UNIT-II

OPTICAL SOURCES AND COMPONENTS

ELECTROLUMINESCENCE:

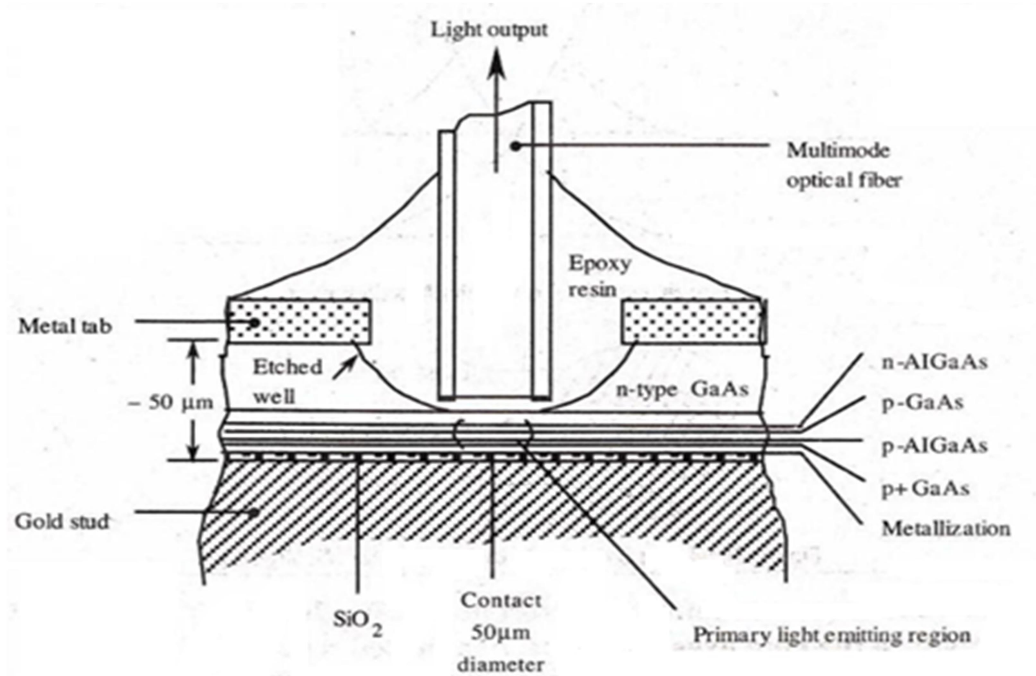
Electroluminescence is the result of Radiative recombination of Electrons sand holes in a material, usually a semiconductor. The excited electrons release their energy as photons - light. Prior to recombination, electrons and holes may be separated either by doping the material to form a p-n junction (in semiconductor electroluminescent devices such as or through excitation by impact of high-energy electrons accelerated by a strong electric field (as with the phosphors in electroluminescent displays).

It has been recently shown that as a solar cell improves its light-to-electricity efficiency (improved open-circuit voltage), it will also improve its electricity-to-light (EL) efficiency

High radiance surface emitting LED:

High radiance is obtained by restricting the emission to a small active region within the device. A well is etched in a substrate (GaAs) to avoid the heavy absorption of the emitter radiation and to accommodate the fiber. These structures have a low thermal impedance in the active region and hence radiance emission into the fiber. Double hetero structures are used to get increased efficiency and less optical absorption. The structure of a high radiance etched well DH

Double Hetero structure-surface emitter which is also known as burrus type LED is as shown



The Sturucture of an AlGaAs DH surface - Emitted LED(Burrus Type)

This structure emits light in band of 0.8 to 0.9 um wavelength. The plane of the active light emitting region is made perpendicular to the fiber axis. The fiber is cemented in a well matched through the substrate of the fiber so that maximum emitted light is coupled to the fiber. Due to large band gap conjoining area, the internal absorption is less and the reflection coefficient at the back crystal face is high, hence forward radiance is good. The active area in circle is of 50μm in diameter and up to 2.5μm thick. The emission from this active area is isotropic with 120° half power beam width is used for practical purpose. Isotropic pattern from a surface emitter is lambertian pattern.

The source is equally bright when viewed from any direction but power diminishes as $\cos\Phi$ where \$ is the angle between viewing direction and to the normal to the surface. Power is down to 50%, when $\Phi = 60°$, so that the total half power beam width is 120°. The power coupled into a multimode step index fiber may be estimated from the relationship.

$$P_C = \Pi(1-r)AR_D\,(NA)^2 \qquad ..(1)$$

Where, P_C = Power coupled into fiber

r = Fresnel reflection coefficient

A = Emission area of source

R_D = Radiance of the source

NA = Numerical aperture

Power coupled into the fiber depends on

(i) Distance and alignment between emission area and the fiber.

(ii) Medium between the emitting area and the fiber.

