Section - B

Lecture 7

Optical Fibers & Cables

Connectors

OPT FIBERS & CABLES

- Opt. Fibers should have stable transmission characteristics over longer lengths
- Range of fibers should be available to suit different system applications
- Fibers may be converted into practical cables and should be easy to handle without any degradation or damage
- Ease of connecting and joining the cables in field

Preparation of Cables

- -Scattering centres such as bubbles, strains and grain boundaries should be avoided
- -Ref index is varied by suitable doping with another compatible material
- -Glasses exhibit the best overall material characteristics for use in fabrication of low loss OFC
- -Glass is processed in molten state
- -Vapour-phase deposition method produces silica rich glasses(very high melting temp)

OPTICAL FIBRE STRUCTURES

a) **MULTI-MODE STEP INDEX FIBER**

b) MULTI-MODE GRADED INDEX FIBER

c) SINGLE-MODE STEP INDEX FIBER

d) PLASTIC CLAD SILICA FIBERS

e) ALL PLASTIC FIBERS

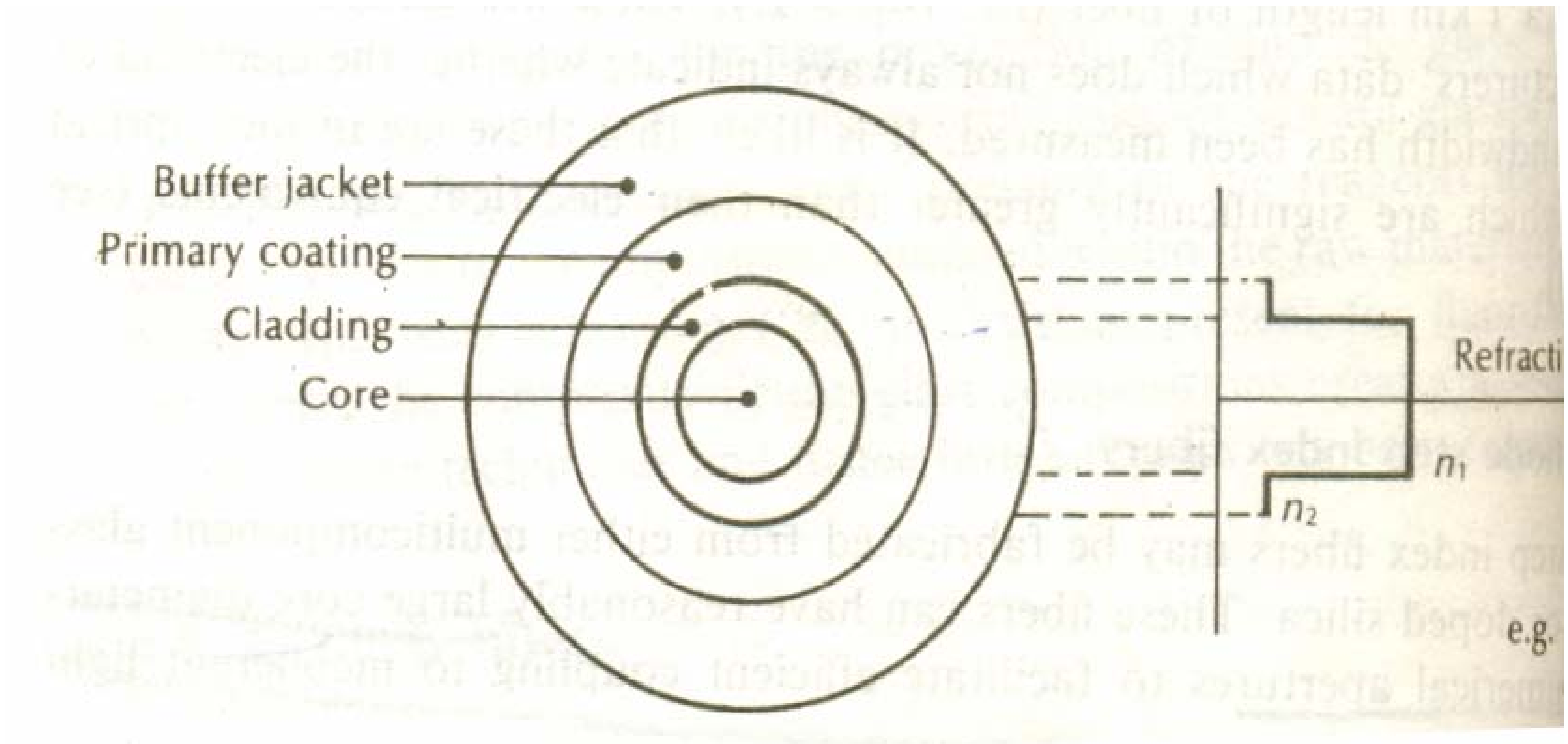
Three major wavelength regions

0.8 to 0.9 μm

1.3 μm

1.55 μm

MULTIMODE STEP INDEX FIBERS



MULTIMODE STEP INDEX FIBERS(contd)

Material– multicomponent glass compounds or doped silica

Attenuation :2.6 to 50 dB /km at 0.85 µm (λ)

The wide variation in attenuation is due to diff. preparation methods .

Attenuation is 40 db/km at 0.85 µm (λ) 0.4dB /km at 1.3µm (λ) for silica fibers.

BANDWIDTH: 6 to 50 MHZ km.

Applications: best suited for short haul, limited BW and low cost applications

MULTIMODE STEP INDEX FIBERS(contd)

- n1=1.48,   n 2=1.45

- Core dia : : 50 to 400 μm
- Cladding dia : 125 to 500 μm
- Buffer jacket dia : 250 to 1000 μm
- NA : 0.16 to 0.5

MULITI MODE GRADED INDEX FIBERS

- MATERIAL FOR FABICATION :MULTICOMPONENT GLASS or DOPED SILICA
- **Materials used are of high purity** (than in SI fiber) to reduce fiber losses
- Hence these fibers exhibit better performance characteristics and lower attenuation .
- Core dia is normally smaller than that of step index fiber
- STRUCTURE : core dia: 30 to 100 μm

  : cladding dia: 100 to 150 μm

  : Buffer jacket dia : 250 to 1000 μm

  :Num aperture: 0.2 to 0.3

MULTI MODE GRADER INDEX FIBERS (contd)

Major groups available: (core –cladding dia)

50μm /125μm, 62.5μm / 125μm

85μm /125 μm 100μm / 125μm

Wave length range : (0.85-1.3 μm)

PERFORMANCE CHARACTERISTICS:

ATTENUATION: 2 to 10 db / km at 0.85μm (λ)

0.4db / km at 1.3 μm (λ)

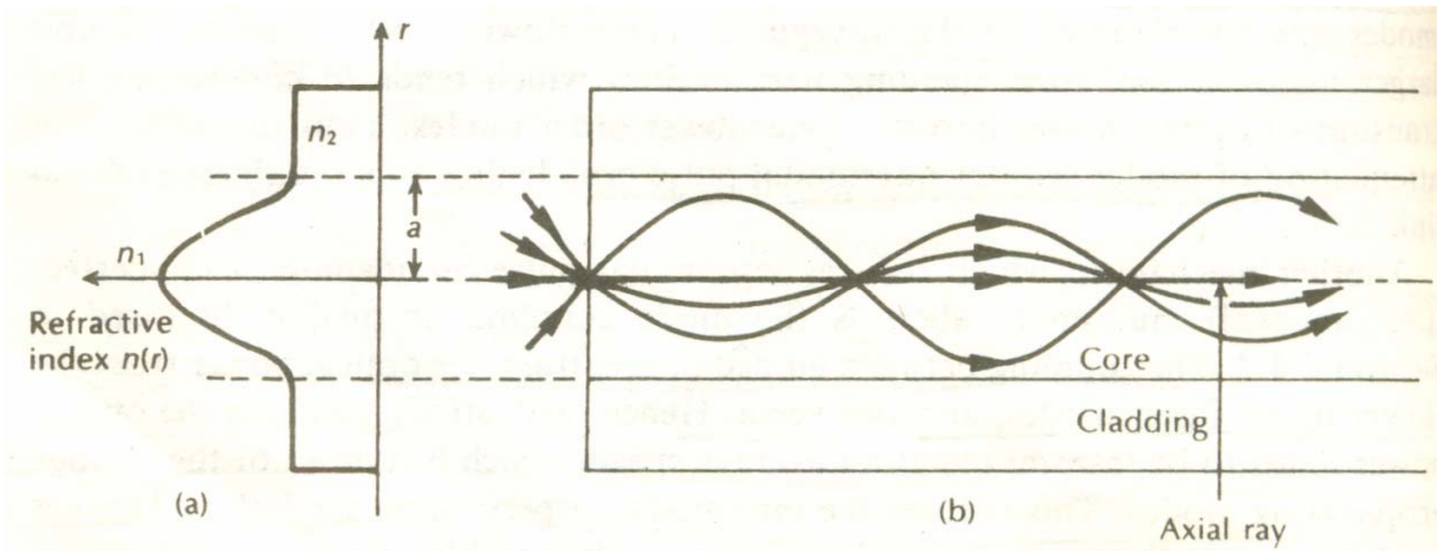
0.25 db / km at 1.55 μm (λ)

Bandwidth (BW): 300 MHz km to 3 GHz km

APPLICATION: best suited for medium haul, medium to high BW applications using LED & injection laser resp.

