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CMR INSTITUTE OF TECHNOLOGY, BENGALURU.
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Internal Assessment Test 2 – November, 2017

Sub:	Engineering Physics					Sub Code:	17PHY12	Branch:	All
Date:	09/11/2017	Duration:	90 mins	Max Marks:	50	Sem / Sec:	I / I,J,K,L,M,N,O		OBE

Answer any **FIVE FULL** Questions

Note: Value of Constants: $h = 6.625\times10^{-34}$Js $k = 1.38\times10^{-23}$ J/K $m = 9.11\times10^{-31}$ kg. $e = 1.6 \times 10^{-19}$C, $c = 3\times10^{8}$ m/s

		MARKS	CO	RBT
1 (a)	Derive an expression for conductivity in an intrinsic semiconductor. State and explain law of mass action for semiconductors.	[07]	CO2	L3
(b)	The electron and hole mobilities of silicon are 0.15 $m^2 V^{-1} s^{-1}$ and 0.09 $m^2 V^{-1} s^{-1}$ respectively at a certain temperature. If the electron density is 1.6×10^{16} electron/ m^3, calculate the resistivity of silicon.	[03]	CO2	L3
2 (a)	Define superconductivity. Describe how BCS theory explains superconductivity.	[06]	CO2	L1
(b)	Distinguish between Type I and Type II superconductors.	[04]	CO2	L2
3 (a)	Obtain an expression for energy density of radiation under equilibrium condition in terms of Einstein's coefficients.	[06]	CO3	L3
(b)	Describe briefly the applications of lasers in welding and cutting.	[04]	CO3	L1
4 (a)	Describe the construction of CO_2 laser and explain its working with the help of energy level diagram.	[07]	CO3	L3
(b)	The ratio of population of two energy levels is 1.6×10^{-30}. Find the wavelength of light emitted by spontaneous emission at 300 K.	[03]	CO3	L2
5 (a)	Describe the recording and reconstruction processes in holography with the help of suitable diagrams.	[06]	CO3	L3
(b)	Define the terms i) stimulated emission ii) population inversion iii) metastable state iv) Optical pumping	[04]	CO3	L1
6 (a)	Obtain an expression for numerical aperture and arrive at the condition for propagation of signal in an optical fiber.	[07]	CO3	L2
(b)	The attenuation in an optical-fiber is 5 dB/km. What fraction of its initial intensity remains after 3 km?	[03]	CO3	L2
7 (a)	With the help of neat diagrams explain the different types of optical fibers.	[06]	CO3	L2
(b)	Describe point to point communication system using optical fibers with the help of a block diagram.	[04]	CO3	L2

ENGG PHYSICS IAT-2
SCHEME OF EVALUATION

1. a. [4]

Conductivity of Intrinsic semiconductors:

Current density J = n e V_d

For a semiconductor, J = n_e e V_d(e) + n_h e V_d(h) ……………(1) .

But drift velocity V_d = μE=μ.J/σ

Using (1), σ = n_e e μ_e + n_h e μ_h

In an intrinsic semiconductor, number of holes is equal to number of electrons.

$$\sigma_{int} = n_e e[\mu_e + \mu_{hole}].$$

n_e is the electron concentartion

n_p is the hole concentration

μ_e is the mobility of electrons

μ_h is the mobility of holes

Law of mass action: . [3]

The product of electron and hole concentration is constant at any given temperature independent of Fermi energy & type of doping.This principle is used to calculate hole and electron densities.

$$n_e n_h = 4\left(\frac{kT}{2\pi h^2}\right)^3 (m_e^* m_h^*)^{\frac{3}{2}} e^{-\frac{E_g}{kT}} = a \ \text{cons tan t}$$

Electron concentration n_e = $2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{\frac{3}{2}} e^{-\left(\frac{E_c - E_F}{kT}\right)-}$

Hole concentration n_h = $2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{\frac{3}{2}} e^{-\left(\frac{E_F - E_{VF}}{kT}\right)-}$

For Intrinsic semiconductor n_e =n_h =n_i

hence

$$n_i^2 = n_e n_h = 4\left(\frac{kT}{2\pi h^2}\right)^3 (m_e^* m_h^*)^{\frac{3}{2}} e^{-\frac{E_g}{kT}} = a \ \text{cons tan t}$$

