+Cr_2O_3$. It is a mixture of Aluminum oxide in which some of ions Al^{3+} ions concentration doping of $Cr^{3+}$is about 0.05%, then the colour of rod becomes pink. The active mediumin ruby rod is Cr^{3+}ions. The length of the ruby rod is 4cmand diameter 5mm and both the ends of the ruby rod are silvered such that one end is fully reflecting and the other end is partially reflecting. The ruby rod is surrounded by helical xenon flash lamp tube which provides the optical pumping to raise Cr^{3+}ions to upper energy level.



RUBY LASER

The chromiumatomhasbeen excited to anupper energy level by absorbing photons of wave length 5600A^{0}fromthe flash lamp. Initially the chromiumions (Cr^{3+})are excited to the energy levels $E_1$to E_3, the population in E_3increases. Since the life time of E_3level is very less (10^{-8}Sec).The Cr^{3+}ions drop to the level E_2which is matastable oflife time 10^{-3} Sec.
The transition from$E_3$to $E_2$is non-radiative.

Since the life time of metastable state is muchlonger, the no of ions in this state goes on increasing hence population inversion achievedbetween the excited metastable state $E_2$and the ground state E_1.



ENERGY LEVEL DIAGRAM OF Cr^{+++} IN A RUBY CRYSTAL

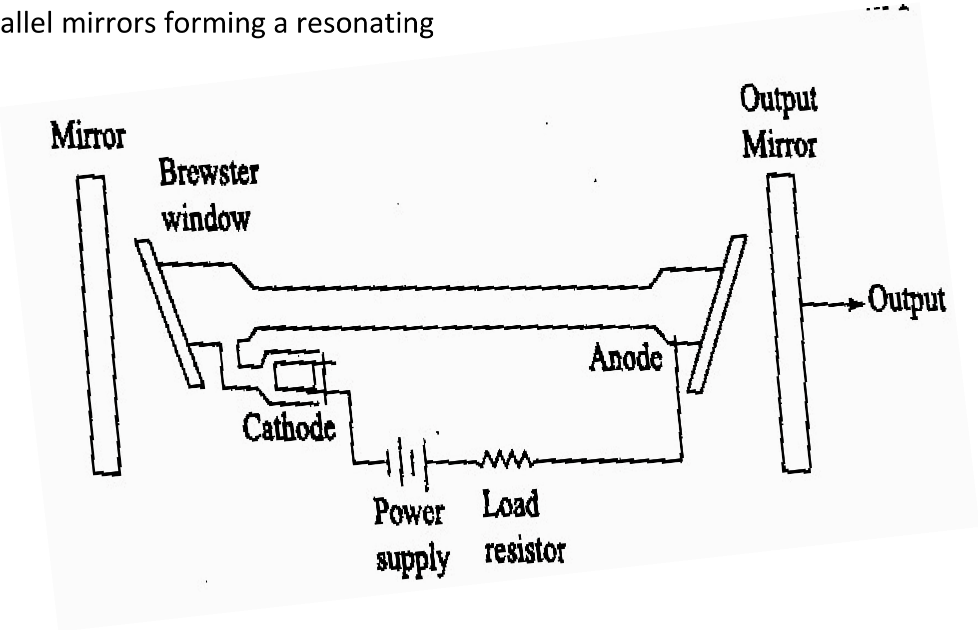
When an excited ion passes spontaneously fromthe metastable state E$_2$to the ground state E$_1$.It emit a photon of wave length 6993A^{o}this photon travel through the ruby rod and if it is moving parallel to the axis ofthe crystal and itis reflected back and forth by the silver ends until it stimulates an excited ion in E$_2$. The emitted photon and stimulated photon are in Phase the process is repeated again and again finally the photon beambecomes ntense; it emerges out through partially silvered ends.Since the emitted photon and stimulating photon in phase, and has same frequency and is traveling in the same direction, the laser beamhas directionality along with spatial and temporal coherence.

IMPORTANCEOFRESONATORCAVITY: Tomakethebeamsparalleltoeachother curved mirrors are used in the resonator cavity. Resonator mirrors are coated with multi layer dielectric materials to reduce the absorption loss in the mirrors. Resonators act as frequency selectors and also giverise to directionality to the output beam. The resonator mirror provides partial feedback to the protons.

He- Ne Laser

CONSTRUTION:

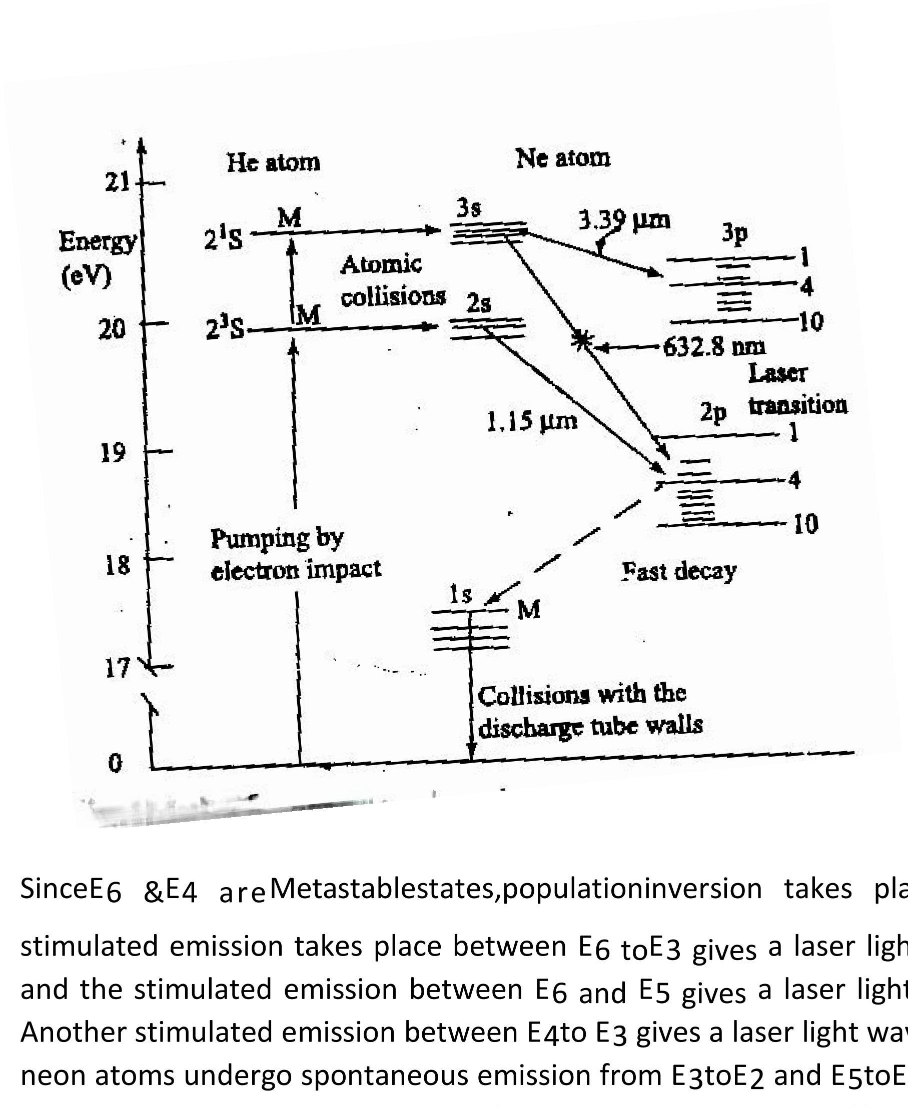
He-Negaslaserconsistsofagasdischargetubeoflength80cmand diameter of 1cm. The tube is made up of quartz and is filled with a mixture of Neon under a pressureof0.1mm ofHg. TheHelium underthepressureof1mm ofHgtheratioofHe-Ne mixtureofabout10:1,hencethenoofheliumatomsaregreaterthanneonatoms.The mixtures is enclosed between a set ofparallel mirrors forming a resonating Cavity,oneof



themirrorsiscompletelyreflectingandtheotherpartially reflectinginorderto amplify the output laser beam.

WORKING:

Whena discharge ispassedthroughthegaseousmixtureelectronsareaccelerated downthetubetheseacceleratedelectronscollidewith thehelium atomsandexcitethem to higher energy levels since the levels are meta stable energy levels he atoms spend sufficientlylong time and collide with neon atoms in the ground levelE_1. Then neon atoms areexcitedtothehigherenergylevelsE_4&E_6andhelium atomsaredeexcitedtotheground state E_1



SinceE_6 &E_4 areMetastablestates,populationinversion takes place at there levels.The stimulated emission takes place between E_6 toE_3 gives a laser light of wavelength 6328A^0 and the stimulated emission between E_6 and E_5 gives a laser light wavelength of 3.39µm. Another stimulated emission between $E_4$to E_3 gives a laser light wave length of 1.15µm. The neon atoms undergo spontaneous emission from E_3toE_2 and E_5toE_2.Finally the neon atoms are returned to the ground state E_1 from E_2 by non-radiative diffusion and collision process.

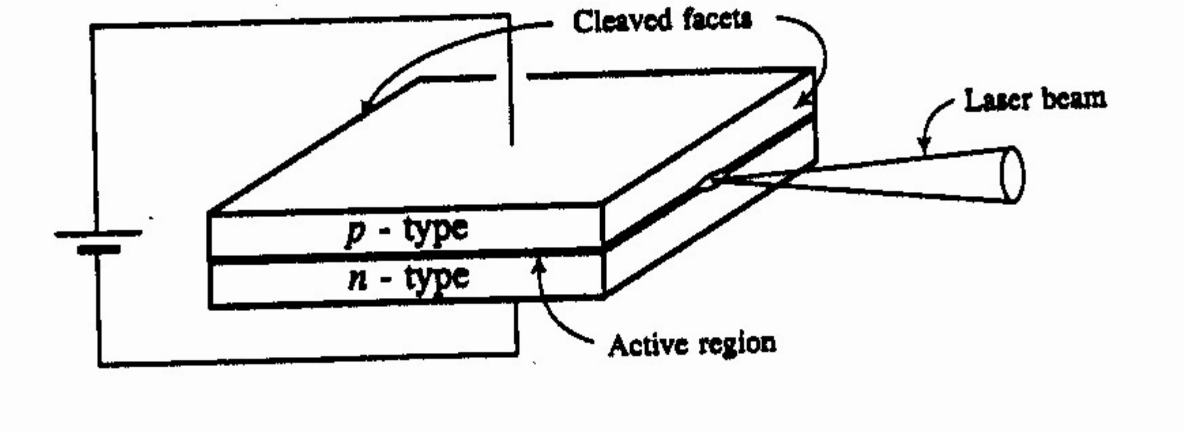
After arriving the ground state,once again the neon atoms are raised to E_6&E_4 by excited helium atoms thus we can get continuous out put from He-Ne laser.

But some optical elements placed insides the laser system are used to absorb the infrared wavelengths 3.39µm and 1.15µm.hence the output of He-Ne laser contains only a single wave length of 6328A^{0}and the output power is about few milli watts .

SEMICONDIRCTORLASER(GalliumArsenide Diode Laser or Homojunction Laser):
Semiconductor laser is also known as diode laser
PRINCIPLE:

In the case of direct band gap semiconductors there is a large possibility for direct recombination of hole and electron emitting a photon. GaAs is a direct bandgap semiconductor and hence it is used to make lasers and light emitting diodes.The wave lengths of the emitted light depend on the band gap ofthe material.

CONSTRUCTIONS: The P-region and N-region in the diode are obtained by heavily doping germanium and tellurium respectively in GaAs.The thickness of the P-N junction layer is very narrow at the junction;the sides are well polished and parallel to eachother. Since the refractiveindex of GaAs is high the reflectance at the material interface is sufficiently large so that the external mirror are not necessary to produce multiple reflections.The P-N junction is forwardbiased by connection positive terminal to P-type and negative terminal to N type.



SEMICONDUCTOR LASER

WORKING: When the junction is forward biased a large current of order10^4amp/cm^2 is passed through the narrow junction to provide excitation. Thus the electrons and holes injected from N side and P side respectively. The continuous injection of charge carries the population inversion of minority carriers in N and P sides respectively.

The excess minority electrons in the conduction band of P–layers recombine with the majority holes in the valence band of P-layer emitting light photons similarly the excess minority holes in the valence band of N-layers recombine with the majority electrons in the conduction band of N- layer emitting light photons.
The emitted photons increase the rate of recombination of injected electrons from the N-region and holes in P-region.Thus more no of photons are produced hence the stimulated emission take place, light is amplified.

The wavelength of emitted radiation depends upon the concentration of donor and acceptor atoms in GaAs the efficiency of laser emission increases, when we cool the GaAs diode.

DRAWBACKS:-

1. Only pulsed laser output is obtained
2. Laser output has large divergence
3. Poor coherence

APPLICATION OF LASERS: Lasers

In scientific research

1) Lasers are used to clean delicate pieces of art, develop hidden finger prints
2) Laser are used in the fields of3D photography called holography
3) Usinglaserstheinternalstructureofmicroorganismsandcellsarestudiedvery accurately
4) Lasers are used to produce certain chemical reactions.

Laser in Medicine:

1) The heating action of a laser beamused to remove diseased body tissue

2)Lasers are used for elimination of moles and tumours,which are developing in the skin tissue.

3) Argon and CO_2 lasers are used in the treatment liver and lungs

4) Laser beam is used to correct the retinal detachment by eye specialist

Lasers in Communication:

1) More amounts of data can be sent due to the large band with ofsemiconductor lasers
2) More channels can be simultaneously transmitted
3) Signals cannot tapped
4)Atmospheric pollutants concentration, ozone concentration and watervapour concentration can be measured

Lasers in Industry: Lasers are used

1) To blast holes in diamonds and hard steel
2) To cut, drill,welding and remove metal fromsurfaces
3) To measure distance to making maps by surveyors.

4) For cutting and drilling of metals and non- metals such a ceramics plastics glass

Unit 111

Fibre optics

1. What is optical fiber? Explain the principle of optical fibers.

BasicprincipleofOpticalfiber:

The mechanism of light propagation along fibers can be understood using the principle of geometrical optics. The transmission of light in optical fiber is based on the phenomenon of total internal reflection.

Let n_1 and n_2 be the refractive indices of core and cladding respectively such that $n_1 > n_2$. Let a light ray traveling from the medium of refractive index n_1 to the refractive index n_2 **be incident** with an angle of incidence "i" and the angle of refraction "r". By Snell's law

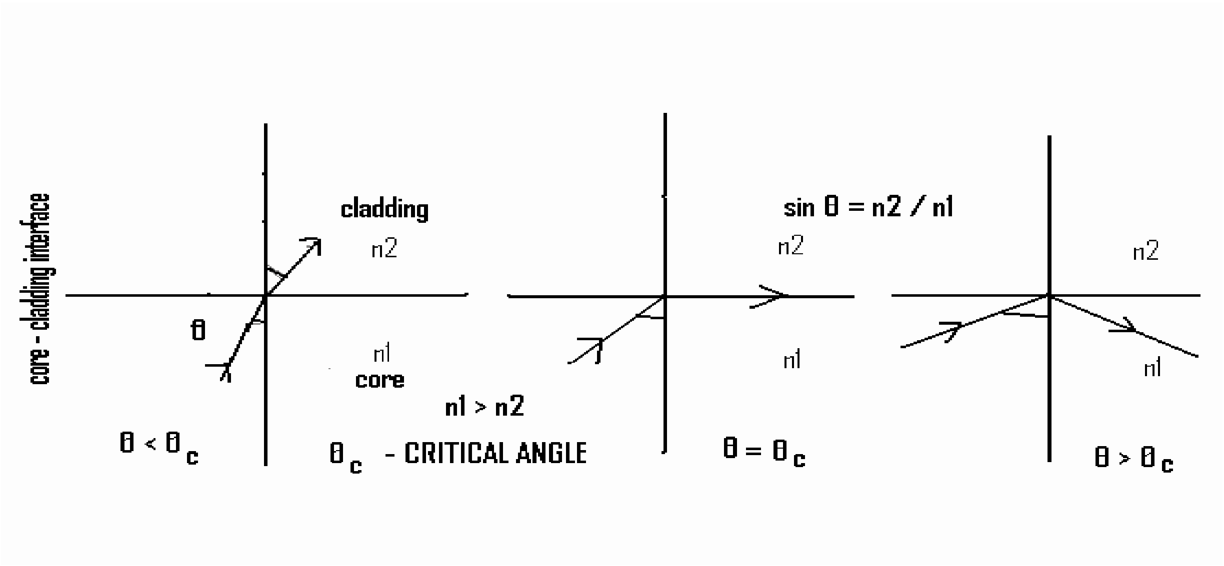
$$n_1 \sin i = n_2 \sin r \text{………………}(1)$$

The refractive ray bends towards the normal as the ray travels from rarer medium to denser medium.On the other hand,the refracted ray bends away from normal as it travel from denser medium to rarer medium.In the later case,there is a possibility to occur total internal reflection provided;the angle of incidence is greater than critical angle (θ_C). This can be understood as follows.

1.When $i < \theta_C$, then the ray refracted is into the second medium as shown in below fig1.

2.When $i = \theta_C$, then the ray travels along the interface of two media as shown in fig2.

3.When $i > \theta_C$ then the ray totally reflects back into the same medium as shown in fig3.



Suppose if i= $\theta_C$then r =90^{O}, hence

$$n_1 \sin \theta_C = n_2 \sin 90^{O}$$

$$\sin \theta_C = n_2/n_1 \qquad (\text{since } \sin 90^{O}=1)$$

$$\theta_C = \sin^{-1}(n_2/n_1)\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Thus any ray whose angle of incidence is greater than the critical angle, total internal reflection occurs, when a ray is traveling from a medium of high refractive index to low refractive index.

Construction of opticalfiber:

The optical fiber mainly consists of the following parts.

i .Core ii .Cladding iii .Silicon coating iv .Strength material v. Outer jacket

A typicall glass fiber consists of a central core of thickness 50µm surrounded by cladding.Cladding is made up of glass of slightly lower refractive index than core's refractive index, whose over all diameter is 125µm to 200µm.

Of course both core and cladding are made of same glass and to put refractive index of cladding lower than the refractive index of core, some impurities like Boron, Phosphorous.

Silicon coating is provided between buffer jacket and cladding in order to improve the quality light.Buffer jacket over the optical fiber is made of plastic and it protects the fiberfrommoisture.In order to provide necessary toughness and tensile strength,a layer of strength material is arranged surrounding the buffer jacket.Finally the fiber cable is covered by black polyurethane outer jacket.Because of this arrangement fibercable willnot be damaged during hard pulling, bending, stretching or rolling, though the fiber is of brittle glass.

AcceptanceangleandNumericalapertureofopticalfiber:

When the light beam is launched into a fiber, the entire light may not pass through the core and propagate. Only the rays which makes the angle of incidence greater than critical angle at the core –cladding interface undergoes total internal reflection. The other rays are refractedto the cladding and are lost. Hence the angle we have to launch the beam at its end is essential to enable the entire light to pass through the core .This maximum angle of launch is called acceptance angle.

Consider an optical fiber of cross sectional view as shown in figure no, n1and n2 are refractive indices of air, core and cladding respectively such that $n_1>n_2>n_o$.let light ray i s incidenting on interface of air and core medium with an angle of incidence α.This particular ray enters the core at the axis point A and proceeds after refraction at an angle α_r fromthe axis .It then undergoes total internal reflection at B on core at an internal incidence angle θ.

To find α at A:-

In triangle ABC,$\alpha_r = 90 - \theta$ …………………… (1)

From Snell's law,

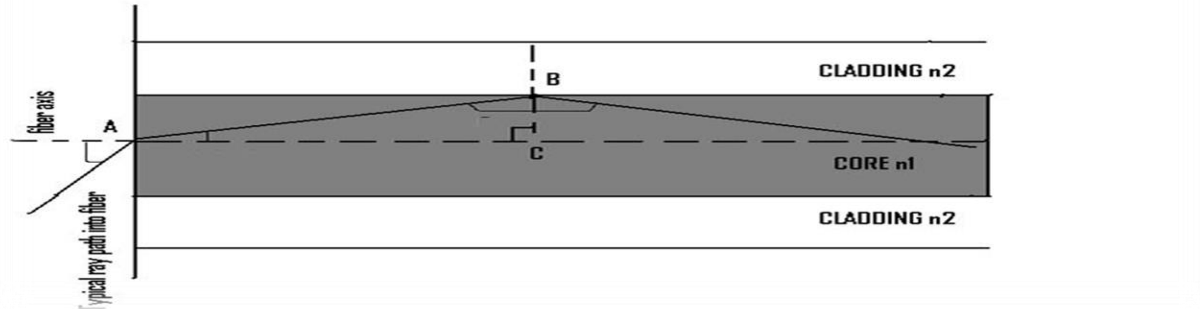
$n_0 \sin\alpha = n_1 \sin\alpha r$…………….(2)

$\sin\alpha = n_1/n_0 \sin\alpha_r$…………………….(3)

Fromequations 1, 3

$\sin\alpha = n_1/n_0 \sin(90-\theta) \Rightarrow \sin\alpha = n_1/n_0 \cos\theta$……… (4)

If$\theta<\theta_c$,the ray will be lost by refraction.Therefore limiting value for the beam to be inside the core,by total internal reflection is θ_c.Let α(max) be the maximum possible angle of incident at



the fiber end face at A for which $\theta=\theta_C$.If for a ray α exceeds α(max),then $\theta<\theta_C$ and hence at B the ray will be refracted.