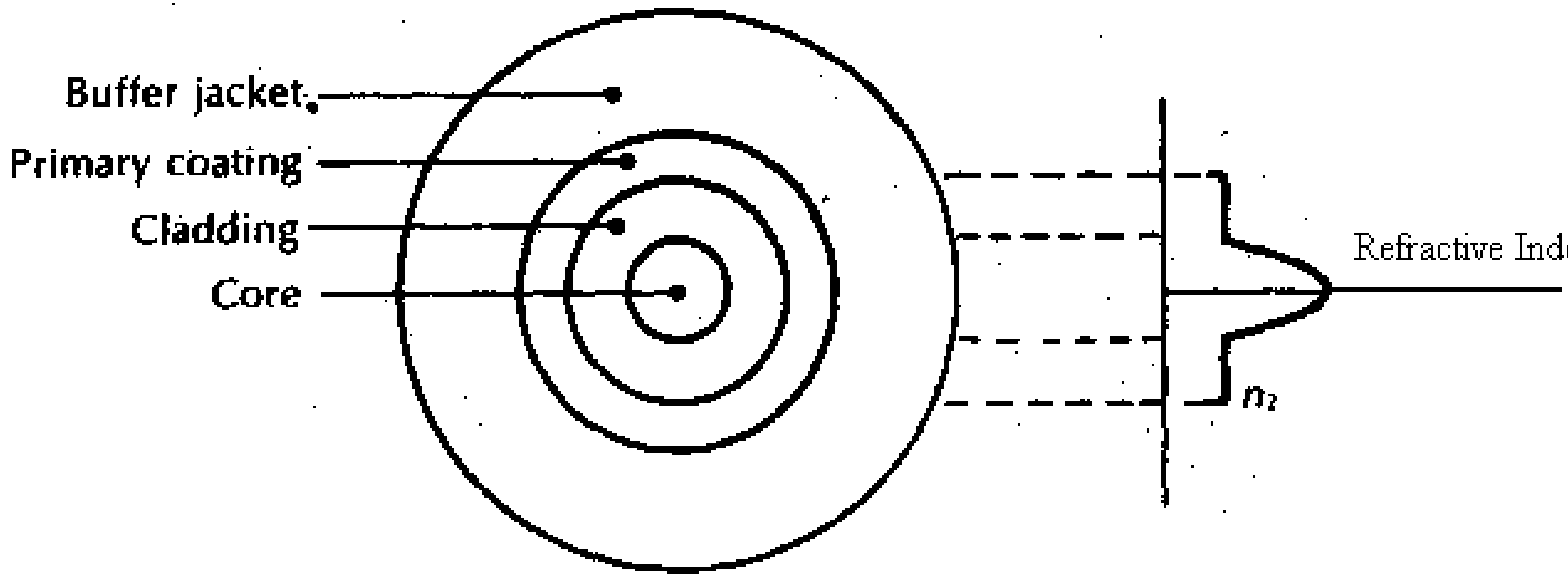
MULTIMODE GI FIBER(contd)

- The gradual decrease in ref index from the centre of the core ,creates many refractions of the rays .(High to low ref. index)



A multimode graded index fiber: (a) parabolic refractive index profile; (b) meridional ray paths within the fiber core.

GRADED INDEX FIBER (contd)



GRADED INDEX FIBER (contd)

MMGI fibers exhibit far less intermodal dispersion than MMSI fibers, due to their ref .index profile.

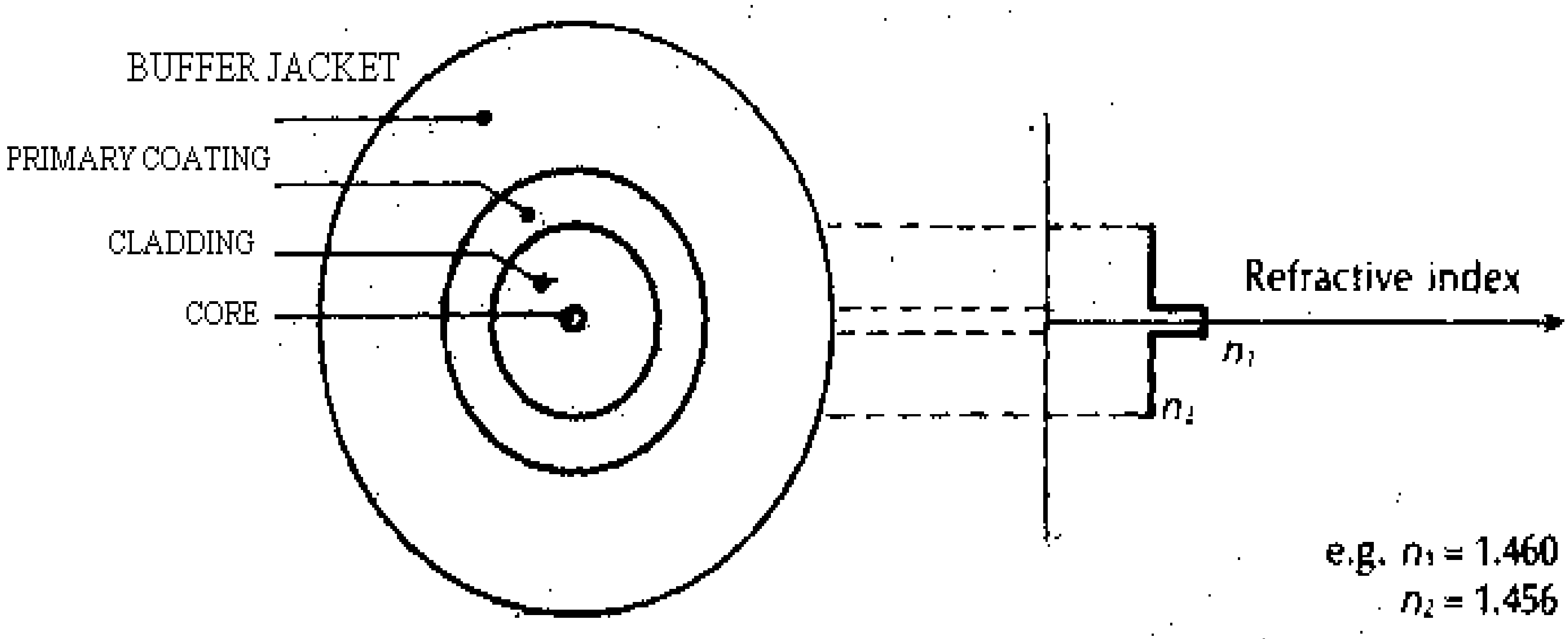
The diff. group velocities (of diff modes) tend to be normalizd by index grading.

Rays closer to the fiber axis have shorter paths when compared with rays travelling into the outer regions of the core

Nearer to axis, rays have lower velocity (travelling thr higher index) than more extreme rays. This compensates for shorter paths and reduces dispersion in the fiber.

Hence higher transmission BW^s than multimode step index fiber are available.

SINGLE MODE FIBERS



SINGLE MODE FIBERS

Commercially available single mode fibers are usually step index , as graded index type is expensive.

Material for fabrication: doped silica.

(in order to reduce attenuation)

Core dia is quite small . (**cladding dia must be at least 10 times the core dia. to avoid losses** (evanescent field)

Overall dia is similar to multimode fiber .

STRUCTURE: Core dia: 5 to 10 µm (typically 8.5 µm)

Cladding dia : 125 µm

Buffer jacket dia: 250 to 1000 µm

Num. Aperture: 0.08 TO O.15 (0.10 typically)

$n1= 1.46$, $n 2= 1.456$.

SINGLE MODE FIBER (contd)

Performance characteristics:

Attenuation: 2 to 5 db/km (0.85 µm λ)

0.35 db/km (1.3 µm λ)

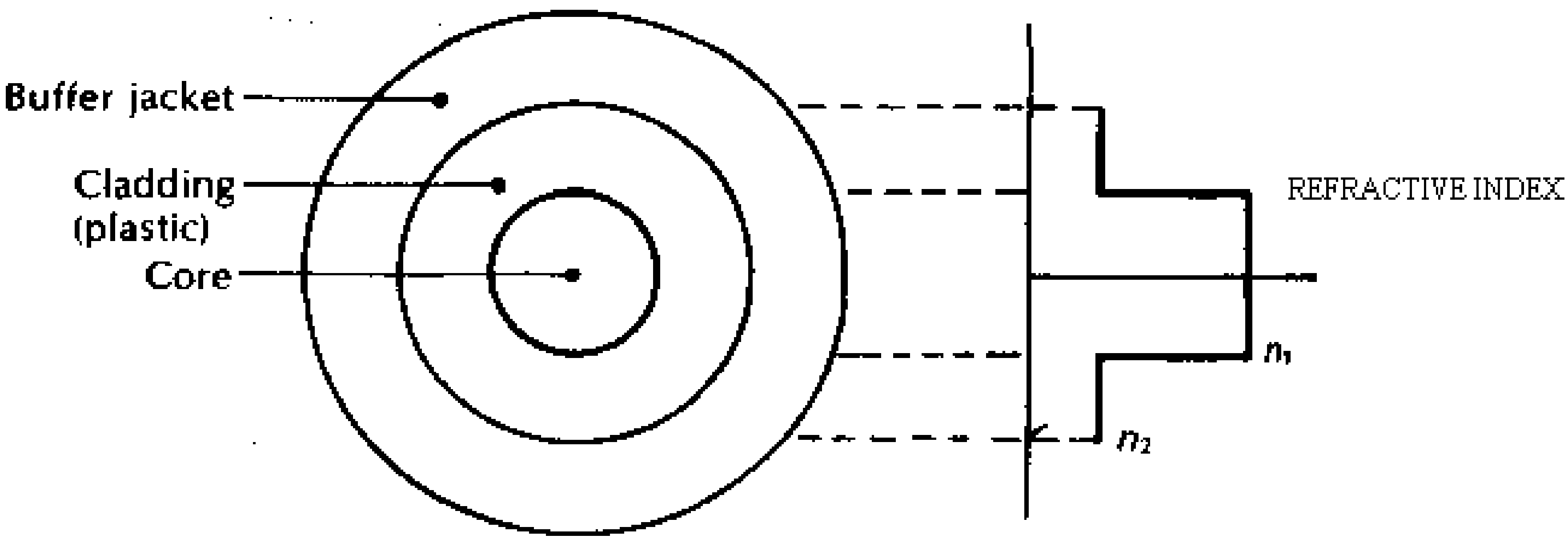
0.21 db/km (1.55 µm λ)

