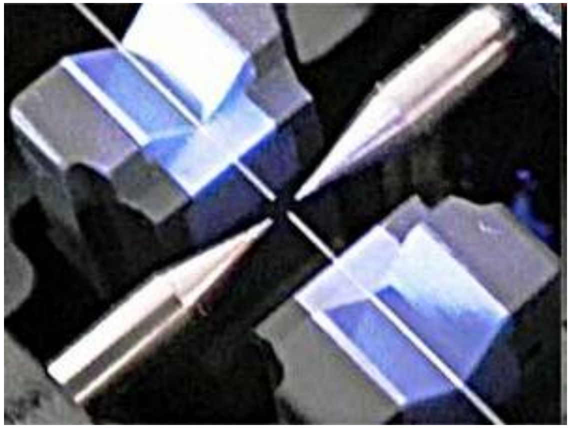
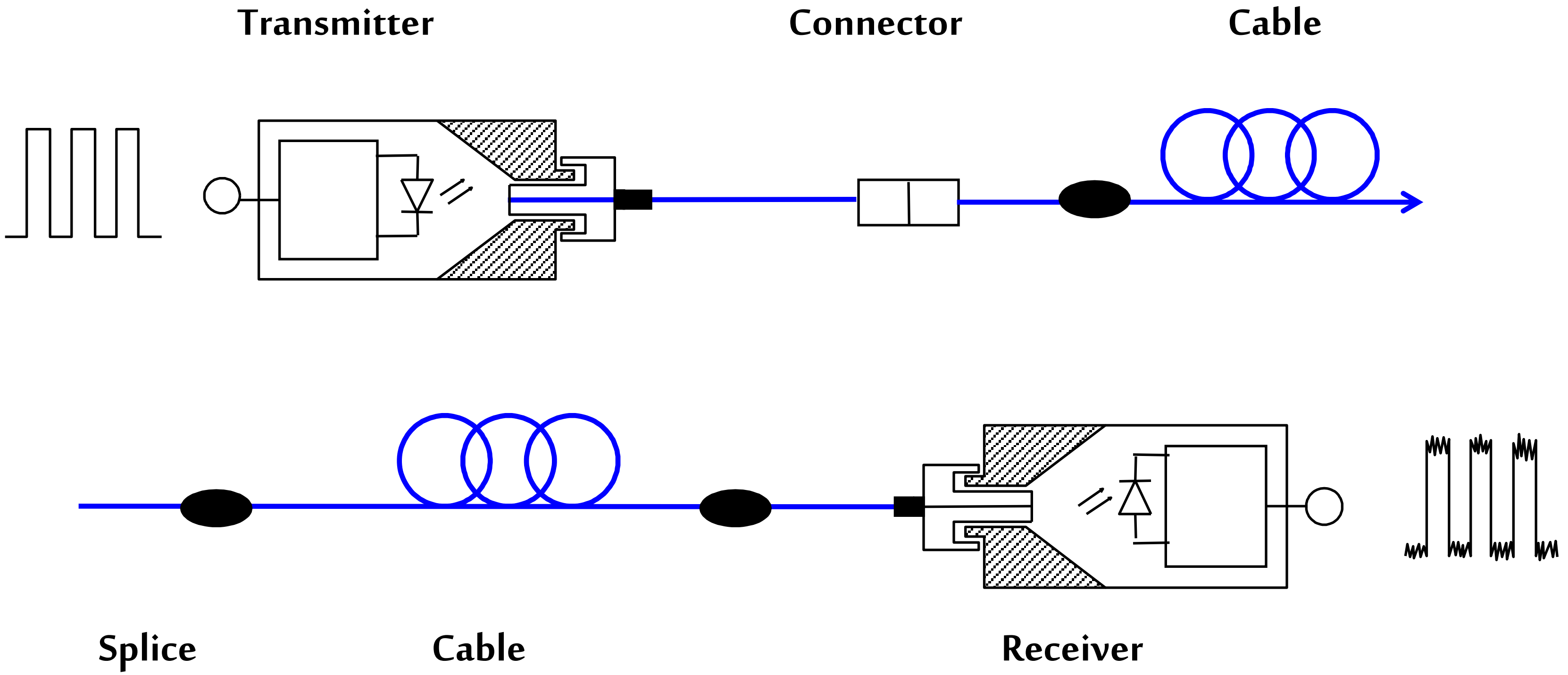
OPTICAL FIBER JOINTS & CONNECTIONS



Basic Fiber Optic Link



OPTICAL FIBER JOINTS

❖ Technical requirement for both jointing & termination of transmission media

❑ **Number of Joints or Connections**

- Link length between repeaters
- Continuous length of fiber
- Length of fiber cable practically or conveniently installed as continuous length

- **Repeaters Spacing** (A continuously increasing parameter)

➢Ranges from ≈ 40-60 km at 400 Mbits/s

≈ 100 km at 2.4 Gb/s

≈ 300 km at 1.7-10 Gb/s using SMDSFs

FIBER JOINTS

- **Source- Fiber**
- **Fiber- Fiber**
- **Fiber- Detector**

❖ Manufacturers supply ***Electro-optical devices*** (Sources and Detectors) with fiber optic ***pigtail*** to facilitate direct fiber-fiber connection

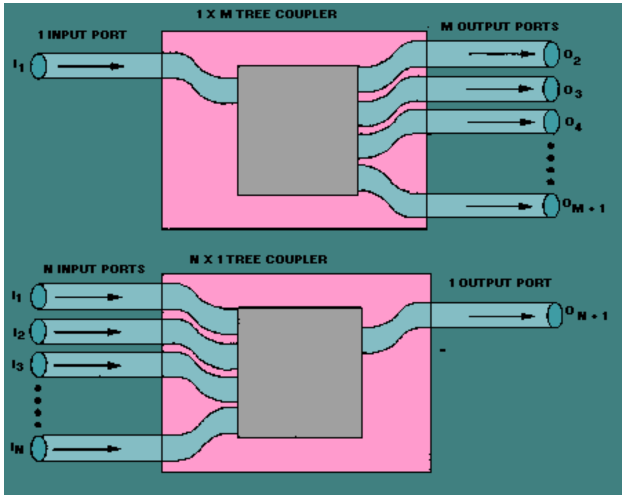
❑ **IMPORTANT ASPECT IS FIBER-TO- FIBER CONNECTION WITH LOW LOSS AND MINIMUM DISTORTION**

Two major categories of fiber joints

- **FIBER SPLICES:** Permanent or Semi-permanent joints
  - ✓**Soldering**

- **FIBER CONNECTORS:** Demountable or Removable joints
  - ✓Plugs or Sockets

❖ **FIBER COUPLERS:** Branching devices
  - ➢ Splitters or Combiners
  - ➢ Importance in Networks