Hence equation 4 can be written as

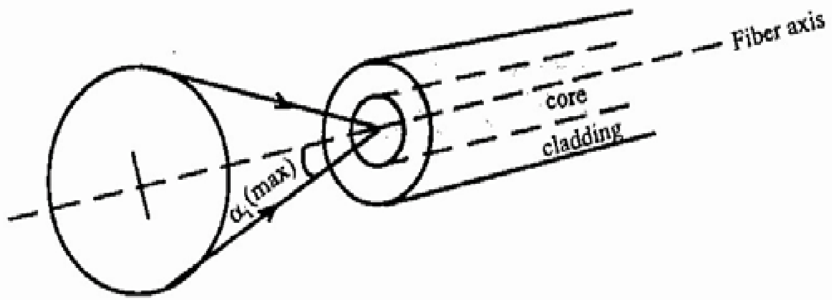
$$\sin\alpha_{(max)} = n_1/n_0\cos\theta_C \text{……………………(5)}$$

Therefore, we know that

$$\cos\theta_C=\surd(1-\sin^2\theta_C) = \surd(1- n_2^2/n_1^2)$$

$$=\surd(n1^2-n2^2)/n_1 \text{……………………(6)}$$

$$\sin\alpha\ (max) =\surd(n1^2-n_2^2)/n_o$$



Acceptance cone obtained by rotating the acceptance angle about the fiber axis

$$\alpha\ (max)=\sin^{-1}\surd(n_1^2-n_2^2)/n_o$$

Numericalaperture:-

Light collecting capacity of the fiber is expressed in terms of acceptance angle using numerical aperture. Sine of the maximum acceptance angle is called the numerical aperture of the fiber.

$$\text{Numerical aperture} =NA = \sin\alpha\ (max) =\surd(n1^2-n_2^2)/n_o \text{……………. (7)}$$

$$\text{Let}\quad \Delta= (n_1^2-n_2^2)/2n_1^2 \text{…………… (8)}$$

For most fiber $n_1 = n_2$

Hence $\Delta= (n_1+n_{2)}(n_1-n_{2}/2n_1^2 \quad = 2n_1(n_1-n_2)/ 2n_1^2$

$\Delta = \quad (n_1-n_{2)}/ n_1$(fractional difference inrefractive indices)…………… (9)

Fromequation (8) $\quad n_1^2-n_2^2= \Delta\ 2n_1^2$

Taking under root on both sides

Hence $=\surd(n_1^2-n_2^2)= \surd2\Delta\ n_1$

Substituting this in equation (7) we get

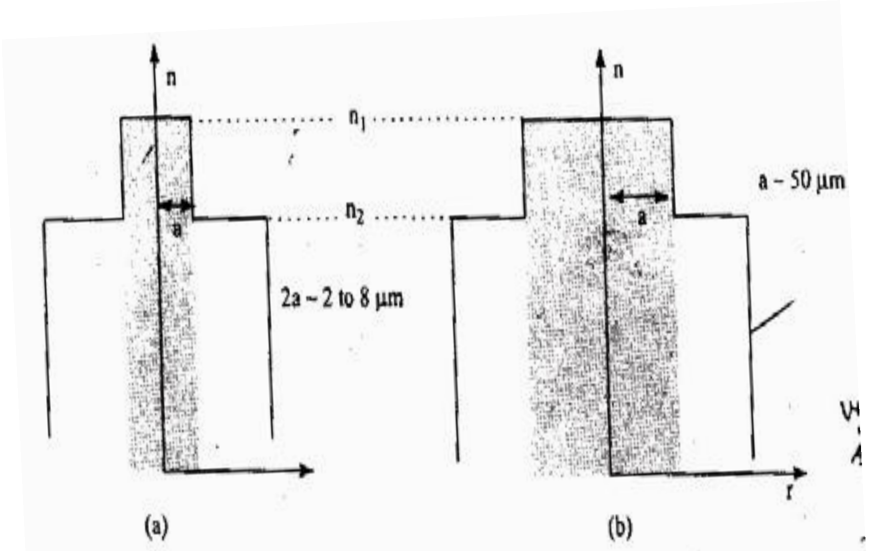
$NA \approx \sqrt{2\Delta}\, n_1/n_O$……… (10)

For air n_O= 1, then the above equation can changed as

$$\boxed{NA \approx \sqrt{2\Delta} n_1}$$

Numerical aperture of the fiber is dependent only on refractive indices of the core and cladding materials and is not a function of fiber dimensions.

Step index fibers:-In step index fibers the refractive index of the core is uniform through out the medium and undergoes an abrupt change at the interface of core and cladding.The diameter of the core is about 50-200µm and in case of multimodefiber.And 10µm in the case of single mode fiber.The transmitted optical signals travel through core medium in the form of meridonal rays, which will cross the fiber axis during every reflection at the core-cladding interface. The shape of the propagation appears in a zig-zac manner.

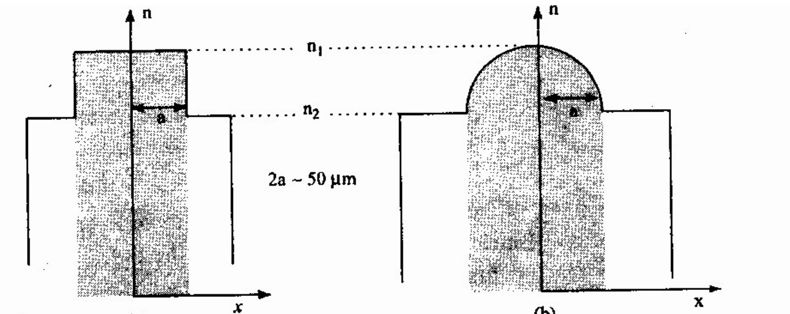


Refractive index profile for (a) monomode and (b) multimode step index fi

2. What are graded index optical fibers

Graded index fiber:-

In these fibers the refractive index of the core varies radially.As the radius increases in the core medium the refractive index decreases. The diameter of the core is about 50µm.The transmitted optical signals travel through core medium in the form of helical rays, which will not cross the fiber axis at any time.



Refractive index profile for (a) multimode step index and (b) multimode graded index fibers

Applicationsofopticalfibers:

1. Optical fibers are used assensors
2. These are used in Endoscopy
3. These are used in communication system
4. For decorative peaces inhome needs.
5. These are used in defence areas for the sake of high security.
6. These are used in electrical engineering.

Advantagesofopticalfibercommunication:

- Enormous Bandwidth:-

In the coaxial cable transmission the band width is up to around 5000MHz only,where as in fiber optical communication it is as large as 10^5GHz.Thus the information carrying capacity of optical fiber system is far superior to the copper cable system.

- Electricalisolation:-

  Since fiber optic material are insulators unlike there metallic Counter part,they donot exhibit earth loop and interface problems.Hence communication through fiber even in electrically hazard in environment do not cause any fear of spark hazards.

- Immunity to interference and cross talk:-

  Since optical fibers are dielectric waveguides,they are free from any electromagnetic interference (EMI) and radio frequency interference (RIF). Hence fiber cable does not require special shielding from EMI.Since optical interference among different fiber is not possible, unlike communication using electrical conductor cross talk is negligible even when many fibers are cabled together.

- Signal security:-

Unlike the situation with copper cables a transmitted optical signal cannot be drawn fiber without tampering it.Such an attempt will affect the original signal and hence can easily detect.

- Small size and weight:-

  Since fibers are very small in diameter the space occupied the fiber cable is negligibly small compare to metallic cables.Optical cables are light in weight; these merits make them more useful in air craft’s and satellites.

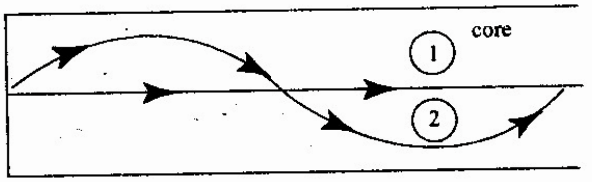
- Low transmission loss:-

  Since the loss in fibers is as low as 0.2 dB/Km,transmission loss is very less compare to copper conductors.Hence for long distance communication,fibers are preferred. Number of repeaters required is reduced.

- Low cost:-

  Since fibers are made up of silica which is available in nature, optical Fibers are less expensive.

Attenuationsinopticalfiber(orlosses):



) Propagation of different model rays inside graded index fiber

While transmitting the signals through optical fiber some energy is lost due to few reasons. The major losses in fibers are 1.Distotrion losses 2.Transmission losses 3.Bending losses.

1. Distortion losses:-

When a pulse is launched at one end of the fiber and collected at the other end of the fiber, the shape and size of the pulse should not be changed. Distortion of signals in optical fiber is an undesired feature.If the output pulse is not same as the input pulse,then it is said that the pulse is distorted. If therefractive index of the core is not uniform most of the rays will travel through the medium of lower refractive index region.Due to this the rays which are traveling fiber will become broadened. Because of this the output pulses will no longer matches with the input pulses.

The distortion takes place due to the presence of imperfections, impurities and doping concentrations in fiber crystals.Disperion is large in multi mode than in single mode fiber.

2. Transmission losses (attenuation):-

The attenuation or transmission losses may be classified into two categories i) Absorption losses ii) scattering losses

i) Absorption losses:-

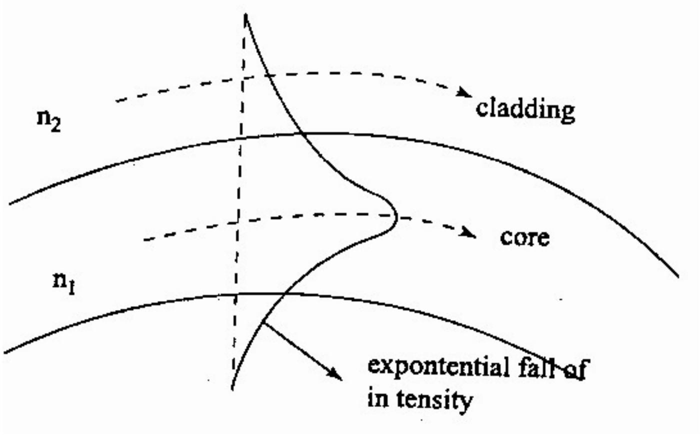
Absorption is a characteristic possessed by all materials every material in universe absorb suitable wavelengths as they incident or passed through the material. In the same way Core material of the fiber absorbs wavelengths as the optical pulses or wavelengths pass through it.

ii) Scattering losses:-

The core medium of the fiber is made of glass or silica .In the passage of optical signals in the core medium if crystal defects are encountered, they deviate from the path and total internal reflection is discontinued, hence such signals will be destroyed by entering into the cladding however attenuation is minimum in optical fibers compared to other cables.

ii) Bending losses:-

The distortion of the fiber from the ideal strait line configuration may also result in fiber.As per the theory each mode extends an infinite distance into the cladding though the intensity falls exponentially.Since the refractive index of cladding is less than that of the core($n_1>n_2$),the part of the mode traveling in the cladding will attempt to travel faster. As per Einistein's theory of relativity since the part of the mode cannot travel faster the energy associated with this particular part of the mode is lost by radiation.



Attenuation loss is generally measured interms of decibels(dB), which is a logarithmic unit.Loss of optical power = -10 log (P_{out}/ P_{in}) dB Where $P_{out}$is the power emerging out of the fiber

P_{in} is the power launched into the fiber.

Unit 4

CRYSTALLOGAPHY

Introduction:

Matter exists in three physical states.

They are gaseous state, liquid state and solid state. In gaseous and liquid states the atoms or molecules of the substance move from one place to other place and there is no fixed position of atoms in the substance. In solids, the positions of atoms or molecules are fixed and may or may not be present periodically at regular intervals of distance.

Based on atomic arrangement, these solids are can be classified into two types:

1. Crystalline solids
2. Amorphous solids

1. **Crystalline solids:** In a solid, the atoms or molecules are arranged in regular manner or periodic manner. It is called crystalline solid.

Eg: Metallic crystals (Cu, Al, Pb, etc)

Noon-metallic crystals (Diamond, Si, Ge, Nacl, etc)

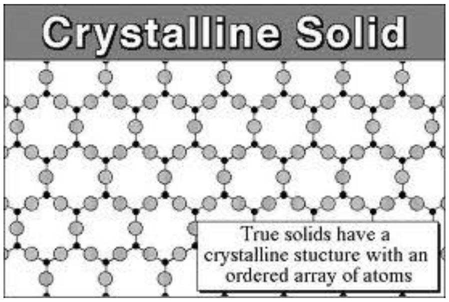


Fig: 2D`s crystalline solids

Crystalline solids can either be two types:

They are a. Single crystalline solids

b. Poly crystalline solids

a. Single crystalline solids: The entire solid consist of only one crystal that solid is called single crystalline solid.

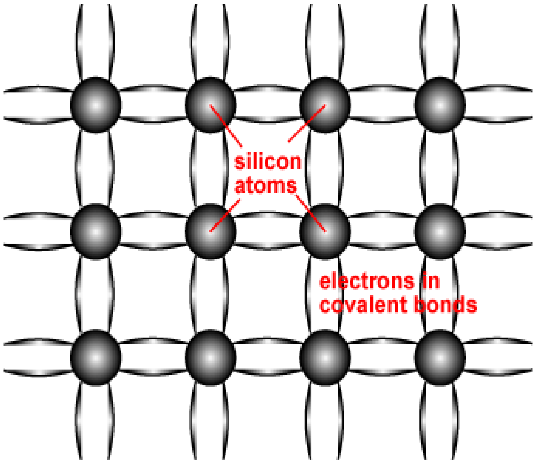


Fig: single crystalline solid.

b. Poly crystalline solid:

The entire solid consist of many no. of small crystals with well defined boundaries, that boundaries are called **grain boundaries**.

Eg: fiber texture

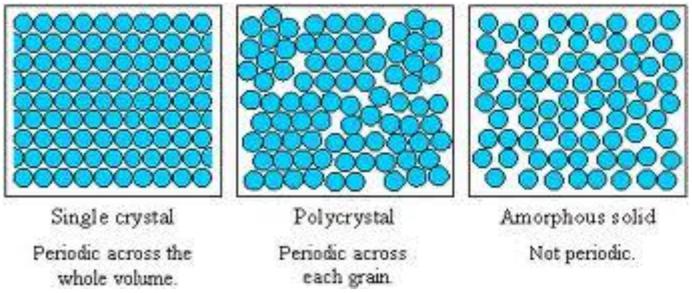
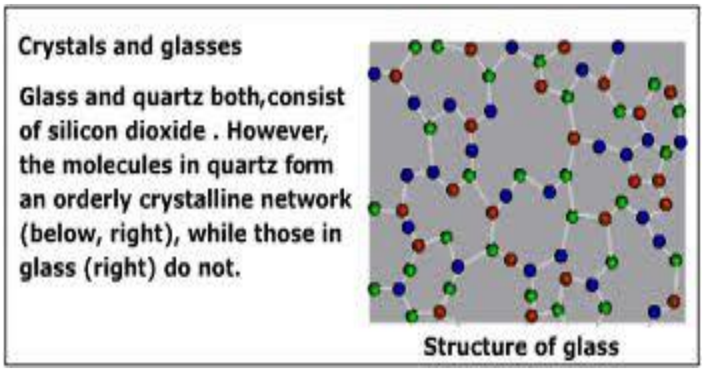


Fig: Poly crystalline solid.

2. **Amorphous solids:** In a solid, the atoms or molecules arranged in an irregular manner in 2D or 3D`s. is called Amorphous solid.

Eg: Glass



Crystals and glasses

Glass and quartz both, consist of silicon dioxide . However, the molecules in quartz form an orderly crystalline network (below, right), while those in glass (right) do not.

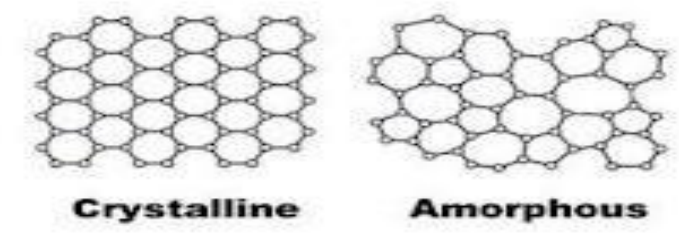
Structure of glass

Fig: 2D`s Amorphous solid.

DIFFERENCES B/W THE CRYSTALLINE SOLIDS AND AMORPHOUS SOLIDS:

Crystalline solid	**Amorphous solid**

1. The atoms or molecules of the crystalline solids are periodic in space.	1. The atoms or molecules of the amorphous solids are not periodic in space.
2. Some crystalline solids are anisotropic i.e The magnitude of physical properties such as refractive index, electrical conductivity. Thermal conductivity etc are different along different directions of the crystal.	2. Amorphous solids are isotropic i.e The magnitude of the physical properties are same along all directions of the solid.
3. When it is broken, all broken pieces are same in shape. Because the atomic arrangement is regular manner.	3. When it is broken, all broken pieces are random in shape. Because: the atomic arrangement is random manner.
4. They have sharp melting points.	4. They do not posses sharp melting point. (wide range of melting points)
5. They posses plane faces.	5. They do not possess plane faces.



Lattice Points:

Position of atoms in a crystal is called Lattice points.They are Imaginary points.

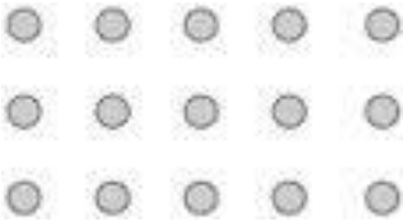


Fig: Lattice Points

Crystal structure:

Atomic arrangement in a crystal is called crystal structure.

(Or)

Crystal is 3Dimensional body. These are made up of regular and periodic 3D Pattern's of atoms of molecules in space is called the crystal structure.

Space lattice:

The atomic arrangement in a crystal is called crystal structure. It is very convenient to imagine periodic arrangement o0f points in space about which these atoms

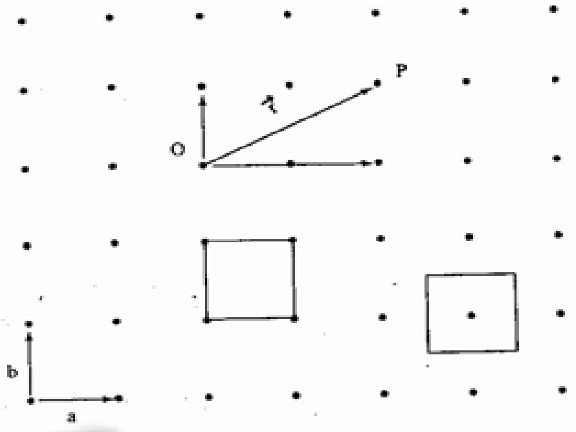


Fig. A two-dimensional square array of points.

are located. This leads to the

concept of space lattice.

A space lattice is defined as an infinite array of points in 3-dimensions in which every point has surroundings identical to that of every other point in the array.

Let us consider the 2D square array of points as shown in figure.

Let us choose any arbitrary point `o` as origin and a, b are two fundamental translational vectors along x and y directions the angle b/w these two vectors is 90^0. The magnitudes of 'a' and 'b' are equal and can be taken to be unity.

Let l, m are two integers along x and y direction and T_1 is the translational vector along x-axis and T_2 is the translational vector along y-axis.

$T_1 = la$ ---------------- (1)

$T_2 = mb$ --------------- (2)

L = 1+1 = 2 Units

M = 1 Units

Then the resultant translational vector T is

$T = T_1 + T_2$

$$\boxed{T = la + mb}$$

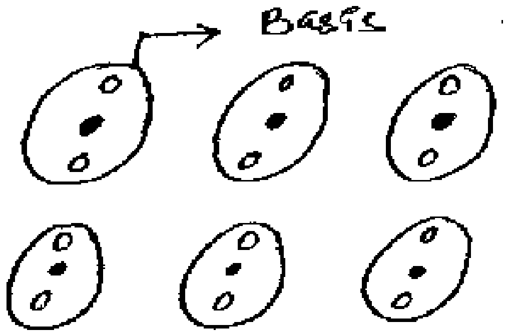
For 3Dimensions,

The resultant translational vector T = la + mb + nc

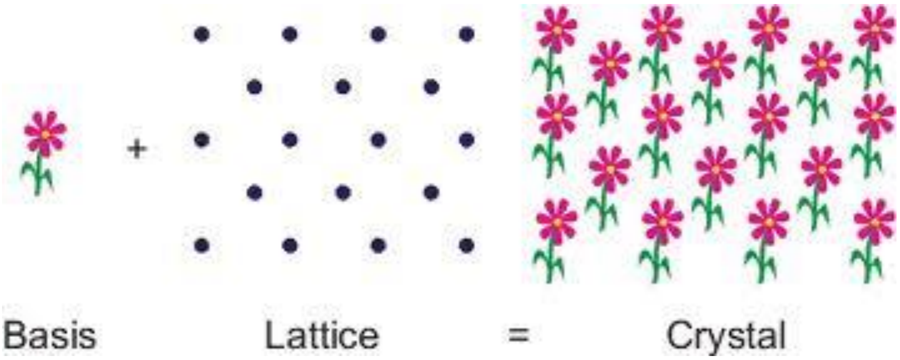
Where n, c is fundamental translational vector and integer along Z- axis.

Basis: A Group of identical in composition is called basis. It provides the no. of atoms per lattice point.

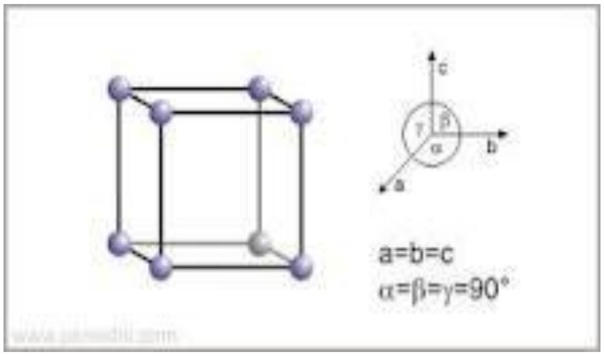
FIG:



Space lattice + Basis → Crystal structure.



Unit cell: It is the smallest geometric figure. The repetition which gives the actual crystal structure.

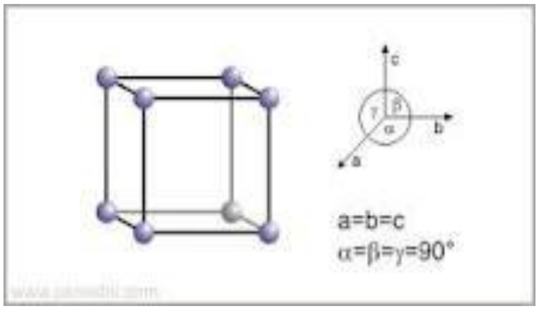


a = b = c = 1 and $\alpha = \beta = \gamma = 90^0$

Primitive cell:

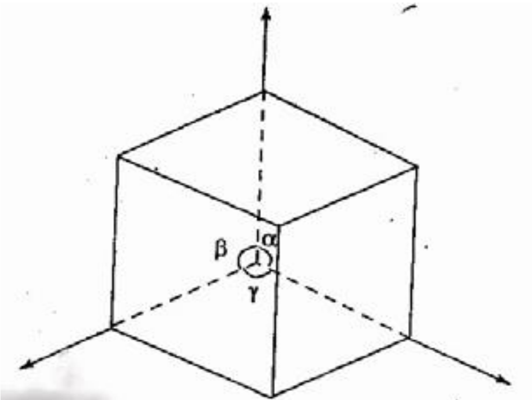
Unit cell have only one lattice point is called the primitive cell.

Eg: simple cubic structure.



Lattice points = 1/8 x8 = 1.

Lattice parameters of an unit cell:



Lattice parameters of an unit cell.

The lines drawn parallel to the lines of intersection of any three faces of the unit cell. Which do not lie in the same plane are called crystallographic axes (x ,y and z). Let a, b, c are three translational vectors along x , y and z- directions. Unit cell shown with three crystallographic axes (x , y and z) and the intercepts a , b, c, are define the dimensions of an unit cell and are known as its primitives.