(iii) Emission pattern of SLED

Addition of Epoxy resin in the etched well reduces the refractive index mismatch and increases the external power efficiency of the device. Hence the power coupled in the double hetero structure surface emitters are more than P_c(optical power) that is given by equation (1), For graded index fiber-direct coupling requires the source diameter of about one half the fiber core diameter

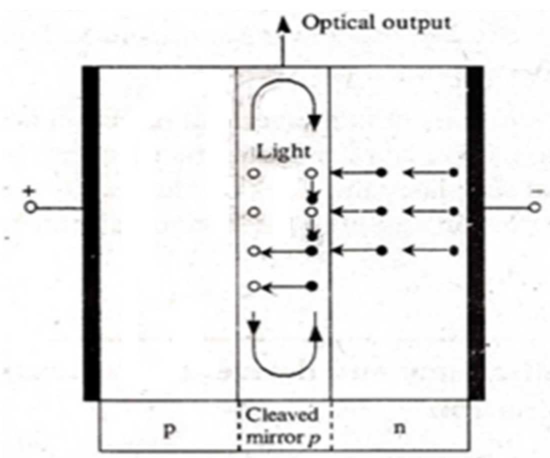
Edge emitting double hetero junction LED : If a single p-n junction diode is fabricated from suitable single crystal semiconductor material it exhibits photo emissive properties. It is known as 'homo junction' p-n diode. However the emissive properties of a junction diode can be improved considerably by the use of 'hetero junction'. A hetero junction is an interface between two adjoining crystal semiconductors having different values of band gap energies. Devices are fabricated with hetero junction are said to have hetero structures.

They are of two types,

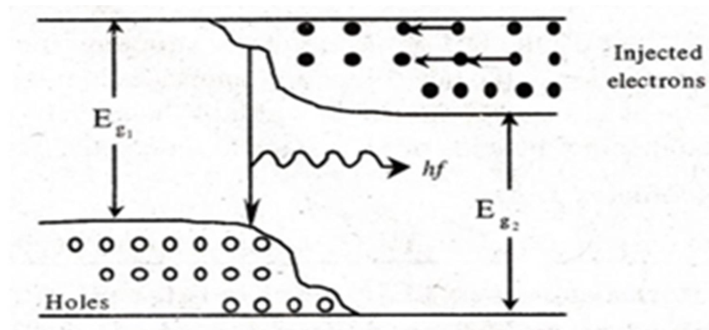
(i) Isotopes such as n-n or p-p type

(ii) Anisotope such as p-n type.

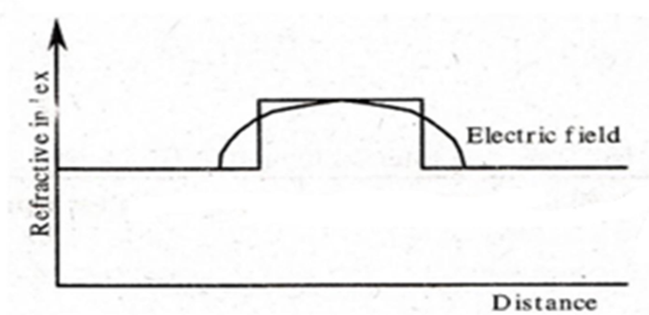
The isotope p-p junction has a potential barrier within the structure. The structure is capable of confining min carriers to small active region called cavity. It effectively reduces the diffusion length of the carrier and thus the volume of the structure where radioactive recombination may occur.



