Fibre optics and optoelectronics

Sub code : 18EC0107T

UNIT - I

Introduction to optical fibers

Evolution of fiber optic systems

1880 – Alexander Graham Bell

1950 – Patent for 2 layer glass WG.

1960 – Laser used as light source. (glass fiber).
↳ attn – 1dB/m

1965 → High loss of light discovered

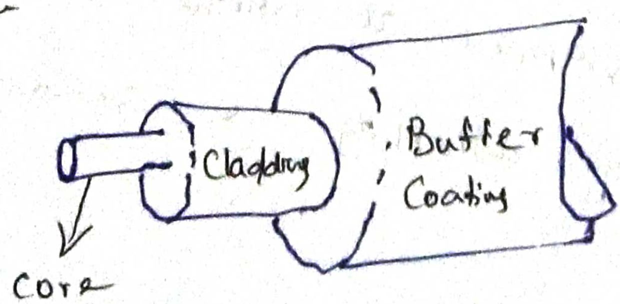
1970 – Refining manufacturing process.

1980 – Tech. becomes backbone for long dist comm.

Optical fiber

– Hair thin cylindrical fiber of glass or any transparent dielectric medium
– To guide visible & infrared light over long distances.

Structure



Core – central tube of very thin size made of optically transparent dielectric medium & carries the light form transmitter to rxer.

dia – 5μm to 100 μm.

Cladding

outer optical material surrounding core having Refractive Index (RI) lower than core. It helps to keep the light within the core throughout the phenomena of Total Internal reflection.

Buffer coating – plastic coating – protects the fiber made of silicon rubber.

dia of fiber after coating – 250–300μm.

Element of optical link

The function of an optical fiber link is to transport a signal from a electronic equipment (eg. a computer, telephone) at one location to corresponding equipment at another location with high degree of reliability & accuracy.

Transmitter

- Consist of light source & associated electronic Circuitry.
- Light source - LED/Laser.

optical fiber

optical fiber is placed inside a cable that offers mechanical & environmental protection.

Receiver Inside the rxer is a photodiode that detects the weakened & distorted optical sld emerging from end of optical fiber & converts in to electric signal.

- It also contains amplification devices.

Passive devices

- optical connectors for connecting cables, splices for attaching one fiber to another, optical isolators to prevent unwanted light from flowing in backward direction; optical filters that select only a narrow spectrum of desired light, couplers to tap off certain % of light.

