FIBER JOINT

Ref : Keiser, Palais

Sambungan

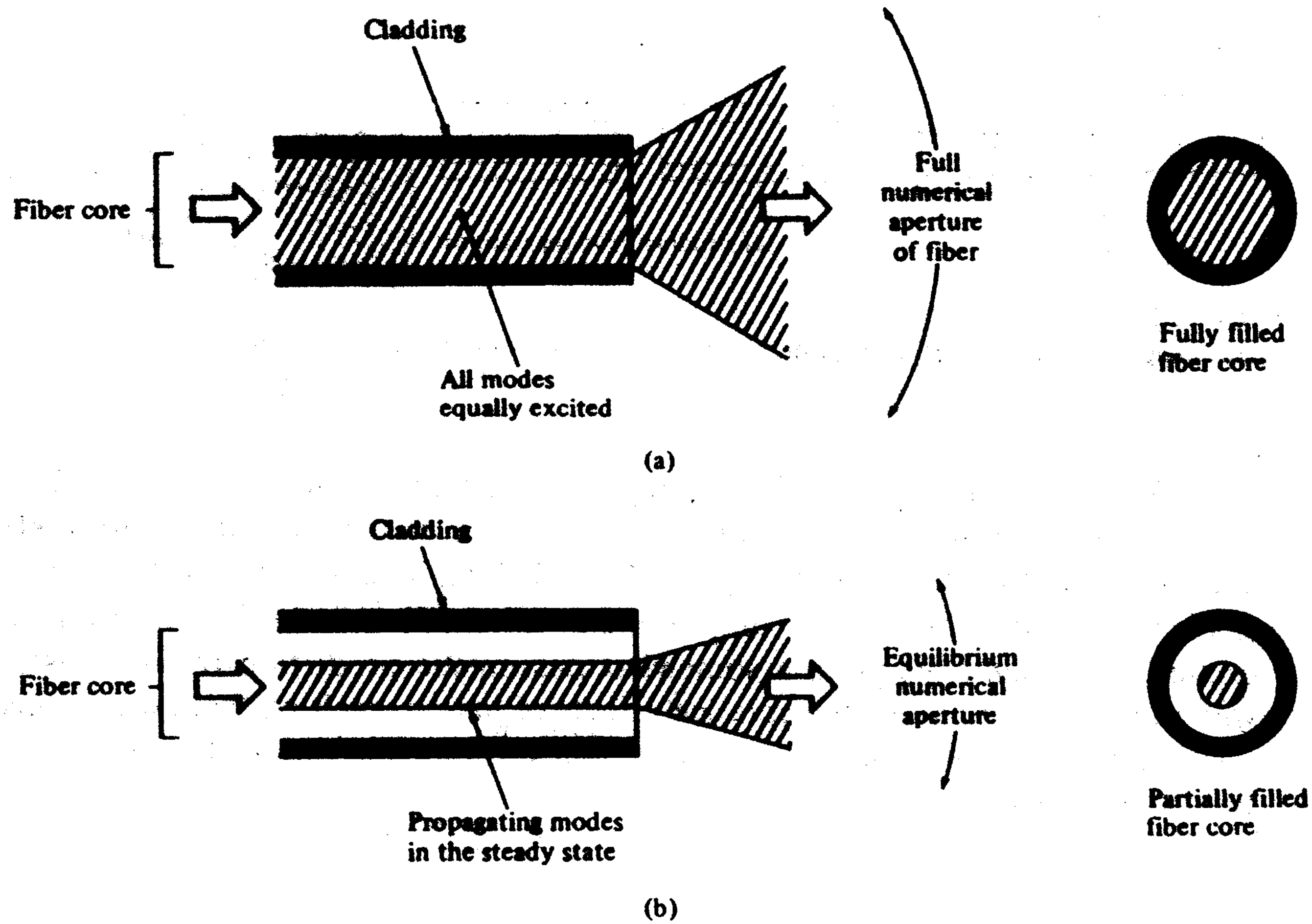
- **Sambungan fiber dng fiber :**
  - **Permanen ➔ splice**
  - **Tdk permanen ➔ konektor**
- **Parameter redaman sambungan :**
  - **Distribusi daya masukan ke sambungan**
  - **Jarak sumber optik dan sambungan**
  - **Ukuran dan karakteristik ke dua ujung fiber**
  - **Kualitas permukaan ujung fiber**

Efisiensi gandengan : $$\eta_F = \frac{M_{comm}}{M_E}$$

M_{comm} : jumlah common mode

M_E : jumlah mode di fiber pengemisi

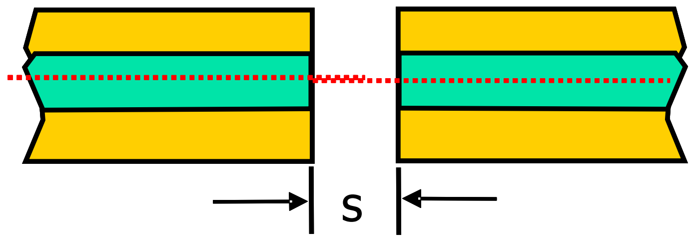
Loss gandengan : $$L_F = -10 \log \eta_F$$