1.b. [3]

Conductivity of an Intrinsic semiconductor is given by

$$\sigma_{int} = n_e e[\mu_e + \mu_{hole}]$$

On substitution, we get

$$\rho_{int} = 1627.6 \ \Omega m$$

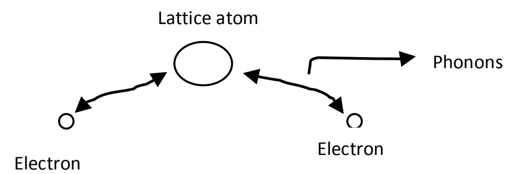
2.a. [1]

It is a phenomenon in which some materials loose their resistance completely below certain temperature.

BCS Theory :[Bardeen , Cooper, Schrieffer] [5]

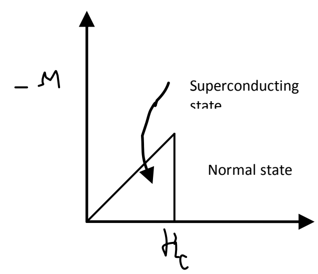
According to this theory superconductivity occurs when an attractive interaction known as electron-lattice-electron interaction is established resulting in the formation of cooper pairs.

In a lattice, an electron passing close to a lattice atom is attracted towards it and displaces it. This lattice atom will interact with another electron and in turn forms an **electron – lattice –interaction.** This system of two electrons of equal and opposite momentum attached to a lattice atom is known as a **cooper pair**. The electrons are bound to the lattice atom through the exchange of phonons (Lattice vibrations).Collective flow of cooper pairs under the influence of applied electric field reduces resistance. The energy gap between the normal state and superconducting state is of the order of milli electron volts. The thermal energy at low temperatures is not sufficient to break cooper pair interaction. Cooper pairs are represented collectively by a coherent matter wave function.



2b.

Type 1 Superconductors:

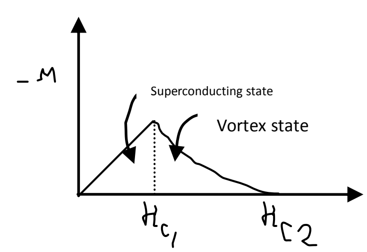


These are pure superconductors.When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At critical magnetic field there is a sharp transition to normal state due to the penetration of magnetic flux lines. The transition is sharp.

These possess low critical magnetic fields. Their critical temperatures also low.They are generally pure metals.

Ex: Al, Pb

Type 2 superconductor: [4]



These are generally alloys.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At lower critical magnetic field H_{C1}, the flux lines start penetrating .As the magnetic field is increased, the super conductivity coexists with magnetic field and this phase is known as mixed state(vortex state). At higher critical magnetic field H_{C2}, the penetration is complete and the material transforms to normal state. They possess higher critical magnetic fields. Their critical temperatures are high.

Ex: Nb_3Ge, $YBa_2Cu_3O_7$

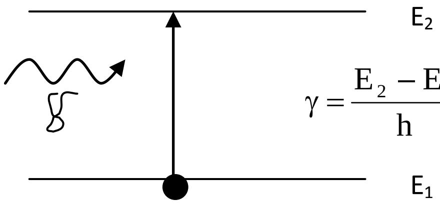
3.a [6]

Expression for energy density:

Induced absorption:

It is a process in which an atom at a lower level absorbs a photon to get excited to the higher level.

Let E_1 and E_2 be the energy levels in an atom and N_1 and N_2 be the number density in these levels respectively. Let U_γ be the energy density of the radiation incident.



$$\gamma = \frac{E_2 - E_1}{h}$$

Rate of absorption is proportional to the number of atoms in lower state and also on the energy density U_γ.

Rate of absorption = $B_{12} N_1 U_\gamma$

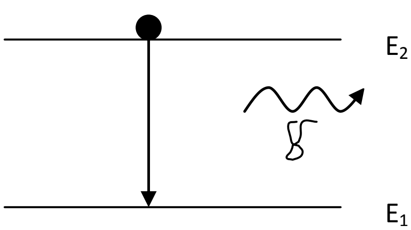
Here B_{12} is a constant known as Einsteins coefficient of spontaneous absorption.