Band width : > 500 MHz km

Practical BW >10GHz km at 1.3 µm (λ)

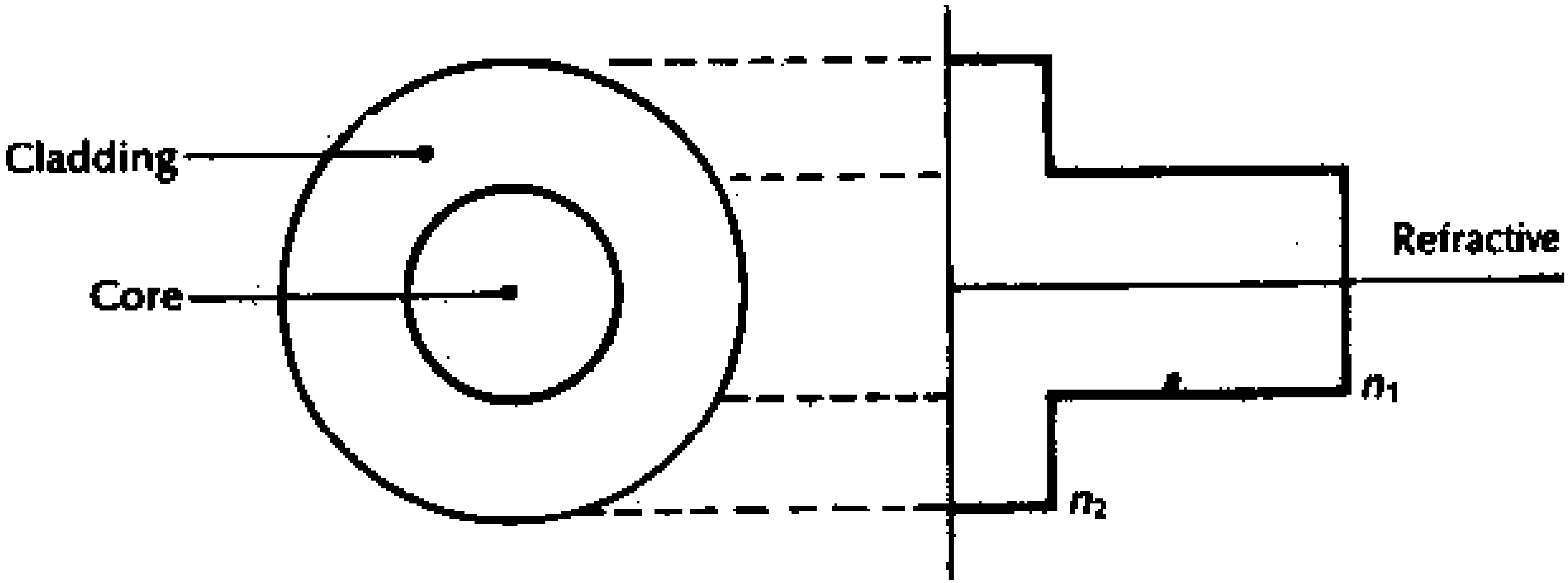
Applications: **ideally suited for high BW, very long haul applications with injection laser source**.

PLASTIC-CLAD FIBERS



Typical structure for a plastic-clad silica multimode Step Index Fiber.

ALL PLASTIC FIBERS



Typical structure for an all-plastic fiber.

PLASTIC-CLAD & ALL PLASTIC FIBERS

Plastic- clad fibers:These are multimode and have a SI or GI profile.

- Construction: core - glass (silica or plastic clad silica-PCS)

  Cladding –plastic (silicone rubber)

- PCS fibers exhibit lower losses than silica clad silica fibers and so improved performance.
- Plastic clad fibers are generally cheaper than corresponding glass fibers.

PLASTIC-CLAD FIBERS (contd)

	Step index	**graded index**
Core dia	100 to 500 µm	50 to 100 µm
Cladding dia	300 to 800 µm	125 to 150 µm
Buffer jacket dia	500 to1000 µm	250 to 1000 µm
NA	0.2 to 0.5	0.2 to o.3
Attenuation	5 – 50 db/km	4 – 15 db / km.

ALL PLASTIC FIBERS

-These fibers are multi mode SI type with large core & cladding dia n_1=1.50, n_2=1.40

-**No need of buffer jacket** for fiber protection & strengthing

-Cheaper to produce ,easier to handle than silica based glass variety

Performance is restricted (in Infrared region) and

hence **limited use** in comm. applications.

- Core dia: 200 to 600µm, cladding dia 450-1000 µm
- NA:0.5 to 0.6 Attn. 50 to 1000 db/km.at 0.65 µm (λ)

- APPLICATION:These fibers can be used for short haul (in-house) low cost links.

FIBER JOINTS

Number of joints will depend on link length (BETWEEN REPEATERS)

Repeater station distance of 40 to 60 km is practical at data rate of 400 Mb/sec.

Advances in the field have resulted in achieving a distance of 100 km in practical systems at a data rate of upto10 G bits/sec

FIBER JOINTS:(Types)

1)FIBER SPLICES.

2)FIBER CONNECTORs (REMOVABLE)

FIBER JOINTS (contd)

Fiber splices :semipermanent /permanent joints (analogous to soldered joints)

Fiber Connectors: Removable/ demountable joints which allow easy fast manual coupling/decoupling of fibers (analogous to elect. plugs /sockets)

DIFF BETWEEN JOINTS &COUPLERS:

JOINTS: To **couple all the light** propagating in one fiber into an adjoining fiber.

COUPLERS: Branching devices that **split the light** from main fiber into two or more fibers **or couple the light** from branches to main fiber.

FIBER ALIGNMENT & JOINT LOSS

JOINT loss critically depends on alignment of two fibers.

<u>Fresnel Reflection</u> : even when two jointed fiber ends are smooth and perpendicular to fiber axis with 2 axes perfectly aligned **,a small portion of light is reflected back into the transmitting fiber** causing attenuation at the joint.

<u>This is due to step changes in refractive index at jointed interface (GLASS-AIR- GLASS)</u>

r= fraction of light reflected at a single interface=$(n_1-n/n_1+n)^2$

where n_1= ref index of core ,n= ref index of medium bet .fibers.

FRESNEL LOSS (db)= -10 $\log_{10}$ (1-r)

FIBER ALIGNMENT & JOINT LOSS (Contd)

FRESNEL Reflection can be reduced by using ***an index* matching fluid** in the gap between the jointed fibers.

INHERENT CONNECTION PROBLEMS:

a) Different core and/or cladding diameter

b) Different NA and/or ref. index difference

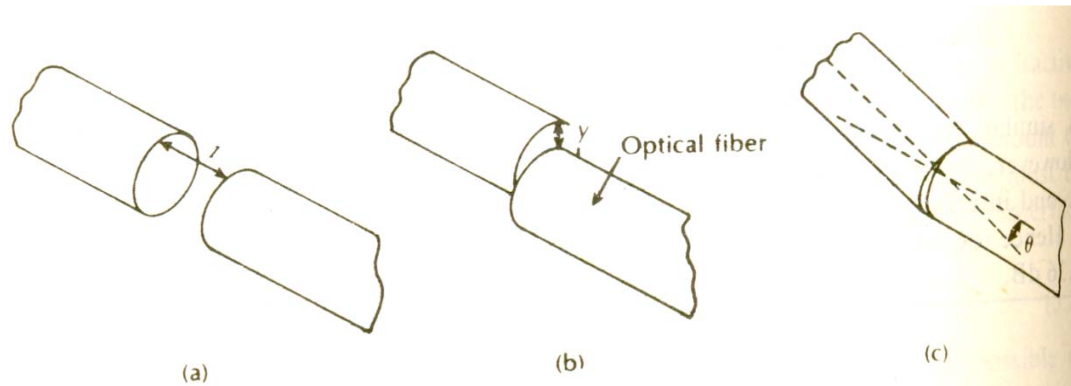
c) Different REF.INDEX profile

d) Fiber faults (ellipticity, concentricity)

MISALIGNMENT PROBLEM

- 3 dimensions of misalignment

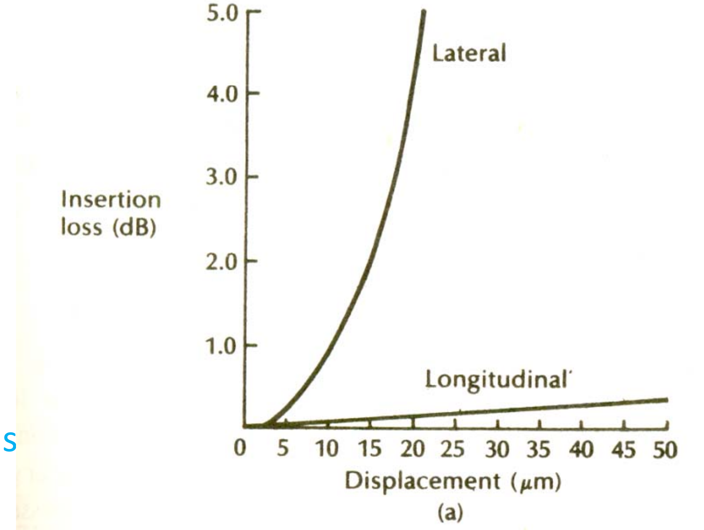
- -LONGITUDNAL
- -LATERAL
- -ANGULAR

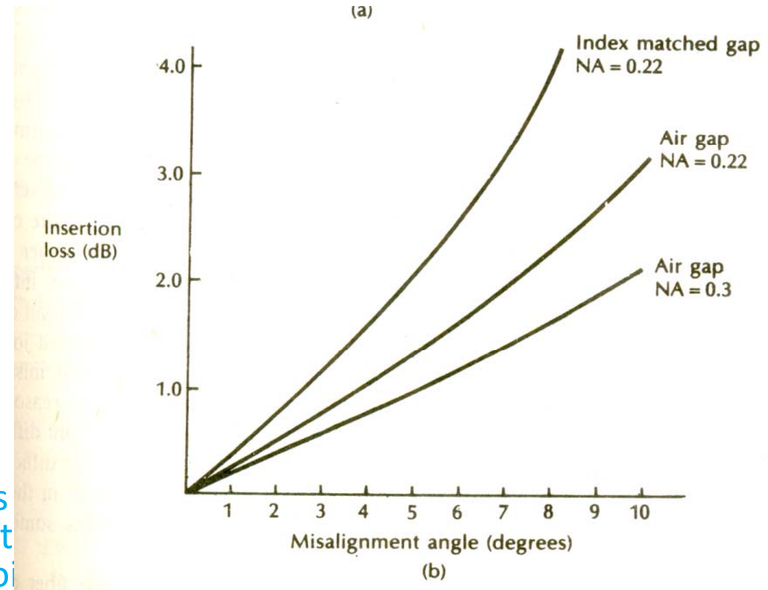


The three possible types of misalignment which may occur when joining compatible optical fibers (a) longitudinal misalignment; (b)lateral misalignment; (c) angular misalignment.