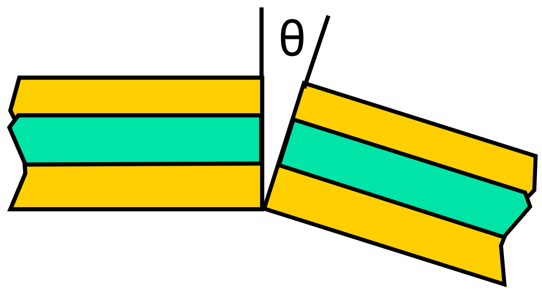
Distribusi modus berbeda berkas optik memancar dr fiber menghasilkan loss gandengan berbeda

Misalignment mekanis

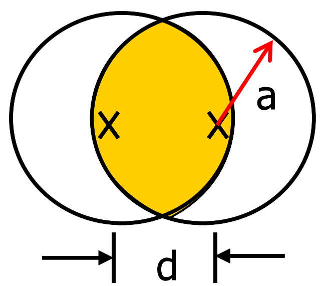
- Jenis misalignment utama :
  - **Separasi longitudinal, terjadi jika fiber memiliki sumbu sama tetapi memiliki celah s**
  - **Misalignment sudut (angular), terjadi jika dua sumbu membentuk suatu sudut shg permukaan ujung fiber tidak sejajar**
  - **Axial/lateral displacement, terjadi jika kedua sumbu fiber terpisah sejauh** d.
- Misaligment paling banyak terjadi : axial displacement



(a) Separasi longitudinal



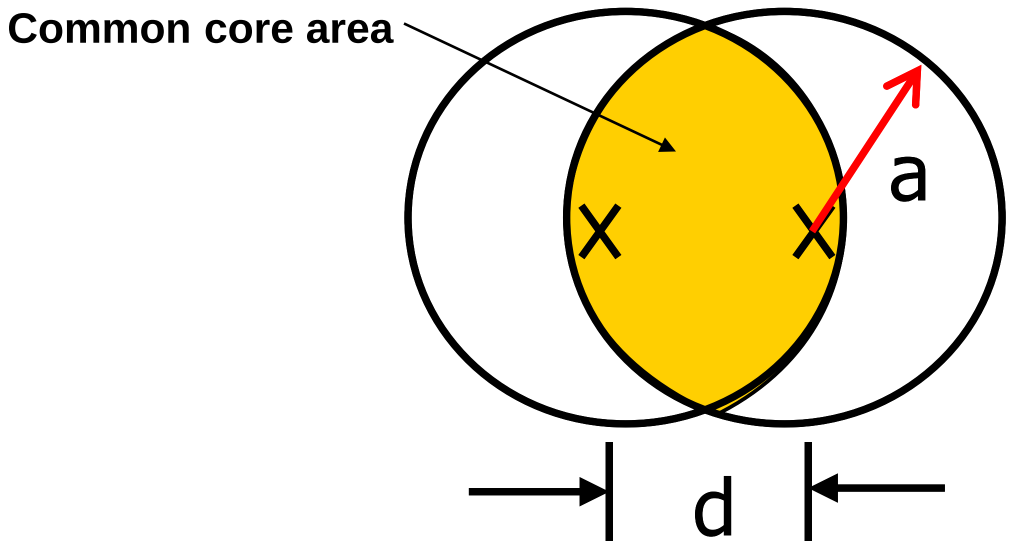
(b) Angular misalignment



(c) Lateral displacement

Jenis misaligment mekanis

Axial/lateral displacement



Efisiensi gandengan fiber SI :

$$\eta_{F,step} = \frac{A_{comm}}{A_F} = \frac{2}{\pi} \arccos \frac{d}{2a} - \frac{d}{\pi a}\sqrt{1 - \frac{d^2}{4a^2}}$$

Efisiensi gandengan fiber GI :

$$\eta_{F,grad} = \frac{P_T}{P} = \frac{2}{\pi}\left\{\arccos\frac{d}{2a} - \sqrt{1-\frac{d^2}{4a^2}}\,\frac{d}{6a}\left(5-\frac{d^2}{2a^2}\right)\right\}$$

Jika d/a < 0,4 :

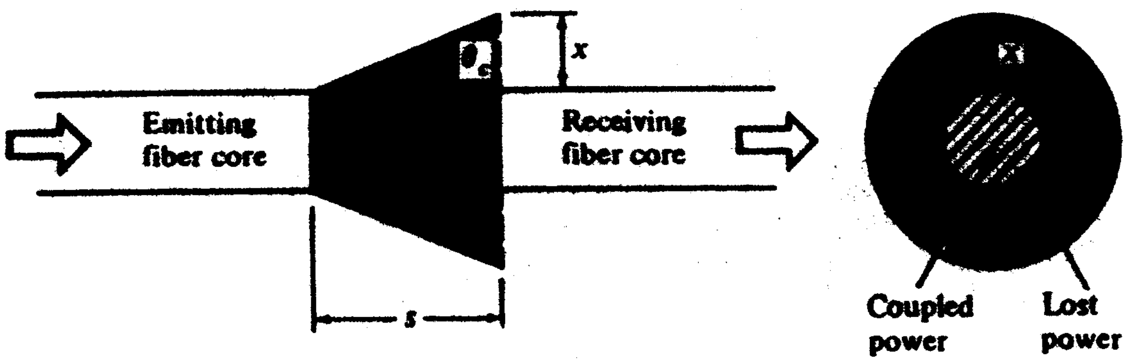
$$\eta_{F,grad} \cong 1 - \frac{8d}{3\pi 4a}$$

