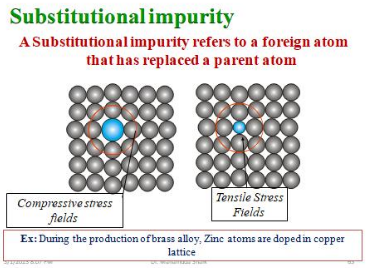
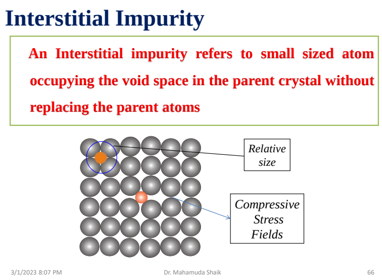
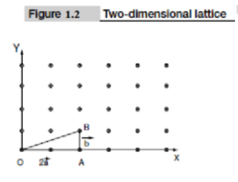
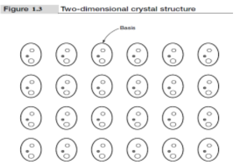
Koneru Lakshmaiah Education Foundation
(Deemed to be University estd. u/s. 3 of the UGC Act, 1956)
Accredited by **NAAC** as '**A**' Grade University ❖Approved by AICTE ❖ ISO 9001-2015 Certified
Campus: Green Fields, Vaddeswaram - 522 502, Guntur District, Andhra Pradesh, INDIA.
Phone No. 0863 - 2399999; www.klef.ac.in; www.klef.edu.in; www.kluniversity.in
Admin Off: 29-36-38, Museum Road, Governorpet, Vijayawada - 520 002. Ph: +91 - 866 -2577715, Fax: +91-866-2577717.

Course Name: Applied Physics
Course Code: SEPH0009
Sem-In-I-Key

<table>
<tr><td>1</td><td>




</td></tr>
<tr><td>2</td><td>
A space lattice or a crystal lattice is defined as a three-dimensional infinite array of points in space in which every point has surroundings identical to that of every other point in the array The atomic arrangement in a crystal is called crystal structure. The crystal structure is formed by associating every lattice point with an atom or an assembly of atoms or molecules or ions, which are identical in composition, arrangement and orientation, called the basis




</td></tr>
<tr><td>3</td><td>

Miller indices gives the position and orientation of crystal planes
If a plane is parallel to any of the coordinate axis, then its
intercepts will be infinity.
All the parallel equidistant planes have the same Miller Indices.
Miller Indices define a set of equidistant parallel planes.
If the Miller Indices of two planes have the same ratio then the
planes are parallel to each other.
If (hkl) are the Miller Indices of a plane, then the plane cuts the
axis into h, k and l equal parts.

</td></tr>
<tr><td>4</td><td>
The edge defect can be easily visualized as an extra half-plane of atoms in a lattice. The dislocation is called a line defect because the locus of defective points produced in the lattice by the dislocation lie along a line. This line runs along the top of the extra half-plane. The inter-atomic bonds are significantly distorted only in the immediate vicinity of the dislocation line.
Understanding the movement of a dislocation is key to understanding why dislocations allow deformation to occur at much lower stress than in a perfect crystal. Dislocation motion is analogous to movement of a caterpillar. The caterpillar would have to exert a large force to move its entire body at once. Instead, it moves the rear portion of its body forward a small amount and creates a hump. The hump then moves forward and eventual moves all of the body forward by a small amount.
</td></tr>
</table>

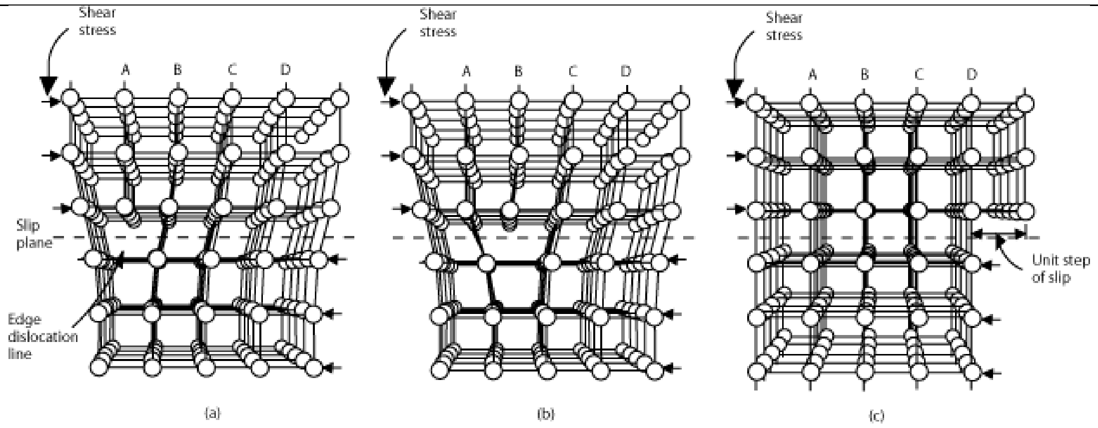
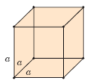
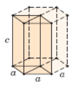
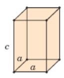
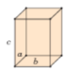
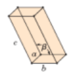
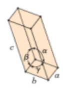