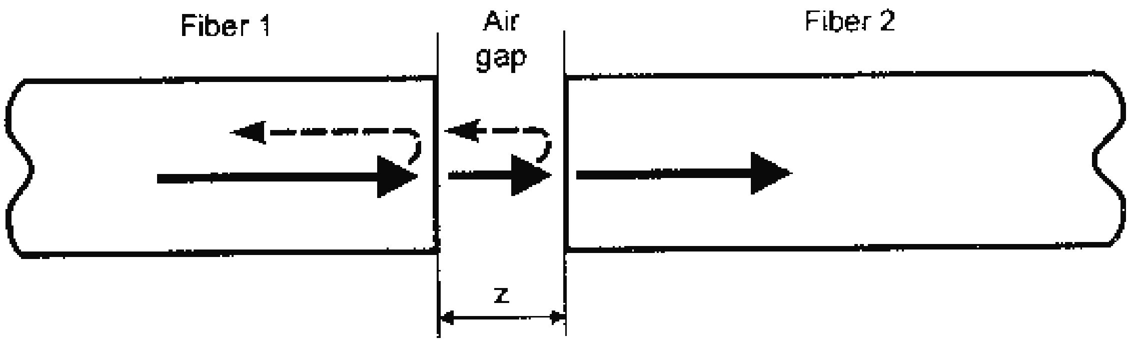
- **Crucial aspect of fiber joints concerning *Optical Losses* associated with the connection**

  - **Fiber Alignment**

LOSS MECHANISMS AT JOINTS

1. Fresnel Reflection

- **Optical Loss encountered at the interfaces** (Even when two fiber ends are smooth, perpendicular to fiber axes and perfectly aligned)
- **A small proportion of light may be reflected back into transmitting fiber causing attenuation at the joint.**
  - **Fresnel Reflection**



Reflection Loss

- **Occurs due to step changes in refractive index at jointed interface**

Glass – Air - Glass

Fraction of light reflected at a single interface

$$r = \left(\frac{n_1 - n}{n_1 + n} \right)^2$$

n_1 : R.I. of core, n : R.I. of interfacing medium (= 1 for air)

Loss in decibel due to FR at single interface

$$\text{Loss}_{\text{Fres}} = -10 \log_{10}(1-r)$$

- **Can be reduced to a very low level using index matching fluid in the gap between jointed fibers.**

2. Deviation in Geometrical & Optical Parameters

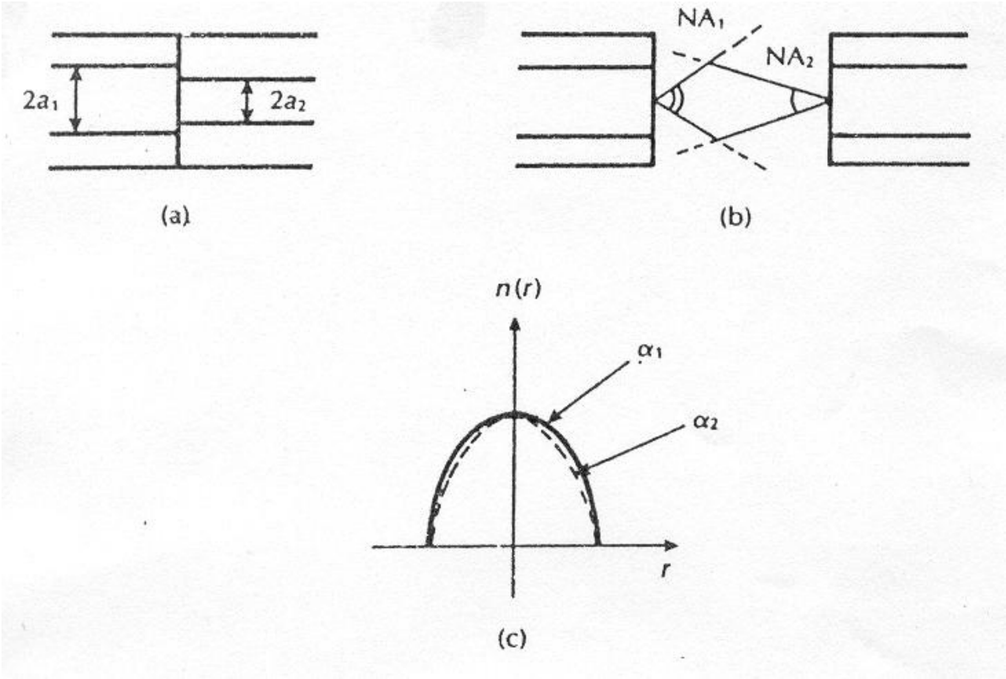
- All light from one fiber is not transmitted to another fiber ; **Because of mismatch of mechanical dimension**

Three major cases :

a) **Core mismatch**

b) **NA mismatch**

c) **Index Profile**



Intrinsic Losses

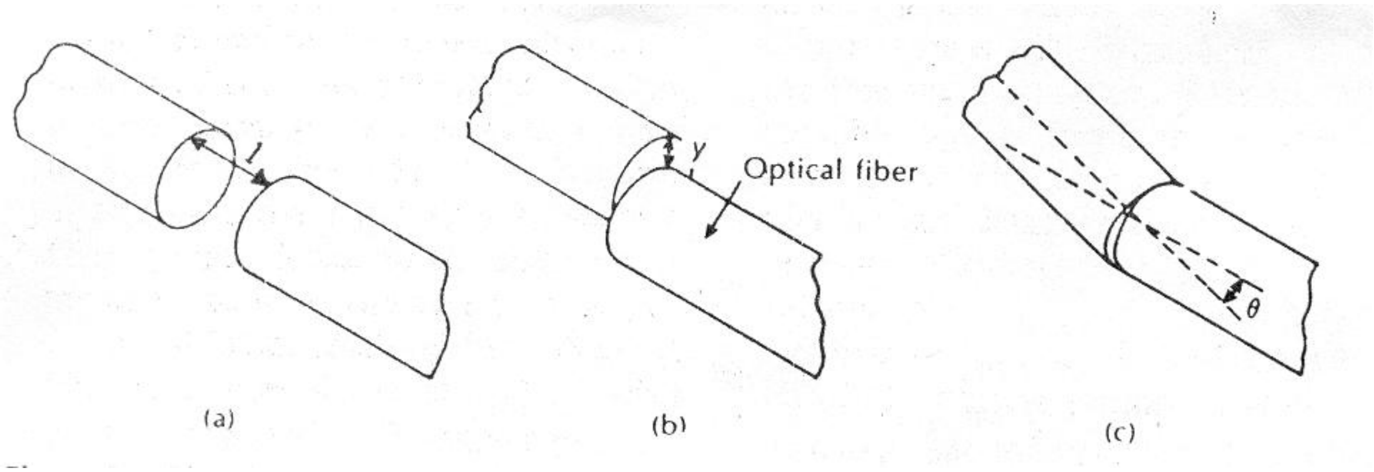
Losses due to:

- Fresnel Reflection
- Deviation in Geometrical & Optical parameters

➢ **Minimized using fibers manufactured with lowest tolerance i.e.(same fiber)**

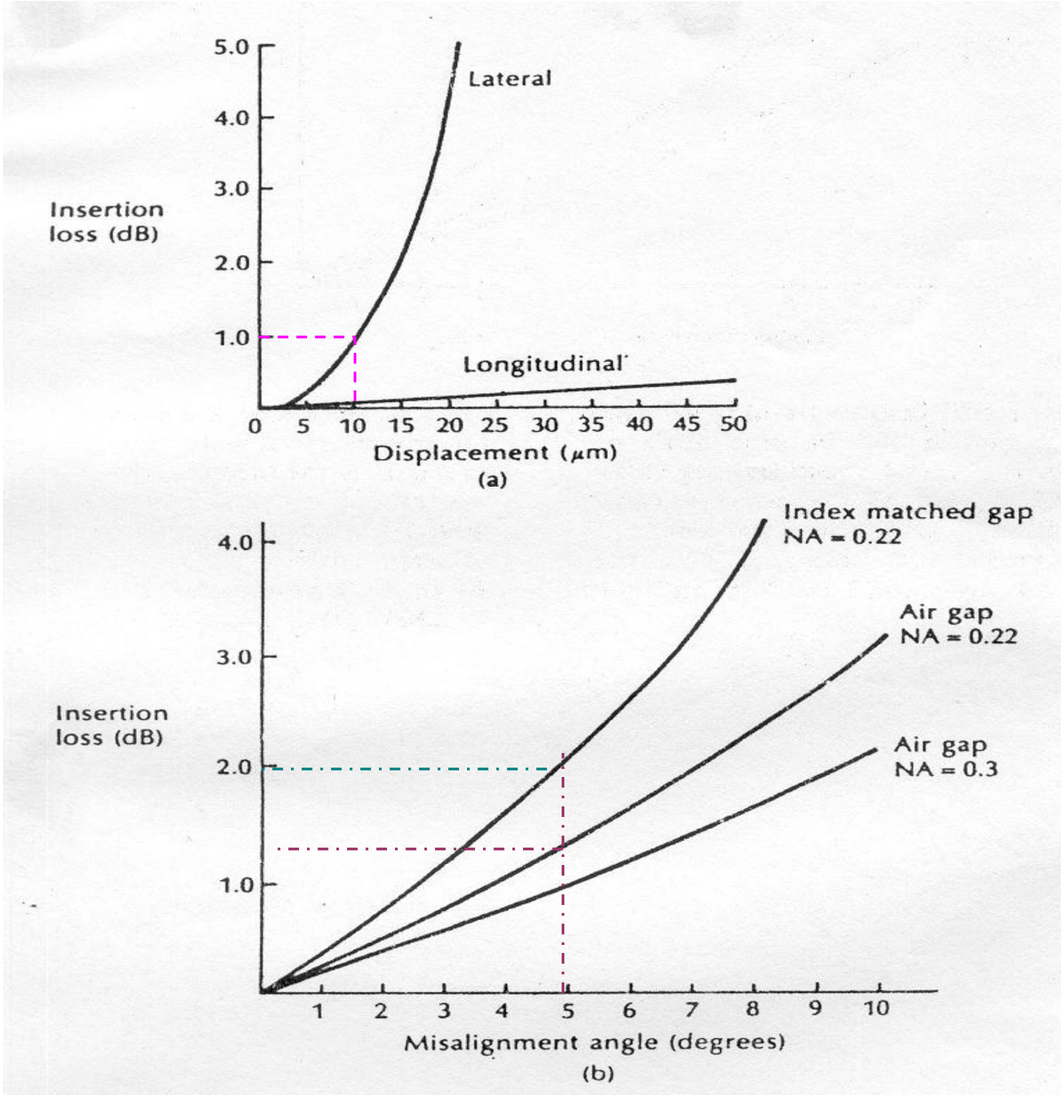
Extrinsic Losses

- Losses due to some imperfection in splicing
  - Caused by Misalignment



Three possible types of misalignment at joint

(a) Longitudinal misalignment
(b) Lateral misalignment;
(c) Angular misalignment



(a) Loss due to lateral and longitudinal misalignment for a 50 μm core diameter GI fiber; (b) insertion loss due to angular misalignment for joints in two MMSI fibers with NA of 0.22 and 0.3.

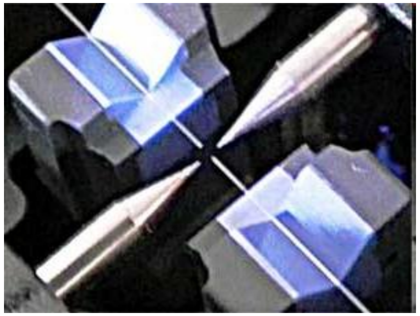
FIBER SPLICES

- A permanent joint formed between two fibers

TWO BROAD CATEGORIES

- **Fusion Splicing or Welding**

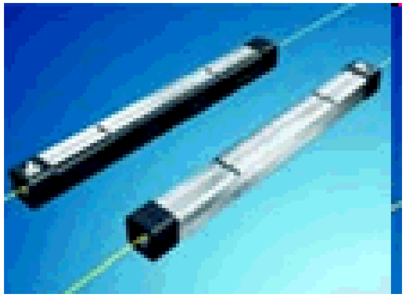
  Accomplished by applying localized heating (a flame or an electric arc) at the interface between two butted, prealigned fiber ends causing them to soften and fuse.