The angles b/w the three crystallographic axes are known as interfacial angles.

The angle between b and c is α

The angle between c and a is β and

The angle between a and b is γ.

The primitives a, b and c and interfacial angles are the Basis lattice parameters. Because they are used to determine the **size** and **dimension** of the unit cell. The unit cell formed by the primitives a, b, c is called `primitive cell`.

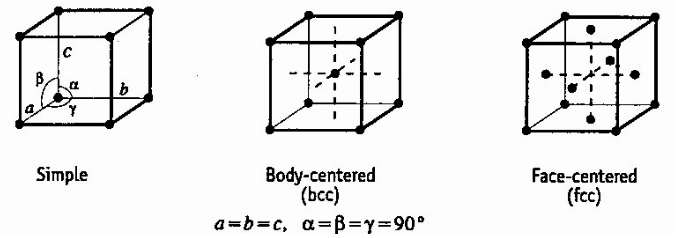
Crystal systems and Bravais lattices:

Based on lattice parameters [three vectors a, b, c and inter facial angles α, β, γ] seven different crystal systems and 14 bravais lattices are available.

1. Cubic crystal system
2. Tetra gonal
3. Orthorhombic
4. Trigonal
5. Hexagonal
6. Monoclinic
7. Tri clinic

1. Cubic crystal system:

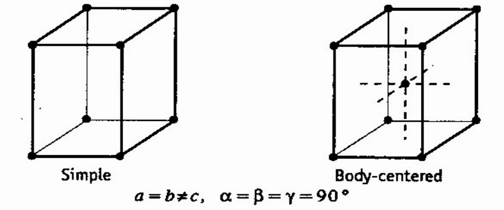
$a = b = c, \alpha = \beta = \gamma = 90^0$



The crystal axes are perpendicular to one another and the repetitive interval in the same along all the three axes. Cubic lattices may be simple (p), Body centered (I) and face centred (F).

2.Tetra gonal:

$a = b \neq c, \alpha = \beta = \gamma = 90^0$

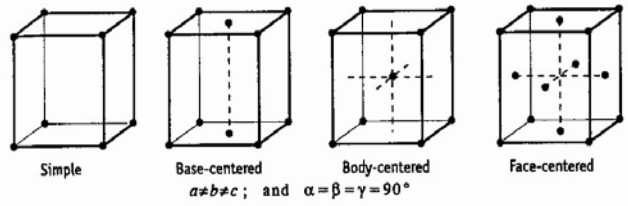


TETRAGONAL SYSTEM

The crystal axes are perpendicular to each other. The repetitive intervals along the two axes are the same, but the interval along the third axes is different. Tetragonal lattices may be simple (p) and Body centered (I).

3. Orthorhombic crystal system:

$a \neq b \neq c, \alpha = \beta = \gamma = 90^0$

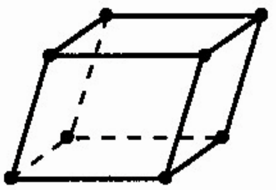


ORTHORHOMBIC SYSTEM

The crystallographic axes are perpendicular to one another but the repetitive intervals are different along three axes. This system may simple (p), Body centered (i), Base centered (c), and face centered (f).

4. Trigonal crystal system:

$$a = b = c, \alpha = \beta = \gamma \neq 90^0$$

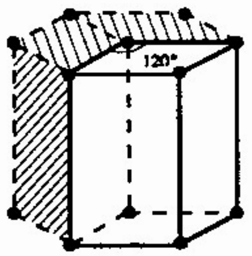


$a = b = c$
$\alpha = \beta = \gamma \neq 90°$
IOMBOHEDRAL (TRIGONAL) SYSTEM

The three axes are equal in length and are equally inclined to each other at an angle other than 90^0.

5. Hexagonal crystal system:

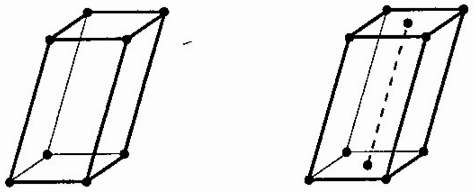
$$a = b \neq c, \alpha = \beta = \gamma = 90^0 , \gamma = 120^0$$



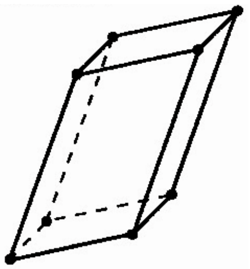
$a = b \neq c$
$\alpha = \beta = 90°, \ \gamma = 120°$
HEXAGONAL SYSTEM

6. Mono clinic crystal system:

$$a \neq b \neq c, \alpha = \beta = 90^0 \neq \gamma$$



Simple   Base-centered
$a \neq b \neq c, \ \alpha = \gamma = 90° \neq \beta$
MONOCLINIC SYSTEM



$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma \neq 90°$
TRICLINIC SYSTEM

Crystal systems	Bravais lattices	Lattice parameters	Examples

7. Tri clinic crystal system:

$a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^0$

Table:

1. cubic	Simple (p), body centered (I), Face centered (F)	$A= b =c$, $\alpha = \beta = \gamma =90^0$	Na, Cu_2o, Ag, Au, Pb, Cu etc
2. Tetragonal	Simple (p), body centered (I)	$a = b \neq c$, $\alpha = \beta = \gamma =90^0$	Tio_2, Sno_2, KH_2pc
3.Orthorhombic	Simple (p), body centered (I), Face centered (F), Base centered (c).	$a \neq b \neq c$, $\alpha = \beta = \gamma =90^0$	$Pbco_3$, $Baso_4$, Kno_3, K_2so_4 Etc
4. Trigonal	Simple (p)	$a = b = c$ $\alpha = \beta = \gamma \neq 90^0$	Calcite, As, Sb, Bi
5. Hexagonal	Simple (p)	$a = b \neq c$, $\alpha = \beta =90^0$, $\gamma = 120^0$	Quartz, Zn, C
6.Monoclinic	Simple (p), Base centered (c)	$a \neq b \neq c$, $\alpha = \beta = 90^0 \neq \gamma$	($Caso_4$, $2H_2o$) gypsum, $6H_2o$ K_2Mgso_4,
Triclinic	Simple (P)	$a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^0$	$K_2Cr_2o_7$

None of the crystal axes are perpendicular to any one of the others and the repetitive intervals are different along the three axes.

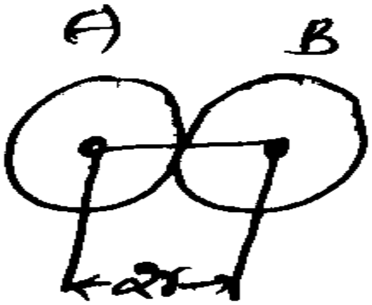
Basic crystal structures:

The important fundamental quantities which are used to study the different arrangements of atoms to form different structures are.

1. **Nearest neighboring distance (2r):**

The distance b/w the centers of two nearest neighboring atoms are called nearest neighboring distance.

If r - is the radius of the atom.



. Nearest neighboring distance = r + r = 2r

2. **Atomic radius (r):** It is defined as half the distance b/w the nearest neighboring distance or atoms in a crystal.

Atomic radius = 2r/2 = r

3. **Coordination Number [CN] :** It is defined as the no. of equidistant nearest neighboring atoms. How many nearest neighboring atoms are surrounded by the atom is called as co-ordination number [CN].

Coordination number for Simple cubic structure is 6

Coordination number for Body centered structure is 8 and

Coordination number for Face centered structure is 12.

4. **Atomic packing factor or fraction:** It is the ratio of volume occupied by all the atoms in an unit cell (v) to the total volume of the unit cell ((V).

Atomic packing factor (APF) = v/V

1. Simple cubic structure (SC): There is one lattice point at each of eight corners of the unit cell. There is no lattice point inside the unit cell.

The unit cell of a simple cubic structure is shown in figure. If we take an atom at one corner as the centre, it is observed that this atom is surrounded by 6 equidistant nearest neighbors.

Hence the coordination number of simple cubic structure is 6. In this each corner atom is shared by eight unit cells. Hence the share of each corner atom to a unit cell is one-eight of an atom.

The total no. of atoms in one unit cell will be 1/8x8 = 1. So no. of lattice lattice points in simple cubic cell is one. Thus simple cubic structure is a primitive cell.

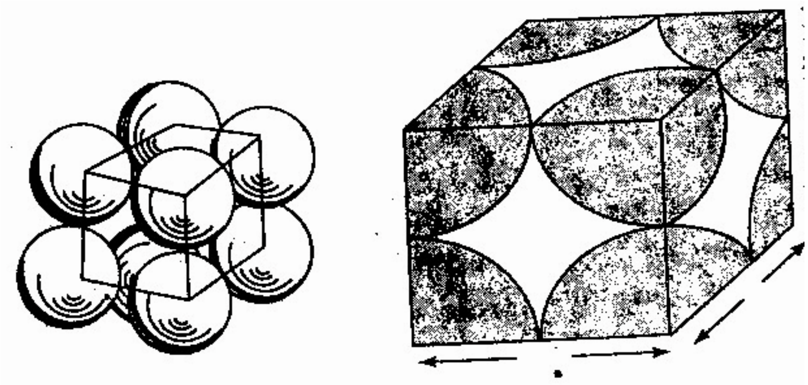


Figure:

Nearest neighboring distance 2r = a

Lattice constant a = 2r

Atomic radius r = a /2

Coordination number of SC structure (CN) = 6

No of atoms per unit cell (n) = 1/8x8 =1

Lattice point = 1

Volume of all atoms in a unit cell (v) = $1 x 4/3 \pi r^3$

Total volume of unit cell (V) = a x a x a = a3 = $(2r)^3 = 8r^3$

$$\text{Packing factor} = \frac{volume of all atoms in a unit cell}{Total volume of unit cell}$$

$$= \frac{1x\frac{4}{3}\pi r^3}{8r^3}$$

$$= \frac{\pi}{6} = \frac{22}{7x6}$$

$$PF = \frac{22}{42} = 0.52$$

$$PF = 0.52x100$$

$$\boxed{PF = 52\%}$$

The packing factor of simple cubic structure is 52%.

Examples: Polonium (Po) Only

2. Body centered cubic structure (BCC):

Elements that exhibit this structure are Li, Na, K and Cr. In a unit cell there is one lattice point at each of the eight corners and one lattice point at the centre of the each cell.

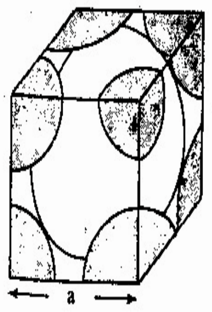


Fig (b)

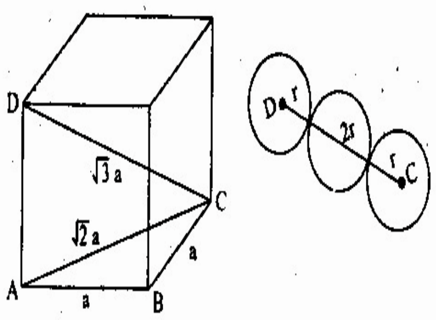


Fig (a)

As the body centre is contained entirely within the unit cell and it not shared by any surrounding unit cell.

Number of atoms per BCC structure is 1/8x8+1 = 2.

The corner atoms do not touch each other, but each corner atom touch the body centre atom.

Hence the coordination no.of this structure is 8.

Lattice constant (a):

Δ^{ll} ABC

$$(AC)^2 = (AB)^2 + (BC)^2$$

$$(AC)^2 = a^2 + a^2 = 2a^2$$

From Δ^{ll} ACD

$$(CD)^2 = (AD)^2 + (AC)^2$$

$$(AD)^2 = (CD)^2 - (AC)^2$$

$$(CD)^2 = (AD)^2 + (AC)^2 = a^2 + 2a^2 = 3a^2$$

$$(CD)^2 = 3a^2$$

But from Fig: CD = 4r

$$(CD)^2 = 3a^2$$

$$(4r)^2 = 3a^2$$

$$16r^2 = 3a^2$$

$$a^2 = 16/3\, r^2$$

$$a = \frac{4}{\sqrt{3}}r$$

Lattice constant (a) = $\frac{4}{\sqrt{3}}r$

Atomic radius (r) = $a\frac{\sqrt{3}}{4}$

Nearest neighboring distance (2r) = $a\frac{\sqrt{3}}{2}$

Coordination no.of BCC is 8

No.of atoms per unit cell = 1/8 x 8 +1 = 2

Packing factor = $\frac{volumeofallatoms\sin aunitcell}{Totalvolumeofunitcell}$

$$= \frac{2x\frac{4}{3}\pi r^3}{(\frac{4r}{\sqrt{3}})^3} = \frac{2x\frac{4}{3}\pi r^3}{a^3}$$

$$= \frac{2x\frac{4}{3}\pi r^3}{4r^3x16}x3\sqrt{3}$$

APF = $\frac{\pi\sqrt{3}}{8}$ = $\frac{\sqrt{3}}{8}x\frac{22}{7}$

PF = 0.68 x 100

PF = 68 %

Packing factor of BCC structure is 68 %

3. Face centered cubic structure (FCC):

In case of FCC lattice, there are eight atoms at the eight corners of the unit cell and six atoms at the centers of six faces. This center atom touches four corner atoms in its plane. It can be observed that this face is common to two unit cells and there are 12 atoms surrounding it.

Thus the coordination no. of FCC lattice is 12.

So the no. of atoms per unit cell = contribution due to 8 corner atoms +

contribution due to 6 face centered atoms

$= 1/8 \times 8 + (1/2 \times 6)$

$= 1 + 3 = 4$

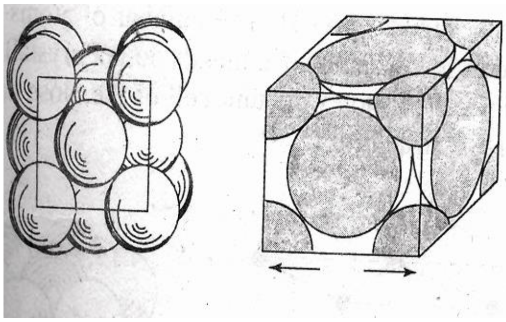


Fig: (a)

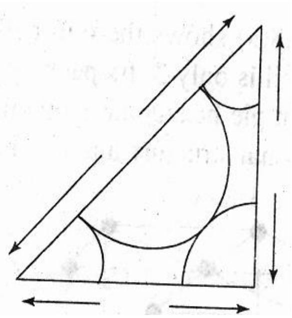


Fig: (b)

From Fig(b)

Face diagonal $(AC)^2 = AB^2 + BC^2$

$= a^2 + a^2$

$AC^2 = 2a^2$

But $AC = 4r$

$(4r)^2 = 2a^2$

$16 r^2 = 2a^2$

$$a^2 = 8r^2$$

Atomic radius (r) $= \frac{1}{2\sqrt{2}}a$

Nearest neighboring distance (2r) $= \frac{a}{\sqrt{2}}$

Coordination no. of FCC lattice is 12

Volume occupied by all the atoms in a unit cell (v) $= 4x\ 4/3\pi r^3$

Volume of unit cell $(a)^3 = (2\sqrt{2}r)^3 = V$

Packing factor $= \frac{volume of all atoms \sin a unit cell (v)}{Total volume of unit cell (V)}$

$$= \frac{4x\frac{4}{3}\pi r^3}{(2\sqrt{2}r)^3}$$

$$= \frac{\frac{16}{3}\pi r^3}{8x2\sqrt{2}xr^3}$$

$$= \frac{\pi}{3\sqrt{2}}$$

$$= \frac{3.14}{3x1.414}$$

PF = 0.74

PF = 0.74 x100=74 %

$$\boxed{\text{PF} \quad =74\ \%}$$

The packing fraction of FCC structure is 74 %. It is closely packed structure. Compared to SC and BCC structures. Al, Cu, Ag, etc are the examples of this structure.

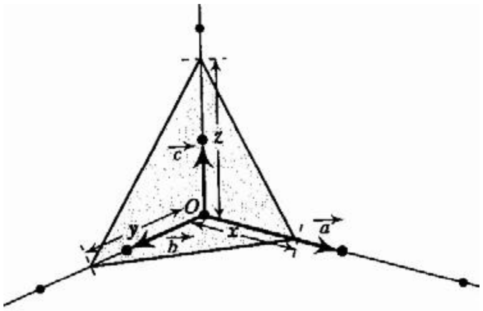
Lattice planes and miller indices:

The use of miller indices for the notation of the crystallographic planes is universal miller indices are the set of 3 integers (h, k, l) which are used to designate the different crystal planes in the crystal lattice.

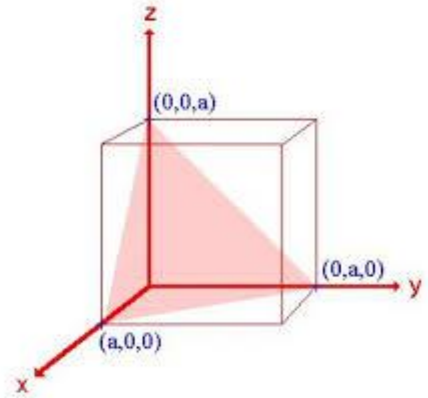
Miller indices of the plane are given by the reciprocal of its 3-numerical parameters expressed as whole numbers,

Procedure for the finding of miller indices:

(i) Find the intercepts of the desired plane on the 3-coordinate axis. Let these be (pa, qb, rc).



PLANE ORIENTATION IN A LATTICE



(ii) Express the intercepts as multiples of the unit cell dimensions or lattice parameters. i.e (p,q,r)

(ii) Take the ratio of reciprocal of these numbers.

i.e (1/p, 1/q, 1/r)

(iv) Convert these reciprocals into whole numbers by multiplying each with their LCM to get the smallest whole number this gives the miller indices (h, k, l) of the plane.

Important features of miller indices:

1. When a plane is parallel to the any axis, intercept on the plane on that axis infinitely. Hence its miller index that axis is zero.
2. When the intercept of a plane on any axis is negative, a ba is put on the corresponding miller index.
3. All equally spaced parallel planes have the same miller index no.s is (h, k, l).
4. If a plane passes through origin it is defined interns of a parallel plane having non-zero intercepts.

Eg: Intercepts are (1, 1, 2)

Miller indices is (1/1, 1/1, ½)

LCM of 1,1,2 is 2

M.I = (1 x2, 1x2, ½ x2)

= (2,2,1)

5. If a normal is drawn to the plane (h,k,l) the direction of normal is (h, k, l).

Inter planer spacing of orthogonal crystal system:

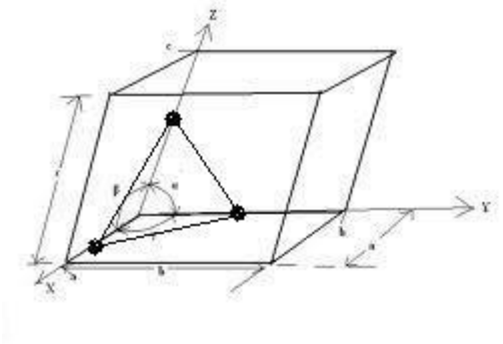


Fig:1

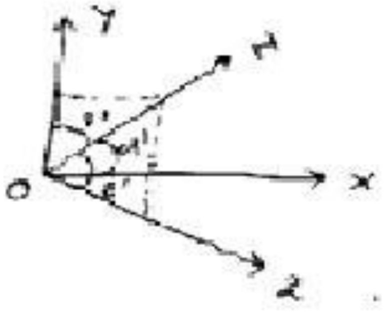


Fig: 2

The distance `d` b/w a series of planar in a crystal is known as inter planar spacing (d).

Let us consider a plane ABC with miller indices (h,k,l) has intercepts OA, OB,OC and three axes X, Y and Z – directions respectively.

The intercepts of the plane on three axes are OA = a/h , OB = b/k and OC = c/l

Let ON = d perpendicular distance from the origin to the plane. Let the direction cosines of ` ON` be $\cos\alpha^1$, $\cos\beta^1$, $\cos\gamma^1$.

$$\cos\alpha^1 = ON/ OA = d/(a/h) = dh/a$$

similarly $$\cos\beta^1 = ON/ OB = d/(b/k) = dk/b$$

$$\cos\gamma^1 = ON/ OC = d/(c/l) = dl/c$$

But we know that $\cos^2\alpha^1 + \cos^2\beta^1 + \cos^2\gamma^1 = 1$

$$(dh/a)^2 + (dk/b)^2 + (dl/c)^2 = 1$$

$$d^2 [\frac{h^2}{a^2} + \frac{k^2}{b^r} + \frac{l^2}{c^2}] = 1$$

$$d^2 = \frac{1}{\frac{h^2}{a^2} + \frac{k^2}{b^r} + \frac{l^2}{c^2}}$$

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}} \text{ -------- (1)}$$

OM be the $\perp^{lar}$ distance pf the next parallel plane from the origin. Its intercepts are $\frac{2a}{h}, \frac{2b}{k}, \frac{2c}{l}$.

$$OM = d = \frac{2}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}} \text{ ----------- (2)}$$

The spacing b/w two adjacent planes OM-ON = MN is called the inter planer spacing `d`.

$$d = OM-ON = \frac{2}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} - \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$$

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} \quad \text{---------} (3)$$

In case of SC structure a=b=c

Than the inter planar spacing for SC structure is

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{a^2}+\frac{l^2}{a^2}}}$$

$$d = \frac{a}{(h^2+k^2+l^2)^{1/2}} \quad \text{----------} (4)$$

Problems:

1. Copper has FCC structure and the atomic radius is 0.1278 nm calculate the inter planar spacing for (110) and (212).

Sol: Lattice constant $a = 2\sqrt{2}r$

$$= 2\sqrt{2}x0.1278x10^{-9} \text{ m}$$

$$d_{(110)} = \frac{a}{(h^2+k^2+l^2)^{1/2}} = \frac{2\sqrt{2}x0.1278x10^{-9}}{\sqrt{2}}$$

$$= 2 \times 0.1278 \times 10^{-9}$$

$$d_{(110)} = 0.2556 \times 10^{-9}$$

$$d_{(212)} = \frac{2\sqrt{2}x0.1278x10^{-9}}{(4+1+4)^{1/2}} = \frac{2\sqrt{2}x0.1278x10^{-9}}{3}$$

$$d_{(212)} = 2 \times 1.414 \times 0.0426 \times 10^{-9}$$

= 1.204728×10^{-9}m

2. Draw the (112) and (120) and the [120] direction of a simple cubic structure crystal.

Sol: (i) (112) = (1/1, 1/1, ½)

Miller indices of (112) = (1 1 1/2)

(ii) (120)

Miller indices of (120) = (1/1, ½, 1/0)

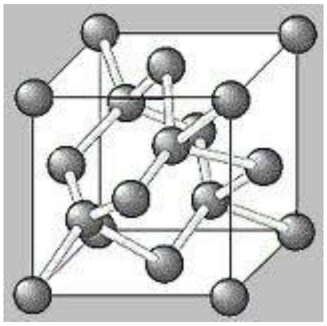
= (1 ½ ∞)

(iii) [120]

<u>Diamond structure</u>:

Germanium, silicon and carbon (diamond) possesses the structure which is a combination of two inter penetrating FCC sub lattices. As seen from the unit cell of diamond cubic structure, one sub. lattice say `X` has its origin at point (0,0,0) and the other say Y at the point one quarter (1/4)a. The way along the body diagonal.

i.e at the point (a/4, a/4, a/4).