- Optical losses due to misalignment depend on fiber type, core dia and distribution of optical power between propagating modes.

MISALIGNMENT PROBLEM (contd)





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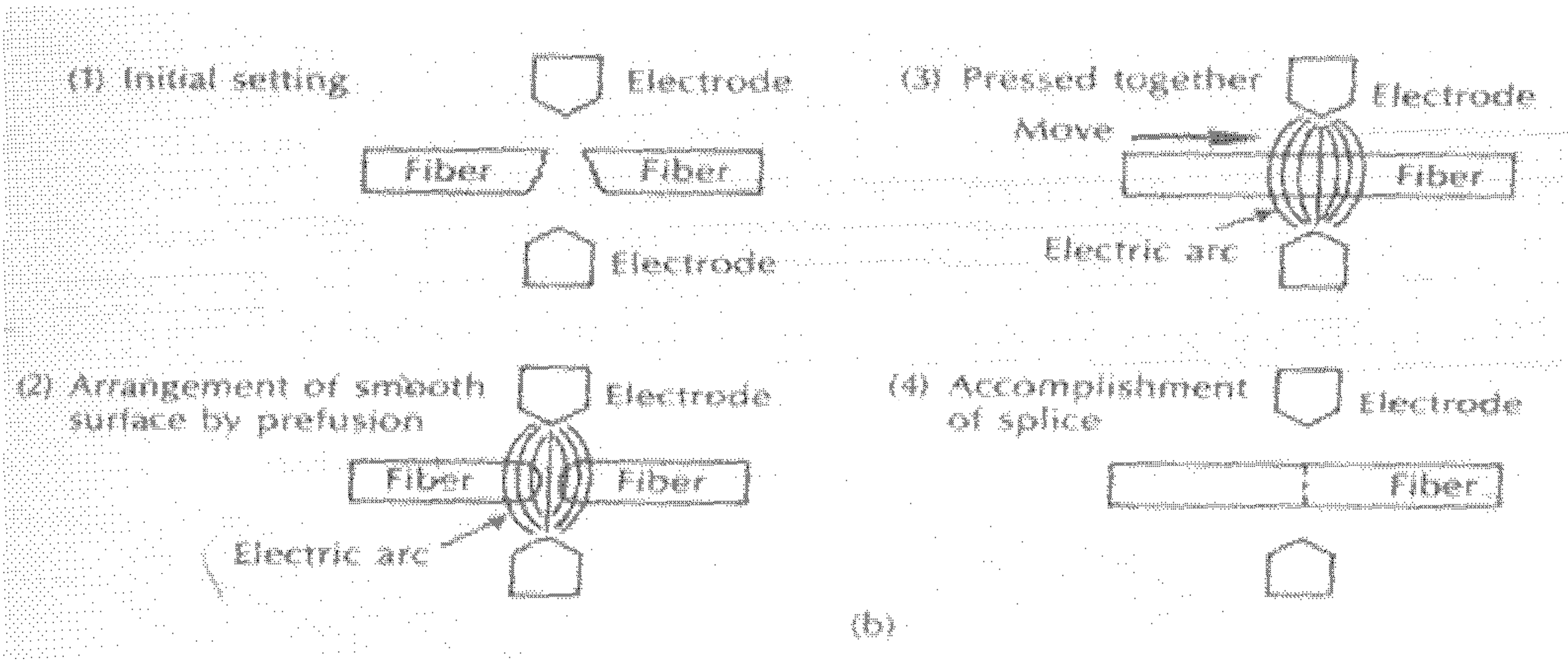
numerical apertures of 0.22 and 0.3

Note: **lateral misalignment gives significantly more losses per unit displacement than longitudinal displacement**.

FUSION SPLICING(contd)



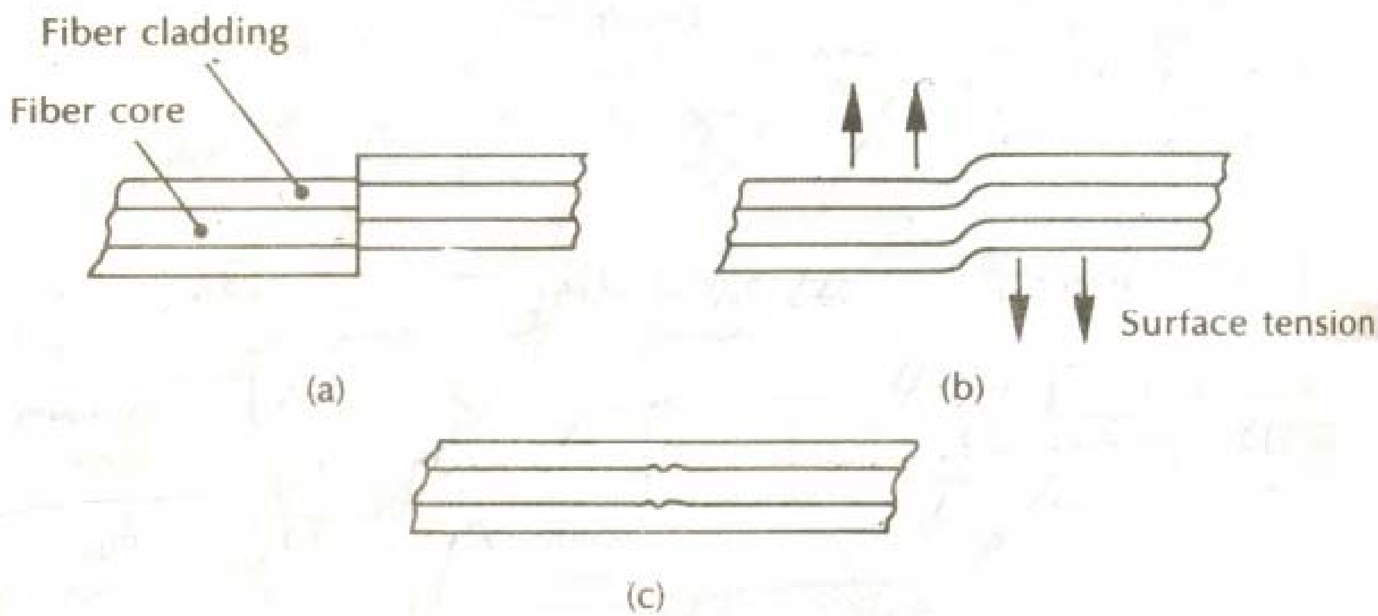
(b) schematic illustration of the perfusion method for accurately splicing optical fibers.

PREFUSION
METHOD FOR SPLICING FIBERS

- FLAME HEATING SOURCES: Argon, hydrogen, OXHYDRIC MICROBURNERS (O_2, H_2, ALCHOL VAPOUR)
- **Electric arc is the most widely used source**
- **Prefusion: This removes the requirement for fiber end preparation, an advantage in field environment.**
- AVG SPLICE LOSSES: 0.09 db.
- Disadvantage: tensile strength of fused fiber is down by 30 % (as compared to before fusion process) due to surface damage & changes in chemical composition

SELF ALIGNMENT

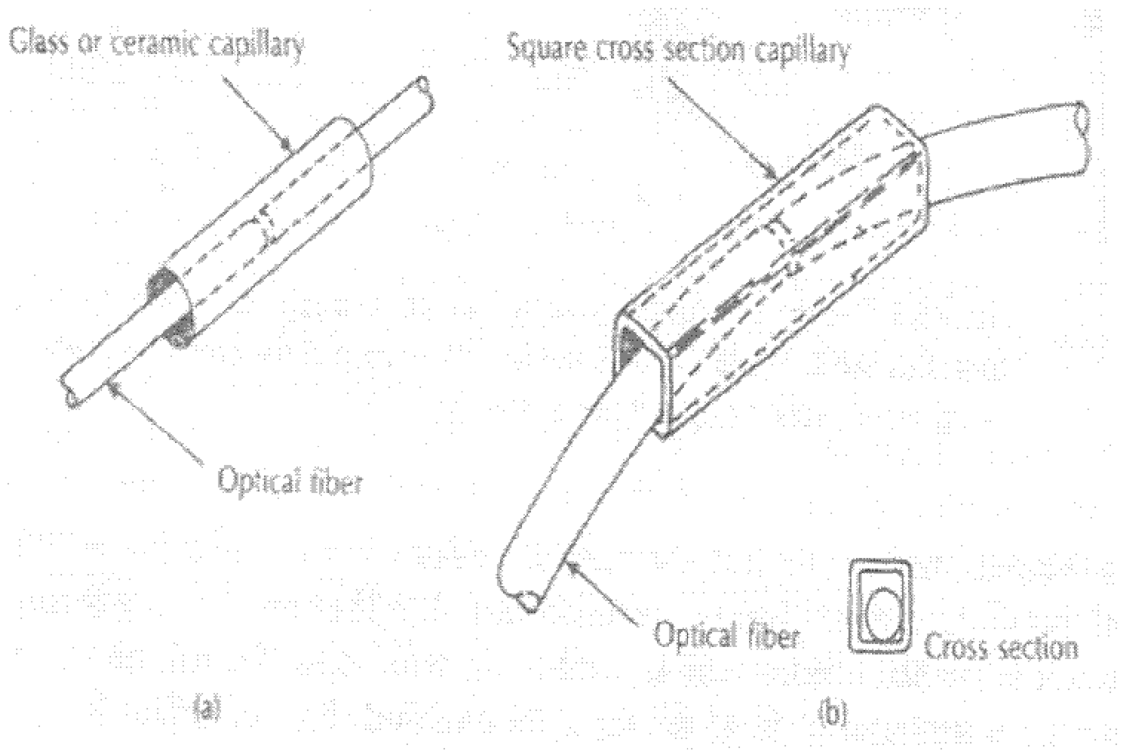
- Self alignment partially compensates for any lateral offset
- Lower splice Insertion losses may be achieved due to **self alignment process caused by surface tension effect** between the two fiber ends during fusing
- Mean splice losses of only 0.06 db have been obtained with single mode fiber fusion splicing machine



Self -alignment phenomenon which takes place during fusion splicing : (a) before fusion , (b) during fusion; (c) after fusion.