- **Mechanical Splicing**

  Fibers are held in alignment by some mechanical means

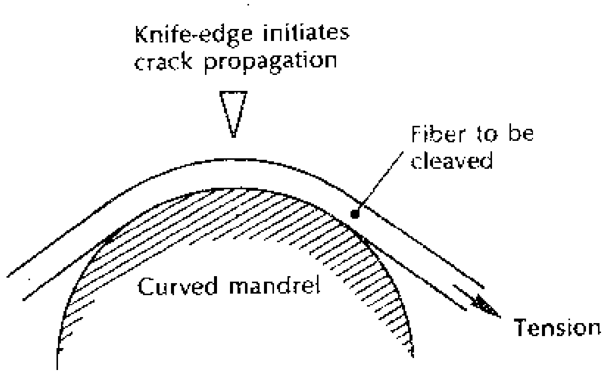
  - **Achieved by various methods;**
    - **Tube Splices**
    - **Groove Splices**



> MUST HAVE SMOOTH AND SQUARE END FACES

> End preparation achieved using suitable tools - “ Cleavers” “ Scribe and Break” or **“Score and Break”**

- Scoring of fiber surface under tension with cutting tool **(Sapphire, Diamond or Tungsten Carbide blade)**



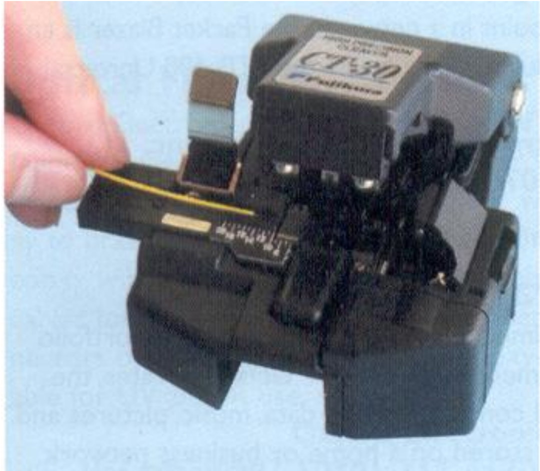
Optical fiber end preparation: the principle of scribe and break cutting.

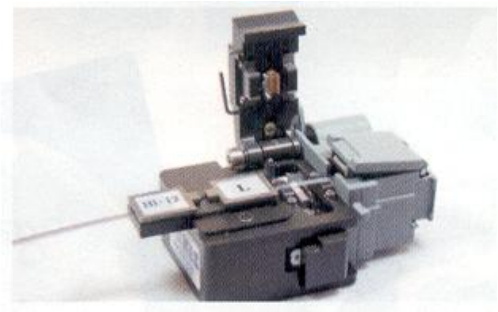
Fiber Cleavers

Two Action Cleaver:

Fiber cleaving &

Fusion splicing tool





One Action Cleaver

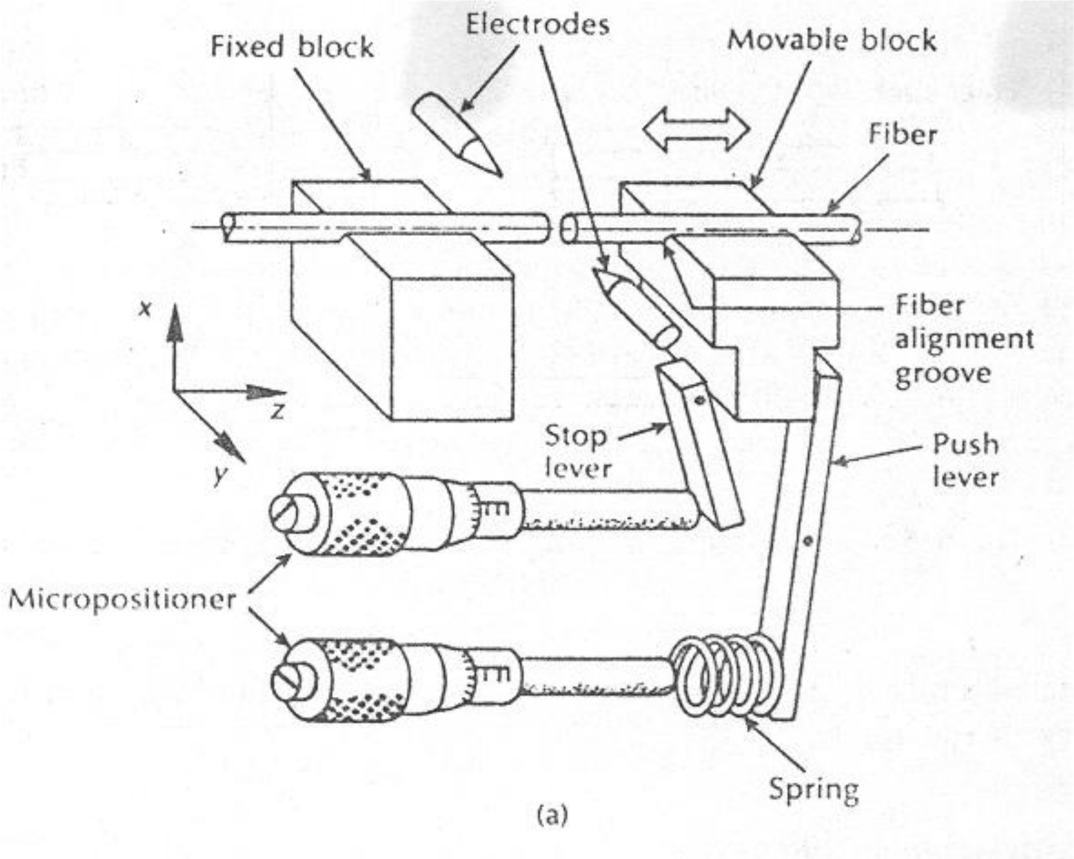
Handheld Cleaver

Cable Preparation Equipment

Multipack;

- Enhanced quality to prevent cracks and fiber strength degradation.
- Allow skill-free operation of factory fiber prep and field splicing applications.
- Equipped with a high precision tensile strip and automatic ultrasonic cleaning action.