Efisiensi gandengan SM :

$$\eta_{SM,lat} = e^{-(d/W)^2}$$

W : jari-jari Mode Field

Separasi



Efek loss jika ujung fiber terpisah sejauh s

Efisiensi gandengan Fiber SI :

$$\eta_F = \left(\frac{a}{a + s\tan\theta_c} \right)^2$$

θ_C : sdt kritis fiber

Efisiensi gandengan Fiber SM :

$$\eta_{SM,long} = \frac{4(4Z^2+1)}{\left(4Z^2+2\right)+4Z^2}$$

$$Z = s\lambda / \left(2\pi n_2 W^2\right)$$

Angular misalignment

Efisiensi gandengan Fiber SI (mode memancar seragam):

$$\eta_F = \cos\theta \left\{ \frac{1}{2} - \frac{1}{\pi} p\sqrt{1-p^2} - \frac{1}{\pi}\arcsin p - q\left[\frac{1}{\pi} y\sqrt{1-y^2} + \frac{1}{\pi}\arcsin y + \frac{1}{2} \right] \right\}$$

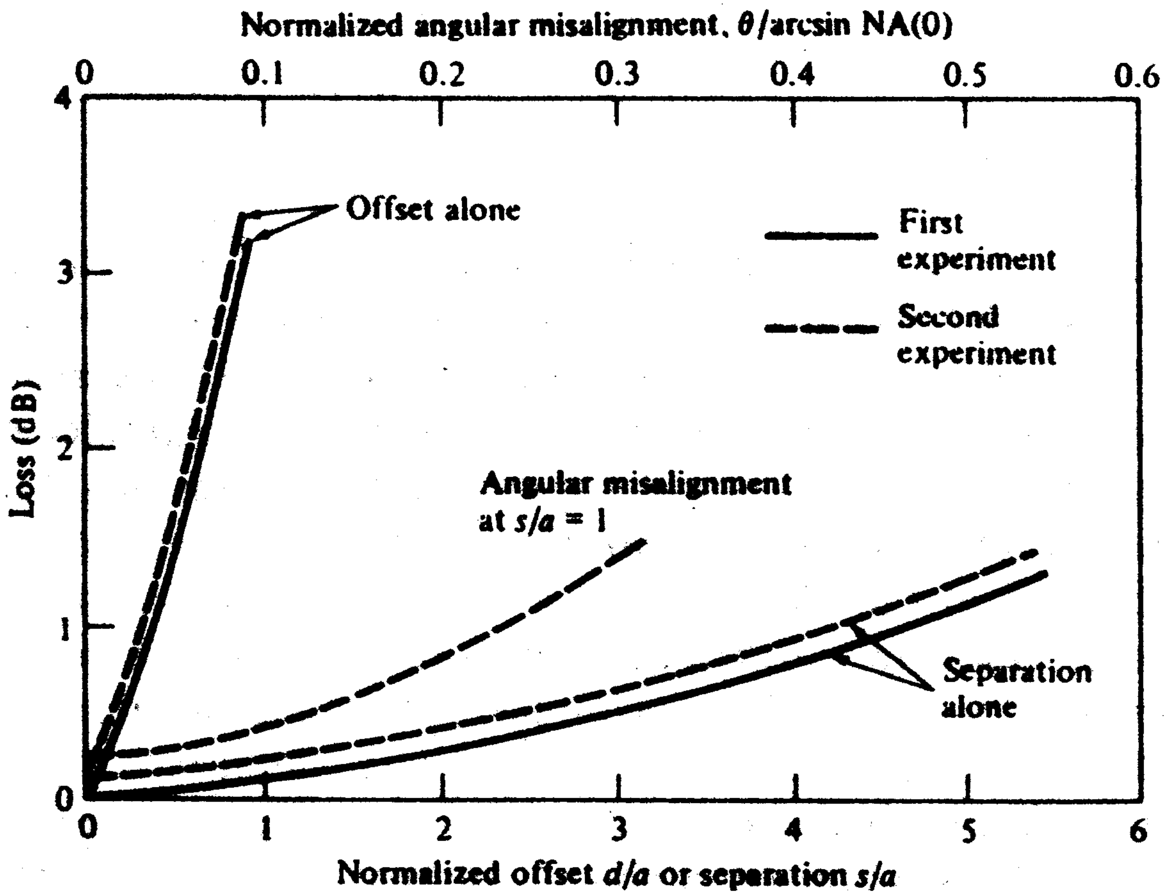
$$p = \frac{\cos\theta_c (1-\cos\theta)}{\sin\theta_c \sin\theta}$$

$$q = \frac{\cos^3\theta_c}{\sqrt{\left(\cos^2\theta_c - \sin^2\theta\right)^3}}$$

$$y = \frac{\cos^2\theta_c (1-\cos\theta) - \sin^2\theta}{\sin\theta_c \cos\theta_c \sin\theta}$$