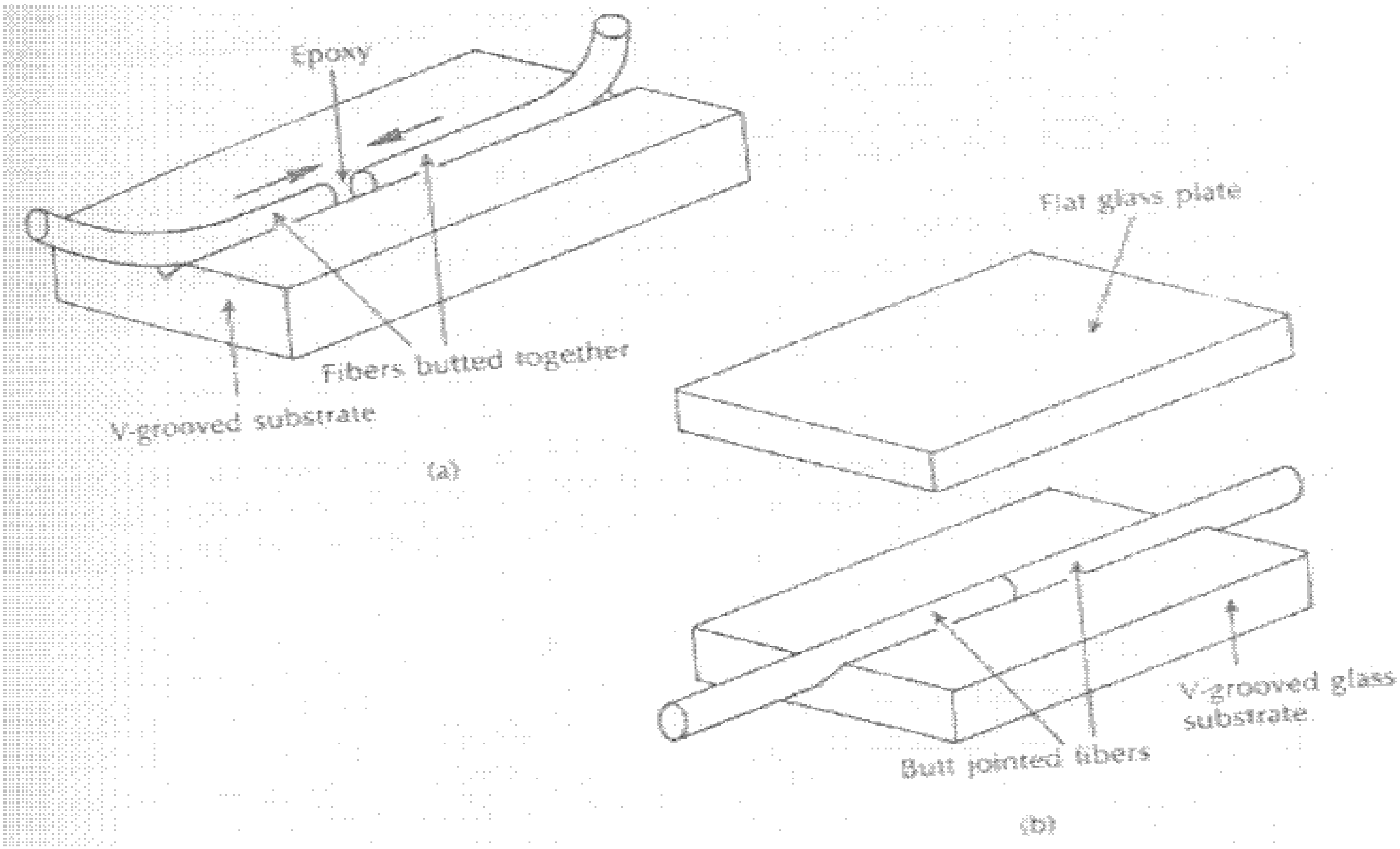
MECHANICAL SPLICES

Insertion loss:



0.1 dB - 0.5 dB 0.073 dB

MECH SPLICES(contd)
joint insertion loss- 0.1dB



FIBER CONNECTORS

REQUIREMENTS FOR OPTIMAL PERFORMENCE.

1) connector design must allow for repeated connection and disconnection, without problems of fiber alignment

2) Connector must protect the fiber ends from damage due to handling.

3) Performance should be independent of environment (insensitive to moisture and dust)

4) Adequate strength to cope with tensile load on the cable.

<u>REQUIREMENTS FOR OPTIMAL PERFORMANCE-contd</u>

5) Ease of fitment

6) Should be a low cost component.

Index matching fluid : Its use increases the light transmission thr the connection (at the joint) and keeps the dust away.

-But practically in field liquids attract dust (at the joint)

Insertion loss of commercially available connector is 0.2 to 0.3 dB

Types of fiber connector

- **1)butt jointed connector**
- **2)expanded beam connector.**

BUTT JOINTED CONNECTORS

These are most widely used connectors.

Types:

1)Cylinderical ferrule connector.

2)Capillary ferrule connector.

3)Biconical ferrule connector.

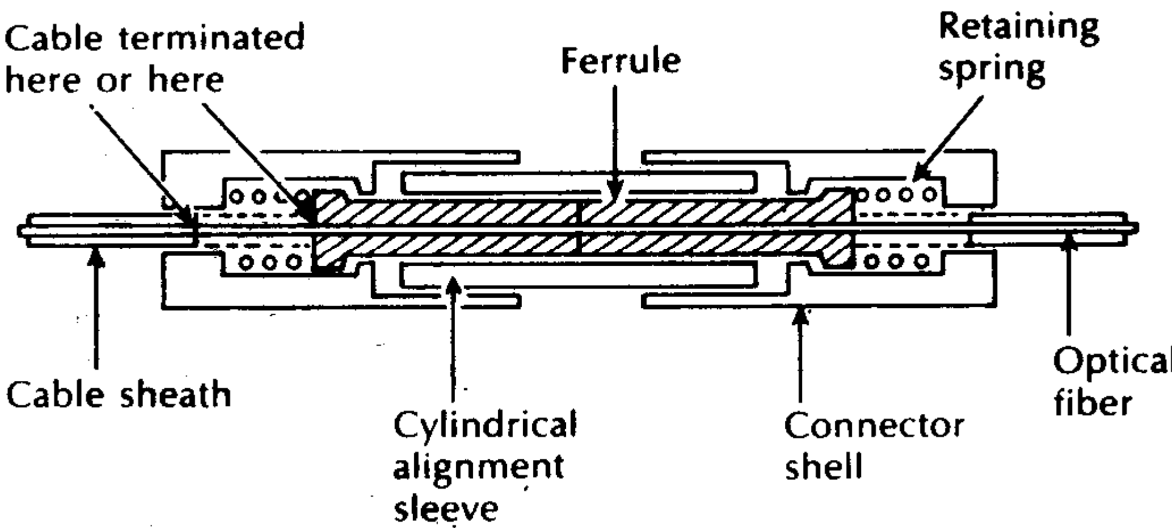
4)Double eccentric connector.

. **EXPANDED BEAM CONNECTOR**

1)Lens coupled expanded beam connectors.

A) using 2 microlenses. , B)using molded plastic lens connector assembly.

2) Using grin-rod lenses.



(a)

<u>STRUCTURE OF BASIC FERRULE CONNECTOR</u>.

- Simplest design
- The 2 ferrules are placed in an alignment sleeve.
- Retaining spring keeps ferrules in place.
- The 2 fibers to be connected are permanently bonded with epoxy resin.

STRUCTURE OF BASIC FERRULE CONNECTOR.(contd)

- The 2 fibers to be connected are permanently bonded with epoxy resin in metal plugs known as ferrules
- **NOTE**: polishing the fiber end face after insertion and bonding provides the best results. However it is time consuming and inconvenient in the field.