Fusion Splicing of Optical Fibers

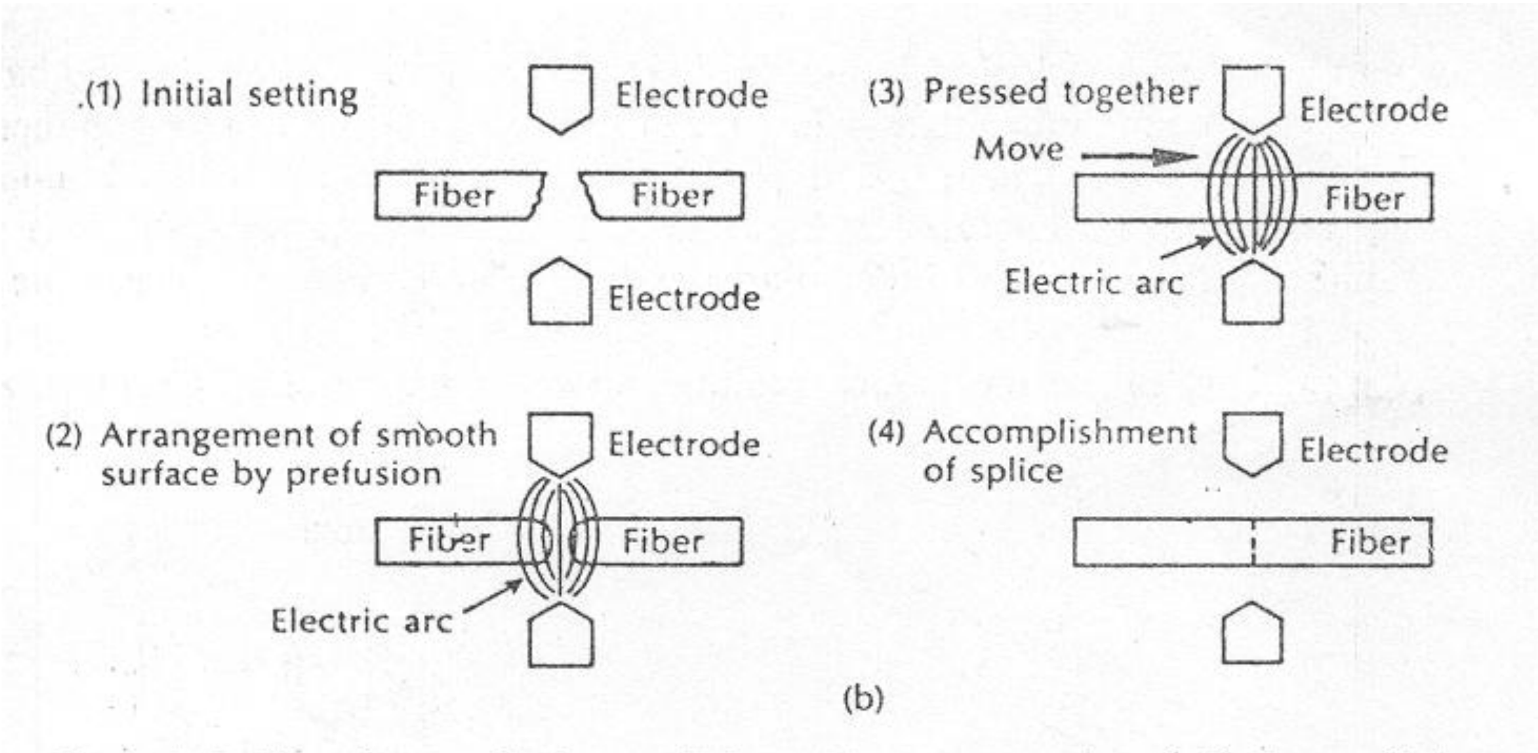


Electric Arc Fusion splicing

- **Require Fiber end surfaces to be prepared for joint**
- **Heating of prepared fiber ends to fusion point with application of axial pressure between two fibers.**
- **Positioning & alignment using microscopes**

Prefusion Method

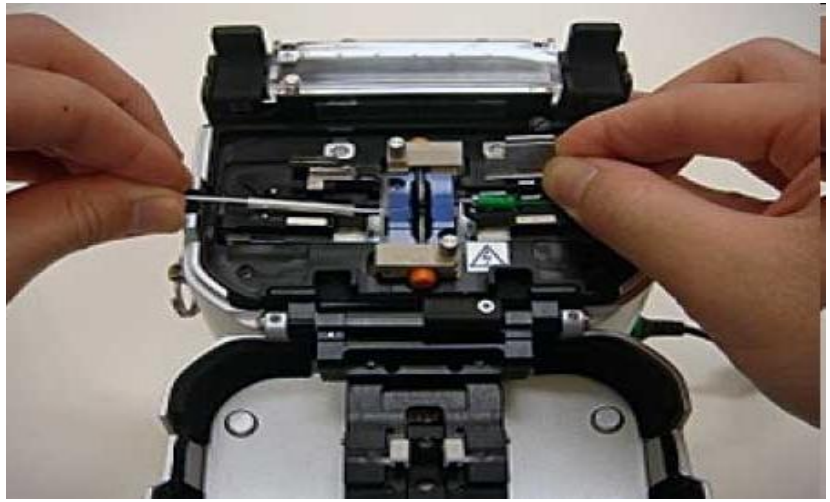
- No need for end preparation



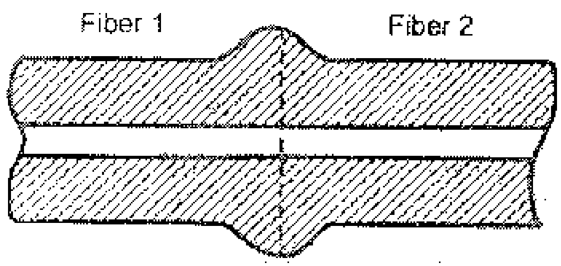
Prefusion method for accurate splicing

- **Smaller Fresnel Reflection loss**
- **Typical Losses : 0.1 to 0.2 dB for MMF**

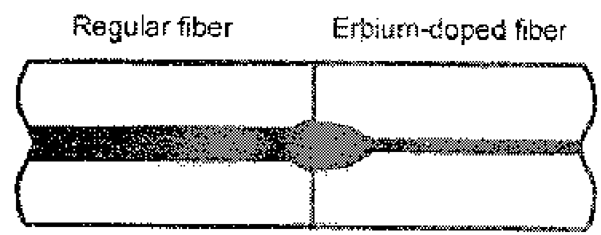
Fusion Splicers



Joint after Fusion Splicing



a) Regular Fiber



b) Erbium-doped Fiber

- Drawback: Fiber get weakened near splice (≈30%)
  - Fiber fracture occurs near the heat-affected zone adjacent to the fused joint.
  - Splice be packaged to reduce tensile loading