Efisiensi gandengan Fiber SM :

$$\eta_{SM,ang} = e^{-\left(\frac{\pi n_2 W\theta}{\lambda}\right)^2}$$



Perbandingan redaman dr 2 hasil percobaan sumber LED, fiber GI :

(1) a = 50 μm, panjang 1,83 m

(2) a : 55 μm, panjang 20 m

Contoh

- Fiber SM memiliki frek normal V = 2,40, indeks bias inti n_1 = 1,47, indeks bias kulit n_2 = 1,465 dan diameter inti 2a = 9 μm.
  - Hitung loss sambungan jika terjadi lateral offset 1 μm.
  - Hitung loss sambungan jika terjadi angular misaligment 1^o pd panj gel 1300 nm.

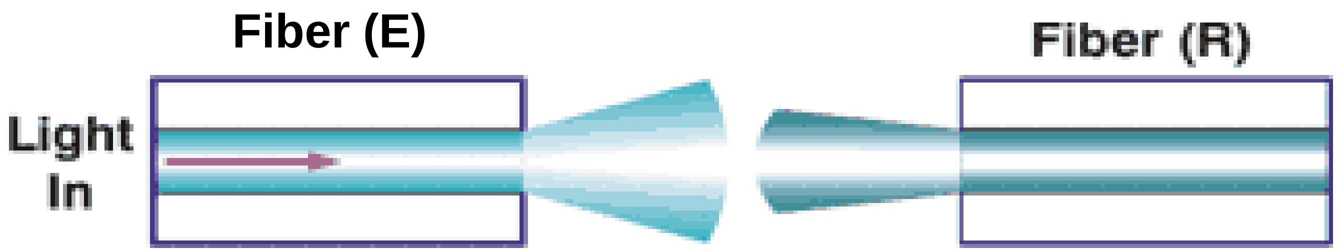
Loss berkaitan dgn perbedaan fiber

Perbedaan dimensi dan karakteristik fiber yg disambungkan akan menambah loss gandengan.

Profil indeks bias berbeda :

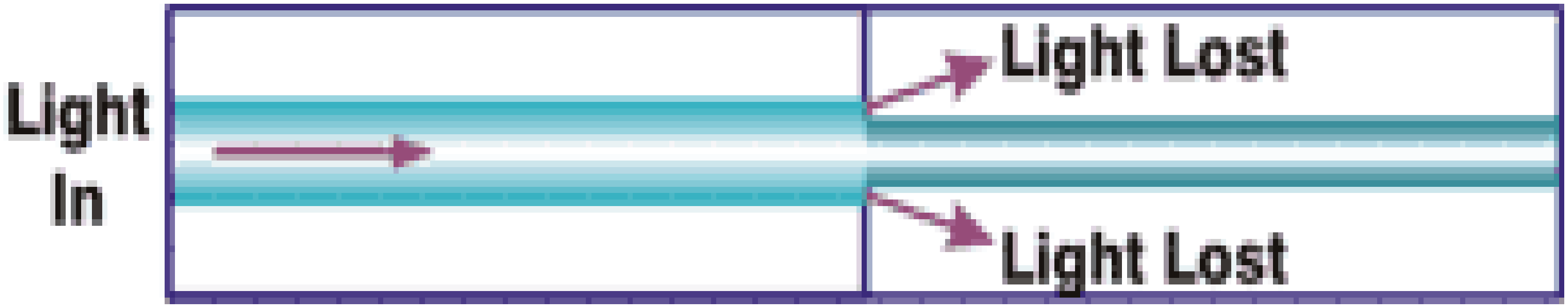
$$\eta_{F(\alpha)} = \begin{cases} \dfrac{\alpha_R(\alpha_E + 2)}{\alpha_E(\alpha_R + 2)} & \textbf{utk} \quad \alpha_R < \alpha_E \\ 1 & \textbf{utk} \quad \alpha_R \geq \alpha_E \end{cases}$$

NA berbeda



$$\eta_{F(NA)} = \begin{cases} \left[\dfrac{NA_R(0)}{NA_E(0)} \right]^2 & \textbf{utk} \quad NA_R(0) < NA_E(0) \\ 1 & \textbf{utk} \quad NA_R(0) \geq NA_E(0) \end{cases}$$