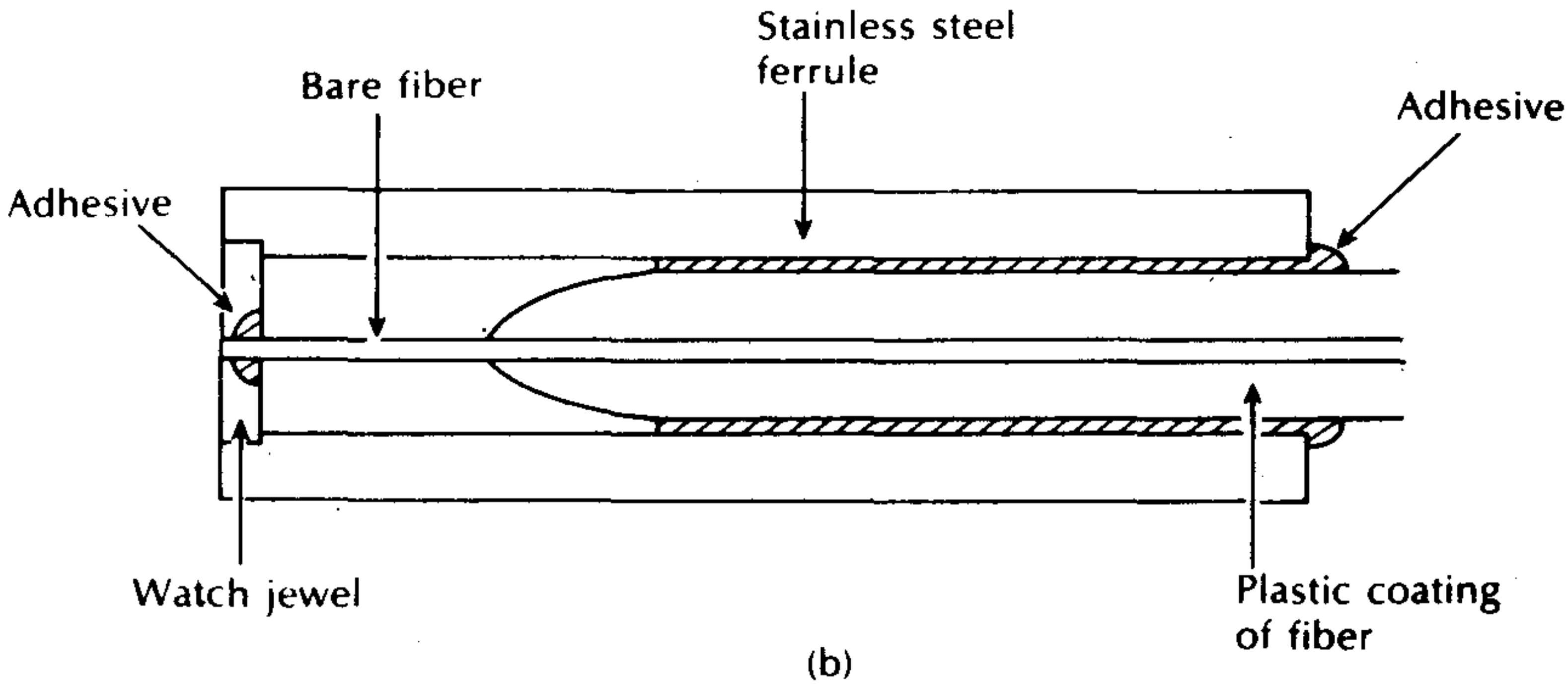
Cylindrical ferrule connectors

.

- Fiber ends to be jointed must be smooth and square. (perpendicular to fiber axis)

- Fiber alignment accuracy largely depends upon ferrule hole into which fiber is inserted.

- For this some ferrule connectors use a watch jewel in ferrule end face (jewelled connector) This allows close dia and tolerance requirements of ferrule end face hole to be obtained easily



(b) structure of a watch jewel connector ferrule

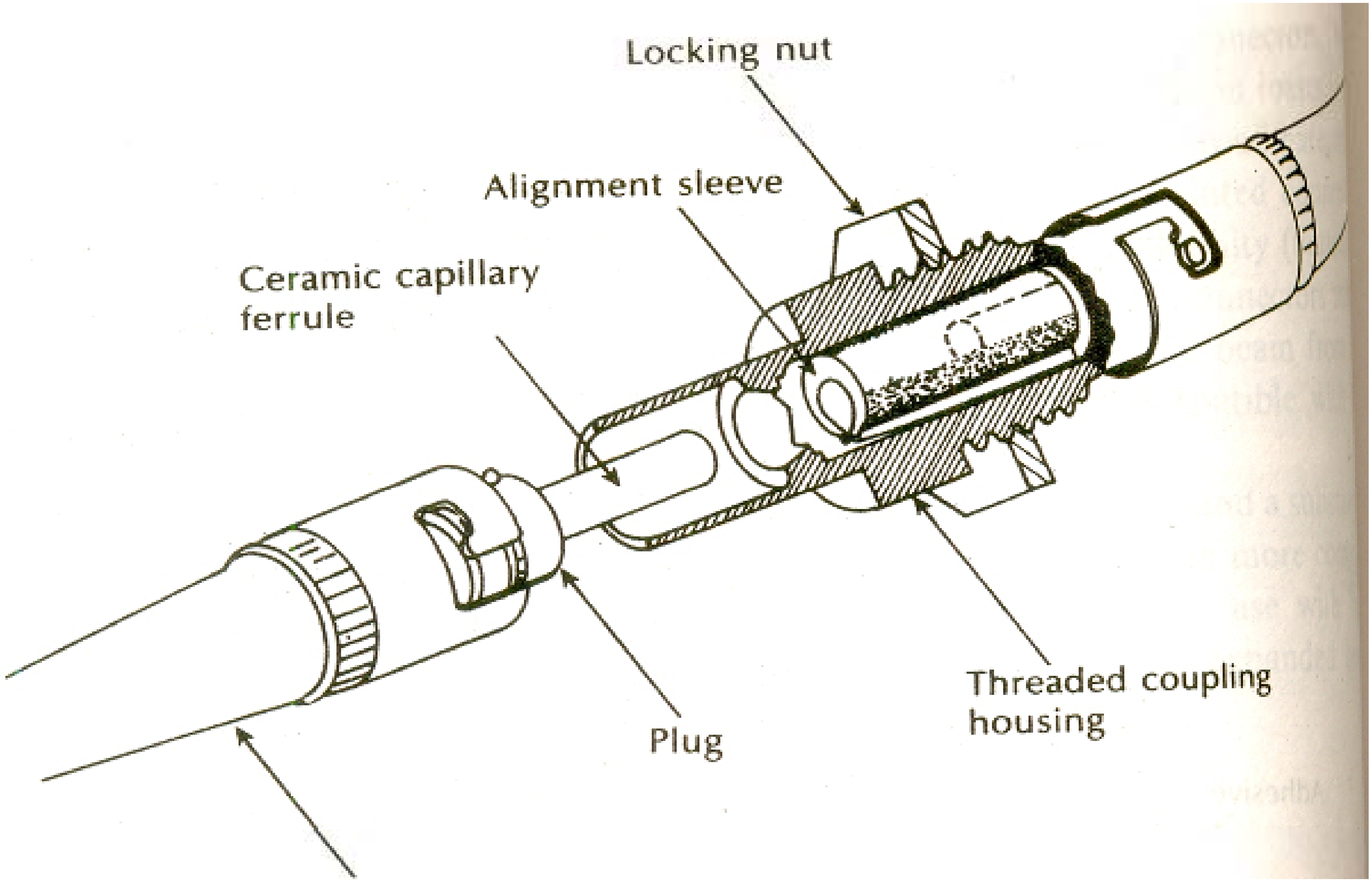
NOTE : FIBER IS CENTERED wrt. FERRULE THR' THE WATCH JEWEL HOLE.

Capillary Ferrules

- Manufactured from ceramic materials like "Alumina Porcelain"
- Capillary ferrules have a precision bore which is accurately centered in the ferrule .
- Ceramic materials posses outstanding thermal mechanical and chemical resistance characteristics in comparison to metals/plastics.

-Typ. loss 0.2 db(MM GI Fiber),0.3 db(SM Fiber)

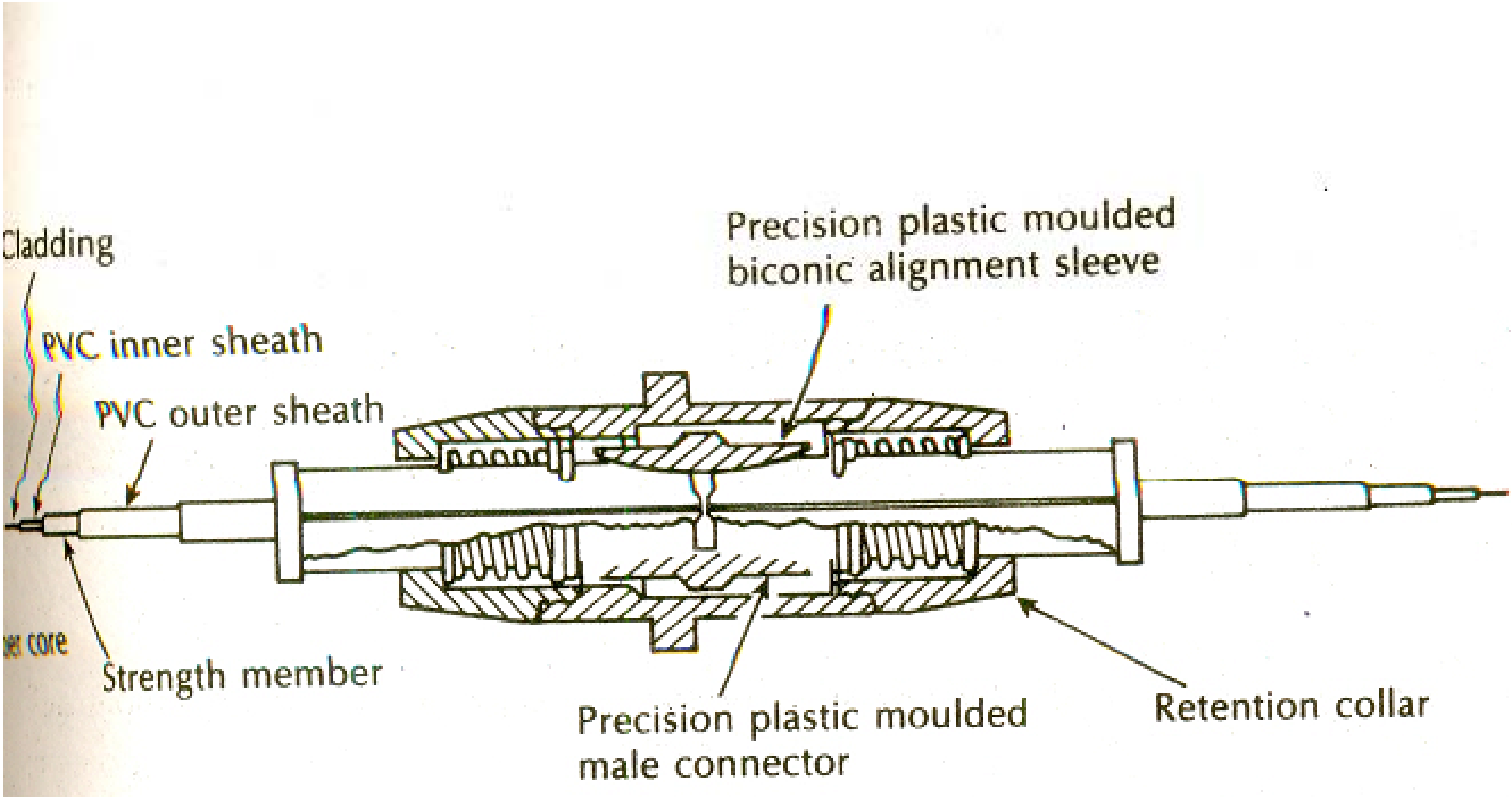
- Types : Straight Tip, D3/D4 Physical contact