Fig 1.22. Burger vectors – Edge dislocations

As shown in the set of images above, the dislocation moves similarly moves a small amount at a time. The dislocation in the top half of the crystal is slipping one plane at a time as it moves to the right from its position in image (a) to its position in image (b) and finally image (c). In the process of slipping one plane at a time the dislocation propagates across the crystal. The movement of the dislocation across the plane eventually causes the top half of the crystal to move with respect to the bottom half. However, only a small fraction of the bonds is broken at any given time. Movement in this manner requires a much smaller force than breaking all the bonds across the middle plane simultaneously.

5

Summary of crystal systems

Crystal System	Axial Relationships	Interaxial Angles	Unit Cell Geometry
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$	
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	
Rhombohedral (Trigonal)	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	

3/1/2023 23 3/1/2023 Click here Crystal systems 24

14 Bravais lattices

Crystal system	Primitive (P)	Body centered (I)	Face centered (F)	Base centered (C)
Cubic	✓	✓	✓	✗
Tetragonal	✓	✓	✗	✗
Orthorhombic	✓	✓	✓	✓
Monoclinic	✓	✗	✗	✓
Triclinic	✓	✗	✗	✗
Rhombohedral	✓	✗	✗	✗
Hexagonal	✓	✗	✗	✗

3/1/2023 Click here for animation for 14 Bravais lattices 27

6

Structure of Simple cubic crystal:

Let *a* is the side of unit cell

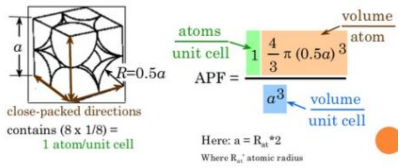
Coordination number: 6

Nearest neighbor distance: *a* units

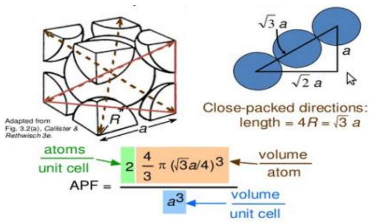
Relationship between atomic radius (R) and side of unit cell: $a = 2R$

Number of atoms per unit cell, $n = 1$

Atomic packing fraction $APF = \frac{n.(4/3)\pi R^3}{a^3} = \frac{1.(4/3)\pi R^3}{8R^3} = \frac{\pi}{6} = 0.52$



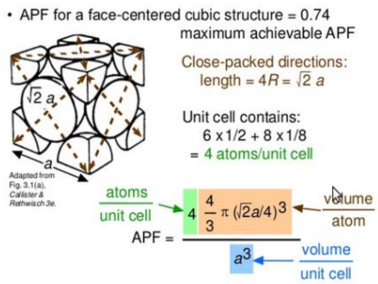
Structure of BCC:
Let *a* is the side of unit cell



Coordination number: 8
Nearest neighbour distance: √3 a /2 units
Relationship between atomic radius (R) and side of unit cell: $4R = \sqrt{3}a$
Number of atoms per unit cell, $n = 2$

Atomic packing fraction $APF = \frac{n.(4/3)\pi R^3}{a^3} = 0.68$

Structure of FCC:



Let *a* is the side of unit cell
Coordination number: 8
Nearest neighbor distance: a / √2 units
Relationship between atomic radius (R) and side of unit cell: $4R = \sqrt{2}a$
Number of atoms per unit cell, $n = 4$

Atomic packing fraction $APF = \frac{n.(4/3)\pi R^3}{a^3} = 0.74$

Therefore, based on the above packing fractions information, FCC is the most closely packed structure among all the three cubic crystal lattices SC, BCC and FCC.

7

Population inversion:
Population inversion is the process in which the population of a particular higher energy state is made more that at a specified lower energy state. Under normal circumstances, for a system in thermal equilibrium, the population of any higher state is less than that of a lower energy state. For laser action to take place N_2 must be greater than N_1 when $E_2 > E_1$.
When this condition is satisfied Population inversion is achieved.