Jari-jari fiber berbeda

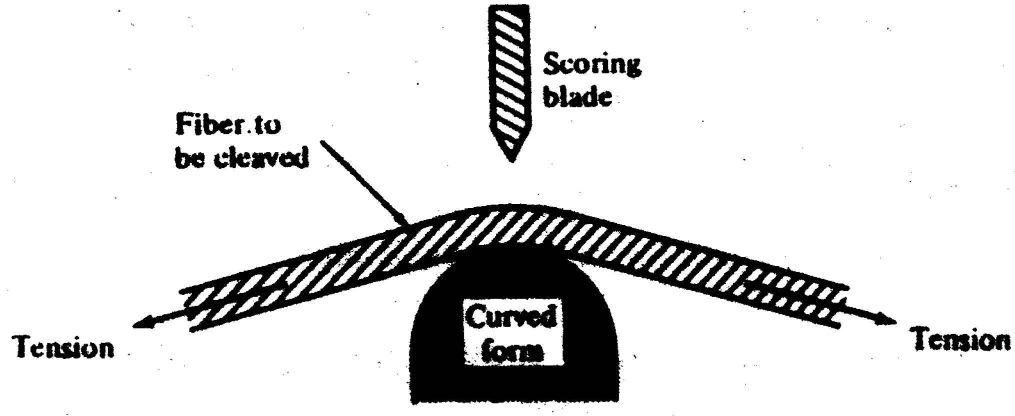


$$\eta_{F(a)} = \begin{cases} \left(\dfrac{a_R}{a_E}\right)^2 & \textbf{utk} \quad a_R < a_E \\ 1 & \textbf{utk} \quad a_R \geq a_E \end{cases}$$

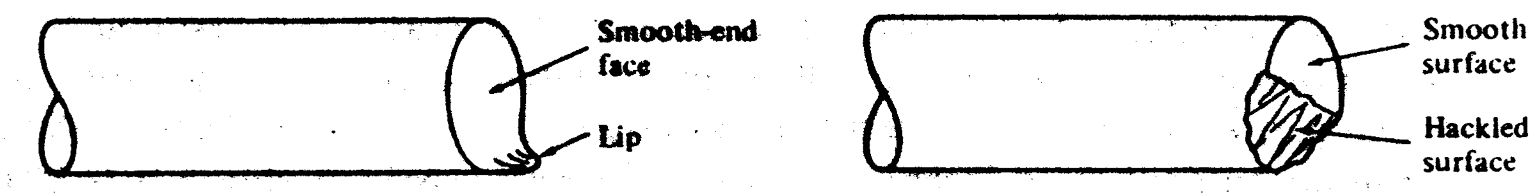
Penyiapan muka ujung fiber

- **Agar cahaya tidak dihamburkan di sambungan, ujung fiber harus dibuat rata, tegak lurus thd sumbu fiber dan halus.**
- **Teknik Grinding dan polishing:**
  - **dpt menghasilkan permukaan fiber yg halus dan tegak lurus sumbu fiber**
  - **perlu banyak waktu dan ketrampilan operator.**
  - **Diaplikasikan di lingkungan terkendali spt laborat, pabrik.**
  - **Tdk cocok utk di lapangan**
- **Teknik controlled-fracture :**
  - **Didasarkan pd cara score-and-break**
  - **Fiber dibentangkan diatas permukaan lengkung dan ditarik, selanjutnya dipotong dng sejenis pisau.**
  - **Dihasilkan ujung permukaan yg sangat halus dan tegak lurus sb fiber**
  - **Perlu pengendalian curvature dr fiber dan besarnya tarikan.**
  - **Jika tidak tepat ➔ beberapa crack.**

- **Akibat ketidak tepatan menghasilkan :**
  - **Lip**
  - **Rolloff, kondisi sebaliknya dr lip**
  - **Chip, frakcture setempat**
  - **Hakle, ketidak teraturan ujung fiber**
  - **Mist, spt hakle tapi lebih sedikit**
  - **Spiral/step, abrupt change di ujung fiber**
  - **Shattering, akibat fracture tak terkendali dan tak dpt didefinisikan karakteristik permukaannya.**