Protection of Joints

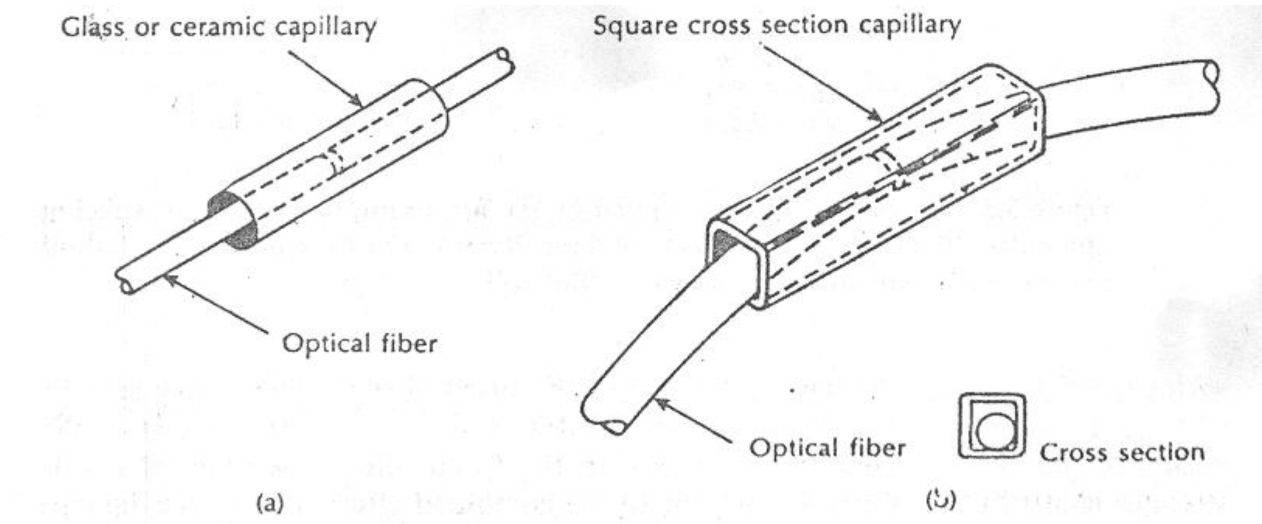
Protection Sleeves for spliced fibers

Underground fiber splice tray

Fiber joint enclosures

Mechanical Splicing

- Uses accurately produced rigid alignment tubes into which the prepared fiber ends are permanently bonded.



- **Techniques for tube splicing of optical fibers**:

  (a) Snug Tube Splice
  (b) Loose Tube Splice; Square Cross section Capillary

Comparison of Two Approaches

Snug Tube Splices

- Exhibits problems with capillary tolerance requirements
- Losses ≈ up to 0.5 dB with Snug tube splice (ceramic capillaries) using MMGI and SM fibers.

Loose Tube Splices

- Avoids the critical tolerance requirements.
- Losses ≈ 0.1 dB with loose tube splice using MMGI fibers.

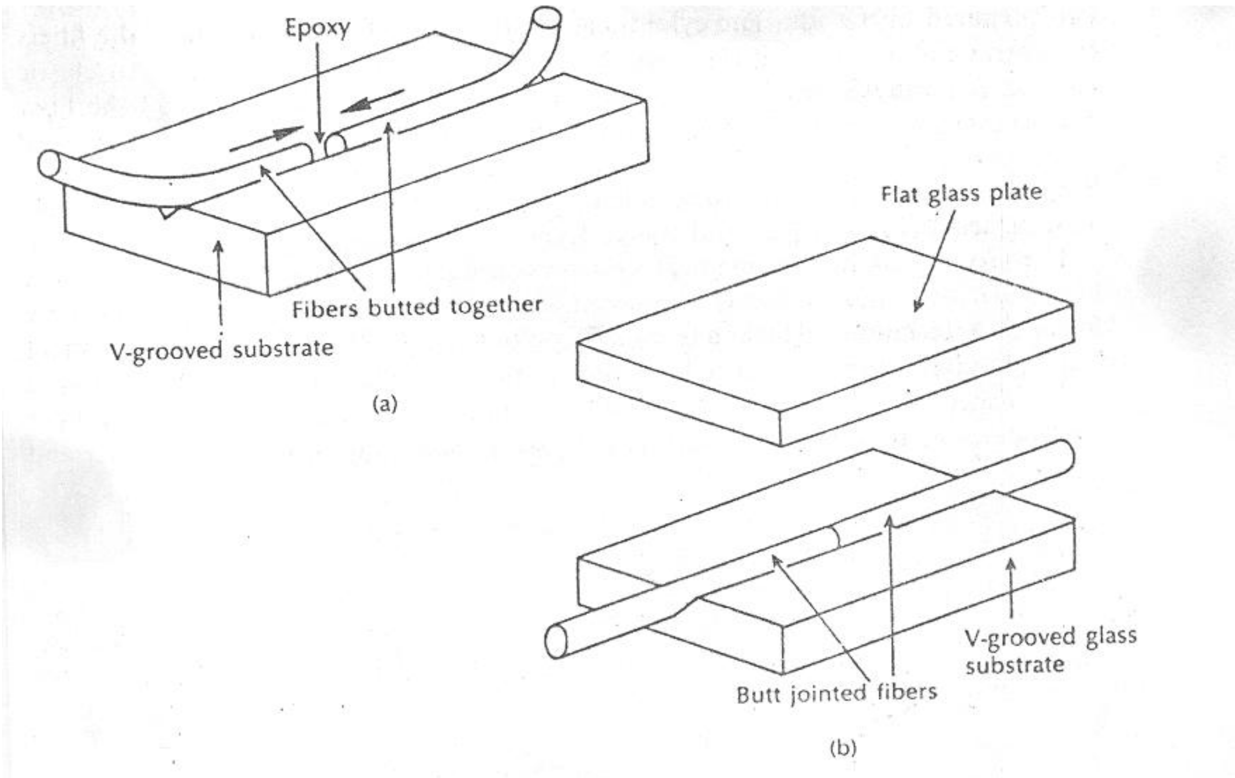
Ultra Splice

Ultra Splice: Reusable mechanical splice.

Average Loss ≅ 0.2 dB

Groove Splices

- **Use of grooves to secure the fibers to be jointed**
  - better alignment to the prepared fiber ends.

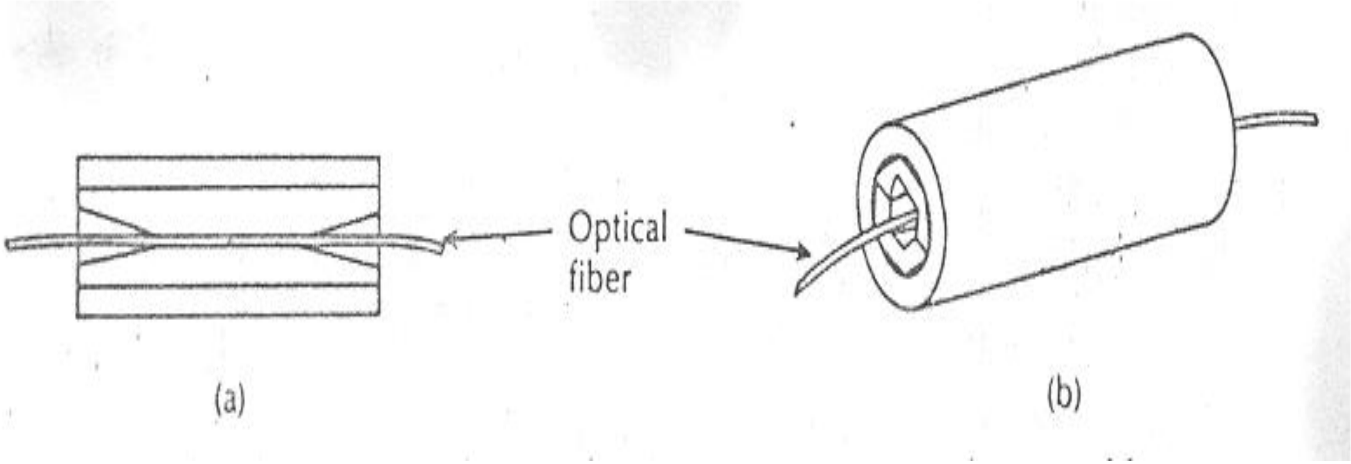


V-groove splices

- **Insertion losses** ≈ 0.1 dB using jigs for producing V-groove splice.