Pumping mechanisms:
Pumping is the process of giving energy to a ground state atom and exciting it to a higher state. This is achieved in several ways.

Optical pumping: High intensity lamps like xenon flash lamp are used to excite atoms. This is used in pumping a Ruby laser. Some lasers are used to pumping by another laser.

8

Applications of lasers

Communications: Laser light has a very large bandwidth (10^5 MHz). A bandwidth of 40000 MHz would permit 10^7 simultaneous telephone calls or 8000 TV channels. The directionality of laser makes it a useful tool in interpolarity communications. Laser radiation is not absorbed by water and so is utilized in under water communications (LIDAR). In conjunction with optical fibers, laser can be used to transmit audio signals over long distances without attenuation.

Material Processing: This involves cutting, welding, hole drilling & surface treatment. Laser radiation can be converted into heat and can be used in the above mentioned applications.

Military Applications: Death-ray: Because of its high energy density a laser beam can destroy aircraft, missiles when targeted. Laser gun: A highly emergent laser beam can evaporate targets.

Computers: Laser printers. To transmit memory banks from one computer to another. 3 D profiling (holography). CDs – ROM.

Pure Sciences: Isotope separation, plasma, thermo-nuclear fusion reactions, holography, nature of chemical bonds, measurements of traces of pollutant gases, making of carbon nanotubes etc., to name a few.

9

4.10. **DIFFERENCE BETWEEN STEP INDEX FIBER AND GRADED INDEX FIBER**

S. No	*STEP INDEX FIBER*	*GRADED INDEX FIBER*
1	The refractive index of the core is uniform throughout and undergoes on abrupt change at the core cladding boundary	The refractive index of the core is made to vary gradually such that it is maximum at the center of the core.
2	The diameter of the core is about 50-200μm in the case of multimode fiber and 10μm in the case of single mode fiber	The diameter of the core is about 50μm in the case of multimode fiber
3	The path of light propagation is zig- zag in manner	The path of light is helical in manner
4	Attenuation is more for multimode step index fiber but for single mode it is very less.	Attenuation is less.
5	This fiber has lower bandwidth	This fiber has higher bandwidth
6	The light ray propagation is in the form of meridional rays and it passes through the fiber axis.	The light propagation is in the form of skew rays and it will not cross fiber axis.
7	No of Mode of propagation $N_{Step} = 4.9\left(\frac{d \times NA}{\lambda}\right)^2 = \frac{V^2}{2}$ Where d= diameter of the fiber core λ= wavelength NA = Numerical Aperture V- V-number is less than or equal to 2.405 for single mode fibers and greater than 2.405 for multimode fibers.	No of Mode of propagation $N_{Graded} = \frac{4.9\left(\frac{d \times NA}{\lambda}\right)^2}{2} = \frac{V^2}{4}$ $N_{Graded} = \frac{N_{Step}}{2}$

10

48

Main components of laser

(a) Any laser device is having three main components. They are

(1) Active medium (or) laser medium.

(2) The pumping source

(3) The optical resonator.

(1) Active medium (or) Laser medium:

- It is the material in which the laser action takes place
- It may be a solid, liquid or gas.
- Depending upon the active medium, lasers are named as follows

(1) solid state lasers – Ruby lasers

(2) Gas laser – He-Ne, CO_2, Nd-YAG laser

(2) The pumping source.

- LASER light is emitted due to stimulated emission.
- To create stimulated emission, more no. of atoms must present in excited state compared with ground state.

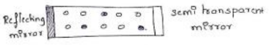
49

- Hence population inversion must be achieved b/w two energy levels.
- To get population inversion, the atoms must be excited to higher energy level that is possible due to pumping mechanism.
- The optical Resonator:

optical resonator contains two mirrors, one is 100% reflecting and another one is partially reflecting. The length of the resonator is $L = m\lambda/2$

m – integral values

λ – wavelength of light in a medium



(a) Non excited state.

(b) using optical pumping atoms goes to excited state.

(b) due to spontaneous emission photons are released that are triggered to get stimulated emission.

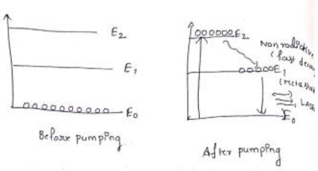
(c) The photons released are amplified by mirrors

(d) final ~~...~~ Laser light after getting proper gain released from semitransparent mirror.

11

50

Three level laser system:



① Before pumping all atoms are in lower energy level E_0

② After pumping, atoms are excited to E_2 from E_0

③ E_2 is not a metastable state

④ atoms returns to lower energy levels due to fast decay

⑤ E_1 is a meta stable state and it is near to E_2.