This structure is loosely packed since each atom has only 4 nearest neighbors i.e coordination no. of the diamond cubic structure is 4. In the unit cell, in addition to the 8 corner atoms there are 6 face centered atoms and 4 atoms located inside the unit cell as shown in fig. Each corner atom is shared by 8 adjacent unit cells, and the total no.of atoms per unit cell

$$= 1/8 \times 8 + ½ \times 6+4 =8$$

From fig (1) Δ^{ll} XYZ

According to Pythagoras law

$$(XZ)^2 = (XY)^2 + (YZ)^2$$

$$(XZ)^2 = (a/4)^2+ (a/4)^2$$

From Δ^{ll} XPZ

$$(XP)^2 = (X2)^2 + (2P)^2$$

But XP = 2r

$$(2r)^2 = \frac{a^2}{8}+(\frac{a}{4})^2$$

$$= \frac{a^2}{8}+(\frac{a^2}{16})$$

$$4r^2 = \frac{2a^2+a^2}{16}$$

$$3a^2 = 64r^2$$

$$a^2 = 64/3\ r^2$$

a = $\frac{8}{\sqrt{3}}r$

Lattice constant (a) = $\frac{8}{\sqrt{3}}r$

Packing factor = $\frac{volumeofallatoms\sin aunitcell}{Totalvolumeofunitcell}$

= v/V

$$= \frac{8x\frac{4}{3}\pi r^3}{(\frac{8}{\sqrt{3}})^3 r^3}$$

$$= \frac{\sqrt{3}\pi}{16}$$

= 0.34 x 100

PF = 34 %

It is loosely packed structure.

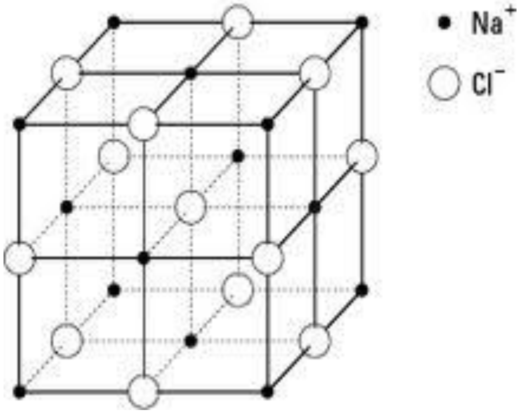
<u>Nacl Structure</u>:

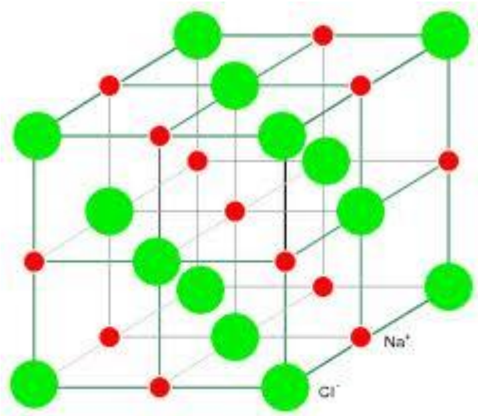
In the Nacl lattice the sodium ion and chlorine ions are situated side by side. It consists of two FCC sub lattices. One of chlorine ions having its origin at the point at the point (0,0,0) and the other of sodium ions having its origin mid way along a cube edge, at the point (a/2, 0,0). Even though there is an attractive force between sodium ion and chlorine ion, they connot come very close to each other due to repulsive fore and the distance is very short range.

Each ion in the Nacl lattice has 6 nearest neighbors ions distance is a/2. Its coordination no, is 6 ionic radius of d is 1.18 atomic units and for sodium is 0.98 AU.

Each unit cell is Nacl has four sodium ions and souf associated chlorine ions. Thus there are four molecules in each unit cell.

Kcl, Kbr, Mgo, Agbr, etc have same structure of sodium chloride structure.





Unit-v

X-RAY DIFFRACTION & DEFECTS IN CRYSTALS

Introduction:

"X-Rays are high frequency electro-magnetic waves produced when fast moving electrons impinge on a metal target".

X-rays exhibit the phenomenon like **"Interference"** and **"Diffraction"**. The wavelength's of X-rays is of the order of 1Å or 0.1nm, this value is very small compared to the wavelength of the centre of visible spectrum. Hence X-rays do not produce observable diffraction effects with ordinary rooted diffraction grating, whose grating spacing is of the order of 20,000 Å. The inter-atomic spacing is of the order of 3-5Å and the inter-planar separation for different sets or planes around 2Å.

Therefore crystals are more suitable to observe diffraction effects with X-Rays and inter-planar separation should be of the same order. Here for X-rays $\lambda \approx 1$ Å (approximately) where as inter-planar separation is about 2 Å. Hence X-rays suit well with crystalline solids for diffraction to occur which can be easily noticed.

Principles of X-ray diffraction:

The principle of X-ray diffraction can be given as follows.

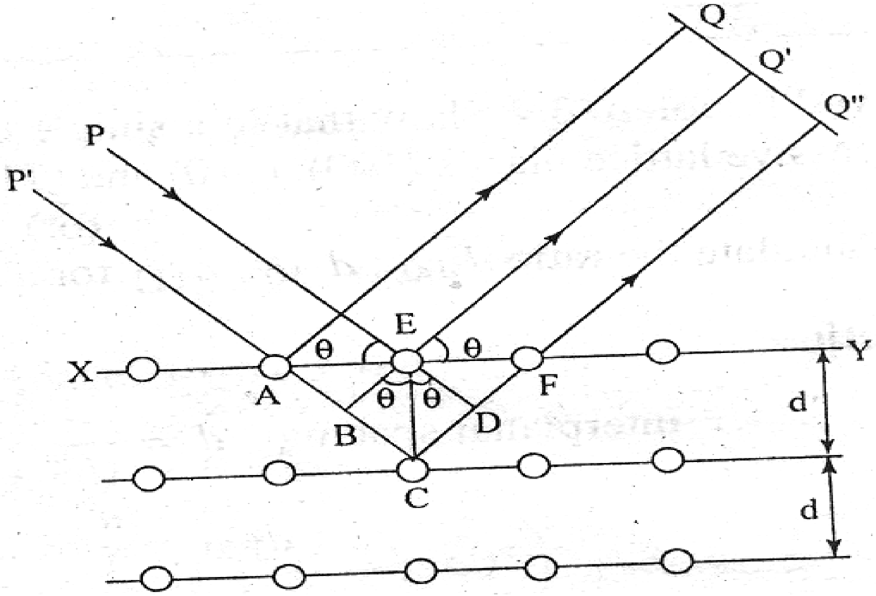
Consider the influence of the X-rays on an atom. When the atoms are exposed to a mono-chromatic beam of X-rays, the electric field vector of the radiation forces its electrons to carry out harmonic vibrations of a frequency equal to that of the incident beam and thus undergoes acceleration. These accelerated charges emit the radiation at the frequency of their vibration.

i.e., at the incident wave frequency.

The emitted wave has a spherical wave front centered about the atom. So the energy radiates in all directions, there are only few directions in which these wave lets wavelengths reinforce with each other to produce plane waves. These waves are said to be produced by diffraction and are designed as zero order, first order, second order etc. diffracted beams.

Bragg's law and X-ray Diffraction:

"Bragg's law states that the X-rays reflected from different parallel planes of a crystal interfere constructively when the path difference is integral multiple of the wavelength of X-rays.



Let us consider a crystal made up of equidistant parallel planes of atoms with the inter-planar spacing 'd' as shown in fig. Let wave front of a mono-chromatic X-ray beam of wavelength 'λ' fall at an angle 'θ' on these atomic planes. Each atom scatters the X-rays in all directions. In certain directions these scattered radiations are in phase.

i.e., they interfere constructively while in all other directions, there is destructive interference.

Let us consider the rays PE and P'A inclined at an angle 'θ' with the top of the crystal plane XY. They are scattered along AQ and EQ' at an angle 'θ' with respect to the plane XY. Let us consider another incoming beam P'C and scattered along CQ''. Let us draw EB normal to AC and ED normal to CF as shown in fig. If 'EB' and 'ED' are parallel to the incident and reflected wave fronts.

Then the path difference between the incident and reflected waves is given by

$$\Delta = BC + CD \text{ --------------- } (1)$$

$$\text{In } \Delta\, BEC,\ \sin\theta = BC / EC = BC / d$$

$$\text{i.e., } BC = d\sin\theta \text{ ------------------- } (2)$$

$$\text{Similarly, in } \Delta\, DEC,\ CD = d\sin\theta \text{ ----------------- } (3)$$

$$\text{Hence, path difference } \Delta = BC + CD$$

$$= d\sin\theta + d\sin\theta$$

$$\Delta = 2d\sin\theta \text{ ---------------- } (4)$$

If two consecutive planes scatter waves in phase with each other, then the path difference must be an integral multiple of wavelength.

i.e., $\Delta = n\lambda$

Where n = 0, 1, 2, 3,……. is the order of reflection

From (4) and (5)

$$\mathbf{2d \sin \theta = n \lambda}$$

The above equation represent's Bragg's equation or Bragg's law.

$$2d \sin \theta = n \lambda$$

$$2d/n\lambda = 1/\sin \theta$$

Since the maximum value of sin θ is 1,

$$2d/n\lambda \geq 1$$

$$\mathbf{n\lambda/2d \leq 1}$$

This sets a limitation on wavelength; the wavelength should not exceed twice the inter-planar spacing for diffraction to occur.

Methods of X-ray diffraction:

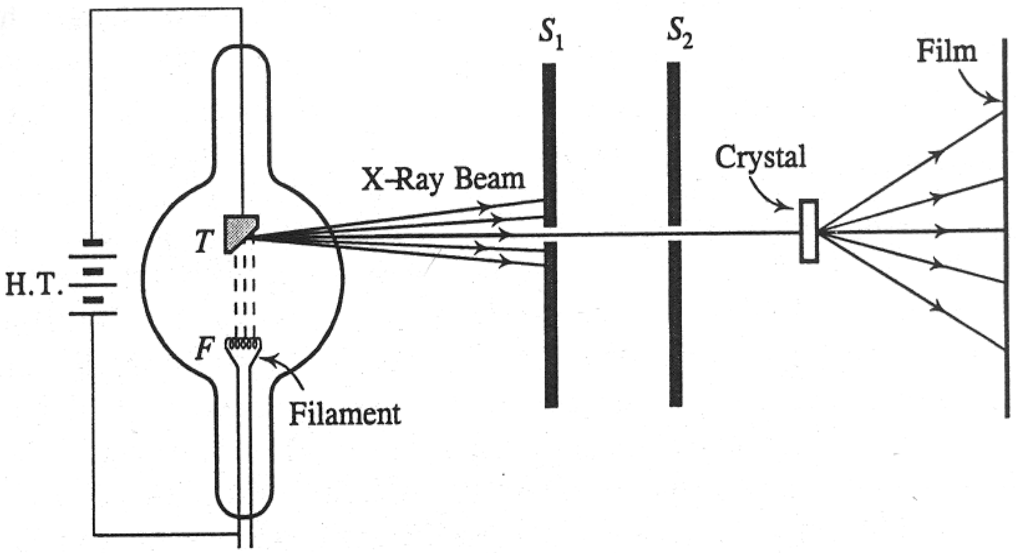
The crystal structures can be analyzed based on two X-ray diffraction methods. They are:

- Laue Method
- Powder Method or Debye-Scherer method.

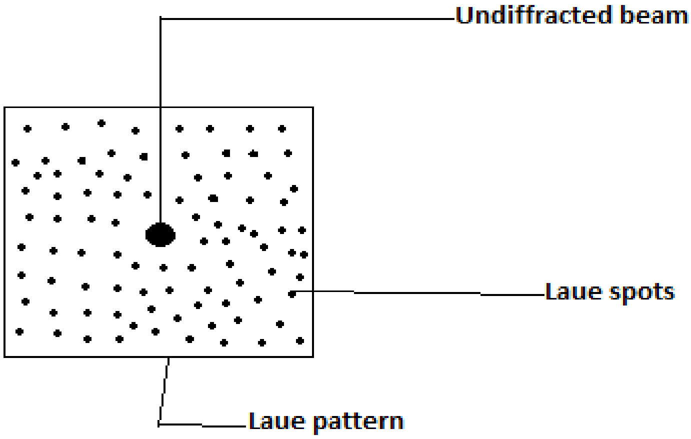
Laue Method:

In 1912 Van Laue first discovered X-Ray diffraction. This Laue method is also called as **"Black Resolution Method"**. This method is used to study crystal orientation and to verify the crystal symmetry.

X-rays are produced by X-ray tube over a wide range of wave lengths preferably 0.2Å-->2Å and they are sent through pin-hole collimeter. A thin crystal 'C' having the dimensions less than 1mm is mounted in the path of X-rays.



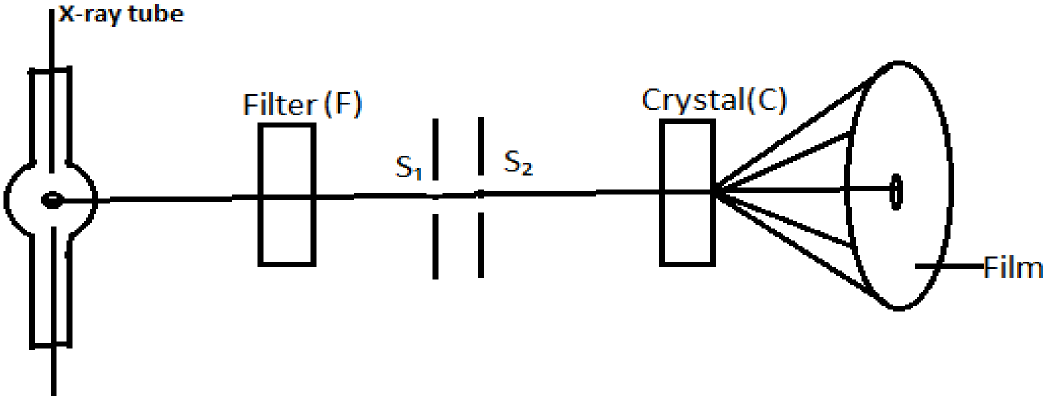
X–RAY DIFFRACTION (LAUE's METHOD)



From above figure, C-rays are coming from X-ray tube allows to pass though pin-hole collimeter. Then fine beam of X-rays are obtained.

This fine beam of X-rays is incident on crystal, they get scattered from different atomic centers of crystal. This scattered beam of X-rays fall on photographic film or plate which will be developed as recorded on the screen on developing the plate. We observed that pattern consists of bright spots corresponding to maximum intensity which will be referred as "Laue-spots". Laue spots depend on orientation of crystal relative to incident beam direction. Laue method subsequently used to determine the crystal structure using X-Rays of known wavelengths.

Powder Method:



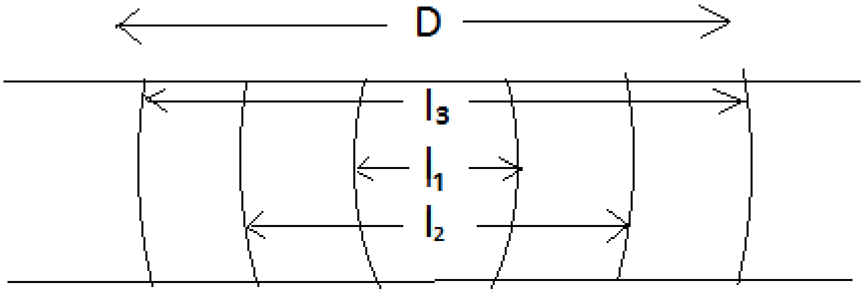
Powder method was developed by Debye and Scherer. It is applicable to finely divided powder. The experiment arrangement of powder method is shown in fig

X-rays are from X-ray tube which allow passing through the filter (F) which absorbs all the wavelengths except one. In this mono-chromatic beam of X-ray is obtained. This mono-chromatic beam of X-rays is allowed to pass through slits 's_1' and 's_2'; we get the fine beam of X-rays. This fine beam of X-rays falls on the powdered specimen which is kept inside the small capillary tube, which would not undergo diffraction. The specimen is located at the centre of drum shaped cassette with photographic film at the inner circumference.

As the beam of X-rays is incident on specimen, it gets scattered and the scattered beam is incident on a photographic film. The intersection of different cones on photographic film is series of concentric circular rings. Radii of these rings are used to find the glancing angle. The pattern recorded on the screen.

Output (recorded pattern):

Due to narrow width of the film only parts of circular rings are recorded on it. Let l_1, l_2, l_3………… are distances b/w symmetrical lines and 'D' be the diameter of circular film.



Then $\frac{l_1}{\pi D} = \frac{4\theta_1}{360°}$: $\frac{l_2}{\pi D} = \frac{4\theta_2}{360°}$1

Using 'θ' in Bragg's law Inter-planar spacing (d) can be calculated.

The powder camera is called Debye-Scherer camera.

Applications of X-ray diffraction:

From knowledge of the experimentally observed Bragg's angles or glancing angles it is possible to determine the inter-planar spacing's of a crystal. From a list of such spacing's it is then possible to deduce the lattice type of a crystal. Now consider the first order spectrum from three planes one after the other reflecting a given mono-chromatic X-ray beam of wave-length 'λ' at the glancing angles θ_1, θ_2 and θ_3. d

From Bragg's law

$$2d\sin\theta = n\lambda$$

$$2d\sin\theta = \lambda \quad \text{(since n=1)}$$

$$\frac{1}{d} = \frac{2\sin\theta}{\lambda}$$

In case of simple cubic:

$$\frac{1}{d_{100}} = \frac{\frac{1}{a}}{\sqrt{(1^2+0^2+0^2)}} = \frac{\frac{1}{a}}{1} = \frac{1}{a}$$

$$d110=\frac{a}{\sqrt{(1^2+1^2+0^2)}} = \frac{a}{\sqrt{2}}$$

$$d111=\frac{a}{\sqrt{1^2+1^2+1^2}} = \frac{a}{\sqrt{3}}$$

$$\frac{1}{d_{100}} : \frac{1}{d_{110}} : \frac{1}{d_{111}} = \frac{1}{a} : \frac{\sqrt{2}}{a} : \frac{\sqrt{3}}{a} = \sin\theta_1 : \sin\theta_2 : \sin\theta_3$$

$$= 1 : \sqrt{2} : \sqrt{3}$$

$$\frac{1}{d_{100}} : \frac{1}{d_{110}} : \frac{1}{d_{111}} = \sin\theta_1 : \sin\theta_2 : \sin\theta_3 = 1 : \sqrt{2} : \sqrt{3}$$

Similarly for body centered ----1 : $\frac{1}{\sqrt{2}}$: $\sqrt{3}$

Similarly for face centered -----1 : $\sqrt{2}$: $\frac{\sqrt{3}}{2}$

So knowing the values of glancing angles ratio of the inter-planar spacing's can be determined even without knowing the wave length of X-rays. From that ratio, the type of lattice can be identified.

2. Knowing the values of λ & θ, one can calculate the value of inter-planar distance d.

$2d\sin\theta=\lambda$ for n=1

$$d=\frac{\lambda}{2\sin\theta}$$

In case of simple cubic structure,

We know that

$$d = \frac{a}{\sqrt{(h^2+k^2+l^2}}$$

Where: a- is the lattice constant.

(h k l)– Miller indices for a plane

$$\sin^2\theta hkl = \frac{\lambda^2}{4a^2}(h^2 + k^2 + l^2)$$

The corresponding relation for the hexagonal system is

$$\sin^2\theta hkl = \frac{\pi}{4}\left[\frac{4h^2+k^2+hk}{3a^2} + \frac{l^2}{c^2}\right]$$

Once d is known a, can be calculated.

Hence knowing a, l and M, the no. of atoms or molecules in the unit cell can be calculated.

Generally the lines of diffraction pattern are enormous for non cubic systems and the lines are only few for cubic systems. Thus the line positions in the photograph of diffraction pattern indicate the shape and size of unit cell.

3. Further in the case of cubic crystals, knowing the values of $h^2+k^2+l^2$ for different planes, one can easily identify the type of cubic crystals by the following manner.

Values of $h^2+k^2+l^2$

Simple cubic : 1,2,3,4,5,6,8,9,10,11,12,13,14,16

Body centered : 2,4,6,8,10,12,14,16

Face centered cubic: 3, 4, 8,11,12,16

Diamond cubic: 3, 8, 11, 16

Similarly if the individual values of h k l set i.e. (311 or 200) are purely odd or even, immediately one can identify that the given type of crystal belongs to FCC lattice.

4. Once the structure of the cubic lattice is known, the no. of atoms or molecules in the unit cell can be calculates. If $\rho \rightarrow is\ density\ of\ the\ crystal,$

Now $\rho a^3 = \frac{nM}{N}$

Where $\frac{nM}{N} \rightarrow mass\ of\ the\ unit\ cell$

$n \rightarrow no.of\ atoms\ or\ molecules\ in\ the\ unit\ cell.$

$M \rightarrow atomic\ or\ molecular\ weight\ of\ the\ crystal.$

$N - Avagadro\ number.$

For example, if we take Nacl crystal, there are 4 molecules in the unit cell of Nacl because it belongs to FCC structure.

Now $a^3 = \frac{nM}{\rho N} = \frac{4 * 58.5}{2180 * 6.023 * 10^{23}}$

a=5.63 Å

This is the distance b/w two adjacent atoms of the same kind i.e. chlorine or sodium atoms. But the distance b/w two adjacent atoms is half of the above value

i.e., d=a/2=2.815Å

The spacing between atoms and hence spacing b/w atomic (100) planes is 2.815Å

PROBLEMS:

1. A beam of X-rays of wavelength 0.071nm is diffracted by (110) plane of rock salt with lattice constant of 0.28 nm. Find the glancing angle for second order diffraction?