Layer Structure



Energy Band Diagram



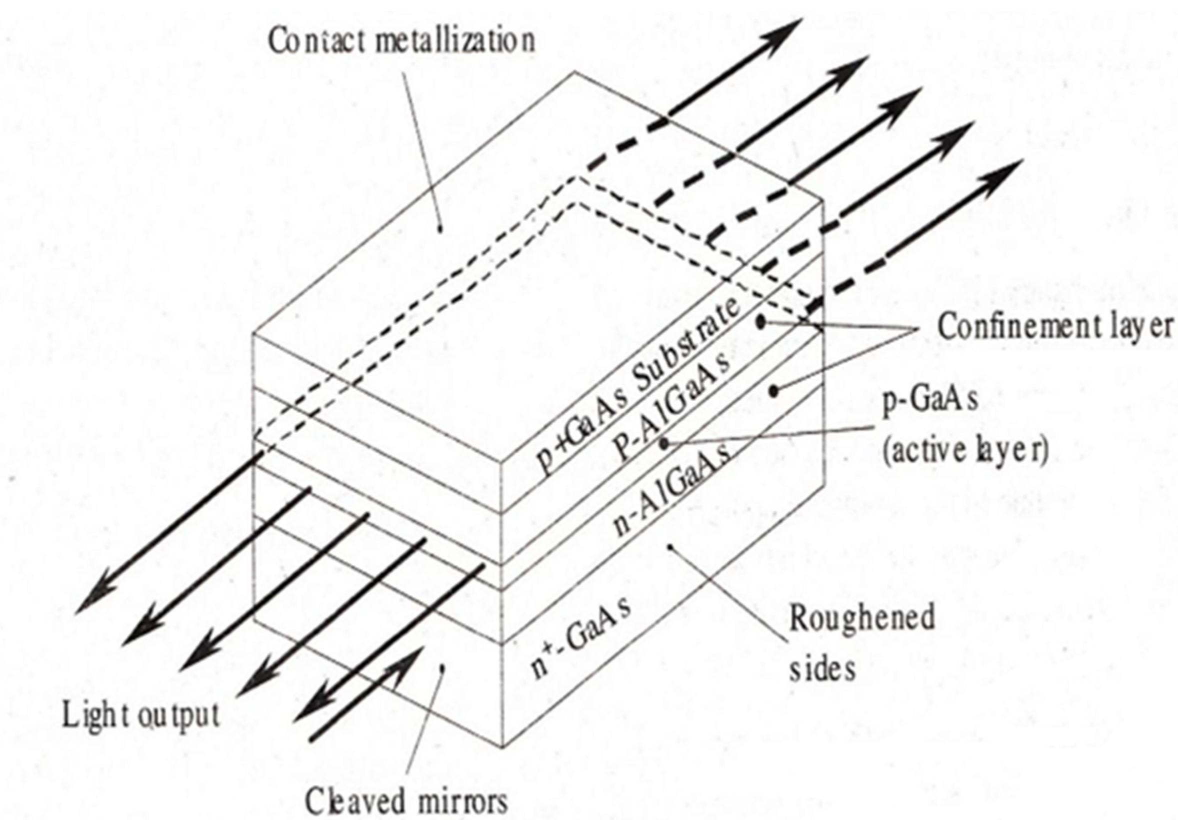
Refractive index Profile and Electric field distribution

Figures show the schematic layer structure, energy band diagram and refractive index profile, for a double hetero junction injection laser diode with biasing. The laser oscillations take place in the central p-type GaAs region which is known as active layer.

There is hetero junction at the both sides of the active layer. A forward bias voltage is applied by connecting the positive electrode of the power supply voltage to the P-side of the structure and negative electrode to the n-side when a voltage which is almost equal to the band gap energy. The hetero junctions are used to provide potential barrier in the injection laser. In this structure it is possible to obtain both carrier and optical containment to the active laye

LASERS AND THEIR EXCITATIONS:

Broad Area Double Heterojunction Laser (DH Laser):



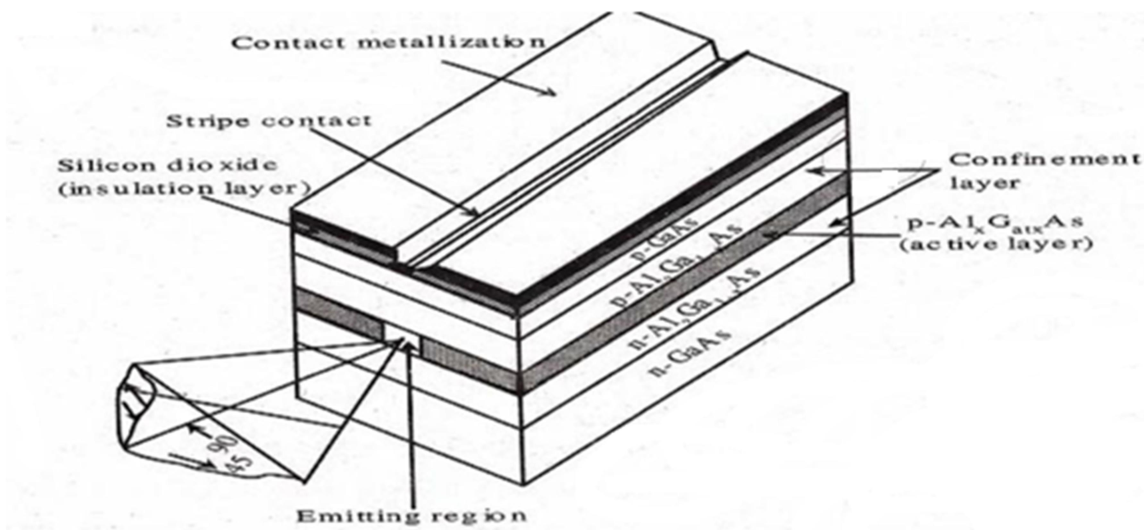
The layered structure of a Based Area GaAs/GaAs DH injection laser

The above figure represents the layer structure of a broad area DH. The GaAs layers acts as active layer which is sandwiched between p-type AZGaAs and n-A/GaAs layer and these two layers act as the confinement layers. Light is emitted from the central GaAs active layer through the front and back side of the device.