Spontaneous emission:

It is a process in which ,atoms at the higher level voluntarily get excited emitting a photon. The rate of spontaneous emission representing the number of such deexcitations is proportional to number of atoms in the excited state.

Rate of spontaneous absorption = $A_{21} N_2$

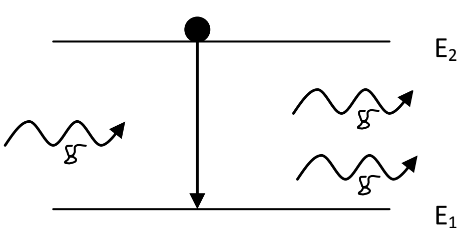
Here B_{12} is a constant known as Einsteins coefficient of spontaneous emission.



$$\gamma = \frac{E_2 - E_1}{h}$$

Stimulated emission:

In this process, an atom at the excited state gets deexcited in the presence of a photon of same energy as that of difference between the two states.



$$\gamma = \frac{E_2 - E_1}{h}$$

The number of stimulated emissions is proportional to the number of atoms in higher state and also on the energy density U_γ.

Rate of stimulated emission = $B_{21} N_2 U_\gamma$

Here B_{21} is the constant known as Einsteins coefficient of stimulated emission.

At thermal equilibrium,

Rate of absorption = Rate of spontaneous emission + Rate of stimulated emission

$B_{12} N_1 U_\gamma = A_{21} N_2 + B_{21} N_2 U_\gamma$

$$U_\gamma = \frac{A_{21} N_2}{B_{12} N_1 - B_{21} N_2}$$

Rearranging this, we get

$$U_\gamma = \frac{A_{21}}{B_{21}} \left[\frac{1}{\frac{B_{12} N_1}{B_{21} N_2} - 1} \right]$$

By Boltzmans law , $\frac{N_1}{N_2} = e^{\frac{h\gamma}{kT}}$

Hence

$$U_\gamma = \frac{A_{21}}{B_{21}} \left[\frac{1}{\frac{B_{12}}{B_{21}} e^{\frac{h\gamma}{kT}} - 1} \right]$$

From Planck's radiation law,

$$U_\gamma = \frac{8\pi h \gamma^3}{c^3} \left[\frac{1}{e^{\left[\frac{h\gamma}{kT}\right]} - 1} \right]$$

Comparing these expressions, we get

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h \gamma^3}{c^3} \quad \text{and} \quad \frac{B_{12}}{B_{21}} = 1$$

$$\therefore U_\gamma = \frac{A}{B} \left[\frac{1}{e^{\frac{h\gamma}{kT}} - 1} \right]$$

3.b. **Laser Welding:** [4]

Lasers are used for welding metals, by virtue of its ability to focus large power in a small region.

In laser welding, the laser beam is focussed to the spot to be welded by means of a lens and a very high temperature is generated at this spot by virtue of its high intensity.

Due to the heat, the metal used for welding is melted and a strong, homogeneous joint is formed.

Advantages:

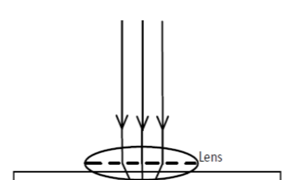
a) It is a contactless process. Therefore, unwanted materials like oxides can be eliminated.

b) Only the focussed region is heated and so it can be used in micro-electronics, where heat-sensitive components are involved.

c) There is no mechanical stress on the components involved, thus there is no deformation.

d) It can be used to weld joints where man cannot physically be present, for example, in nuclear power plants.

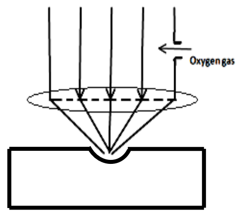
Carbon di-oxide lasers are the most popular one in this particular applica



Laser Cutting:

A laser beam, assisted by a jet of gas is used for cutting materials. The laser beam is surrounded by a nozzle into which oxygen gas is fed. The gas helps in combustion and also assists by blowing out the molten metal. The flowing action increases the depth and also the speed of cutting. The cutting accuracy is well controlled.

Laser cutting is used in the tailoring industry where large number of layers of cloth is stockpiled. In this case the laser beam is focussed on the pile and moved along the path, along which the cut is to be made.