Sol: $\text{Wavelength } \lambda = 0.071 nm = \frac{0.071}{10^9} m$

$\text{Lattice constant } (a) = 0.28\ nm = \frac{0.28}{10^9} m$

(h k l) = (1 1 0)

$d_{hkl} = \frac{a}{\sqrt{(1^2+1^2+0^2}} = \frac{0.28}{\sqrt{2} * 10^9}$

Second order mean n=2

Bragg's equation is $2d\sin\theta = n\lambda$

$\sin\theta = n\lambda / 2d$

$\sin\theta = \frac{\sqrt{2}}{0.28} \times 0.071$

$\underline{\theta = \sin^{-1} 0.37}$

2. The first order diffraction occurs when a X-ray beam of wavelength 0.6755 Å, incident at a glancing angle of 30°,Calculate at a glancing angle for third Order diffraction.

Sol: Bragg's equation is $2d\sin\theta = n\lambda$

$\sin\theta \alpha \lambda$

$\sin\theta^0 = \sin 30° = 0.5$

$n_1=1$

$n_2=3$

$\theta_2=?$

$$\frac{\frac{1}{2}}{\sin\theta_2} = \frac{1}{3}$$

$$\sin\theta_2 = \frac{3}{2}$$

$$\theta_2 = \sin^{-1}\frac{3}{2}$$

3. if we take Nacl crystal, there are four molecules in the unit cell of the Nacl crystal because it belongs to FCC structure.

Sol: Now $\rho a^3 = \frac{nM}{N}$

No. of molecules (n)=4

M→ $mass\ of\ the\ Nacl\ crystal = 58.5$

Density $\rho = 2180 * \frac{10^3\,kg}{m^3}$

N→ $Avagadro's\ no. = 6.023/10^{23}$

$a^3 = Nm/n\rho$

$a^3 = (a \times 58.5)/(2180 \times 10^3 \times 6.023 \times 10^{23})$

a=5.63Å

This is the distance b/w two adjacent atoms of the same kind. Chlorine atoms or Na atoms. But the distance b/w two adjacent atoms that is (Nacl) Na and cl atoms is half of the above value.

D=a/2=2.815Å

The spacing b/w atomic planes (1 0 0) is 2.815 Å

4. A X-ray beam of wave length 1.5Å & falling on a set of planes whose separation is 2.8Å. Calculate the maximum orders of diffraction that can be notices in this case.

<u>Sol</u>. According to Bragg's law

$2d\sin\theta = n\lambda$

For maximum order of diffraction, we take $\sin\theta = 1$

$n\lambda = 2d$

$n = 2d/\lambda$

$n = 3.73$

Here n → is the order of diffraction is an integer value. Hence n=3.73 cannot be accepted. The fractional value has to be neglected.

Hence we get maximum order n=3.

APPLICATIONS OF X-RAY DIFFRACTION

When new materials are synthesized none should know about its elements, composition, crystal structure, crystal symmetry and its grain size. One should have the knowledge about the impurities and strains present inside the materials. Most of the metals and alloys are crystalline in nature. Hence one of the most useful characterization techniques is x-ray diffraction (XRD) studies. Now-a-days instead of recording diffraction pattern on photographic films, one uses detectors to scan the diffracted signal and gets a plot of glancing angle Vs intensity of diffracted beams as shown in Fig 8.

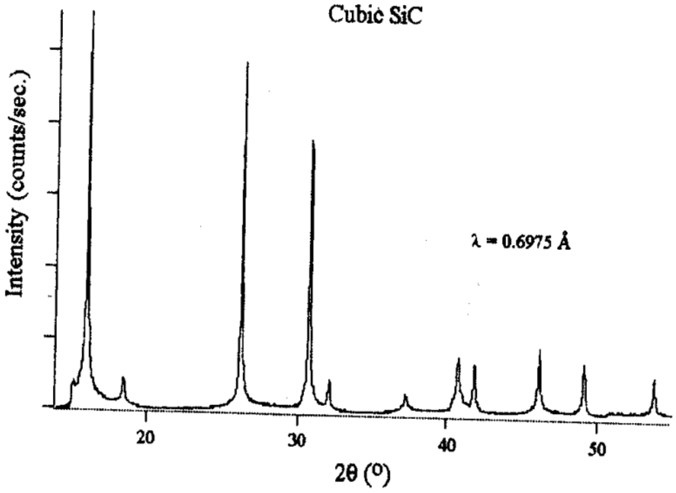


Fig.8 X-ray diffraction pattern

Now let us study the applications of different methods in some more detail.

(i) Laue diffraction method

Laue diffraction is most used for mounting the single crystals in precisely known orientation.

It is very much useful for study of crystal symmetry.

(ii) Powder diffraction has large number of applications.

From the (XRD) pattern

- The d-spacing are recorded.
- The relative intensities of strongest lines are measured and compared with the patterns of the known compounds using powder diffraction file that contains the pattern of many standard compounds.

Study of mixtures

If a mixture is used for the study, measuring the relative intensities of non overlapping lines the relative concentration of each component can be obtained.

Study of alloys

If an alloy is used for the study, for uniform composition a typical powder diffraction pattern is produced. If one of the components precipitates, separate lines corresponding to that component is observed. Fig 9 is the XRD pattern indicating the formation of Mg Al_2 O_4 alloy during heat treatment.

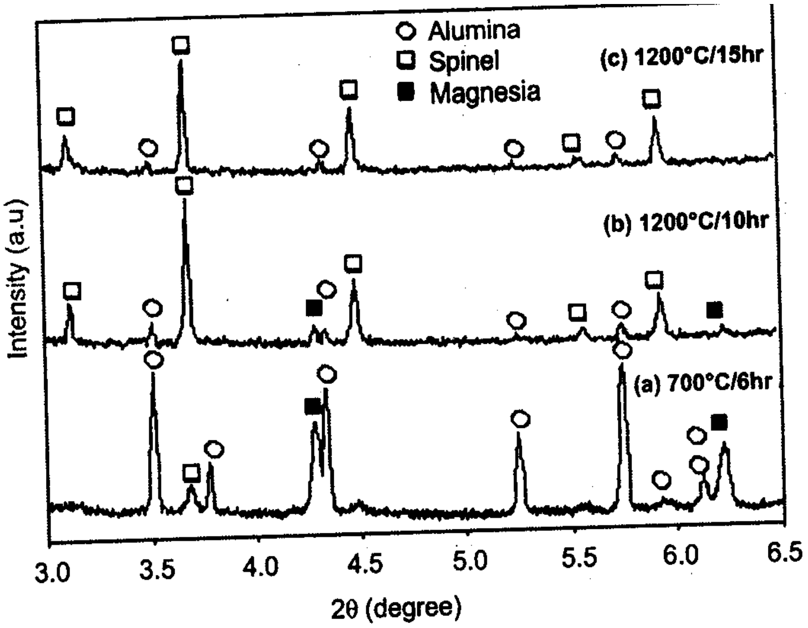


Fig.9 XRD pattern indication the formation of Mg Al_2 O_4 alloy during heat treatment

Stress determination in metals

If there is a stress in a metal, it changes the d-spacing. This results in change of angle of diffraction core. By measuring this change, accurate measurements of stress is possible.

Determination of particle size

When the size of the crystallite decreases, the angular spread of X-ray diffraction increases. Hence width of the observed diffraction pattern also increases. By measuring the full width at half maximum (FWHM), the mean particle size crystal size of the sample can be measured. Fig.10, we find that with decrease of crystal size, the width of the diffraction pattern increases.

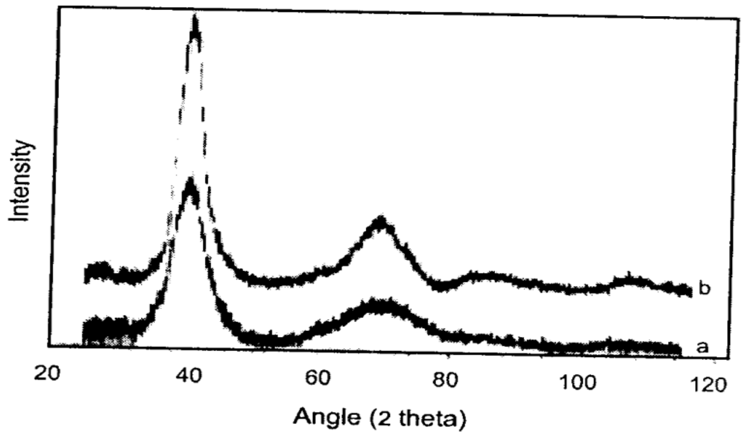


Fig.10 XRD patterns of nano-crystals corresponding to grain size a) about 1-5 nm and b) about 5-20 nm

- Rotating crystal method is generally used to align the crystals and measure lattice parameters and determine the crystal structure.

DEFECTS IN CRYSTAL

Introduction:

Theoretically a perfect crystal is a extremely a useful concept. In actual crystals, imperfections or defects are always present and their presence greatly affects the properties of crystals. Any derivation from prefect periodicity is an imperfection called as "Lattice defect".

A lattice defect is a state in which the atomic arrangement in the small region of size of only few lattice constants of a crystal has departed from regularity. On the basis of perfect atomic periodicity of crystals, we have been able to explain the properties like density, stiffness, dielectric capacity, specific heats and elastic properties of the lattice. Such properties "structure insensitive properties".

On the other hand, atomic imperfections arising due to irregularities of atomic arrangement in the crystals are greatly affecting the following properties

1) Like color ability, crystal growth and diffusion process.

2) These defects scatter the conduction electrons in a metal and thus increase its electrical resistance. This character is found to be more effective in the case of alloys.

3) Certain kinds of defects exist very rarely but decrease the mechanical strength of the crystal.

4) The durability of the material.

5) Magnetic hysteresis.

6) Conduction in semiconductors.

These six properties greatly influenced the presence of defects are called as structure sensitive properties.

The imperfection or the defect can be classified on the basis of their geometry, under four main types.

1) Point defects (Zero dimensional defects).
2) Line defects (One dimensional defect).
3) Surface defect (2D defects).
4) Volume defects (3D defects)

Point defects:

A point defect or imperfection is much localized interruption in the regularity of the crystal. It produces strain in small volume of the crystal surrounding the defect, but does not affects the perfection of more distant parts of the crystal. Such defects may be in the form of vacancy Interstitial and impurity. When the vacancy is trapped (filled) by electron or holes constitute new types of point defects called as color centres.

Vacancy or vacancies:

These are the lattice sites from which the atoms are missing from their regular positions. It is shown in Fig 1. A vacancy is called Schottky defect. In ionic crystals, a Schottky defect is one anion vacancy together with cation vacancy. This is because the interior of ionic crystal is electrically neutral. It is shown in Fig. 2.

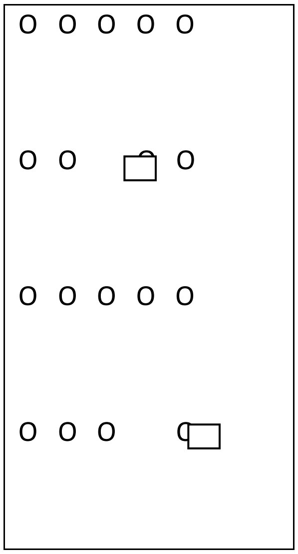


Fig 1: Crystal

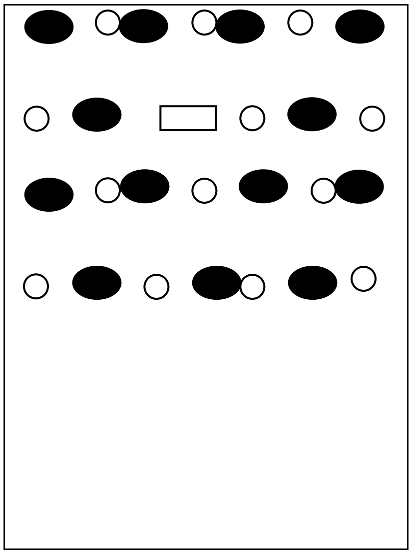


Fig 2 : Ionic Crystal

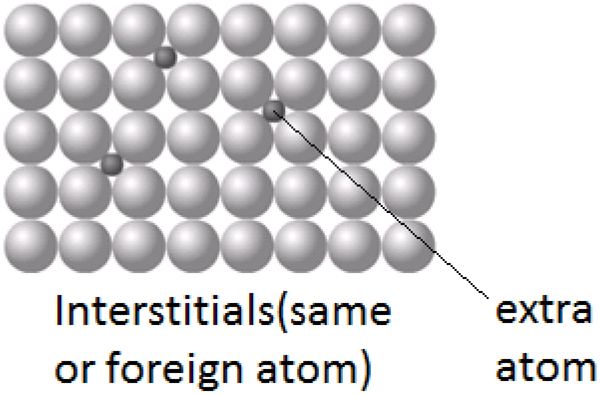
They are usually referred as the intrinsic defects as the associated vacancies are the intrinsic vacancies. It is clear that these clear defects preserve the stoichiometry of the crystal.

For most of the crystals, the thermal energy required to create a vacancy is about 1ev.

Interstitial atoms:

This is an extra atom inserted into the voids called intertice of the lattice between the regularity occupied sites as shown in figure. Thus such an atom does into occupy regular lattice sites. This extra atom may be in an impurity atom are an atom of the same type as on the regular lattice sites.

An atom can enter the interstitial void or space between the regular positioned atoms only when it is substantially smaller or equal to the parent atoms, otherwise it will produce atom distortion.



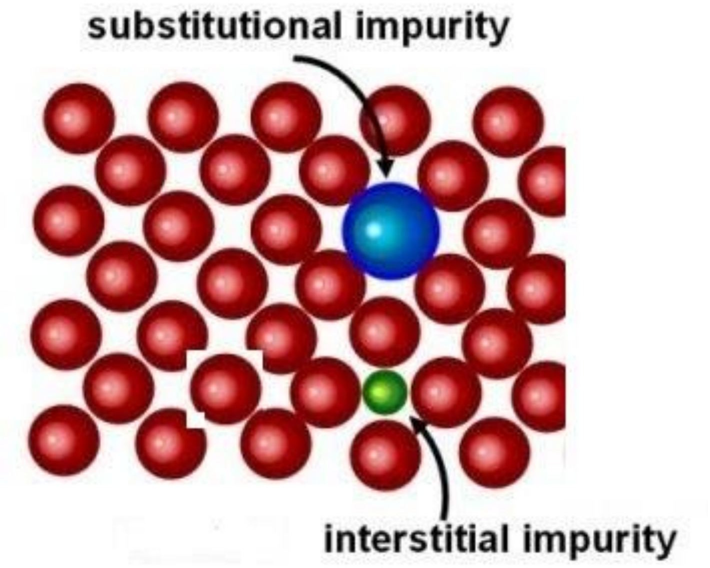
Impurity Defects:

Impurity defects are foreign atoms introduced into a crystal lattice. The most obvious point defect is the presence of a impurity atom in a perfect crystal. It may fit into the structure in two ways.

1.It may occupy a position normally occupied by the crystal atom .i.e. host atom in which case it will be called as “ substitutional impurity “ .

2.It may lodge normally unfilled volume, termed as void interstice between the atoms of the host crystal and called as interstitial impurity.

These are shown in figure



If the impurity atoms has roughly the same size and vacancy as the host atom, then the substitutional impurity created on the other hand, if the host crystal has relatively large interstices, then the interstitial impurity is accommodated in the crystal. Obviously, the interstitial impurity can exist only in ionic and covalent crystals and not in close packed crystal. In closed pack crystal substitutional impurity can take place. Impurities are usually deliberately added to pure crystals in order to modify their properties. The electrical conductivity of pure Ge, Se is enormously increased by adding trivalent or pentavalent which are well known in semi conductor devices.

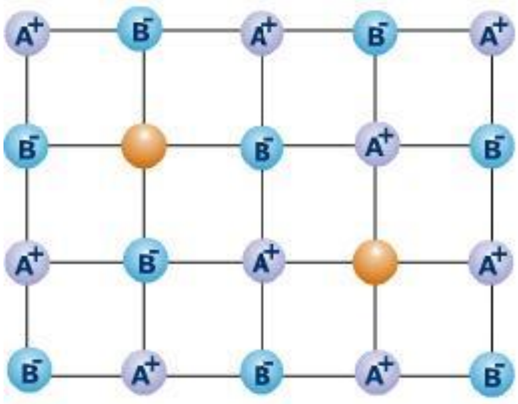
Electronic Defects:

Errors in change distribution in solids are called electronic defects. These defects are produced when the composition of an ionic crystal does not correspond to the exact stoichiometric formula. Ex: ZnO, FeO etc.,

Schottky Defects:

1. Ion vacancies are called Schottky defects.
2. A pair of one cation and one anion can be missing from an ionic crystal as shown in figure. The valance of the missing pair of ions should be equal to maintain neutrality. So these are normally generated in equal number of anion and cation vacancies in a crystal.
3. A Schottky defect is the combination of one cation vacancy and one anion vacancy.
4. When vacancies are created by movements of an anion and one cation from positions inside the crystal to positions on the surface of the crystal. A Schottky defect is said to have been formed.
5. The concentration of Schottky defects decreased the density of the crystal.

6. This type of point defect is dominant in alkali halides



Energy Formation of a Vacancy or Schottky Defects:

Thermal energy in solid results in elastic vibration of the lattice atoms. Large displacements may cause atoms to jump from normal to interstitial positions. This results in creation of both interstitial atoms and vacant lattice sites. At any finite temperature, some of the lattice points normally occupied by metal ions are vacant, giving rise to vacancy defects. The number of vacancies is determined by the temperature. The total number of metal atoms and the average energy required to create a vacancy.

Hence $n = f(N, Ev, T) \xrightarrow{(1)}$

Where n = nos. of vacancies

N = the total no, of atoms/ ions

Ev = the average energy required to create a vacancy

T = Absolute temperature

Under thermal equilibrium condition, the density of imperfections so produced is given by the law of statistical mechanics.

It can be shown that

$$Ev = KT\ Ln\ (^{N-n}/_{n}) \xrightarrow{(2)}$$

Where k is Boltsmann's constant.

The above eqn 2, gives average energy of formation of a vacancy in a crystal. This is equal to the energy required to remove an atom from a lattice site in site the crystal to a lattice site on the surface. This is called the enthalpy of formation of the point imperfection.

Number of Vacancies at any temperature in elemental solids:

From eqn (2)

$$Ev = KT \, Ln \left({}^{N-n}/_{n} \right)$$

$$Ev/KT = Ln \left({}^{N-n}/_{n} \right)$$

$${}^{N-n}/_{n} = \exp \left({}^{Ev}/_{KT} \right)$$

If the number of vacancies is much smaller than the total number of atoms.

i.e., If $n << N$

Then $N-n \approx N$

Therefore $${}^{N}/_{n} = \exp \left({}^{Ev}/_{KT} \right)$$

$$N = n \exp \left({}^{Ev}/_{KT} \right)$$

$$N = n \exp \left(- {}^{Ev}/_{KT} \right) \qquad \xrightarrow{(3)}$$

Usually, the numbers of vacancies (n) is always very small compared to the total numbers of metal atoms / ions (N). Hence eq(1) can be used to calculate the number of vacancies when the temperature is much below the melting point.

Equilibrium concentration of Schottky defects in ionic crystals:

In ionic crystals, Schottky defect is due to the missing of a cation – anion pair from the respective lattice positions. Let Ev be the average energy required to create a Schottky defect and 'n' be the numbers of Schottky defects produced by removing 'n' numbers of cations and 'n' number of anions. If N is the total number of cation-anion pairs.

The number of Schottky defect & given by

$${}^{N-n}/_{n} = \exp \left({}^{Ev}/_{2KT} \right)$$

if $n << N$, then $N-n \sim N$

$${}^{N}/_{n} = \exp \left(+ {}^{Ev}/_{2KT} \right)$$

$$n = N \exp \left(- {}^{Ev}/_{2KT} \right) \qquad \xrightarrow{(4)}$$

Thus then number of Schottky defects depends on

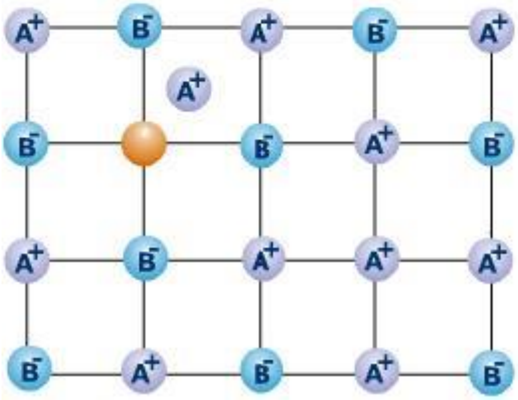
(i) The total number of ionic pairs (N)
(ii) The average energy required to produce Schottky defect and
(iii) Temperature (T)

The above eqn (4), if the confirmed that the fraction of Schottky defects increases exponentially with increasing temperature.

We can determine the number of Schottky defects present in binary ionic crystals such as NaCl and MgO using the above eqn (4).

Frenkel Defect:

1. In the case of ionic crystals an ion displaced from the lattice in to an interstitial site is called a Frenkel defect.
2. As cations are generally the smaller ions, it is possible for then to get displaced into the void space present in the lattice. Anions do not get displaced like this as the void space is just too small for their size.
3. A Frenkel defect s the combination of one cation vacancy and one cation interstitial defect.
4. The concentration of Frankel defects does not change the density of the crystal.
5. A Frankel imperfection does not change the overall electrical neutrality of the crystal.
6. The point imperfections in silver halides and calcium floride are of the Frenkel type.
7. Frenkel and Schottky defects together are called “Intrinsic defects”.



Equilibrium Concentration of Frenkel Defects in Ionic Solids:

Frenkel defects are prevalent in open structures such those of silver halides.

Let Ev→ is the average energy required to displace a cation from its normal lattice position to an interstitial site and Ni→is the number of interstitial sites. If N →is the total number of cations (in an ionic crystal A^+, B^-).

The number of Frenkel defects is given by

$$n = (N\ Ni)^{1/2} \exp\left(-\,{}^{Ev}/_{2KT}\right) \qquad \xrightarrow{(5)}$$

Hence at low temperature, the number of Frenkel defects is small.

1. **If the average energy required to create a vacancy in t metal 1ev calculate the ratio of vacancies in the metal at 1000 to 500K.**

Sol:

Formula $n = N \exp^{(-Ev}/_{kt})$

$N_{500} = N \exp(-^{Ev}/_{500k})$

$N_{1000} = N \exp(-Ev/1000K)$

$^{N1000}/_{n500} = \exp(-^{Ev}/_{1000k} + {}^{Ev}/_{500K})$

$= \exp(^{EV}/_{1000k})$

Given values EV – 1ev

$K = 1.38 \times 10^{-23} J/k$

$K = 1.38 \times 10^{-23}/1.60s \times 10^{-19}$ ev/k $= 8.625 \times 10\text{-}^{5ev/k}$

Hence $^{N1000}/_{n500} = \exp(1/1000 \times 8.625 \times 10^{-5})$

$= \exp(1/ 8.625 \times 10^{-2})$

$\ln (^{N1000}/_{n500)} = 1/8.625 \times 10^{2}$

$\text{Log } 10 (^{N1000}/_{n500}) = 1/(2.303)(8.625)10^{2}$

$(^{N1000}/_{n500}) = 1.082 \times 10^{5}$

2. The fraction of vacancy sites in a metal is 1 x 10^{-10} at 500^0c what be the fraction of vacancy sites at 1000^0c?

Sol:

Formula n = N exp (-Ev/KT)

n/N = exp (-Ev/KT)

At T1 = 500 + 273 = 773K, n1/N = 1 x 10-10

Let at T2 = 1000+273 = 1273K, n2/N = x = ?