In the case of the DH broad area laser structure, the optical confinement in the vertical direction is achieved by the refractive index at the hetero junction interfaces between the active layer and the containment layers, but the laser .action takes places across the whole width of the device. In a broad area laser the sides of the cavity are formed by simple roughening the ends of the device to reduce the unwanted emission and limit the horizontal transverse modes.

Stripe Geometry Laser

In order to overcome the difficulties in a broad area laser structure, the stripe geometry laser structure has developed and in this structure the active area does not enter upto the edges of the device.



The Stucture of Strips Geometry Laser

A common method is used to introduce the stripe geometry to the structure which provides the optical contaminant in the horizontal plane as shown in the figure above. The stripe geometry is usually formed by creating a high resistance area on either side of the stripe by 'Proton bombardment' technique or by oxide oscillation. The stripe usually acts as a guiding mechanism which avoids all major difficulties encountered in the case of a broad area laser. The contact stripe provides the balance of guiding single transverse mode operation in a direction parallel to the junction plane, whereas broad area devices allow multiple mode operation in this horizontal plane. The width of the stripe generally ranges from 2.0 to 65 mm and stripe laser find wide application in fiber communications.

FIBER SPLICES AND CONNECTORS:

Connectors are mechanisms or techniques used to join an optical fiber to another fiber or to a fiber optic component.

Different connectors with different characteristics, advantages and disadvantages and performance parameters are available. Suitable connector is chosen as per the requirement and cost

Various fiber optic connectors from different manufacturers are available SMA 906, ST, Biconic, FC, D4, HMS-10, SC, FDDI, ESCON, EC/RACE,

Principles of good connector design

1. Low coupling loss.
2. Inter-changeability.
3. Ease of assembly.
4. Low environmental sensitivity.
5. Low cost.
6. Reliable operation.
7. Ease of connection.

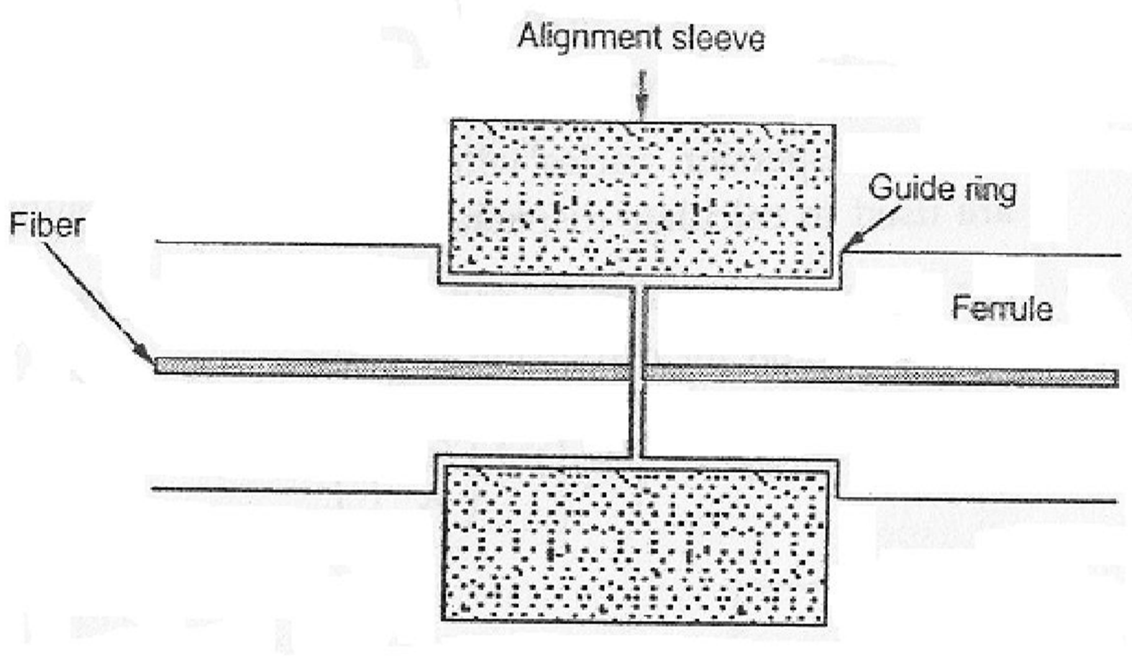
Connector Types Connectors use variety of techniques for coupling such as screw on, bayonet-mount, push-pull configurations, butt joint and expanded beam fiber connectors.