4.a. [7]

CO_2 LASER

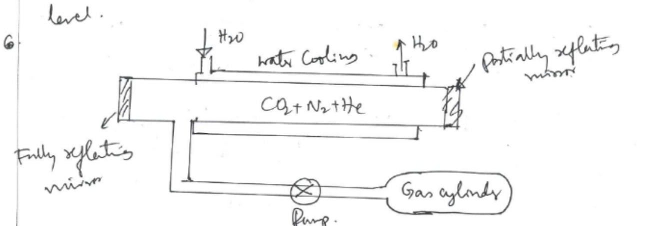
It belongs to the catagory of gas lasers with 4 level Lasing system.

Active medium: Mixture of CO_2, N_2 & He in the ratio 1:2:8

Nitrogen is used as Molecular Nitrogen absorbs energy more efficiently from electric discharge than CO_2 does.

Construction:

1. A glass plasma tube of 10-15mm diameter with an integral water cooling Jacket.
2. Partially reflecting and fully reflecting mirrors are mounted on the ends of the tube.
3. A Coaxial water jacket around the plasma tube serves to remove heat through the tube walls
4. optical pumping is achieved by Electric discharge caused by applying a P.D of over 1000V.
5. Helium gas Conducts away heat generated and also catalyses Collisional deexcitation of CO_2 molecules from Lower Laser level.
6.



Working:

① CO_2 is a linear molecule and has three fundamental modes of vibration: Symmetric Stretching, bending and asymmetric stretching, represented as (001), (100) & (020) with Corresponding Energy states E_1, E_2, E_3 ----.

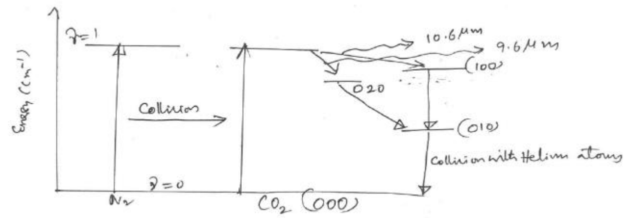
② The energy level 001 corresponding to asymmetric stretching is the upper Lasing level. The energy levels (100), (020) are the lower Lasing states.

③ During electric discharge, electrons released due to ionization excite N_2 molecules to the first vibrational level which is close to upper Lasing level of CO_2.

④ N_2 molecules undergo collisions with CO_2 molecules and Cause their excitation leading to Population inversion

⑤ Lasing action usually takes place due to transition from 001 to 100, (001) to (020) corresponding to a wavelength $\lambda_1 = 10.6\mu m$ and $9.6\mu m$ respectively.

⑥. The CO_2 molecules deexcite to ground state through Collisions with Helium atoms.



4.b. . [3]

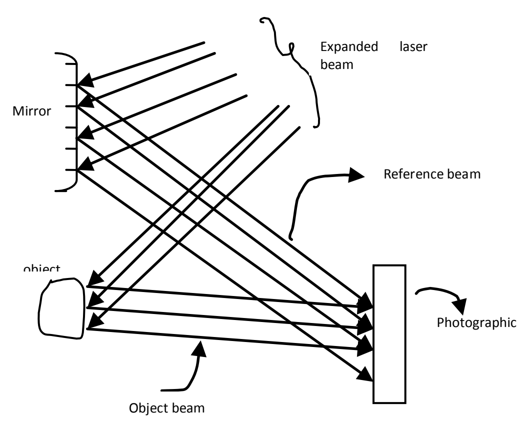
$$\frac{N_2}{N_1} = \frac{1}{e^{(\frac{hc}{\lambda kT})}} = 1.6x10^{-30}$$

Substitute for T = 300k, we get

λ =699nm

5.a.. [4+2]

Recording of the image of an object :

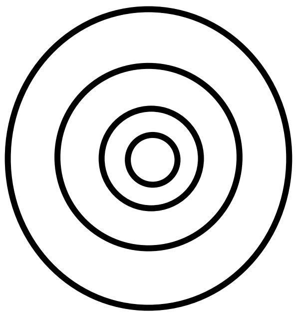


The given object , mirror and photographic plates are arranged as shown in the figure .An expanded laser beam is directed on this arrangement in which a part of the beam is incident on the mirror and the rest falls on the object.