Prosedur controlled-fracture penyiapan ujung fiber

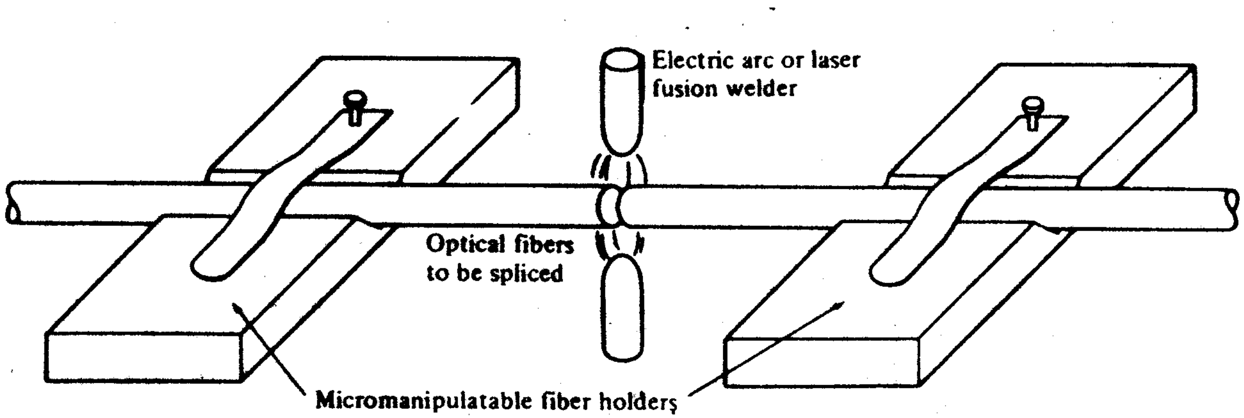


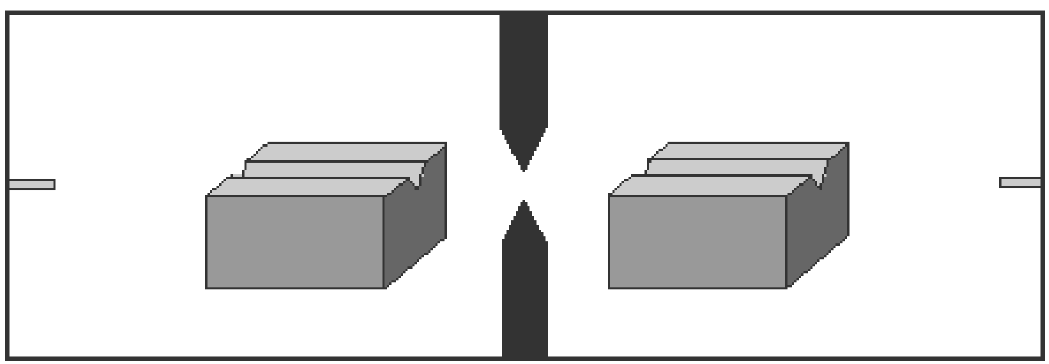
Contoh ketidak tepatan pemotongan ujung fiber

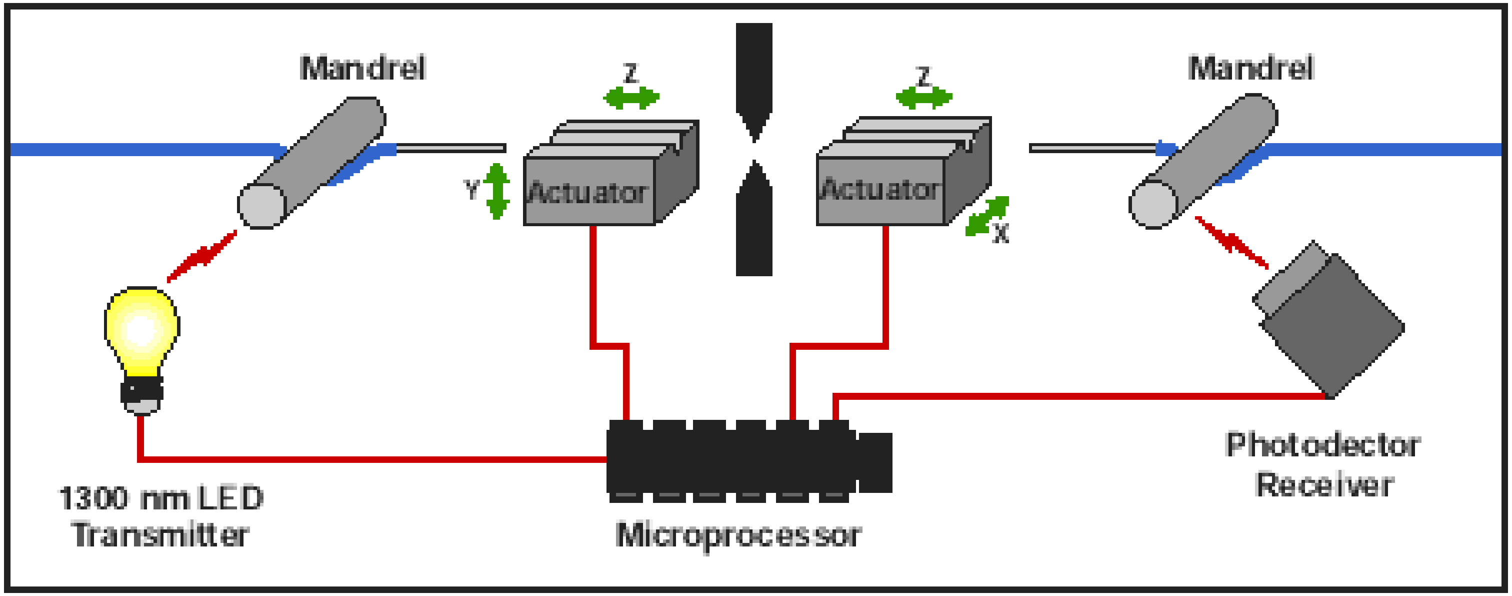
Fiber splicing

- Teknik splicing :
  - Fusi : menyatukan kedua ujung fiber secara termal (di-las)
  - V-groove : menyatukan kedua ujung fiber dgn lem.
  - Tube mechanical splice : pipa terbuat dr bahan elastis
  - Loose-tube splice : menggunakan pipa segiempat, lengkungan fiber mengakibatkan pipa berputar menempatkan fiber di salah satu ujung.
  - 3-rod : menggunakan 3 tongkat bulat.