$\ln (n_1/N) = {}^{-EV}/KT_1$

$\ln (n2/N) = {}^{-EV}/KT_2$

$\ln (n_1/N) / \ln (n_2/N) = T_2/T_1$

$\ln (1 \times 10^{-10}) / \ln (x) = {}^{1273}/_{773}$

$\ln x = 773/1273 \times \ln (1 \times 10^{-10})$

$= 773/1273 \times 2.303 (\log_{10} 10^{-10})$

$= 773/1273 \times (-10) \times 2.303 (1)$

$x= e^{-13.894 = 1}/ e^{13.894}$

$x = 8.449 \times 10^{-7}$

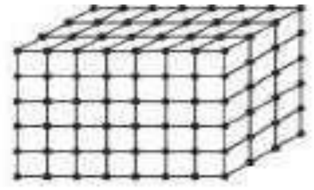
Line Defects:

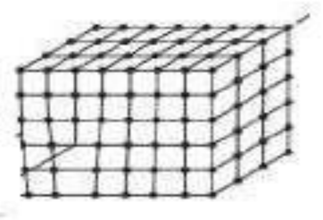
Line defects are one dimensional imperfection in the geometrical sense. Line imperfections are called dislocations. Dislocations are best understood by referring to tow limiting straight line type.

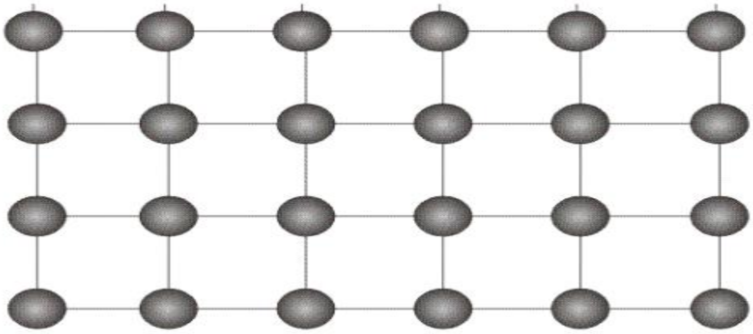
(i) The edge dislocation
(ii) Screw dislocation

Edge dislocation:

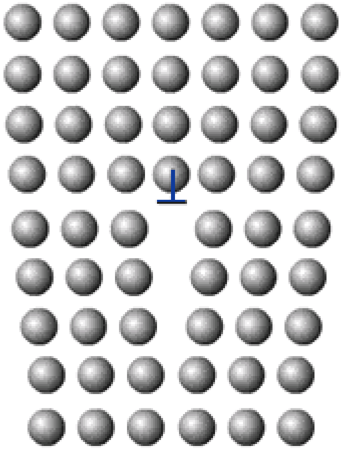
In perfect crystal, atoms are arranged in both vertical and horizontal planes parallel to the side faces as shown in Fig (a). If one of these vertical planes does not extend to the full length but ends in b/w. within the crystal as shown in Fig (b). It is called edge dislocation.







Perfect Crystal



Crystal with edge dislocation.

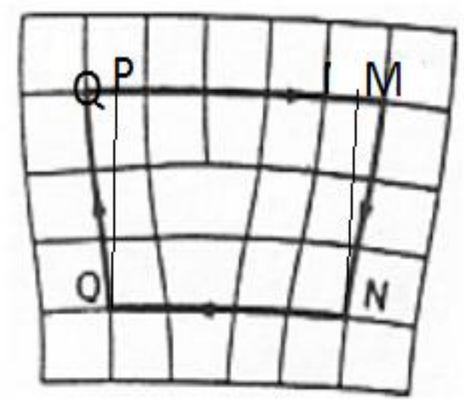
Edge dislocations are symbolically represented by T or ⊥ depending on whether the incomplete plane starts from the top or from the bottom of the crystal. These two configurations are referred to as positive and negative edge dislocations.

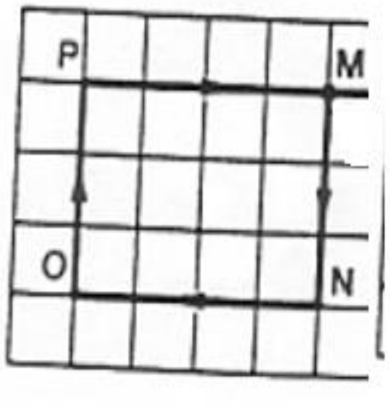
Burgers vector:

The magnitude and direction of the displacement are defined by a vector is called the "Burgers vector".

We understand the burgers vector concept. Let us consider two crystals, one perfect and another with edge dislocation as shown in figure (a) and (b) respectively. In fig (a), starting from the point 'P' we go up by 6 steps, then move towards right by 5 steps and move down by 6 steps and finally move towards left by 5 steps to reach the starting point 'P'. The burgers vector circuit gets closed, when the same operation is performed on the crystal shown in fig (b). We end up at Q instead of the starting point P. Now we have to move an extra step QP to return to "P" in order to close the burgers circuit. The magnitude and the direction of the step defines the burgers vector (BV).

BV=QP=B





Screw dislocation:

Screw dislocation results from a displacement of the atoms in one part of a crystal relative to the rest of the crystal. Forming a spiral ramp around the dislocation line as illustrated in figure. It shows a method of determining the burgers vector applied to an edge dislocation. Arbitrary a positive direction is chosen for the dislocation and then the vector which closes the circuit is found. In the figure one such burgers vector circuit is shown. Burgers vector ‘b’ is required to close the circuit, which is parallel to the dislocation line.

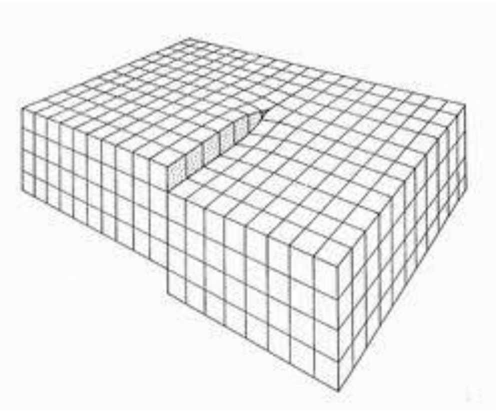


Fig Screw dislocation.

R13

Code No: 111AD

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
B.Tech I Year Examinations, June - 2015
ENGINEERING PHYSICS
(Common to all Branches)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25 Marks)

1.a) Write short notes on properties of ionic crystals. [2M]
b) What are the main conditions for Bragg's law? [3M]
c) State and explain about de Broglie's hypothesis. [2M]
d) Explain origin for energy bands. [3M]
e) Define polarizability, dielectric constant and susceptibility. [2M]
f) Explain Meissner effect. [3M]
g) Discuss briefly about double refraction. [2M]
h) Define Numerical aperture and acceptance angle [3M]
i) Write short notes on direct and indirect band gap semiconductors. [2M]
j) Explain quantum confinement in nano-materials. [3M]

PART-B

(50 Marks)

2.a) Calculate cohesive energy of a diatomic molecule.
b) Discuss about the structure of NaCl with neat diagram.
c) Explain salient features of miller indices. [3+4+3]

OR

3.a) Define unit cell, space lattice, lattice parameters.
b) Prove that fcc is closely packed when compared to simple cube and bcc structures.
c) Estimate number of Schottky defects at a given temperature. [3+4+3]

4.a) Derive Schrodinger time independent wave equation.
b) Write the properties of matter waves.
c) Explain physical significance of 'ψ'. [6+2+2]

OR

5. Discuss in detail about properties of M-B, B-E and F-D statistics. [10]

6.a) Derive expressions for electronic and ionic polarizations.

b) Write short notes on piezoelectricity. [6+4]

OR

7.a) Define permeability, magnetic field induction and magnetic field intensity.

b) Discuss about Bohr magneton.

c) Explain domain theory of ferromagnetism and on the basis of this theory how do you explain hysteresis behavior of ferromagnetic materials. [3+3+4]

8.a) Discuss about Newton's ring experiment and describe the procedure to calculate the radius of curvature of the lens.

b) Discuss the characteristic features of lasers light. [6+4]

OR

9.a) Describe construction of fiber optic cable with the help of block diagram.

b) Explain attenuation in optical fibers. [6+4]

10.a) Estimate the carrier concentration in n-type semiconductor and also find the position of Fermi level in n-type semiconductor.

b) Discuss about the factors affecting the architectural acoustics and suggest the remedies. [5+5]

OR

11.a) Discuss about the origin for nanotechnology.

b) Explain synthesis of nanomaterials by sol-gel technique. [4+6]

---ooOoo---

Code No: 61004 **Set No. 1**

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
I B.Tech. I Mid Examinations, December– 2014
ENGINEERING PHYSICS
Objective Exam

Name: ______________________________ **Hall Ticket No.** | | | | | | A | | | | |

Answer All Questions. All Questions Carry Equal Marks. Time: 20 Min. Marks: 10.

I. Choose the correct alternative:

1. In an atom all the attraction and repulsion force of the system tends to equilibrium, then it can be represented by the equation [ ]

   a) $[dU/dr]_{r=r_0} = 0$ b)$[dU/dr]_{r<r_0} = 0$ c) $[dU/dr]_{r=r_0} > 0$ d) $[dU/dr]_{r=r_0} < 0$

2. The best example for the hydrogen bond is [ ]
   a) HCl formation b) CH_4 formation c) NH_3 formation d) Ice formation.

3. When $r = r_o$, then the cohesive energy is minimum (U_{min}), and is equal to [ ]
   a) $\frac{-A}{r_o^M}\left[1-\frac{M}{N}\right]$ b) $\frac{A}{r^M}\left[1-\frac{M}{N}\right]$ c) $\frac{A}{r_o}\left[\frac{M}{N}-1\right]$ d) $\frac{A}{r_o}\left[1-\frac{M}{N}\right]$

4. If all lattice planes & lattice directions are described by a mathematical description is known as __________ [ ]
   a) Unit cell b) Bravias lattice c) Transitional vector d) Miller index

5. Miller indices represents a set of _____ [ ]
   a) Equidistant perpendicular planes b) Equidistant parallel planes
   c) Set of straight lines d) Set of normals

6. For orthorhombic crystal system the lattice parameters are [ ]
   a) $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$ b) $a \neq b \neq c$ and $\alpha = \gamma = 90^\circ \neq \beta$
   c) $a = b \neq c$ and $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$ d) $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$

7. Among the following which one is not belongs to point defect [ ]
   a)Vacancy b) Substitutional c) Interstial d) Screw defect

8. Extrinsic semiconductors are formed by [ ]
   a) Frankel defects b) Schottky defects c) Interstial defects d) Substitutional defects

9. Dislocations are of ______ [ ]
   a) line defect b) surface defect c) volume defect d) vacancy defect

10. Burger's dislocation is an identification for [ ]
    a) Edge dislocation b) Point defect c) Surface defect d) Screw dislocation

Cont…..2

II Fill in the Blanks

11. Crystal systems are classified as _______groups.

12. In a crystal a, b & c are lattice parameters having different values, the inter planar separati between the planes is ______

13. The coordination no. of the SC & BCC is _________ respectively.

14. The diamond has the nearest neighbor distance with carbon atoms present in it is______

15. The principle of Bragg's law can be expressed as _______

16. In Laue method ____________ X- rays can be used for characterization.

17. In powder method the diffraction pattern will be of ________ shape.

18. Schottky defect is a type of crystal defect which is similar to________ defect.

19. Frankel defect is a type of crystal defect which is similar to__________ defect.

20. If Burger's vector is parallel to the dislocation line then it is _________ dislocation.

-oOo-

Code No: 61004 **Set No. 1**

ENGINEERING PHYSICS

KEYS

I Choose the correct alternative

1. a
2. d
3. a
4. d
5. b
6. d
7. d
8. d
9. a
10. d

II Fill in the Blanks

11. 7
12. $d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$
13. 6&8
14. $\frac{a\sqrt{3}}{4}$
15. $2d\sin\theta = n\,\lambda$
16. continuous
17. Cylindrical
18. Vacancy
19. interstial
20. Screw

Code No: 61004 **Set No. 1**

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
I B.Tech. II Mid Examinations, February-2015
ENGINEERING PHYSICS
Objective Exam

Name: ______________________________ **Hall Ticket No.**

					A				

Answer All Questions. All Questions Carry Equal Marks. Time: 20 Min. Marks: 10.

I. Choose the correct alternative:

1. The relation between Kinetic energy E and momentum (P) of the particle is [ ]
a) E=$\frac{p^2}{2m}$ b) E=2p^{2}m c) E=$\frac{p}{2m}$ d) E=2pm

2. For which there is restriction of the arrangement of particles in each state among the following [ ]
a) Max well – Boltzmann b) Bose – Einstein c) Fermi-Dirac d) All

3. Expression for plank's black body radiation is [ ]

a) $\frac{8\pi chv}{\lambda^4}\left[\frac{1}{e^{hc/K_BT}-1}\right]d\lambda$ b) $\frac{4\pi chv}{\lambda^4}\left[\frac{1}{e^{hc/K_BT}-1}\right]d\lambda$
c) $\frac{\lambda^5}{8\pi chv}\left[\frac{1}{e^{hv/K_BT}-1}\right]d\lambda$ d) $\frac{8\pi ch}{\lambda^5}\left[\frac{1}{e^{hc/K_BT}-1}\right]d\lambda$

4. The black body radiation is example for ______ [ ]
a) Photon gas b) Electron gas c) Oxygen gas d) Hydrogen gas

5. The internal electric field in a material of standard form is given by [ ]
a) $\underset{P}{\rightarrow}+\frac{r\underset{E}{\rightarrow}}{\epsilon_0}$ b) $\underset{E}{\rightarrow}+\frac{r\underset{P}{\rightarrow}}{\epsilon_0}$ c) $\underset{D}{\rightarrow}+r\underset{P}{\rightarrow}$ d) $\epsilon_0\underset{E}{\rightarrow}+\underset{P}{\rightarrow}$

6. Choose the correct relation between electric susceptibility (χ), polarization vector (P) & electric field(E) [ ]
a) $\frac{E}{P}=\chi$ b) $\chi=PE$ c) $\chi=\frac{P}{E}$ d) $\chi=P+E$

7. All Ferro electric materials exhibit [ ]
a) anti-ferro electric b) ferri electric c) peizo-electric d) ultrasonic waves

8. This susceptibility equation $\chi=\frac{C}{T+\theta}$ is valid for the following material [ ]
a) Ferri magnetic materials b) Anti ferro magnetic materials
c) Ferro magnetic materials d) Paramagnetic materials

9. The value of Bhor magneton 'μ_B' is [ ]
a) 9.27×10^{-24}A-m b) 9.27×10^{-24}A-m^2 c) 9.27×10^{-24}A-m^{-2} d) 9.27×10^{-27}A-m^2

Cont....2

10. In an atom the magnetic momentum is due to ________ [ ]
a) Angular momentum of electron b) Magnetic field applied on it
c) Electron spin d) All the above

II Fill in the Blanks

11. If a particle of mass ‘m’ is moving with velocity ‘v’ as a matter wave, its wave length is ‘λ’, then the De-Broglie principle is ________

12. In Davison &Germer experiment, the size of the bump is maximum when the accelerating potential is ______

13. The Heisenberg’s relation between ΔE & Δt represents the uncertainties of energy & time respectively as _________________

14. The equation $\lambda_m = b/T$ where b=proportionality constant and T=temperature in K, named as _______

15. The average occupation of BE statistic is __________

16. When dielectric materials are used in between capacitor plates then capacitance _______ .

17. When a plane polarized electromagnetic wave travels through a _____ magnetic material kept in a magnetic field. The plane of polarization rotates along the applied magnetic field direction. The effect is called Faraday rotation

18. The local electric field E_{local} = _______

19. For ________magnetic materials initially susceptibility increases slightly with temperature and beyond Neel temperature, the susceptibility decreases with the temperature

20. Represent Schrödinger time dependent wave equation with $E(\varphi)$ *and* $H(\varphi)$

-oOo-

Code No: 61004 **Set No. 1**

ENGINEERING PHYSICS

KEYS

I Choose the correct alternative

1. a
2. c
3. d
4. a
5. a
6. c
7. c
8. b
9. b
10. d

II Fill in the Blanks

11 $\frac{h}{mv}$

12. 54V

13. $\Delta E.\ \Delta t \approx h$

14. Weins displacement law

15. $\frac{1}{e^{\alpha+\beta\varepsilon i}-1}$

16 [Increases]

17. Ferri

18. $E+\frac{P}{3\epsilon_0}$

19. Anti ferro

20. H φ =E φ

Code No: 61004 **Set No. 1**

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
I B.Tech. III Mid Examinations, June-2015
ENGINEERING PHYSICS
Objective Exam

Name: ____________________________ **Hall Ticket No.**

					A				

Answer All Questions. All Questions Carry Equal Marks. Time: 20 Min. Marks: 10.

I. Choose the correct alternative:

1. Oil floating on water looks colored due to interference of light. The approximate thickness of oil for such effect to be visible [ ]
a) 100 Å b) 10,000 Å c) 1mm d) 1 cm

2. The ratio of pressure of CO_2 : N_2 :He used in CO_2 laser is [ ]
a) 5:4:1 b) 4:5:1 c) 1:4:5 d) 1:5:4

3. If the ruby rod contains 0.05% of chromium atoms then it appears in__ color [ ]
a) Red b) yellow c) pink d) green

4. Loss of intensity of light in optical fiber is due to [ ]
a) Absorption b) scattering c) reflection d) absorption & scattering

5. In multimode step index fibers the core diameter is in the range [ ]
a) 8 to 10 µm b) 10 to 30 µm c) 50 to 200 µm d) 100 to 200 µm

6. The mobility of a carrier is proportional to [ ]
a) $T^{-3/2}$ b) $T^{3/2}$ c) $T^{-2/3}$ d) $T^{2/3}$

7. Minority carriers life time is defined as the time taken by the minority carriers to decay to ---------% of initial carriers. [ ]
a) 67 b) 33 c) 37 d) 25

8. The walls of a hall built for music concerns should [ ]
a) amply sound b) reflect sound c) transmit sound d) absorb sound

9. When a metal particle having bulk properties is reduced in size, the density of states [ ]
a) increases b) decreases c) remains same d) none

10. Nanotechnology is the engineering of functional systems at the [ ]
a) atomic scale b) molecular scale c) structural scale d) conic scal

Cont.....2

II Fill in the blanks:

11. If the thickness of the parallel film increases, the path difference _________.

12. When white light is incident on a diffraction grating, the light that will be deviated from central image will be __________color.

13. The wavelength of laser radiation from ruby laser is ________Å.

14. Basically a ruby crystal is Aluminum oxide doped with 0.05% to ________% of chromium atoms.

15. By increasing the refractive index of core material, the number of modes of propagation in an optical fiber ____________.

16. Numerical aperture represents ___________________capacity of optical fiber.

17. The electrical conductivity of a semiconductor at absolute zero temperature is __________.

18. The reverberation time is equal to _______________.

19. In nano materials with decrease of size, the inter atomic spacing ____________.

20. Quantum dots are ______________ dimensional nano materials.

-oOo-

Code No: 61004 **Set No. 1**

ENGINEERING PHYSICS

KEYS

I Choose the correct alternative

1. b
2. c
3. c
4. d
5. c
6. a
7. c
8. d
9. b
10. b

II Fill in the Blanks

11. increases
12. red
13. 6943 Å
14. 0.5%
15. increases
16. light gathering
17. zero
18. 0.165V/A
19. decreasing
20. three

STEP MATERIAL

UNIT I

1) What is interference?what are the conditions for interference?

Definition: Interference is based on the principle of superposition of waves. When two or more waves superimpose, the resultant amplitude in the region of superposition is different than the amplitude of individual waves. This modification in the distribution of intensity in the region of superposition is called interference of light.

Def: Superimposing of two or more waves is interference.

Conditions for Interference of light:

(1) Conditions for sustained interference.
(2) Conditions for observation of fringes.
(3) Conditions for good contrast between maxima and minima.

Conditions for sustained interference: The two sources should be coherent, i.e they should vibrate in the same phase or there should be a constant phase difference between the two sources must emit continuous waves of same wavelength and time period.

2)What is coherence? Explain types of coherence?

Two waves are said to be coherent if they have

1.Same wave wavelength

2.same amplitude

3.constant phase diffrerence

Coherence is a property of a wave. A predictable correlation of the amplitude and phase at any point with other point is called as coherence.

There are two types of coherence.they are

1) Temporal coherence
2) spatial coherence

Temporal coherence(longitudinal coherence):
It is possible to predict the amplitude and the phase at a one point on the wave with respect to another point on the same wave is called as Temporal coherence.

Spatial coherence: It is possible to predict the amplitude and the phase at a one point on the wave with respect to another point on the second wave then it is called as spatial coherence.

3) Explain division of amplitude and division of wavefront.

Division of wavefront :

The incident wavefront is divided into two parts by utilizing the phenomenon of reflection,refraction or diffraction .these two parts of the same wavefront travel unequal distances and reunite at some angle to produce interference bands

The fresnel biprism, Lloyd's mirror are the examples.

Division of amplitude:

The amplitude of the incoming beam is divided into two parts either by parallel reflection or refraction.these divided parts reunite after traversing different parts and produce interference.

Newtons rings ,michelsons interferometer coimes under this class.

4) Explain the concept of Newton rings

When a plano-convex lens with its convex surface is placed on a plane glass sheet, an air film of gradually increasing thickness outward is formed between the lens and the sheet. The thickness of film at the point of contact is zero. If monochromatic light is allowed to fall normally on the lens, and the film is viewed in reflected light, alternate bright and dark concentric rings are seen around the point of contact. These rings were first discovered by Newton, that's why they are called **NEWTON'S RINGS.**

5) What are the differences between fresnel and fraunhoffer diffraction?

sno	Fresnel diffraction	Fraunhoffer diffraction
1	Either a point source or an illuminated narrow slit is used.	Extended source at infinite distance is used.