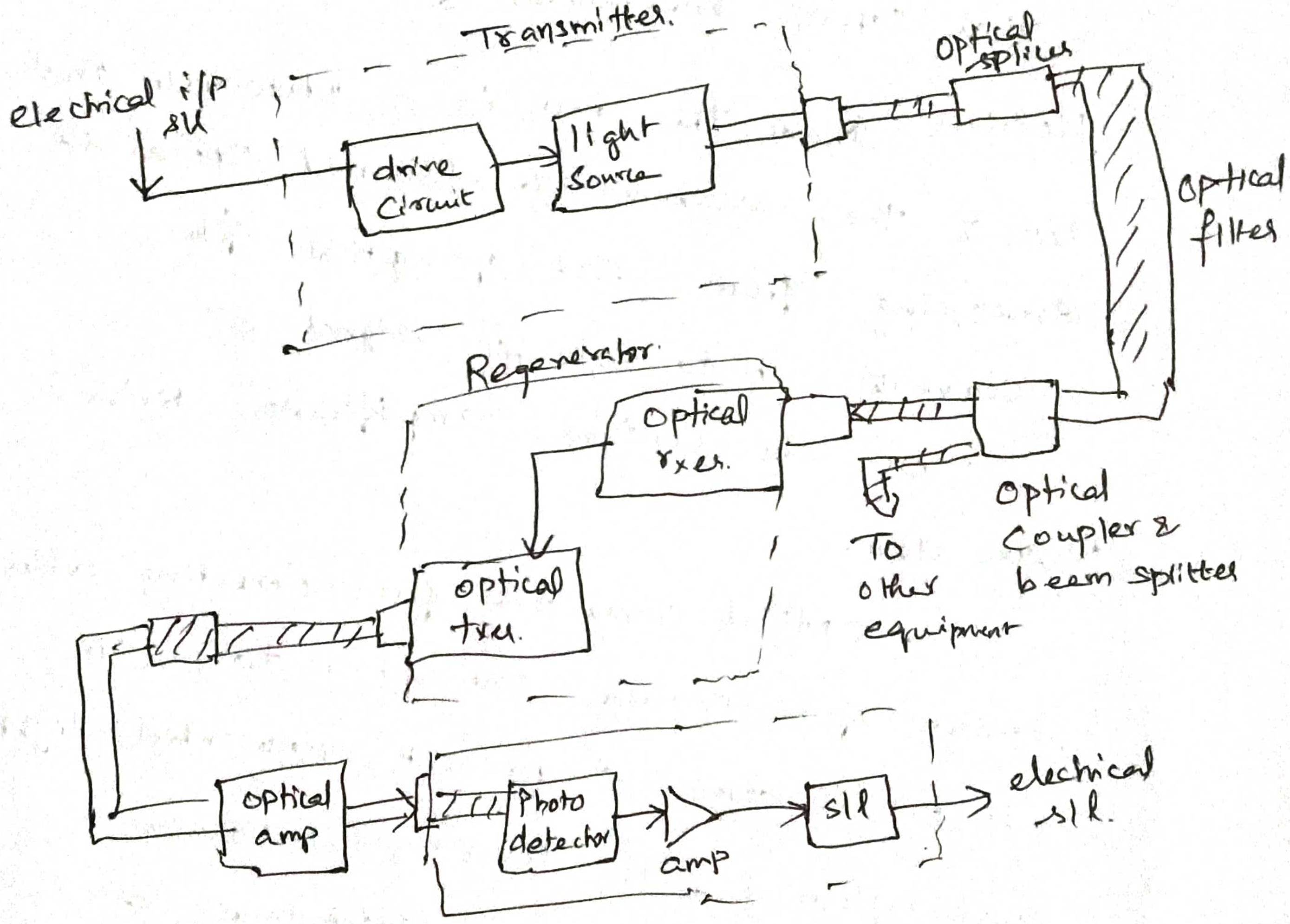
Optical amplifiers

optical s/l becomes weakened due to Power loss after travelling a certain distance.

- amplifiers are required for power boost.

Active components

- Lasers & optical amp.



Advantages of fiber optic system

- Secure communication.
- Electromagnetic Compatability.
  Fiber optic Cabling is resistant to outside forces
- Speed
- Distance.
- Life of fiber is longer than copper wire
- Handling & installation cost is nominal.
- unaffected by electromagnetic interference.
- No ~~prote~~ additional Protection needed.

3. Characteristics & behaviour of light

- Light particles are known as - photons.
- Measure of photon energy - electron volt (ev).
  It is the energy a photon gains when moving through 1-v electric field.
- photons travel in straight lines called rays.

~~rays~~
Ray theory
- Ray theory / geometric optics - rays are used to explain certain light phenomena.

~~Called~~

Concept

It 2 light line up with each other, they Produce a bright spot. If the 2 light waves are 180° out of phase, then they cancel each other.

speed of light

In free space light wave travels at a sped $C = 3 \times 10^8 m/s$

Measuring Properties of light

$C = \lambda \nu$; $\lambda \to$ wavelength, $\nu \to$ freq

$\lambda = c/\nu = \frac{3 \times 10^8 m/s}{\nu}$

Planck's law

$E = h\nu$; $h = 6.63 \times 10^{-34} J.s$
$= 4.14 eV.s$
↳ planck's const.

$h \to$ energy of photon
$\nu \to$ frequency (wavelength.

Refractive Index

The ratio of speed of light in vacuum to that in matter is known as R.I (n)

$n = \frac{c}{s}$; $n =$ 1.00 → air
1.33 → water
1.45 → silica glass
2.42 → diamond.

$C \to$ speed of light in vacuum
$s \to$ speed of light in dielectric / non-conducting medium

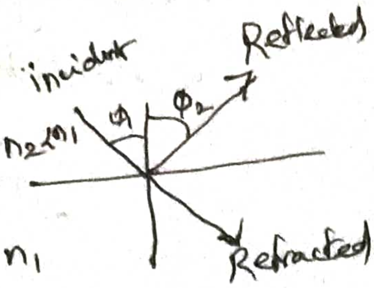
Reflection & Refraction

When a light ray encounters a boundary separating 2 materials that have different Refractive indices, part of ray is reflected to the I^{st} medium & remainder is bent as it enters into second material. $(n_1 > n_2)$

– bending or refraction is a result of difference in speed of light.