ST Series multimode fiber connector using ceramic capillary ferrules

Biconical Ferrule Connector

- The plugs are transfer moulded directly on to the fiber, or cast around the fiber using a silicon loaded epoxy resin.
- After plug attachment, fiber end faces are polished before the plugs are inserted and aligned in biconical moulded centre sleeve
- Mean insertion Loss: 0.21 db (50 µm core dia GI fibers), 0.28dB -0.7 dB (with single mode fibers)



Cross section of the biconical connector

Double Ecentric Connectors

Allows close alignment of fiber axis being an active adjustable assembly.

Two eccentric cylinders are provided within the outer ring.

Opt. fiber is mounted in the inner cylinder eccentrically.

When two connectors halves are mated it is always possible thr' rotation of mechanism to make the fiber core axis coincide.

Inspection microscope can be used to ensure alignment of fiber axis

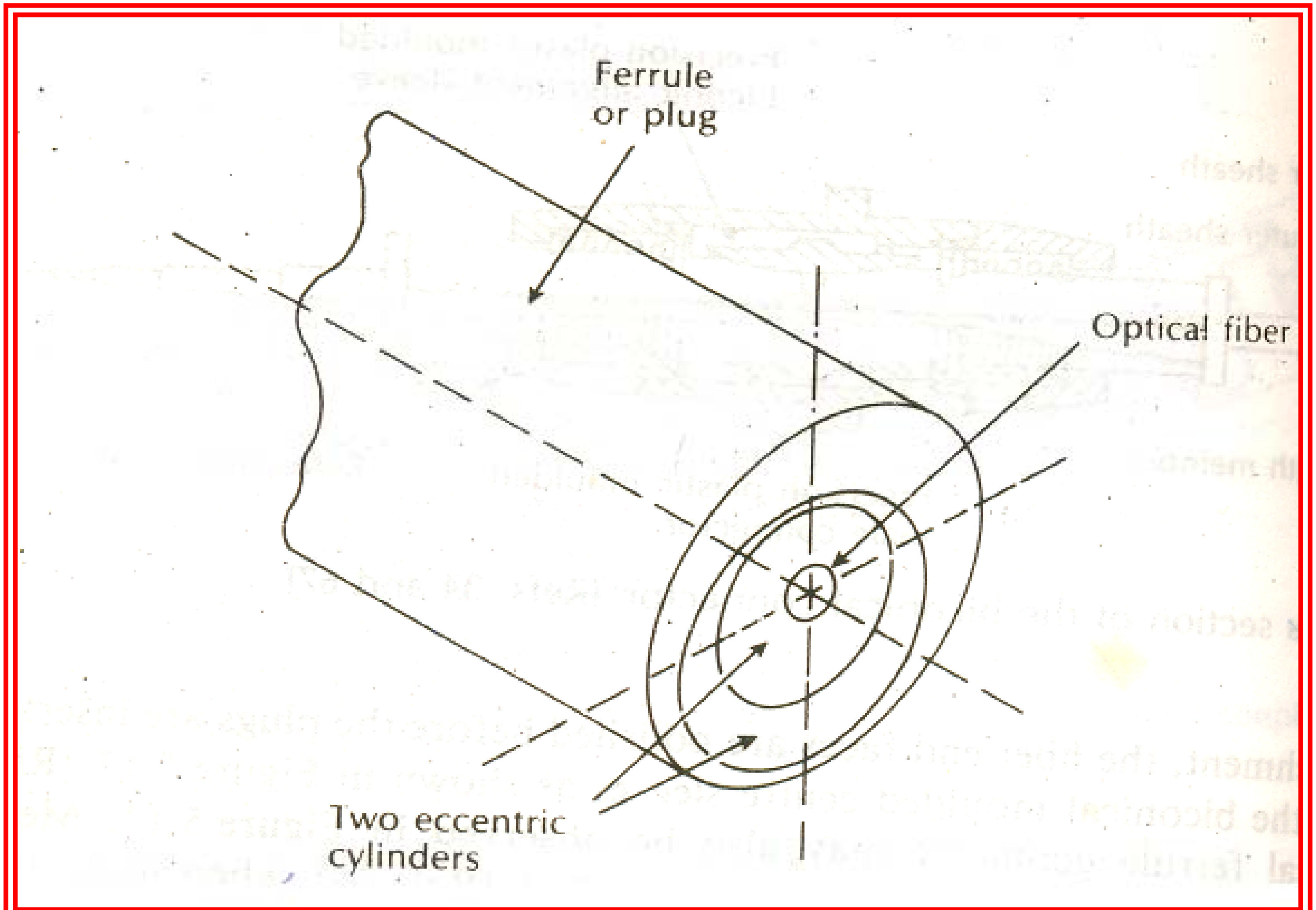
Mechanism can be locked for permanent alignment.

Insertion Loss 0.48 db (MMGI Fiber)

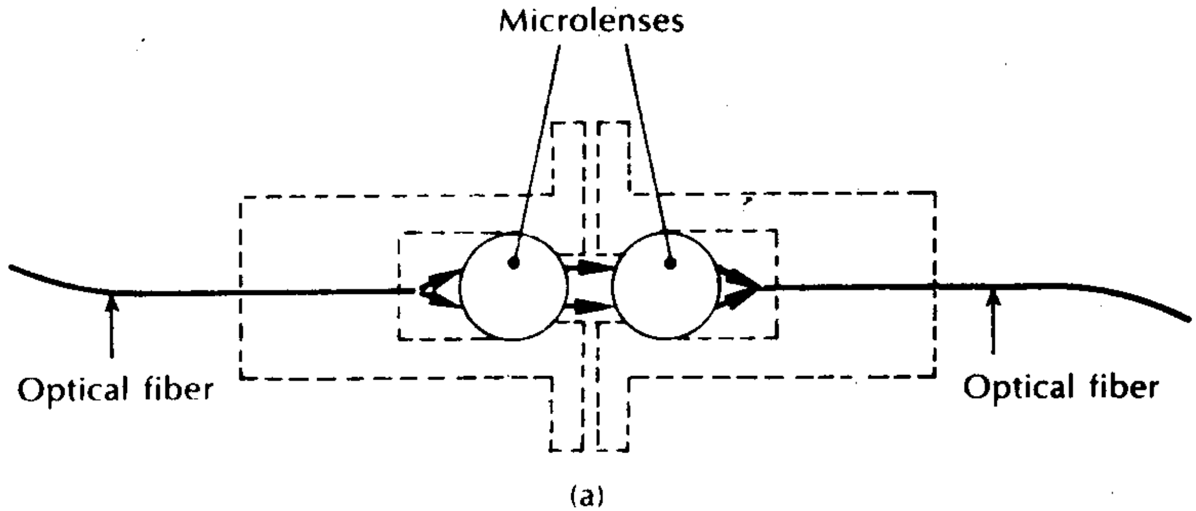
0.20 db (with use of Index matching fluid)

0.46 db (single mode fiber)

Double Ecentric Connectors

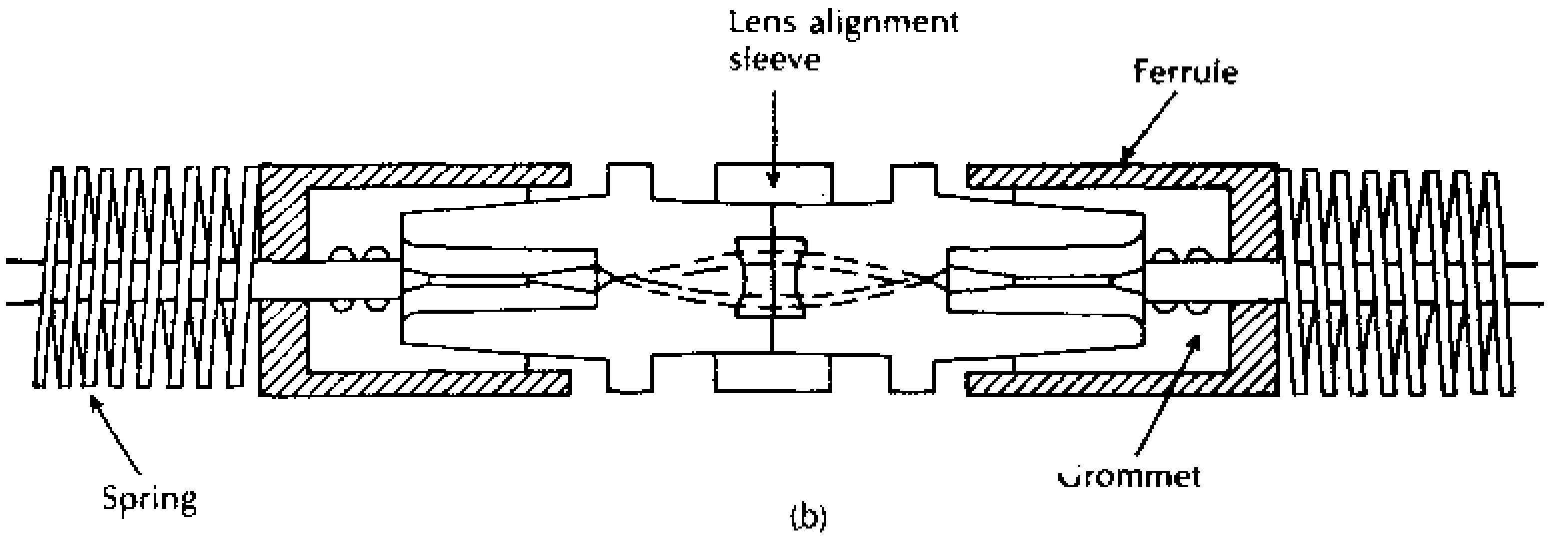


Lens Coupled Expanded Beam Connectors



Lens coupled expanded beam connectors: (a) schematic diagram of a connector with two microlenses making a 1: 1 image of the emitting fiber upon the receiving one