Elastic Tube or Elastomeric Splice

- **Comprises of two elastic parts (inner with V-groove) in compression to ensure alignment of fibers**.

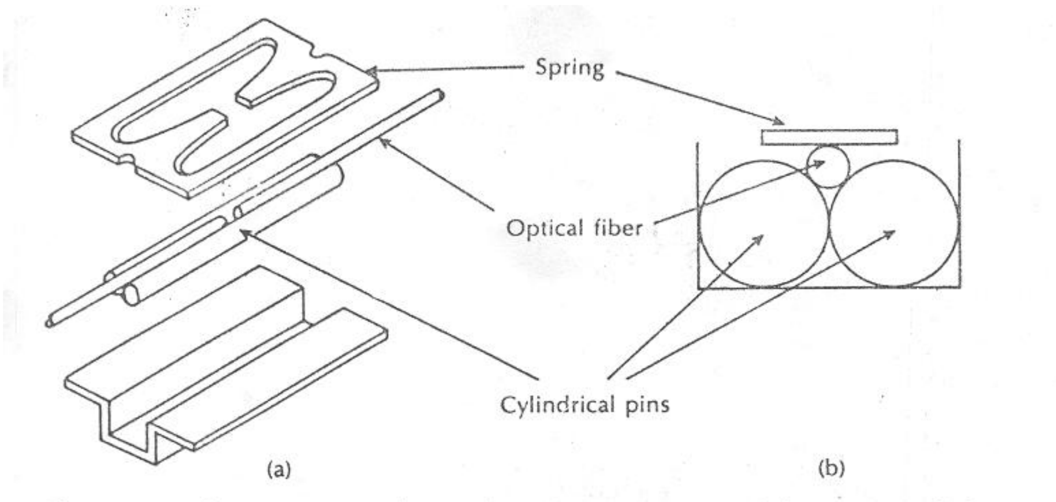


Elastomeric Splice: (a) Cross section (b) Assembly

- Fibers of different diameters tend to be centred and hence successfully spliced.
- General loss ~ 0.25 dB for commercial product

Spring Groove Splice

- Utilizes **a bracket** containing **two cylindrical pins**, which serve **as an alignment guide** for two prepared fibers.
- **An elastic element** (a spring) used to **press the fibers** into groove and maintain alignment of fiber ends.



Springroove Splice : (a) Expanded overview
(b) Cross-section Schematic

Mean Losses ≈ 0.05 dB with MMGI Fibers.

❑ **Practically used in Italy.**

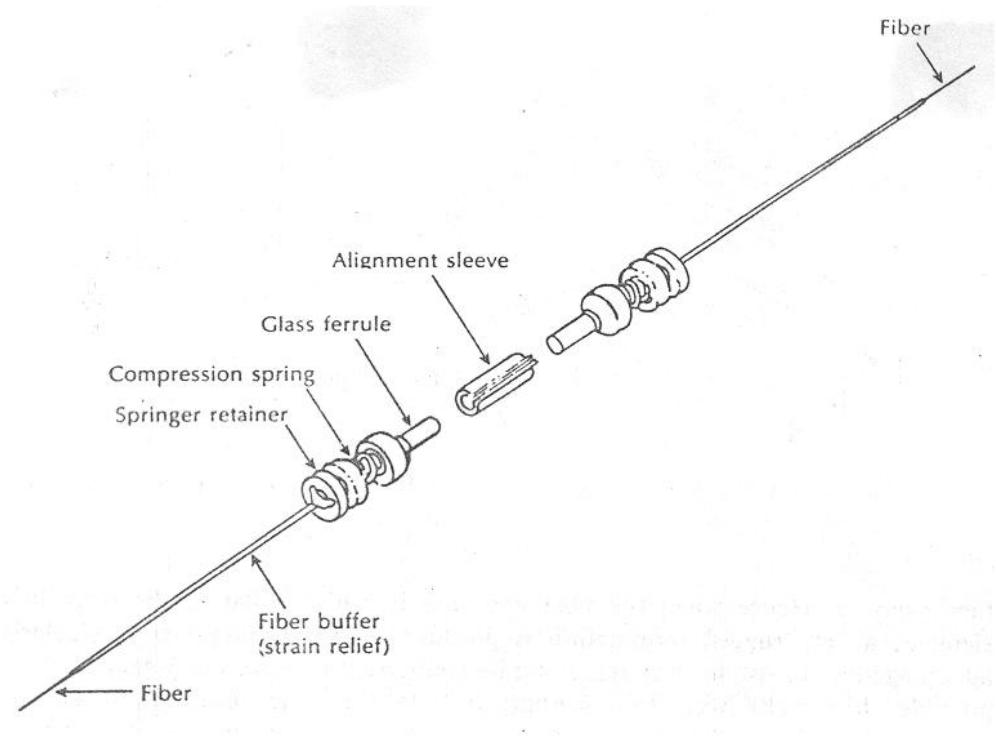
Secondary Alignment Techniques

- **Alignment of secondary elements around the bare fibers**
  - Increased ruggedness
  - Easy ground and polish of fiber end
  - Better termination

Drawbacks:

- **Time consuming for termination**
- **Increased losses due to tolerances on secondary elements $\Rightarrow$ Fiber misalignment.**

Glass capillary tubes (Ferrules)

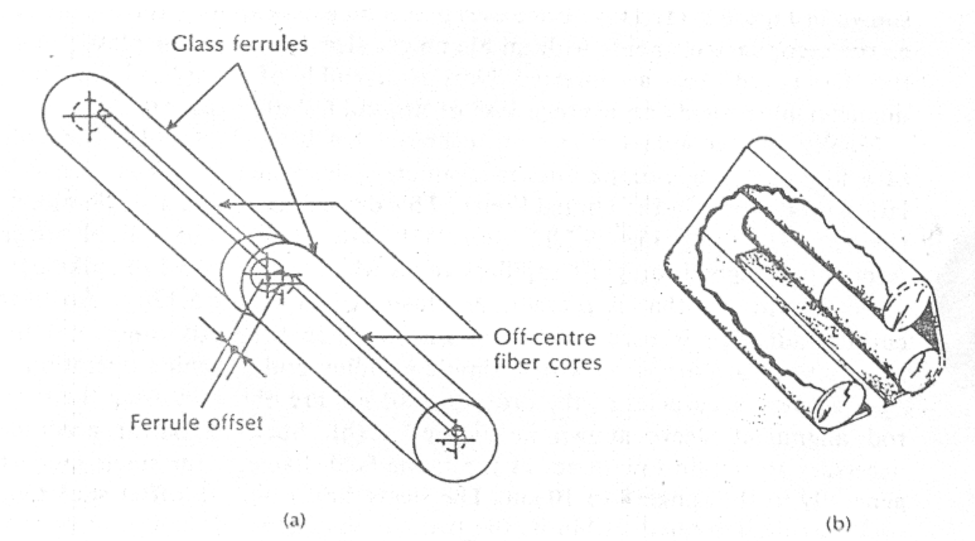


MMF mechanical splice using glass capillary tubes.