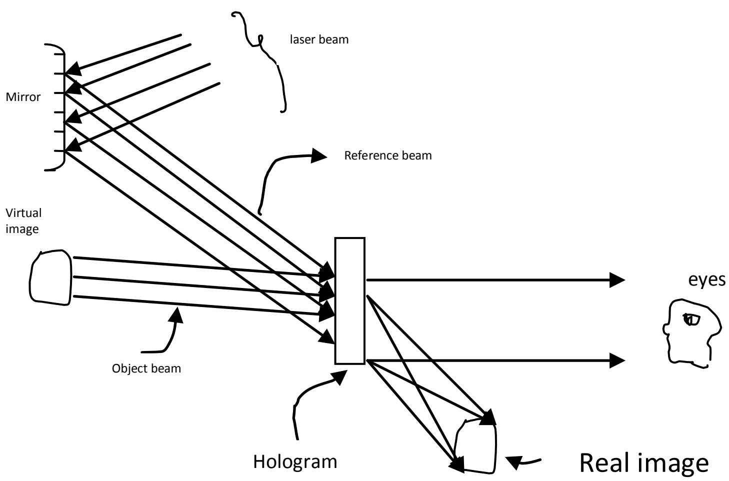
The photographic plate is placed such that it receives the reflected beam (reference beam) and light scattered from the object (object beam).

Due to the interference between plane wavefronts of reference beam and spherical wavefronts of object beam , an interference pattern is formed on the photographic plate. This will be called as a hologram. .

Hologram :



Reconstruction of the image:



The image of the object is reconstructed by passing the reference beam from the same laser through the hologram ,which is oriented with respect to the reference beam .The reference beam is diffracted and two images of the object , real image and virtual image are seen. .

5.b. [4]

Stimulated emission: It is the emission of photons by an atom making a transition from a higher level to a lower level when stimulated by another photon of same energy.

Population inversion: It is a state in which number of atoms in an excited energy state is more than the number of atoms in the ground state.

Metastable state: These are the energy states with relatively higher life time of the order of few milli seconds.

Optical pumping:

The population inversion is achieved by the method of optical pumping. In this process the active medium is excited by the irradiation with light or through electrical discharge .The atoms of the active medium absorb energy and rise to higher energy state. As a result the number of atoms in the higher energy states increases and the population inversion is said to be achieved.

6.a.. [6+1]

Expression for condition for propagation :

Consider a light ray falling in to the optical fibre at an angle of incidence_θ_0 equal to acceptance angle. Let n_0 be the refractive index of the surrounding medium .

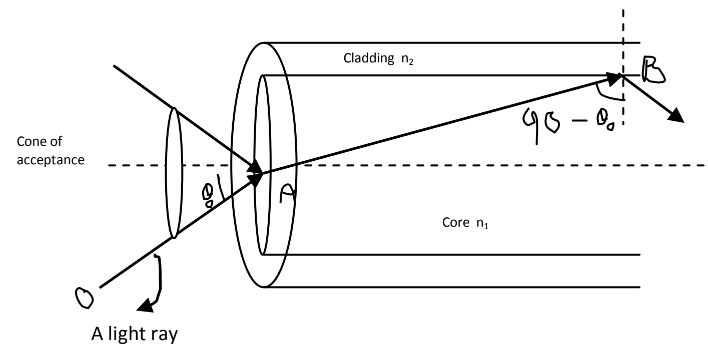
Let n_1 be the refractive index of the core.

Let n_2 be the refractive index of the cladding.

From Snell's Law:

For the ray OA $n_0 \sin\theta_0 = n_1 \sin\theta_1$

$$= n_1(1-\cos^2\theta_1)^{\frac{1}{2}} \quad \text{......................(1)}$$



For the ray AB

$$n_1 \sin(90 - \theta_1) = n_2 \sin 90$$

[here the angle of incidence is $(90 - \theta_1)$ for which angle of refraction is 90^0].

$$n_1 \cos\theta_1 = n_2$$

Substituing for $\cos\theta_1$ in equation (1)

$$n_0 \sin\theta_0 = n_1 \sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\sin\theta_0 = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If the medium surrounding the fibre is air then $n_0 = 1$,

Numerical aperture = $\sin\theta_0 = \sqrt{n_1^2 - n_2^2}$

The total internal reflection will take place only if the angle of incidence $\theta_i < \theta_0$

$$\therefore \sin\theta_i < \sin\theta_0$$

$$\sin\theta_i < \sqrt{n_1^2 - n_2^2}$$

This is the condition for propagation.