Snell's law

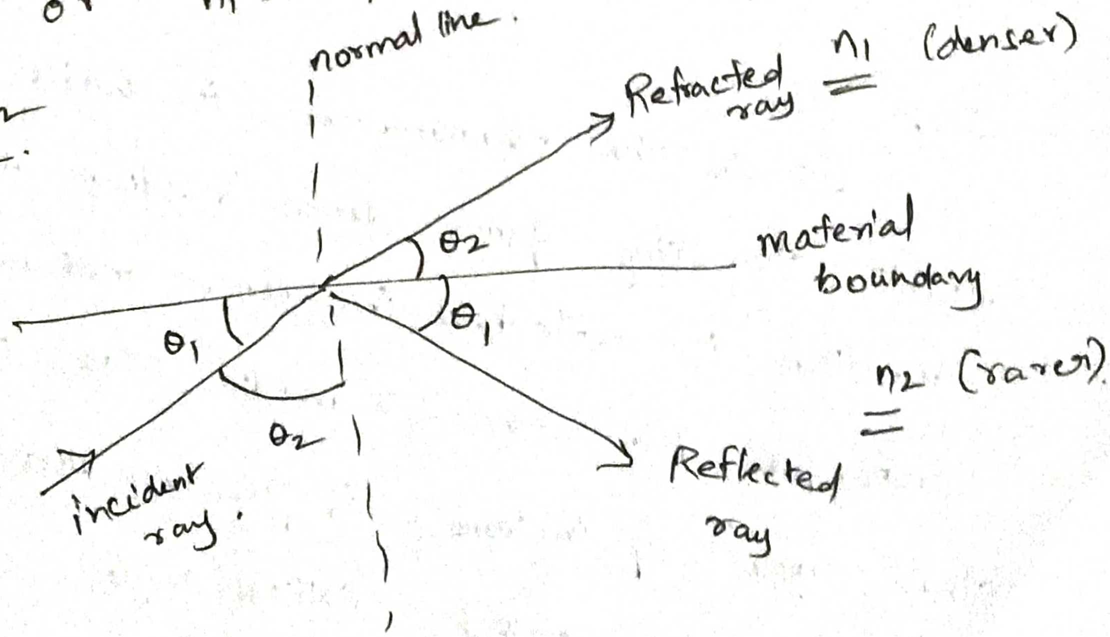
Relationship describing refraction at the interface b/w 2 different light txing material is known as Snell's law



$$n_1 \sin \phi_1 = n_2 \sin \phi_2$$

or $$n_1 \cos \theta_1 = n_2 \cos \theta_2$$

$n_1 > n_2$



4. Total Internal Reflection

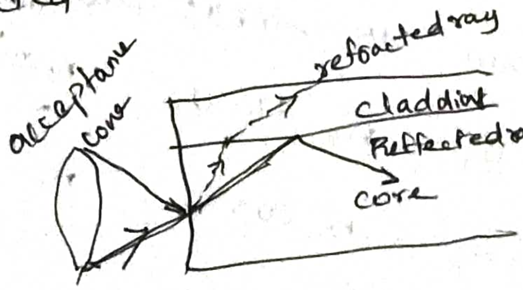
Core R.I → n_1, Cladding → R.I n_2

Core & cladding are made of Silica glass.

- R.I of pure silica varies with wavelength from 1.453 at 850 nm to 1.445 at 1550 nm.

- adding certain impurities such as germanium | boron to silica during manufacturing process. R.I is slightly changed. as an rise in core index.

i.e) $n_2 < n_1$ → Condition reqd for travelling in the core. to be totally internally reflected at the boundary with cladding.



Def:

It is the phenomenon in which a ray of light travelling from denser medium to rarer medium is reflected in denser medium at the interface b/w the 2 media. TIR occurs when the angle of incidence is greater than a certain angle called critical angle.

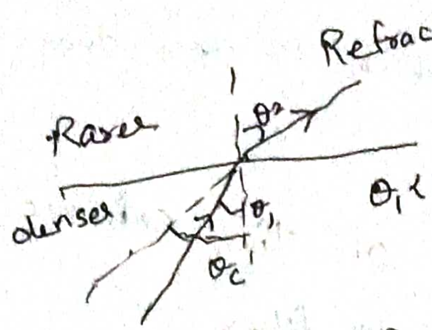
TIR → concept

n_1 = R.I of denser medium $\qquad$ n_2 = R.I of rarer medium

θ_1 = ang. of incidence $\qquad$ θ_2 → angle of refraction

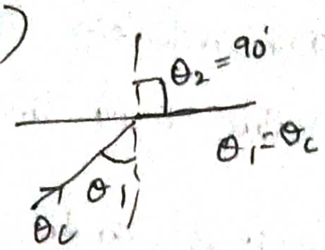
θ_c ⇒ critical angle.