- **Fixing of glass ferrules**
- **Alignment sleeve of metal or plastic in which glass tube fibers are aligned**
- **Average loss** ≅ 0.2 dB

Rotary Splice

- **Use glass capillary tubes for fiber termination with small eccentricity.**



Rotary Splice for SMF:

(a) Alignment using glass ferrules

(b) Glass rod alignment sleeve

- Built-in offset and rotation, for excellent alignment
- Alignment accuracy of 0.05 μm using three glass rod alignment sleeve. (necessary for SMFs; 8-10 μm MFD)
- **Mean Losses** ≅ 0.03 dB using Index matching gels (Not affected by skill levels of the splicer).

❖ **Used in large installations in USA**

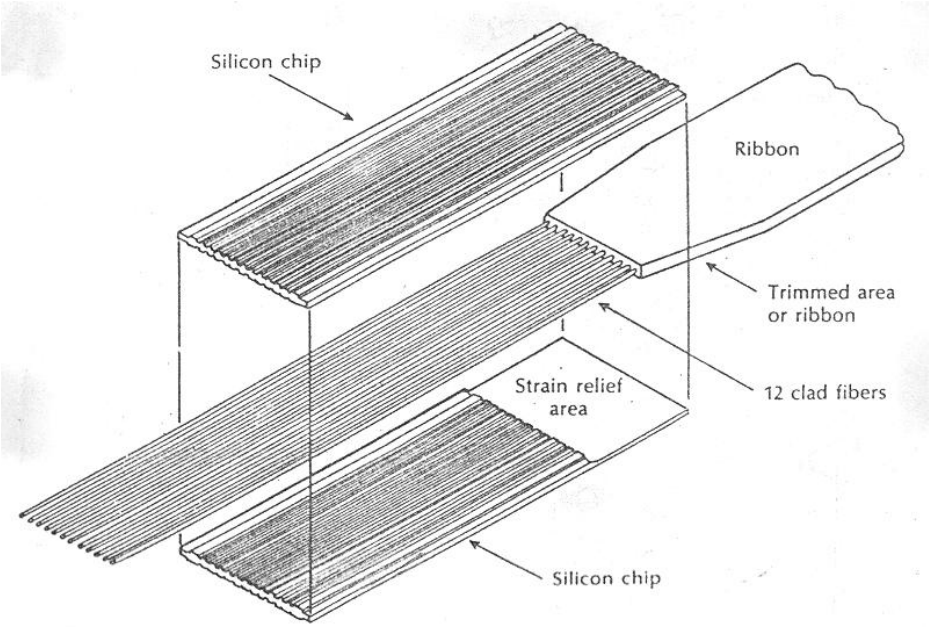
MULTIPLE SPLICES

- **Commercially available for splicing number of fibers simultaneously**
    - **Simultaneous Splicing of Five fibers in 5 minutes;**
    - **15 minutes for five single fusion splicing.**

- **Splice Losses:**
    - **Ranging 0.04 to 0.12 dB- MM GI fibers**
    - **0.13 to 0.4 dB – SM fibers.**

A. Silicon Chip Array

- Utilize trapezoidal grooves of a silicon chip using a comb structure for fiber laying and top silicon chip
- End faces ground & polished after curing.

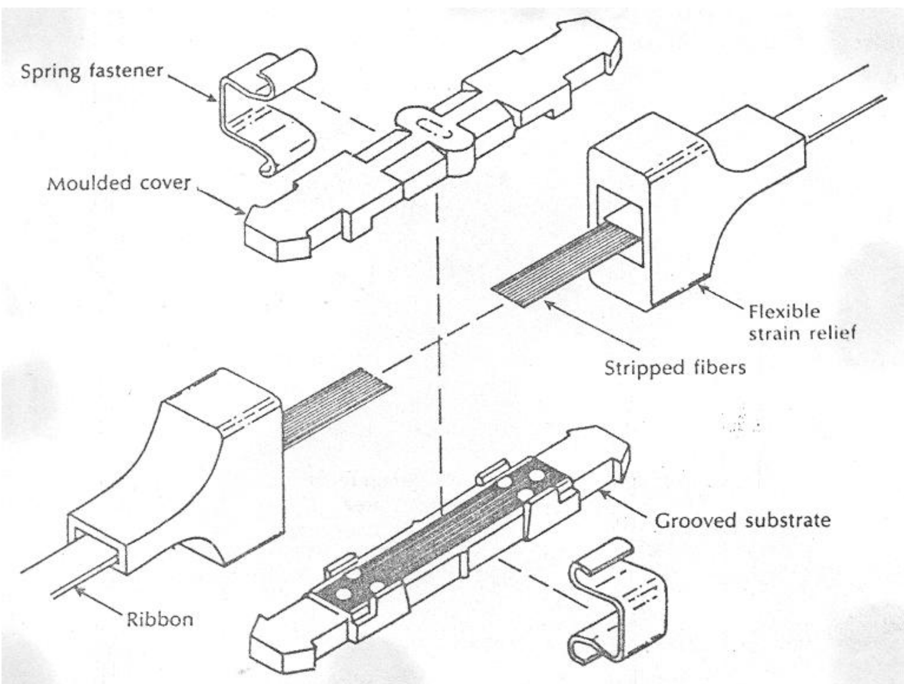


Multiple fibers splicing using a Silicon chip array

Average Splice loss $\cong$ 0.12 dB.

B. V-groove flat Chip

- Moulded from glass filled polymer resin
- Direct mass splicing of 12 fiber ribbons with simultaneous end preparation using ribbon grinding and polishing procedures.
- Fibers positioned in grooves in glass filled plastic substrate.
- Vacuum technique to hold fibers at position whilst cover plate is applied.



V-groove polymer resin ribbon fiber splice.

➢ Spring clips to hold assembly and hole in cover plate for index matching gel.

❑ **Average Splice Losses** ≈0.18 dB with MM fiber.

Fiber Splicing and Connectorization kits

THANK YOU