Butt Joint Connectors

Fiber is epoxies into precision hole and ferrules arc used for each fiber. The fibers are secured in a precision alignment sleeve. Butt joints are used for single mode as well as for multimode fiber systems. Two commonly used butt-joint alignment designs are:

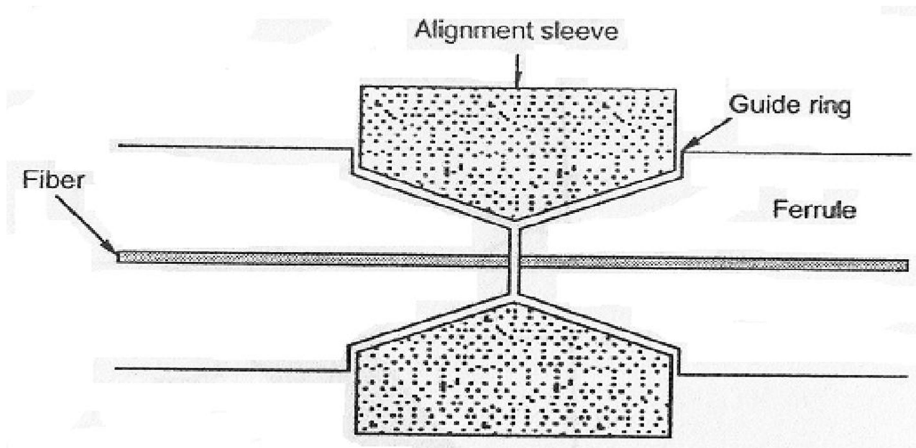
1. Straight-Sleeve.
2. Tapered-Sleeve/Bi conical.

In straight sleeve mechanism, the length of the sleeve and guided ferrules determines the end separation of two fibers. Below Fig. shows straight sleeve alignment mechanism of fiber optic connectors



Straight sleeve connector

In tapered sleeve or bi conical connector mechanism, a tapered sleeve is used to accommodate tapered ferrules. The fiber end separations are determined by sleeve length and guide rings. The below figure shows tapered sleeve fiber connectors



Tapered sleeve connector

LED SPLICING:

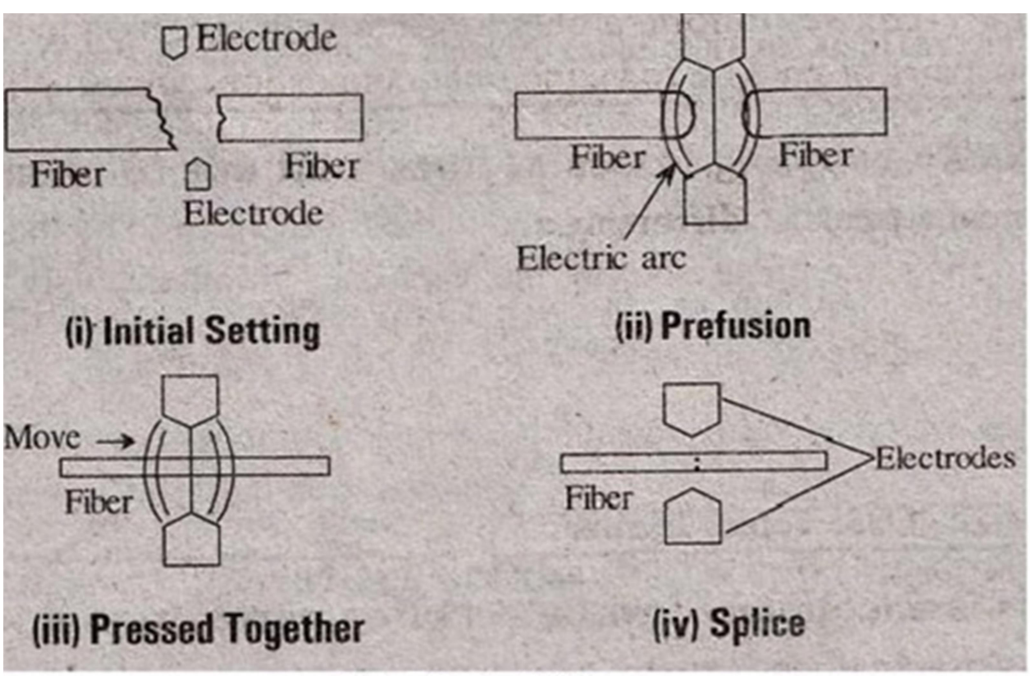
A permanent joint formed between two individual optical fibers in the field is known as splicing. The fiber splicing is used to establish optical fiber links, where smaller fiber lengths are needed to be joined and where there is no requirement for repeated connection and disconnection.

Splicing can be divided into two broad categories depending on the splicing technique utilized. These are fusion-splicing, mechanical or welding splicing.

Fusion Splicing

Fusion splicing of single fibers involves the heating of the two prepared fiber ends to their fusing point with sufficient axial pressure between the two optical fibers. It is essential that the stripped fiber ends are adequately positioned and clamped with the aid of inspection microscope.

The most widely used heating technique is an electric arc. This technique offers advantage of consistent, easily controlled heat with adaptability for use under field conditions.The welding of 2 fibers can be shown as illustrated in the following figure



Fusion Splicing

LED COUPLNG TO SINGLE MODE FIBERS:

The major factor in any fiber optic system is the requirement to interconnect fibers in a low loss manner. These interconnections occur in three stages namely.