i)



$\theta_1 < \theta_c$

ii)



$\theta_1 = \theta_c$

Snell's law of refrac.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

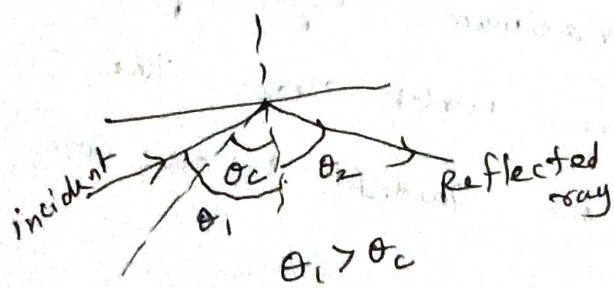
$\theta_2 = 90^\circ$

$n_1 \sin\theta_1 = n_2 \sin 90^\circ$

$n_1 \sin\theta_1 = n_2 \times 1$

$\theta_1 = \theta_c = \arcsin\left(\frac{n_2}{n_1}\right)$

iii) For TIR



$\theta_1 > \theta_c$

Pbm $\quad$ Core index $n_1 = 1.480$, cladding $n_2 = 1.465$

What is critical angle.

$\phi_c = \arcsin(1.465/1.480) = 82^\circ$

$\theta_c = \pi/2 - \phi_c = 8^\circ$

Numerical aperture

- Light acceptance or gathering capability of fibers that have core size much larger than a wavelength.

- Dimensionless quantity which is less than unity. Value 0.14 to 0.50

Def: Critical angle condition on the entrance angle defines (NA) of step index fiber.

$$NA = n \sin \theta_{0,max} = n_1 \sin \theta_c = (n_1^2 - n_2^2)^{1/2}$$

$$\simeq n_1 \sqrt{2\Delta}$$

$\Delta \Rightarrow$ Core - cladding index diff.

Acceptance angle

It is the maximum angle of a ray hitting the fiber core which allows the incident light to be guided by the core.

Types of rays

1. Meridional ray
2. Skew rays.

Meridional ray

Rays that pass through the axis of the optical fiber.

Skew ray

Rays that travels in a non-planar zig-zag path and never crosses the axis of an optical fiber.

Optical Fiber Modes

Single mode fiber

when fiber core diameter is on the order of 8 to 10μm, which is only few times the value of wavelength, only one single fundamental ray that travels straight along the axis is allowed to propagate in a fiber.

Multimode fiber

Fibers with larger core diameters (50μm) support many propagating rays/modes.

Single mode fibers

Cut off wavelength ($\lambda_{cut\ off}$)

Smallest wavelength for which all fiber modes except the fundamental mode are cut off.

i.e) Fiber transmits light in a single mode only for those wavelengths that are greater than $\lambda_{cut\ off}$.

$$\lambda_{cut\ off} = \frac{2\pi a}{2.405} (n_1^2 - n_2^2)^{1/2}$$

$a \rightarrow$ radius of fiber core

$n_1 \rightarrow$ core index

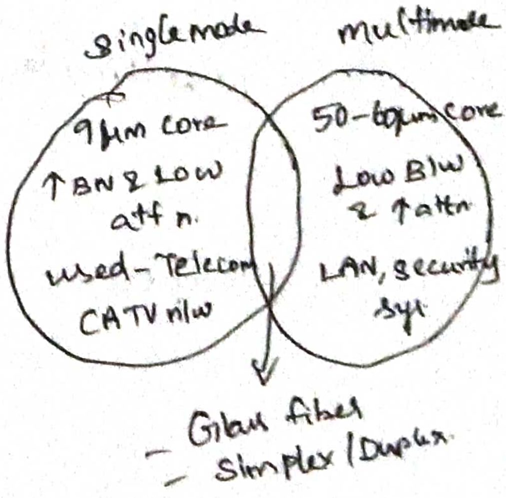
$n_2 \rightarrow$ cladding index

Multimode fibers

- used in LAN environments, storage area n/w & central office connections.
- Short distance communication.
- low cost transmission.

Types of Fiber

- Step Index fiber
- Graded Index fiber



Step Index fiber

R.I of the core is uniform throughout & undergoes an abrupt change at Cladding boundary.

Graded Index

The core R.I varies as a fn of radial distance from the center of the fiber.