6.b.. [3]

Attenuation constant $\alpha = \frac{10}{z}\log\left(\frac{P_{in}}{P_{out}}\right) dB/km$

Here z =3km , α=5dB/km

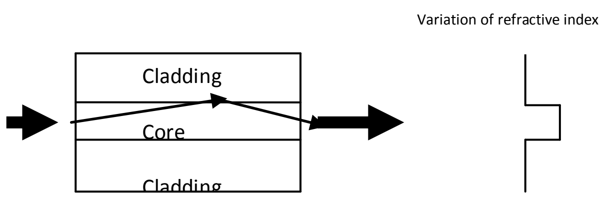
$$\left(\frac{P_{in}}{P_{out}}\right) = 31.62$$

$$P_{out} = 0.031 P_{in}$$

7.a. **Types:** [6]

1. Single mode fiber:

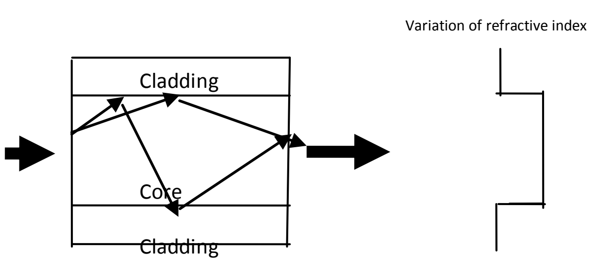
It consists of a core which is made of glass having refractive index n_1.The core is surrounded by a cladding made of glass which is of refractive index n_2 where $n_1 > n_2$.Core diameter is around 5-10 µm. The core is narrow and hence it can guide just a single mode.



- No modal dispersion
- Difference between n_1 & n_2 is less.Critical angle is high. Low numerical aperture.
- Low Attenuation -0.35db/km
- Bandwidth -100GHz

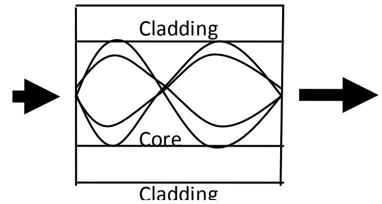
Step index multimode fibre :

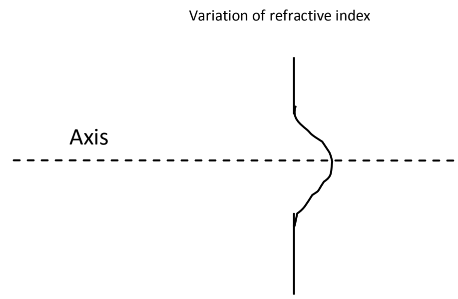
- Here the diameter of core is larger so that large number of rays can propagate. Core diameter is around 50. µm.
- High modal dispersion
- Difference between n_1 & n_2 is high. Low Critical angle. Large numerical aperture.
- Low Attenuation -0.35db/km
- Bandwidth -500MHz
- Allows several modes to propagate



Graded index multimode fiber:

In this type, the refractive index decreases in the radially outward direction from the axis and becomes equal to that of the cladding at the interface.Modes travelling close to the axis move slower where as the modes close to the cladding moce faster.As a result the delay between the modes is reduced. This reduces modal dispersion.





- Low modal dispersion
- High data carrying capacity.
- High cost
- Many modes propagate
- Bandwidth -10GHz

7.b. [4]

Point to point communication system using optical fibers

This system is represented through a block diagram as follows.

The analog information in the form of voice/ picture is converted to electrical signals through the transducers such as microphone.. The analog signal is converted in to binary data with the help of electronic device coder. The binary data in the form of electrical pulses are converted in to pulses of optical power using Semiconductor Laser.. This optical power is fed to the optical fiber. Out of this incident light, only those modes within the angle of acceptance cone will be sustained for propagation by means of total internal reflection. At the receiving end of the fiber, the optical signal is fed in to a photo detector where the signal is converted to pulses of current by a photo diode. Decoder converts the sequence of binary data stream in to an analog signal . Loudspeaker/CRT screen provide information such as voice/ picture.