1. At the optical source
2. At the photo detector
3. At intermediate points.

1. Optical Sources

The optical sources such as Light Emitting Diodes (LEDs), Solid state lasers and semiconductor injection lasers are used because of their efficiency, low cost, longer life, sufficient power output, compatibility and ability to give desired modulations.

2. Photo Detectors

Photo detectors such as semiconductor photodiodes are used because of their high quantum efficiency, adequate frequency response, low dark current and low signal impedance.

3. Intermediate Points

The two fibers are joined at intermediate points with two cables within a cable.

The two major methods for the interconnection of fibers in a low loss manner are as follows,

(i) Fiber Splices

(ii) Simple Connectors.

(i) Fiber splices

In this, the fiber splices are the semi permanent (or) permanent joints which are mostly used for interconnection in optic-telecommunication system.

(ii) Simple Connectors

Simple connectors are the removable joints which allow easy, fast manual coupling of fibers.

We can say that losses in interconnection of two fibers depend on factors like input power distribution to joints, length of fiber between optical source and joint, wave characteristics of two fibers at joint and fiber end face qualities.

If these factors are satisfied low-loss in the interconnection of two fibers is achieved.

FIBER NOISE- TO -FIBER JOINTS:

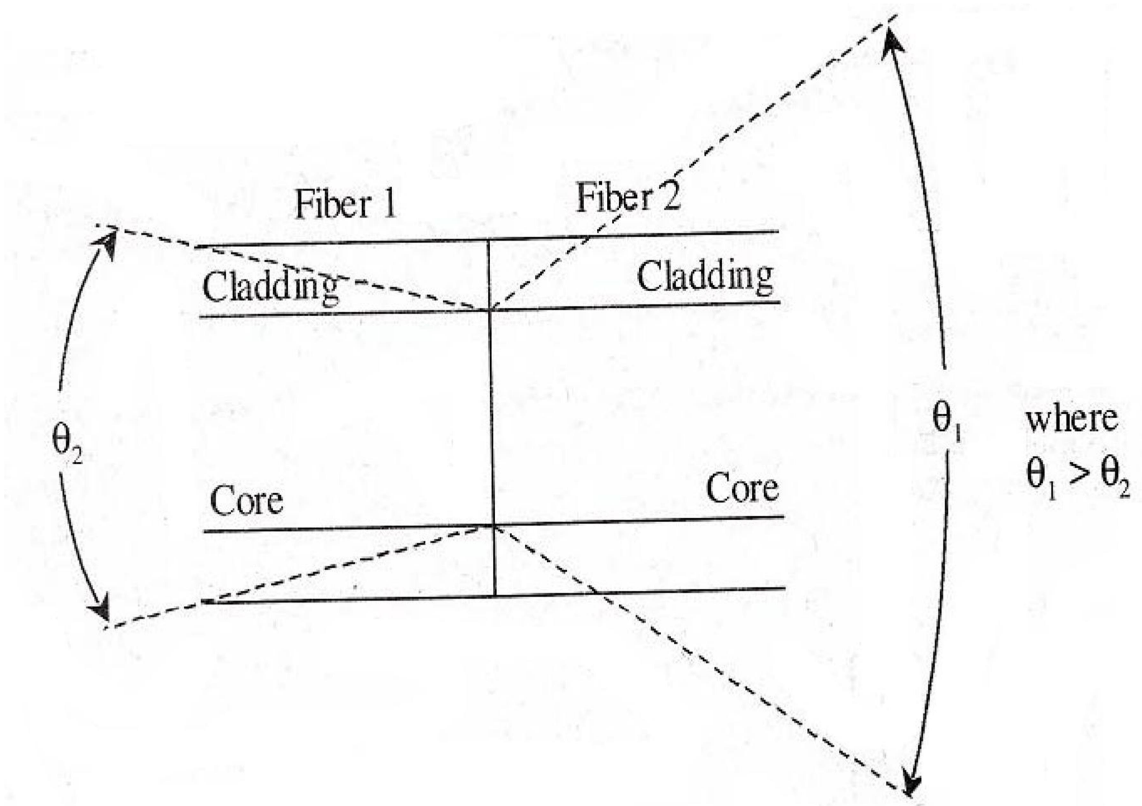
When an optical fiber communication link is established, interconnections occur at the optical source, at the photo detector, at intermediate points within a cable where two fibers are joined and at intermediate points in a link where two cables are connected. If the interconnection is permanent bound then it is generally referred to as splicing whereas a demountable joint is known as connector. At every joint optical power loss takes place depending on input power distribution to the joint, the length of the fiber between the optical source and the joint, the geometrical and waveguide characteristics of the two fiber ends at the joint and the fiber end face qualities. These losses are classified into (i) Intrinsic losses (ii) Extrinsic losses and (iii) Reflection loss.