⑥ Atoms reached E_1 that is meta stable state

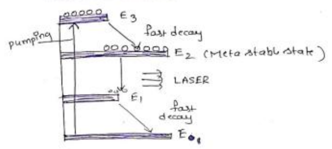
⑦ population inversion achieved b/w E_0 & E_1

⑧ Hence stimulated emission takes place b/w E_1 & E_0

⑨ Laser light is emitted

51

Four Level Scheme



(1) In four level scheme, four energy levels are there.

(2) pumping → atoms excited from $E_0 \rightarrow E_3$

(3) fast decay takes place from $E_3 \rightarrow E_2$ because E_3 is not a meta stable state.

(4) In E_2, all the atoms are retained more than 10^{-8} sec.

(5) Hence population inversion achieved b/w E_2 & E_1 and E_2 & E_0.

(6) LASER emission is possible either in $E_2 \rightarrow E_1$ (or) $E_2 \rightarrow E_0$

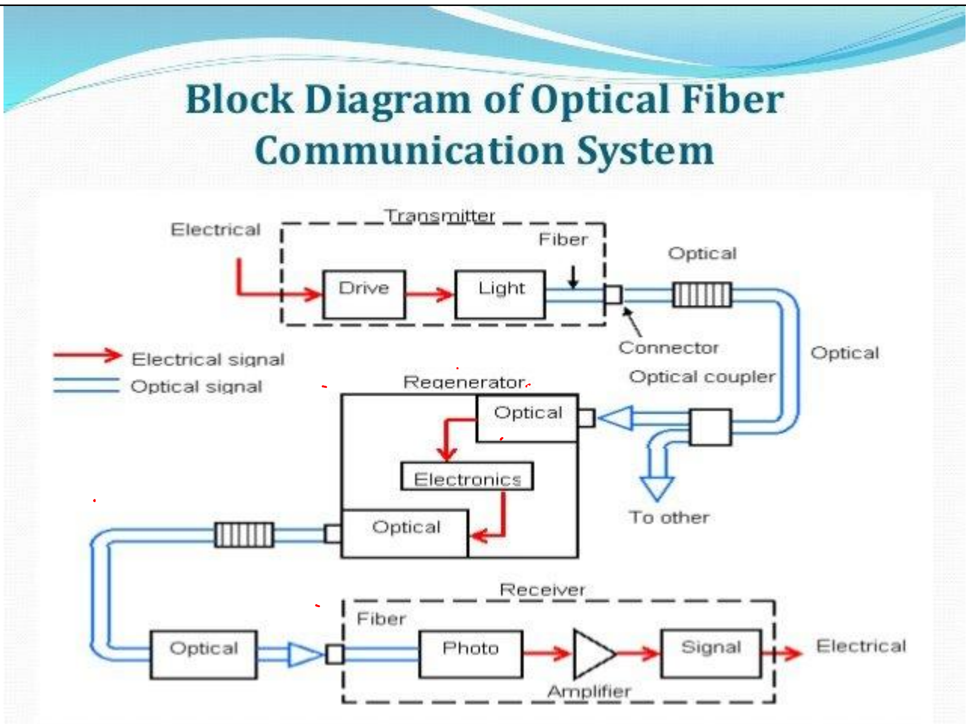
(7) It is easy to maintain population inversion b/w $E_2 - E_1$ when compared with $E_2 - E_0$.

(8) Hence LASER emission takes place b/w $E_2 \rightarrow E_1$ levels.

(9) due to fast decay atoms comes down to E_0 level. from E_1

(10) process continuous → we get continuous laser.

12



Optical fiber is an ideal communication medium by systems that require high data capacity, fast operation and to travel long distances with a minimum number of repeaters.

Encoder:

It is an electronic system that converts the analog information signals, such as voice of telephone user, in to binary data. The binary data consists of series of electrical pulses.

Transmitter:

Transmitter consists of a driver which is a powerful amplifier along with light source. The o/p of amplifier feeds to light source, that converts electrical pulses in to light pulses.

Source to Fiber Connector:

It is a special connector that sends the light from sources to fiber. The connector acts as temporary joint b/w the fiber and light source, misalignment of this joint, leads to loss of signal.,

Fiber to Detector Connector

It is also temporary joint, which collects the source from fiber.

Receiver:

Receiver consists of a detector followed by amplifier. This combination converts light pulses in to electrical pulses.

Decoder:

Electrical pulses containing information are fed to the electronic circuit called decoder. Decoder converts binary data of electrical pulses in to analong information signals.