2	The wavefront undergoing diffraction is either spherical or cylindrical.	The wavefront undergoing diffraction is plane wavefront.
3	The source and the screen are finite distances from the obstacles producing diffraction	The source and the screen are infinite distances from the obstacles producing diffraction
4	No lens is used to focus the rays	Converging lens is used to focus the rays

5) **Define diffraction grating?**

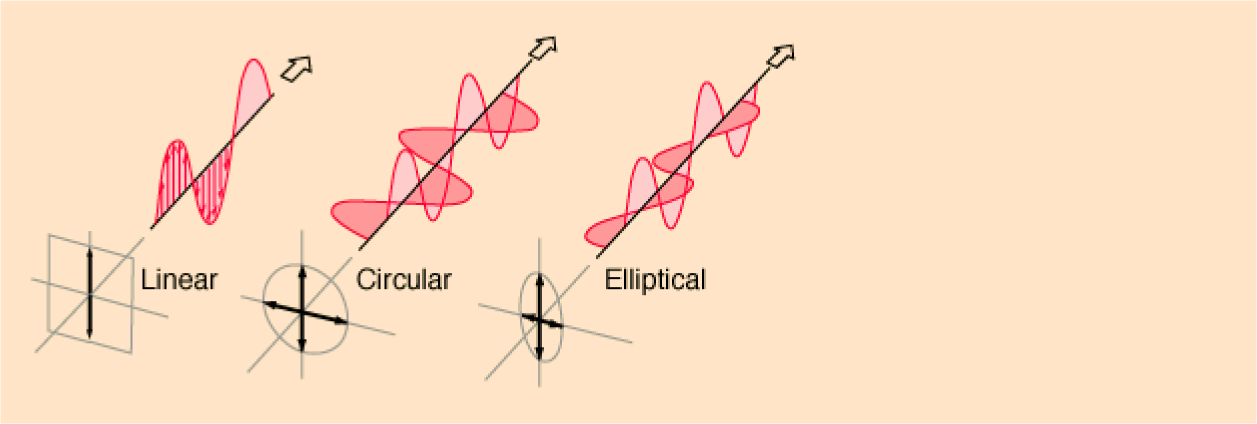
Diffraction grating is nothing but close placed multiple slits. It consists of very large numberof multiple slits sise by side separated by opaque spaces. The incideny light is transmitted through the slits and blocked by opaque spaces. Such a grating is called transmission grating. When light passs through the grating ,each one of the slit diffracts the waves. All the diffracted waves reinforce one another producing sharper and intense maxima on the screen. A plane transmission grating is nothing but a plane sheet of transparent material on which opaque rulings are made. The spaces between the rulings are equal and transparent and constitute the parallel slits. The rulings and slits are of equal width.

UNIT II

1) Define polarization? What are the types of polarization?

The process of converting unpolarized light to polarized light is called as polarization.

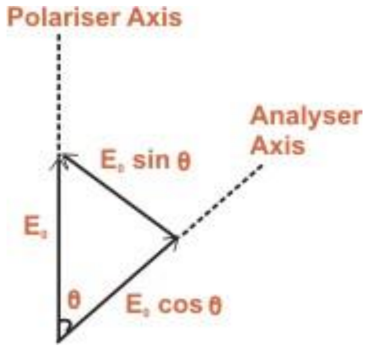
Light in the form of a plane wave in space is said to be linearly polarized. Light is a transverse electromagnetic wave, but natural light is generally unpolarized, all planes of propagation being equally probable. If light is composed of two plane waves of equal amplitude by differing in phase by 90°, then the light is said to be circularly polarized. If two plane waves of differing amplitude are related in phase by 90°, or if the relative phase is other than 90° then the light is said to be elliptically polarized



2)State malus law?

According to malus, when completely plane polarized light is incident on the analyzer, the intensity I of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer.

i.e $I \infty \cos^2\theta$



2) What is double refraction?

Unpolarized light has two components –one vertical and another horizontal. When unpolarized light passes through certain anisotropic crystals such as calcite or quartz, velocity of propagation of these two components vary. This means that the material exhibits two different refractive indices.

Since $\mu = \sin I / \sin r$, though both the components have the same angle of incidence, they have different angles of refraction. Hence when unpolarized light passes through such crystals, we get two refracted beams and this phenomenon is called <u>double refraction or birefringence.</u>

3) Explain the principle of Nicol’s Prism.

It is a device for producing and analyzing a plane polarized light. When an ordinary light is transmitted through a calcite crystal, it splits in o-ray and e-ray which is completely plane polarized with vibrations in two mutually perpendicular planes. If one beam is eliminated then the emergent beam from the crystal will be plane polarized light. Nicol eliminated the o-ray by utilizing the phenomenon of total reflection at thin film of Canada balsam separating the two pieces of calcite. The device is known as Nicol prism.

4) Define quarter wave plate ?

A calcite plate cut with optical axis parallel to the surface.when a plane polarized light falls normally on a thin plate of uniaxial crystal(here calcite plate) cut parallel to its optic axis,the light splits into ordinary and extraordinary plane polarized lights.they travel along the same path but with different velocities.the velocity of extra ordinary ray is greater than the velocity of ordinary ray. As a result a phase difference is introduced between them.

If the thickness of the crystal plate is such that it introduces a phase difference of $\pi/2$ radians or a path difference of $\lambda/4$ then it is called a quarter wave plate.

5) Define half wave plate ?

IF the thickness of the calcite crystal plate,cut with its faces parallel to optical axis,is such that it introduces a phase difference of π or a path difference of $\lambda/2$ between ordinary and extra ordinary wave then it is called as half wave plate. For a half wave plate

$(\mu_o-\mu_e)t=\lambda/2$

6) What is LASER? Explain the characteristics of LASER’s?

Laser is an acronym for light amplification by stimulated emission of radiation.

Characteristics of laser **:**

(1)Laser is highly monochromatic
(2)Laser is highly directional
(3)Laser is highly coherent
(4)The intensity of laser is very high

7)Write the differences between spontaneous emission and stimulated emission of radiation?

SPONTANEOUS EMISSION	**STIMULATED EMISSION**
1) Incoherent radiation	1) coherent radiation
2) Less Intensity	2) high intensity
3) Poly chromatic	3) mono chromatic
4) One photon released	4) two photons released
5) Less directionality	5) high directionality

6) More angular spread during propagation	6) less angular spread during Propagation
Ex:-Light fromsodium Mercury vapour lamp	ex: - light froma laser source ruby laser, He-Ne Laser

8) **What is population inversion?**

The number of atoms in higher energy level is less than the no of atoms in lowest energy level.The process of making of higher population in higher energy level than the population in lower energy level is known as population inversion.

Population inversion is achieved by pumping the atoms fromt he ground level to the higher energy level through optical (or) electrical pumping

9) What are Einstein's coefficients?

Based on Einstein’s theory ofradiation one can get the expression for probability for stimulated emission of radiation to the probability for spontaneous emission of radiation under thermal equilibrium.

E_1,E_2be the energy states

N_1,N_2be the no of atoms per unit volume

ABSORPTION: If $\rho(\upsilon)d\upsilon$ is the radiation energy per unit volume between the frequency range of ν and$\nu + d\nu$

The number of atoms undergoing absorption per unit volume per second fromlevel

$E_1$to E_2= $N_1\rho(\upsilon)B_{12}$

B_{12}represents probability of absorption per unit time

STIMILATED EMISSION: When an atommakes transitionE_2toE_1in the presence of external photon whose energy equal to (E_2-E_1)stimulated emission takes place thusthe number of stimulated emission per unit volume per second from levels.

$E_2$to E_1= $N_2\,\rho(\nu)\,B_{21}$

$B_{21}$is represents probability ofstimulated emission per unit time.

SPONSTANEOUS EMISSION: An atomin the level E_2can also make a spontaneous emission by jumping in to lower energy level E_1.

$E_2$to E_1=N_2A_{21}

10)**What are the applications of lasers in different fields?**

in scientific research

1)Lasers are used to clean delicate pieces of art, develop hidden finger prints

2)Laser are used in the fields of3D photography called holography

3) Using lasers the internal structure of microorganism sand cells are studied very accurately

4) Lasers are used to produce certain chemical reactions.

Laser in Medicine:

1) The heating action of a laser beamused to remove diseased body tissue

2)Lasers are used for elimination of moles and tumours,which are developing in the skin tissue.

3) Argon and CO_2 lasers are used in the treatment liver and lungs

4) Laser beam is used to correct the retinal detachment by eye specialist

Lasers in Communication:

1) More amounts of data can be sent due to the large band with ofsemiconductor lasers

2) More channels can be simultaneously transmitted

3) Signals cannot tapped

4)Atmospheric pollutants concentration, ozone concentration and watervapour concentration can be measured

Lasers in Industry: Lasers are used

1) To blast holes in diamonds and hard steel

2) To cut, drill,welding and remove metal fromsurfaces

3) To measure distance to making maps by surveyors

4) For cutting and drilling of metals and non- metals such a ceramics plastics glass

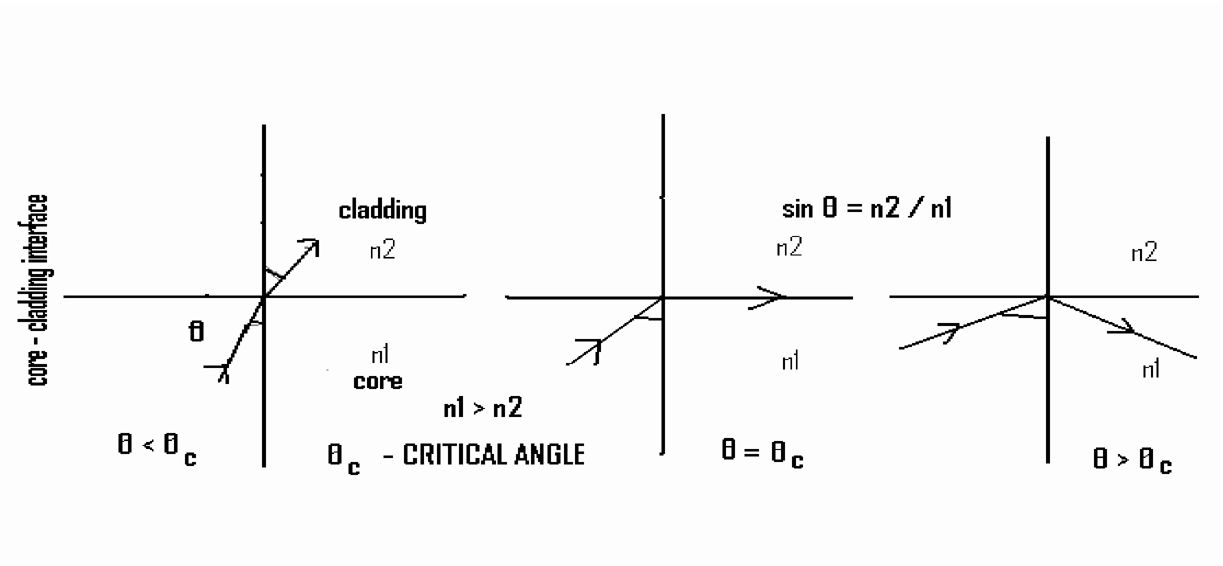
Unit III

1. **What is optical fiber? Explain the principle of optical fibers.**

The optical fiber mainly consists of the following parts.

i .Core ii .Cladding iii . Outer jacket

The mechanismof light propagation along fibers can be understood using the principle of geometrical optics. The transmission of light in opticalfiber is based on the phenomenon of total internal reflection.



2)**Define Acceptance angle of optical fiber?**

When the light beamis launched into a fiber, the entire light may not pass through the core and propagate. Only the rays which makes the angle of incidence greater than critical angle at the core –cladding interface undergoes total internal reflection. The other rays are refracted to the cladding and are lost. Hencethe angle we have to launch the beam at its end is essential to enable the entire lightto pass through the core .This maximum angle of launch is called acceptance angle.

$$\alpha\,(max)=\sin^{-1}\sqrt{(n_1^2-n_2^2)}/n_o$$

3)**Define Numerical aperture?**

Light collecting capacity of the fiber is expressed in terms of acceptance angle using numerical aperture. Sine of the maximum acceptance angle is called the numerical aperture of the fiber.

Numerical aperture = $\sin\alpha\,(max)$

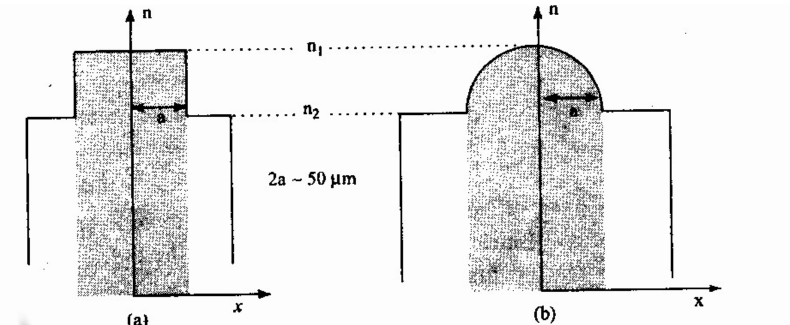
$\sin\alpha\,(max) =\sqrt{(n1^2-n_2^2)}/n_o$

4)**What are step index optical fibers?**

In step index fibers the refractive index of the core is uniform through out the medium and undergoes an abrupt change at the interface of core and cladding.The diameter of the core is about 50-200µm and in case of multimode fiber.And 10µm in the case of single mode fiber.Thetransmittedopticalsignalstravel through core medium in the form of meridonal rays, which will cross the fiber axis during every reflection at the core-cladding interface. The shape of the propagation appears in a zig-zac manner.

What are graded index fibres?

In these fibers the



Refractive index profile for (a) multimode step index and (b) multimode graded index fibers refractive index of the core varies radially.As the radius increasesin the core medium the refractive index decreases. The diameter of the core is about 50µm.The transmitted optical signals travel through core mediumin the formof helical rays, which will not cross the fiber axis at any time.

5)**What are the Applications of optical Fibers?**

1. Optical fibers are used assensors
2. These are used in Endoscopy
3. These are used in communication system
4. For decorative peaces inhome needs.
5. These are used in defence areas for the sake of high security.
6. These are used in electrical engineering.

6)What are the advantages of optical fibers?

- Enormous Bandwidth
- Immunity to interference and cross talk
- Signal security
- Small size and weight
- Low transmission loss
- Low cost

7)What are losses in optical fibres

While transmitting the signals through optical fiber some energy is lost due to few reasons. The major losses in fibers are 1.Distotrion losses 2.Transmission losses 3.Bending losses.

1. Distortion losses:-

When a pulse is launched at one end of the fiber and collected at the other end of the fiber, the shape and size of the pulse should not be changed. Distortion of signals in optical fiber is an undesired feature.If the output pulse is not same as the input pulse,then it is said that the pulse is distorted.If the refractive index of thecore is not uniform most of the rays will travel through the medium of lower refractive index region. Due to this the rays which are travel in fiber will become broadened. Because of this the output pulses will no longer matches with the input pulses.

The distortion takes place due to the presence of imperfections, impurities and doping concentrations in fiber crystals.Disperion is large in multi mode than in single mode fiber.

2. Transmission losses (attenuation):-

The attenuation or transmission losses may be classified into two categories i) Absorptionlosses ii) scattering losses

i) Absorption losses:-

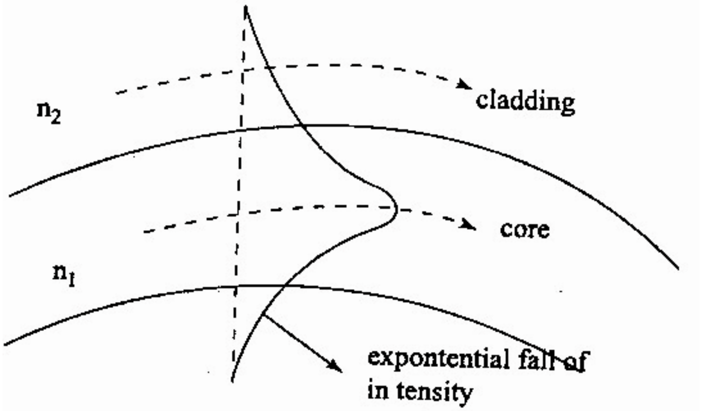
Absorption is a characteristic possessed by all materials every material inuniverse absorb suitable wavelengths as they incident orpassed through the material. In the same wayCore material of the fiber absorbs wavelengths as the optical pulses or wavelengths pass through it.

ii) Scattering losses:-

The core medium of the fiber is made of glass or silica .In the passage of optical signals in the core medium if crystal efects are encountered, they deviate from the path and total internal reflection is discontinued, hence such signals will be destroyed by entering into the cladding however attenuation is minimum in optical fibers compared to other cables.

ii) Bending losses:-

The distortion of the fiber from the ideal strait line configuration may also result in fiber.Let us consider away front that travels perpendicular to the direction of propagation.In order to maintain this, the part of the mode which is on the outside of the bend has to travel faster than that on the inside.As per the theory each mode extends an infinite distance into the cladding though the intensity falls exponentially.Since the refractive index of cladding is less than that of the core($n_1>n_2$),the part of the mode traveling in the cladding will attempt to travel faster. As per Einistein'stheory of relativity since the part of the mode cannot travel faster the energy associated with this particular part of the mode is lost by radiation.



Attenuation loss is generally measured interms of decibels(dB), which is a logarithmic unit.Loss of optical power = -10 log (P_{out}/ P_{in}) dB Where $P_{out}$is the power emerging out of the fiber

P_{in} is the power launched into the fiber.

Unit IV

1)What are the differences between crystalline solids and amorphous solids?

Crystalline solids	**Amorphous solids**
. The atoms or molecules of the crystalline solids are periodic in space.	1. The atoms or molecules of the amorphous solids are not periodic in space.
2. Some crystalline solids are anisotropic i.e The magnitude of physical properties such as refractive index, electrical conductivity. Thermal conductivity etc., are different along different directions of the crystal.	2. Amorphous solids are isotropic i.e The magnitude of the physical properties are same along all directions of the solid.
3. When it is broken, all broken pieces are same in shape. Because the atomic arrangement is regular manner.	3. When it is broken, all broken pieces are random in shape. Because: the atomic arrangement is random manner.
4. They have sharp melting points.	4. They do not posses sharp melting point. (wide range of melting points)
5. They posses plane faces.	5. They do not possess plane faces.

2) Explain the following terms.

- **i) Crystal structure**
- **ii) Space lattice**
- **iii) Basis**

Crystal structure:

Atomic arrangement in a crystal is called crystal structure.

(Or)

Crystal is 3Dimensional body. These are made up of regular and periodic 3D Pattern's of atoms of molecules in space is called the crystal structure.

==0==

Space lattice:

The atomic arrangement in a crystal is called crystal structure. It is very convenient to imagine periodic arrangement of points in space about which these atoms are located. This leads to the concept of space lattice.

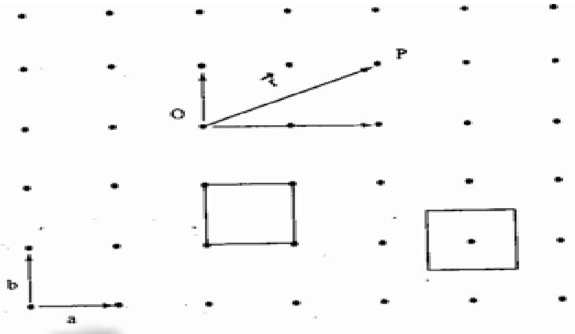


Fig. A two-dimensional square array of points.

A space lattice is defined as an infinite array of points in 3-dimensions in which every point has surroundings identical to that of every other point in the array.

Let us consider the 2D square array of points as shown in figure.

Let us choose any arbitrary point `o` as origin and a, b are two fundamental translational vectors along x and y directions the angle b/w these two vectors is 90^0. The magnitudes of 'a' and 'b' are equal and can be taken to be unity.

Let l, m are two integers along x and y direction and T_1 is the translational vector along x-axis and T_2 is the translational vector along y-axis.

$T_1 = la$ ---------------- (1)

$T_2 = mb$ --------------- (2)

L = 1+1 = 2 Units

M = 1 Units

Then the resultant translational vector T is

$T = T_1 + T_2$

$$\boxed{T = la + mb}$$

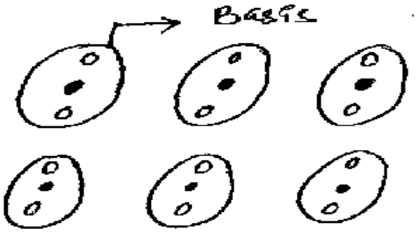
For 3Dimensions,

The resultant translational vector $T = la + mb + nc$

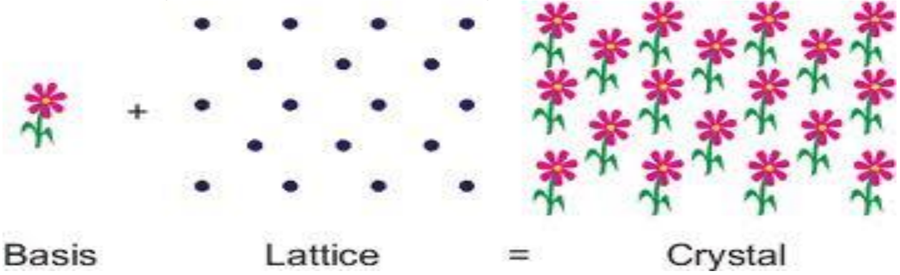
Where n, c is fundamental translational vector and integer along Z- axis.

Basis: A Group of identical in composition is called basis. It provides the no. of atoms per lattice point.

FIG:



- Space lattice + Basis → Crystal structure.



3)Explain the terms:

i) Nearest neighbour distance

ii) Coordination number

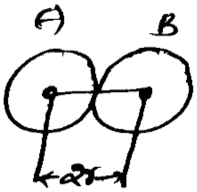
iii)Atomic radius

Nearest neighboring distance (2r):

The distance b/w the centers of two nearest neighboring atoms are called nearest neighboring distance.

If ‘r ‘is the radius of the atom.

FIG:



Nearest neighboring distance = r + r = 2r

2. Atomic radius (r): It is defined as half the distance b/w the nearest neighboring distance or atoms in a crystal.

Atomic radius = 2r/2 = r

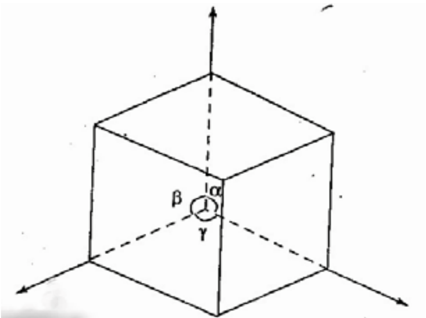
3. Coordination Number [CN]: It is defined as the no. of equidistant nearest neighboring atoms. How many nearest neighboring atoms are surrounded by the atom is called as co-ordination number [CN].