(i) Intrinsic Losses

Intrinsic losses occur when a mismatch occurs between two connecting fibers. Mismatch occurs when fiber's mechanical dimensions are out of tolerance limit. The mismatch can occur due to the following.

(a) Core-Diameter Mismatch

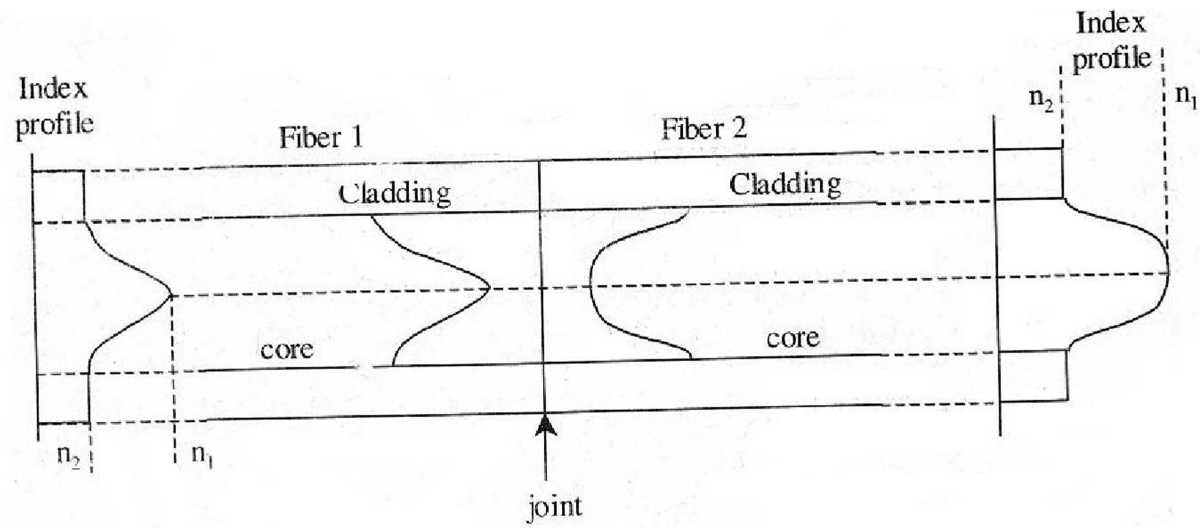
If the core of two joining, fibers has different diameter then core-diameter mismatch occurs. The loss will be more if the light is travelling from larger core into a smaller core than if it is in reverse direction.



Numerical Aperature Mismatch

Mode-Field-Diameter (MFD) Mismatch or Refractive Index Profile (α) Mismatch:

This loss takes place only in graded-index fiber where the index profile emitting fiber is different from the index profile of receiving fiber.



Mode Field Diameter Mismatch

2

$$LOSS_{NA} = -10\log \left[\left(\frac{NA_2}{NA_1}\right)^2\right]$$

The loss due to MFD is given by

$$LOSS_{MFD} = -10\log\left[\frac{\alpha_1(\alpha_1+\alpha)}{\alpha_2(\alpha_2+\alpha)}\right]$$

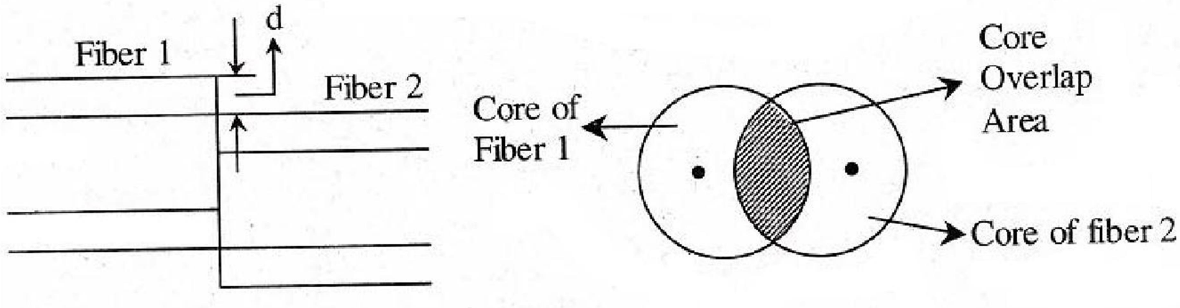
Where α_1= index profile of fiber 1 α_2 = index profile of fiber

(ii) Extrinsic Losses

Extrinsic losses occur due to mechanical misalignment at point of joints. They are,