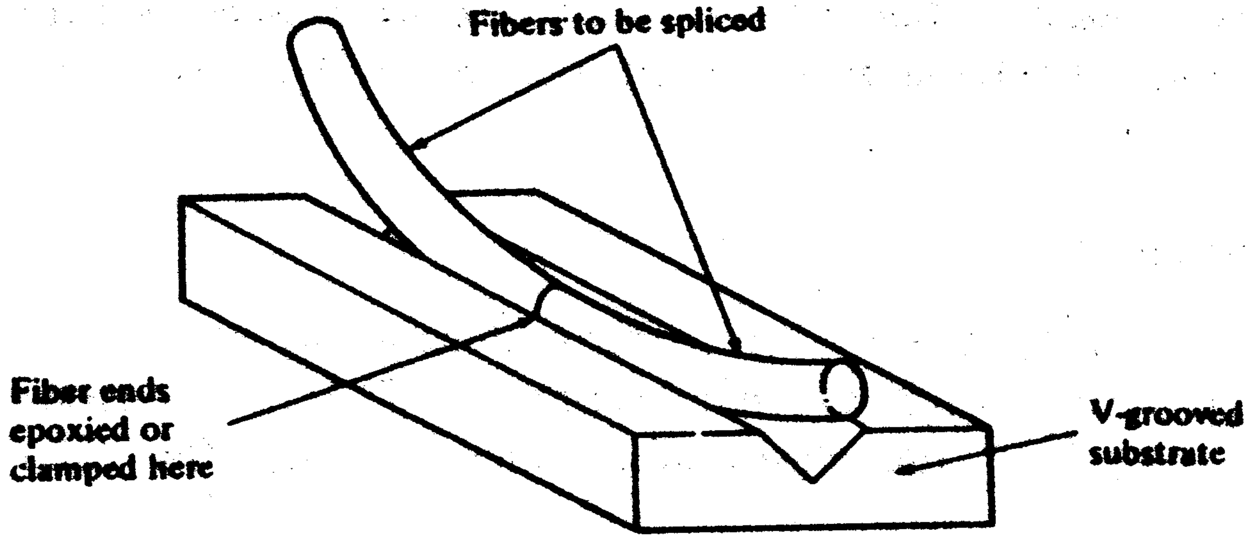
Fusion splicing



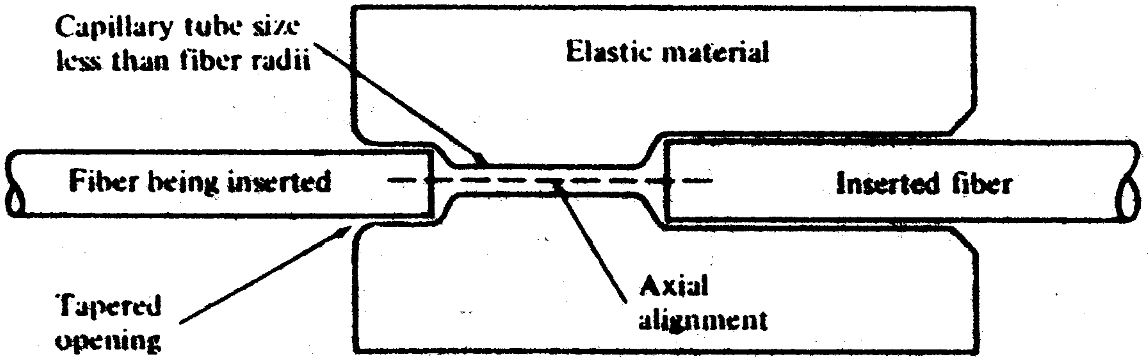




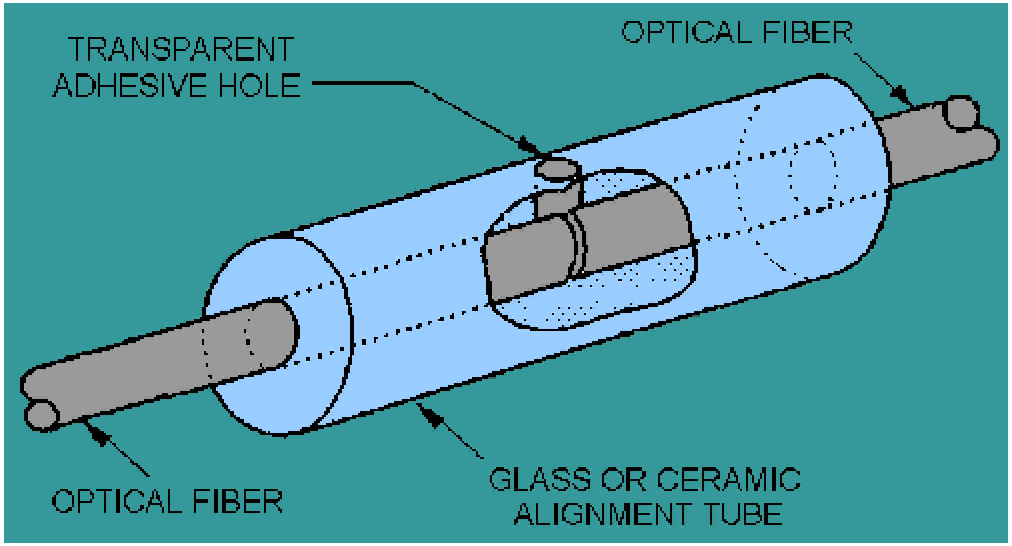
Fused splicer active alignment