Coordination number for Simple cubic structure is 6

Coordination number for Body centered structure is 8 and

Coordination number for Face centered structure is 12.

4) What are the lattice parameters? Explain it.



Lattice parameters of an unit cell.

The lines drawn parallel to the lines of intersection of any three faces of the unit cell. Which do not lie in the same plane are called crystallographic axes (x, y and z). Let a, b, c are three translational vectors along x, y and z- directions. Unit cell shown with three crystallographic axes (x, y and z) and the intercepts a, b, c, are define the dimensions of a unit cell and are known as its primitives.

The angles b/w the three crystallographic axes are known as interfacial angles.

The angle between b and c is α

The angle between c and a is β and

The angle between a and b is γ.

The primitives a, b and c and interfacial angles α,β and γ are the Basis lattice parameters. Because they are used to determine the **size** and **dimension** of the unit cell. The unit cell formed by the primitives a, b, c is called `primitive cell`.

5)Derive an expression for Inter planer spacing of orthogonal crystal system?

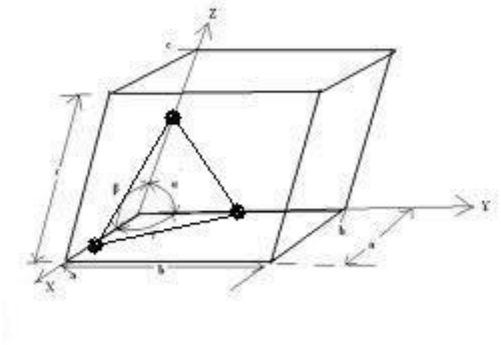


Fig:1

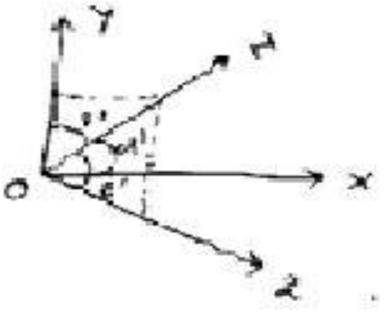


Fig: 2

The distance `d` b/w a series of planar in a crystal is known as inter planar spacing (d).

Let us consider a plane ABC with miller indices (h,k,l) has intercepts OA, OB,OC and three axes X, Y and Z – directions respectively.

The intercepts of the plane on three axes are OA = a/h , OB = b/k and OC = c/l

Let ON = d perpendicular distance from the origin to the plane. Let the direction cosines of ` ON` be $\cos\alpha^1$, $\cos\beta^1$, $\cos\gamma^1$.

$$\cos\alpha^1 = ON/OA = d/(a/h) = dh/a$$

similarly

$$\cos\beta^1 = ON/OB = d/(b/k) = dk/b$$

$$\cos\gamma^1 = ON/OC = d/(c/l) = dl/c$$

But we know that $\cos^2\alpha^1 + \cos^2\beta^1 + \cos^2\gamma^1 = 1$

$$(dh/a)^2 + (dk/b)^2 + (dl/c)^2 = 1$$

$$d^2\left[\frac{h^2}{a^2}+\frac{k^2}{b^r}+\frac{l^2}{c^2}\right] = 1$$

$$d^2 = \frac{1}{\frac{h^2}{a^2}+\frac{k^2}{b^r}+\frac{l^2}{c^2}}$$

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} \text{ -------- (1)}$$

OM be the $\perp^{lar}$ distance pf the next parallel plane from the origin. Its intercepts are $\frac{2a}{h},\frac{2b}{k},\frac{2c}{l}$.

$$OM = d = \frac{2}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} \text{ ----------- (2)}$$

The spacing b/w two adjacent planes OM-ON = MN is called the inter planer spacing `d`.

$$d = OM - ON = \frac{2}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} - \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$$

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}} \text{ --------- (3)}$$

In case of SC structure a=b=c

Than the inter planar spacing for SC structure is

$$d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{a^2}+\frac{l^2}{a^2}}}$$

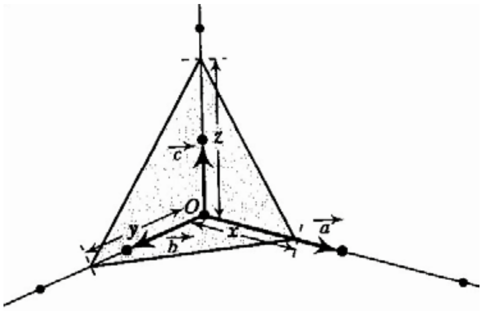
$$d = \frac{a}{(h^2+k^2+l^2)^{1/2}} \text{ ---------- (4)}$$

6)What are miller indices? Explain the procedure for finding miller indices?

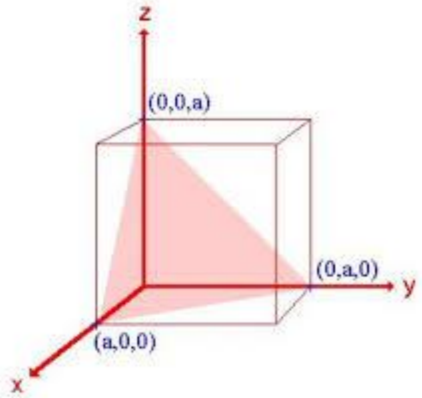
The smallest whole numbers which are used to represent a set of parallel planes.

Procedure for the finding of miller indices:

(i) Find the intercepts of the desired plane on the 3-coordinate axis. Let these be (pa, qb, rc).



PLANE ORIENTATION IN A LATTICE



(ii) Express the intercepts as multiples of the unit cell dimensions or lattice parameters.

i.e (p,q,r)

(ii) Take the ratio of reciprocal of these numbers.

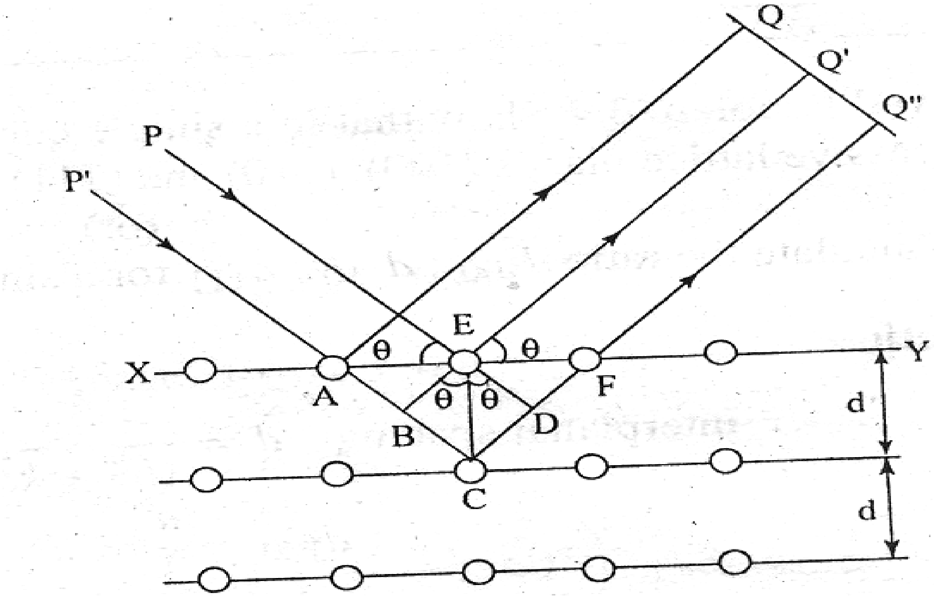
i.e (1/p, 1/q, 1/r)

(iv) Convert these reciprocals into whole numbers by multiplying each with their LCM to get the smallest whole number this gives the miller indices (h, k, l) of the plane.

UNIT V

1) State Bragg's law ? Derive the condition for bragg's law

"Bragg's law states that the X-rays reflected from different parallel planes of a crystal interfere constructively when the path difference is integral multiple of the wavelength of X-rays.



Let us consider a crystal made up of equidistant parallel planes of atoms with the inter-planar spacing 'd' as shown in fig. Let wave front of a mono-chromatic X-ray beam of wavelength 'λ' fall at an angle 'θ' on these atomic planes. Each atom scatters the X-rays in all directions. In certain directions these scattered radiations are in phase.

i.e., they interfere constructively while in all other directions, there is destructive interference.

Let us consider the rays PE and P'A inclined at an angle 'θ' with the top of the crystal plane XY. They are scattered along AQ and EQ' at an angle 'θ' with respect to the plane XY. Let us consider another incoming beam P'C and scattered along CQ''. Let us draw EB normal to AC and ED normal to CF as shown in fig. If 'EB' and 'ED' are parallel to the incident and reflected wave fronts.

Then the path difference between the incident and reflected waves is given by

$$\Delta = BC + CD \text{ --------------- } (1)$$

$$\text{In } \Delta\, BEC,\ \sin\theta = BC / EC = BC / d$$

$$\text{i.e., } BC = d \sin\theta \text{ ------------------- } (2)$$

$$\text{Similarly, in } \Delta\, DEC,\ CD = d \sin\theta \text{ ----------------- } (3)$$

$$\begin{aligned} \text{Hence, path difference } \quad \Delta &= BC+CD \\ &= d \sin\theta + d \sin\theta \\ \Delta &= 2d \sin\theta \quad \text{---------------- } (4) \end{aligned}$$

If two consecutive planes scatter waves in phase with each other, then the path difference must be an integral multiple of wavelength.

$$\text{i.e., } \quad \Delta = n\lambda$$

Where n = 0, 1, 2, 3,……. is the order of reflection

From (4) and (5)

$$\mathbf{2d \sin\theta = n\lambda}$$

The above equation represents Bragg's equation or Bragg's law.

2)Explain Point defects?

A point defect or imperfection is much localized interruption in the regularity of the crystal. It produces strain in small volume of the crystal surrounding the defect, but does not affects the perfection of more distant parts of the crystal. Such defects may be in the form of vacancy Interstitial and impurity. When the vacancy is trapped (filled) by electron or holes constitute new types of point defects called as color centres.

<u>Vacancy or vacancies</u>:

These are the lattice sites from which the atoms are missing from their regular positions. It is shown in Fig 1. A vacancy is called Schottky defect. In ionic crystals, a Schottky defect is one anion vacancy together with cation vacancy. This is because the interior of ionic crystal is electrically neutral. It is shown in Fig. 2.

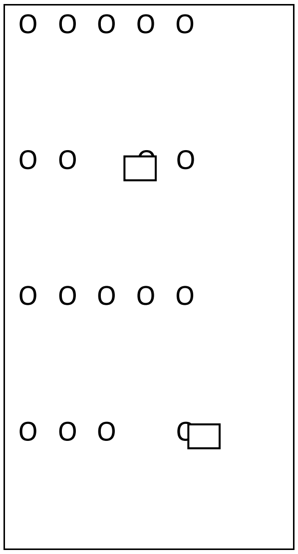


Fig 1: Crystal

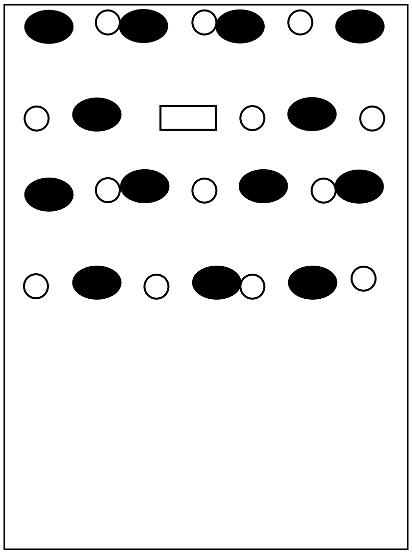


Fig 2 : Ionic Crystal

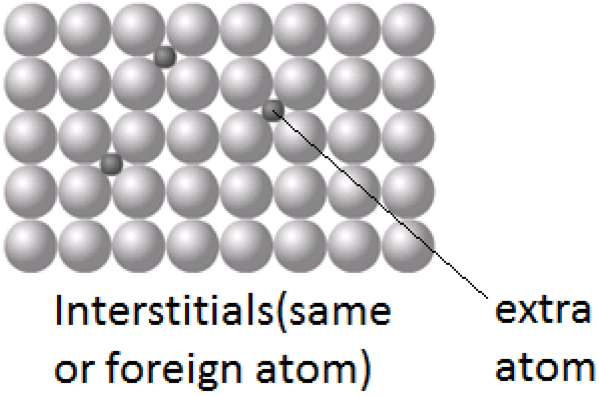
They are usually referred as the intrinsic defects as the associated vacancies are the intrinsic vacancies. It is clear that these clear defects preserve the stoichiometry of the crystal.

For most of the crystals, the thermal energy required to create a vacancy is about 1ev.

Interstitial atoms:

This is an extra atom inserted into the voids called intertice of the lattice between the regularity occupied sites as shown in figure. Thus such an atom does into occupy regular lattice sites. This extra atom may be in an impurity atom are an atom of the same type as on the regular lattice sites.

An atom can enter the interstitial void or space between the regular positioned atoms only when it is substantially smaller or equal to the parent atoms, otherwise it will produce atom distortion.



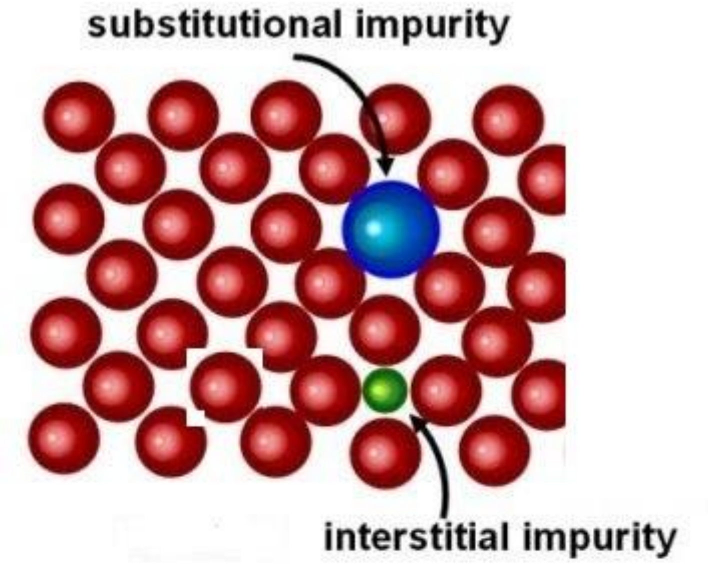
Impurity Defects:

Impurity defects are foreign atoms introduced into a crystal lattice. The most obvious point defect is the presence of a impurity atom in a perfect crystal. It may fit into the structure in two ways.

1.It may occupy a position normally occupied by the crystal atom .i.e. host atom in which case it will be called as “ substitutional impurity “ .

2.It may lodge normally unfilled volume, termed as void interstice between the atoms of the host crystal and called as interstitial impurity.

These are shown in figure



If the impurity atoms has roughly the same size and vacancy as the host atom, then the substitutional impurity created on the other hand, if the host crystal has relatively large interstices, then the interstitial impurity is accommodated in the crystal. Obviously, the interstitial impurity can exist only in ionic and covalent crystals and not in close packed crystal. In closed pack crystal substitutional impurity can take place. Impurities are usually deliberately added to pure crystals in order to modify their properties. The electrical conductivity of pure Ge, Se is enormously increased by adding trivalent or pentavalent which are well known in semi conductor devices.

Electronic Defects:

Errors in change distribution in solids are called electronic defects. These defects are produced when the composition of an ionic crystal does not correspond to the exact stoichiometric formula. Ex: ZnO, FeO etc.,

Schottky Defects:

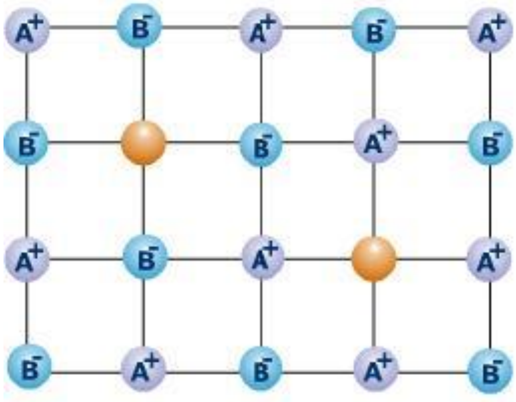
1. Ion vacancies are called Schottky defects.
2. A pair of one cation and one anion can be missing from an ionic crystal as shown in figure. The valance of the missing pair of ions should be equal to maintain neutrality. So these are normally generated in equal number of anion and cation vacancies in a crystal.

3. A Schottky defect is the combination of one cation vacancy and one anion vacancy.

4. When vacancies are created by movements of an anion and one cation from positions inside the crystal to positions on the surface of the crystal. A Schottky defect is said to have been formed.

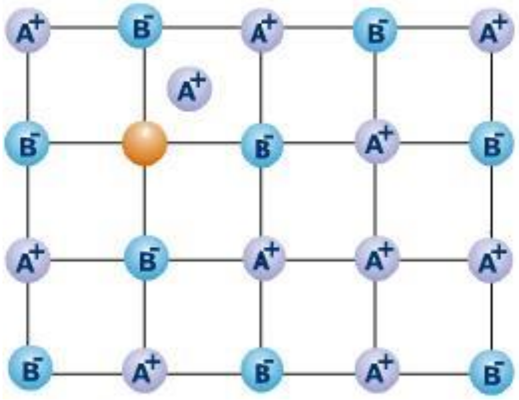
5. The concentration of Schottky defects decreased the density of the crystal.

6. This type of point defect is dominant in alkali halides



Frenkel Defect:

1. In the case of ionic crystals an ion displaced from the lattice in to an interstitial site is called a Frenkel defect.
2. As cations are generally the smaller ions, it is possible for then to get displaced into the void space present in the lattice. Anions do not get displaced like this as the void space is just too small for their size.
3. A Frenkel defect s the combination of one cation vacancy and one cation interstitial defect.
4. The concentration of Frankel defects does not change the density of the crystal.
5. A Frankel imperfection does not change the overall electrical neutrality of the crystal.
6. The point imperfections in silver halides and calcium floride are of the Frenkel type.
7. Frenkel and Schottky defects together are called “Intrinsic defects”.



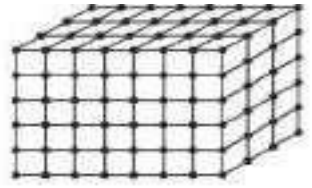
3) Explain Line Defects?

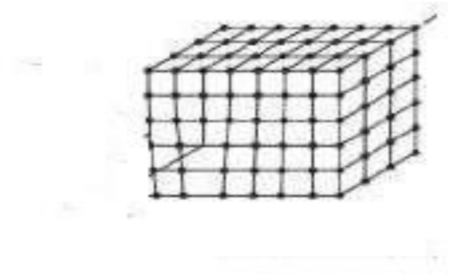
Line defects are one dimensional imperfection in the geometrical sense. Line imperfections are called dislocations. Dislocations are best understood by referring to tow limiting straight line type.

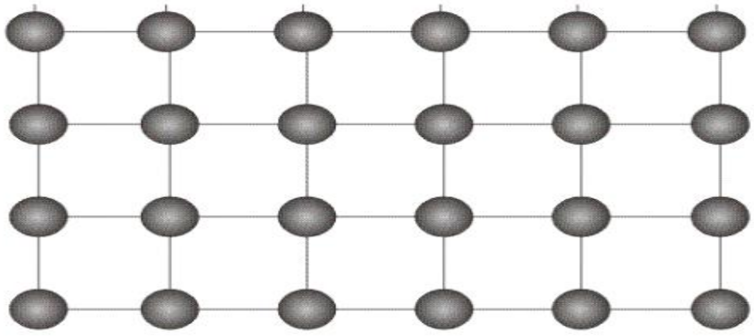
(i) The edge dislocation
(ii) Screw dislocation

Edge dislocation:

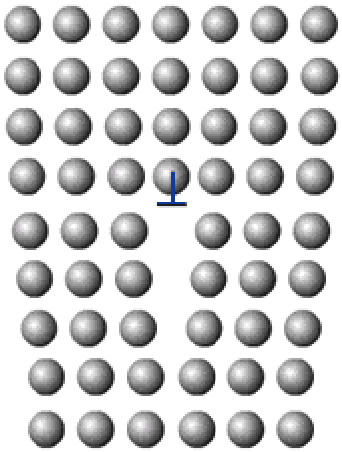
In perfect crystal, atoms are arranged in both vertical and horizontal planes parallel to the side faces as shown in Fig (a). If one of these vertical planes does not extend to the full length but ends in b/w. within the crystal as shown in Fig (b). It is called edge dislocation.







Perfect Crystal



Crystal with edge dislocation.

Edge dislocations are symbolically represented by T or ⊥ depending on whether the incomplete plane starts from the top or from the bottom of the crystal. These two configurations are referred to as positive and negative edge dislocations

Screw dislocation:

Screw dislocation results from a displacement of the atoms in one part of a crystal relative to the rest of the crystal. Forming a spiral ramp around the dislocation line as illustrated in figure. It shows a method of determining the burgers vector applied to an edge dislocation. Arbitrary a positive direction is chosen for the dislocation and then the vector which closes the circuit is found. In the figure one such burgers vector circuit is shown. Burgers vector ‘b’ is required to close the circuit, which is parallel to the dislocation line.

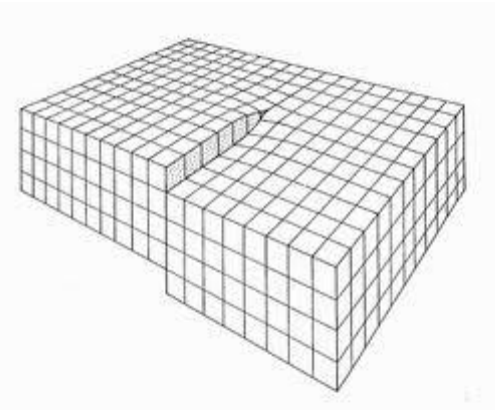


Fig Screw dislocation.

<u>4)</u> Explain Burgers vector?

The magnitude and direction of the displacement are defined by a vector is called the "Burgers vector".

We understand the burgers vector concept. Let us consider two crystals, one perfect and another with edge dislocation as shown in figure (a) and (b) respectively. In fig (a), starting from the point 'P' we go up by 6 steps, then move towards right by 5 steps and move down by 6 steps and finally move towards left by 5 steps to reach the starting point 'P'. The burgers vector circuit gets closed, when the same operation is performed on the crystal shown in fig (b). We end up at Q instead of the starting point P. Now we have to move an extra step QP to return to "P" in order to close the burgers circuit. The magnitude and the direction of the step defines the burgers vector (BV).

BV=QP=B