(a) Lateral Misalignment

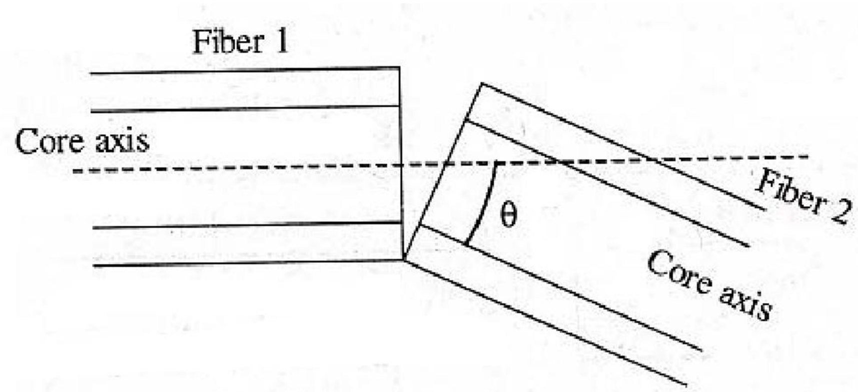
This misalignment occurs when the, fibers are displaced along the face of fiber and hence the core overlapping area is reduced from circular to elliptical form hence power loss from emitting fiber to the receiving is given below,



Lateral MisAlignment

b) Angular Misalignment

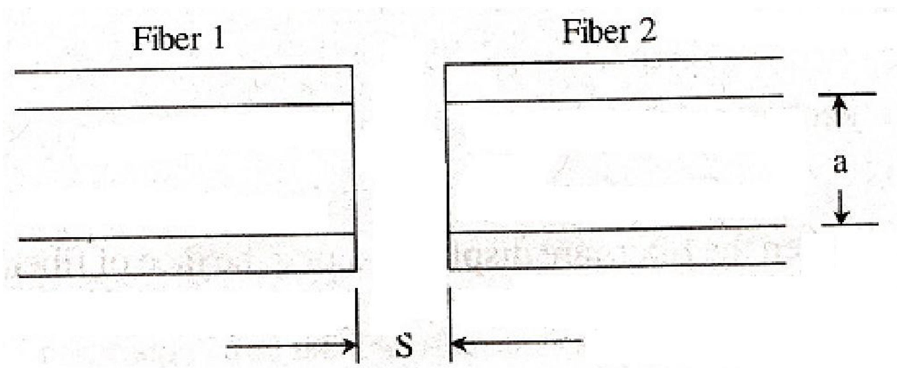
For a perfectly matched fiber, if point of joint at which core axis of fiber 1 is at an angle with the core axis of fiber 2 then angular misalignment occurs and the result is same as due to numerical aperture mismatch.



Angular Misalignment

(c)End separation Misalignment

When two fibers are separated longitudinally by a gap of ‘S’ between them ,then longitudinal end separation misalignment occurs.



End separation mis alignment

(iii) Reflection Loss

At the surface of contact some light will be reflected back. This is called Fresnel reflection. This reflection changes the amount of power transmitted towards a receiver. The loss caused by reflection is called Fresnel loss. If the transmitted power is P_{tran} and input power at the source is P_{in} and reflected power is P_{ref} then they are related by,

Hence reflection loss isgiven by,

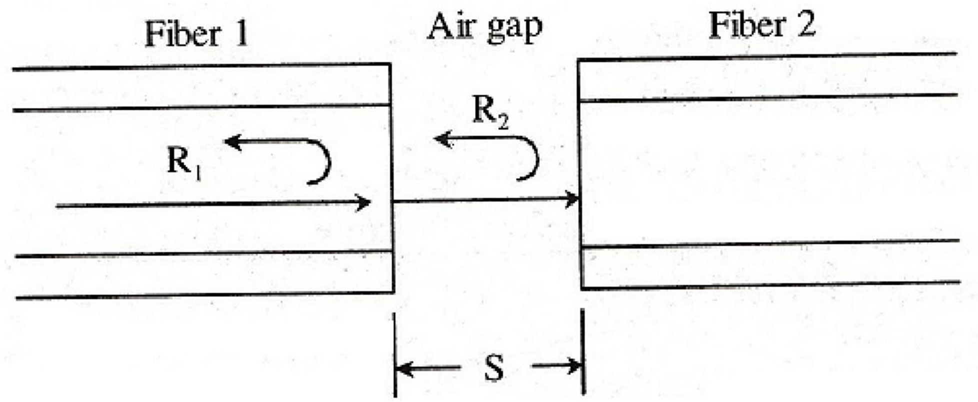
$$Ptrans = Pin - Pref$$

Hence reflection loss is given by,

LOSS(Fresnel) $\frac{4n_1 n_2}{(n_1+n_2)^2}$

or for 2 interface reflections, $LOSS_{(Fresnel)} = -10\log(1-R)$

Where $R = R_1 + R_2 - 2\sqrt{R_1R_2}\cos(4\Pi/\lambda)$ S = The separation between two fiber. R = Total reflection. R_1 and R_2 are reflections at two interfaces



Reflection Losses