- Spherical micro lenses are used for beam expansion and reduction.
- Avg. Loss- 0.7db-1.0 db (lesser fig with the application of anti reflection coating)-(50μm core dia GI fiber)
- 0.7 dB loss with anti reflection coating with single mode fibers(8 μm core dia)



(b) moulded plastic lens connector assembly .

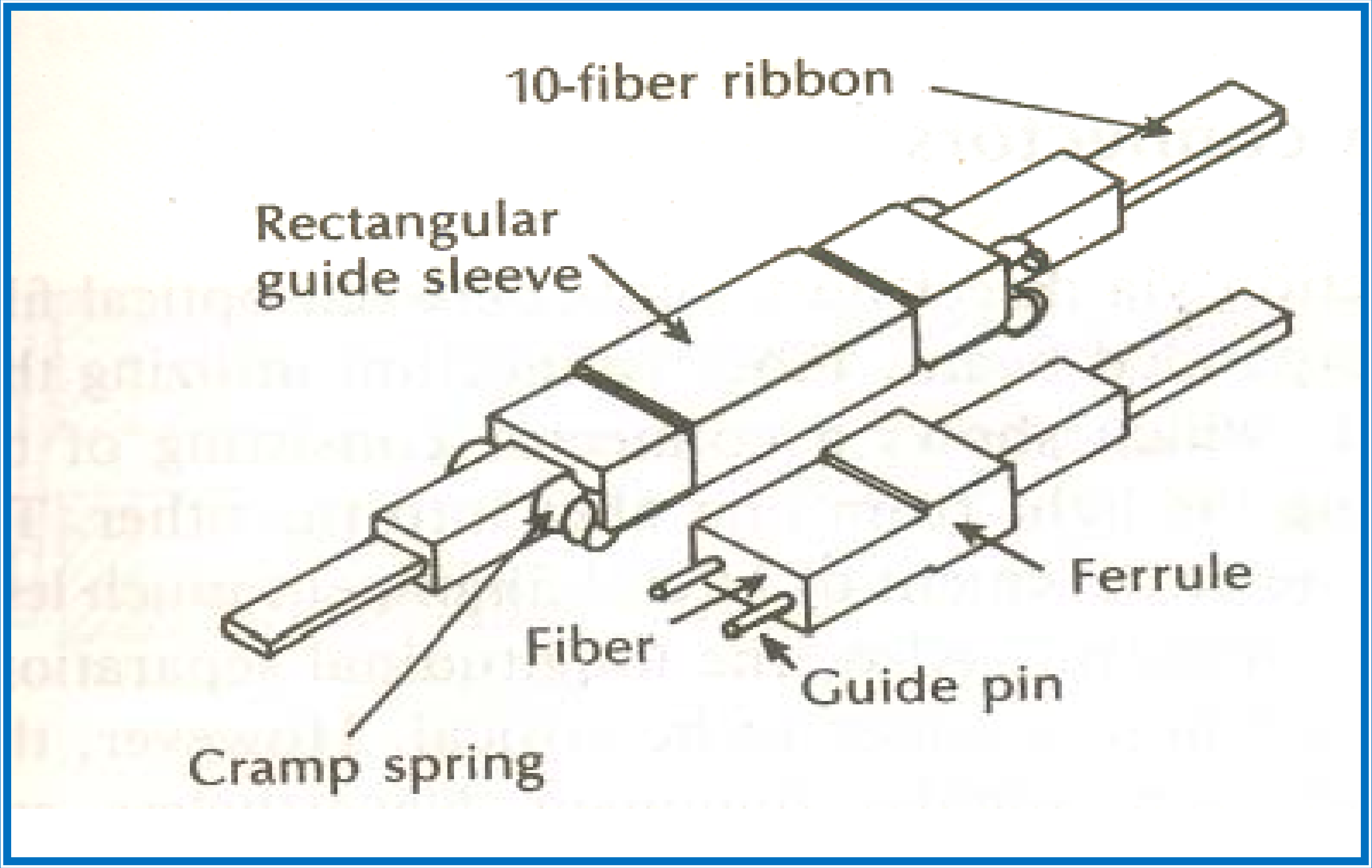
Moulded Spherical Lens (Expanded Beam Connector)

- Fiber is positioned approx. at the focal length of the lens.
- A lens alignment sleeve minimises effects of angular misalignment.
- AVG loss=0.7 db.

Single Mode Ten Fiber Connector

- Consist of 2 moulded ferrules with10 fiber ribbon cables which are accurately aligned by guide pins.
- Held in place by sleeve & spring

- Dimension-   6* 4 mm
- Avg. Loss - 0.43 dB


10-fiber ribbon
Rectangular
guide sleeve
Ferrule
Fiber
Guide pin
Cramp spring

<u>Grin –rod lenses (0.5 to 2mm dia)</u>

Such lenses comprise a cylindrical glass rod typically 0.5 to 2mm in dia, which exhibits a parabolic ref. index profile with max at the axis. (similar to GI Fiber)

Grin –rod lens can produce a collimated output beam with divergent angle α (1^0 to 5^0) from a light source (Situated on /near opp. lens face)

Ref index variation is a wave length dependant parameter. Ref index varies with radius which causes all input rays to follow a sinusoidal path thr' lens medium.

Grin –rod lenses(contd)

One sinusoidal period –One full pitch

Grin rod lenses are manufactured with several pitch lengths: Three Major ones are:

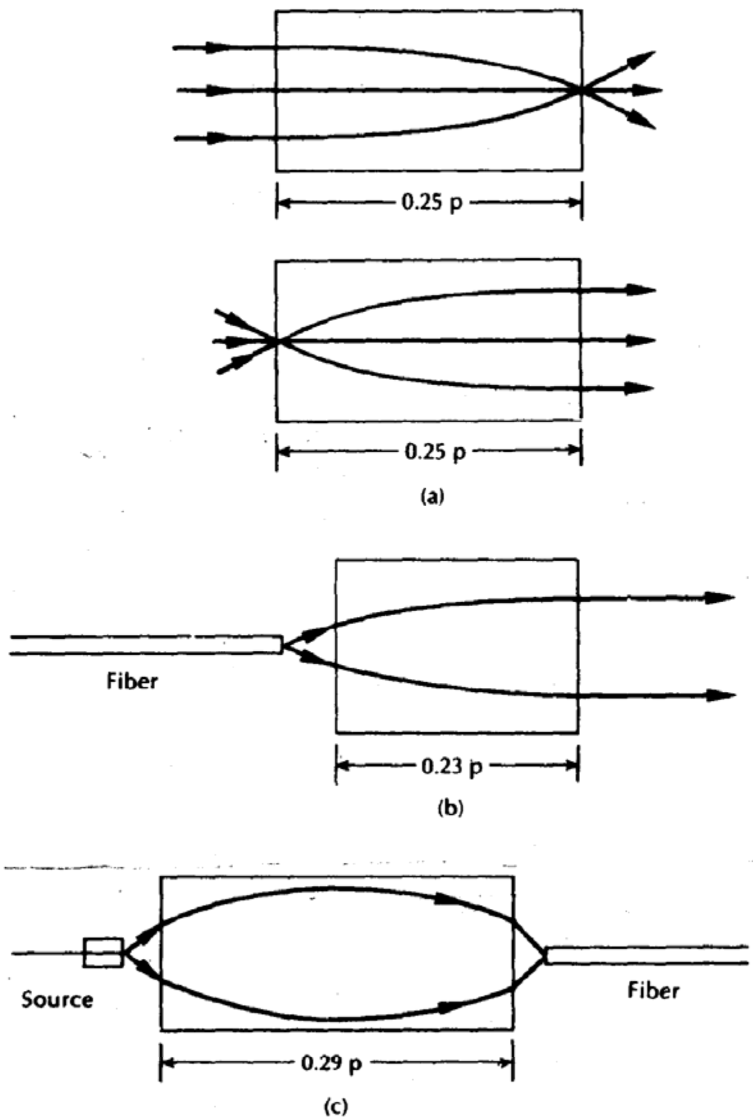
0.25 pitch (quarter pitch)

Produces a perfect collimated o/p beam when light emanates from a pt. source on opp. Lens face. (Focal pt coincident with lens faces)

0.23 Pitch: Focal pt. lies outside the lens when a collimated beam is projected on opp lens face.

0.29 Pitch : Both focal points lie just outside the lens end faces . Used for converting a divergent beam into a convergent beam.

Various Grin-rod lenses -operation



Operation of various GRIN-rod lenses:(a) the quarter pitch lens;(b) the 0.23 pitch lens; (c) the 0.29 pitch lens.

Assignment

- **Describe optical fibre structures in detail.**

- **Explain below terms in details with their types and diagrams for different connectors -**

1. **Fiber splices**
2. **Fiber connectors**