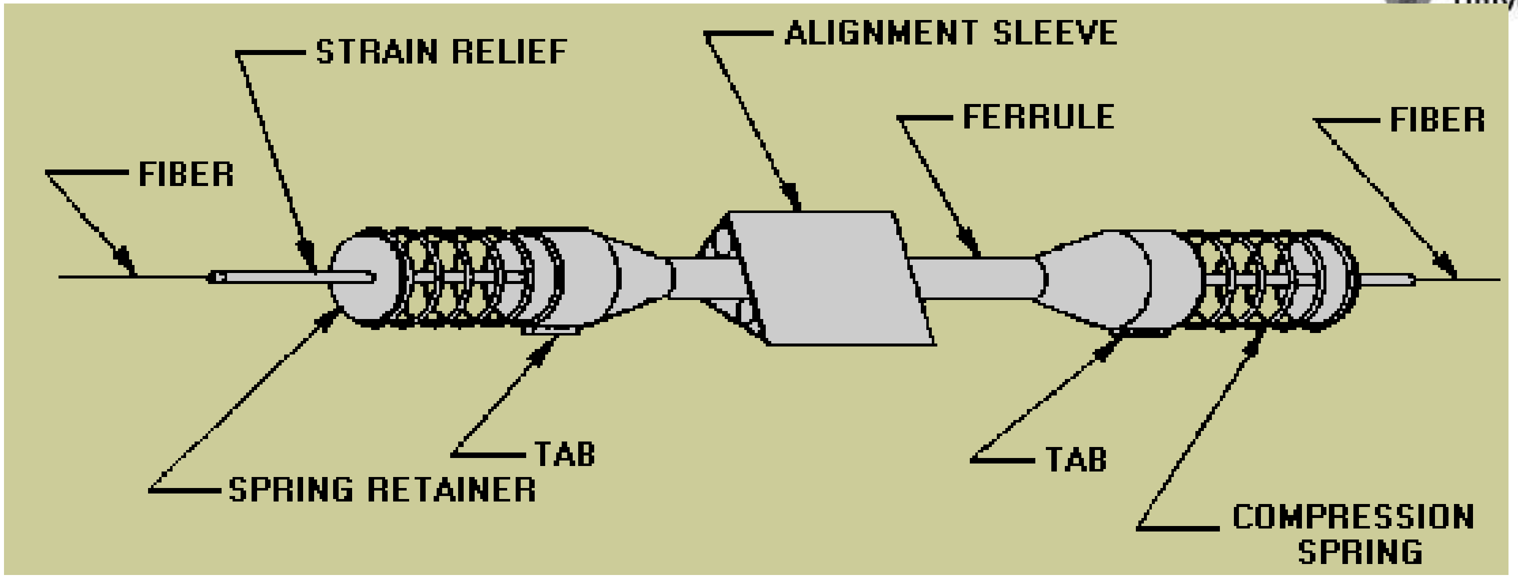


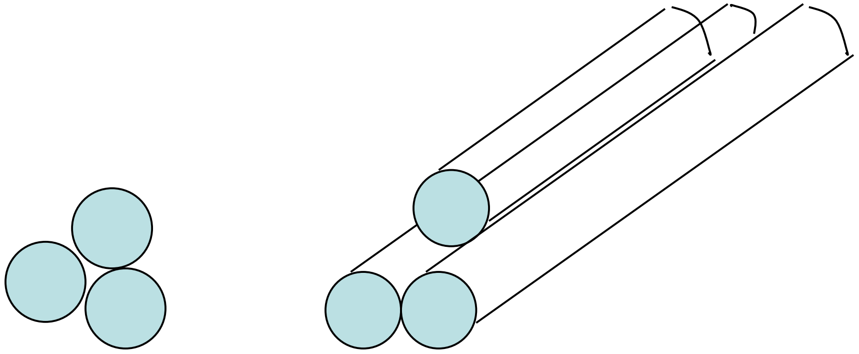
V-groove splicing



Elastic tube splicing



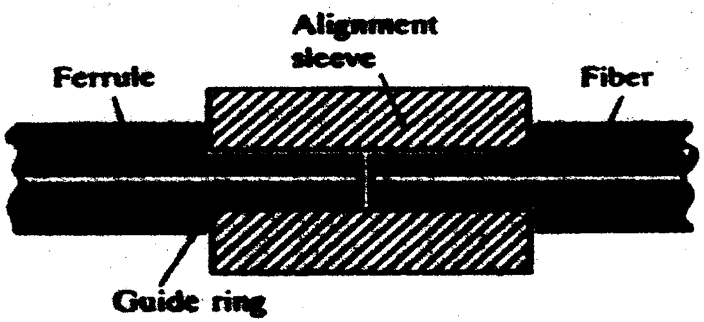




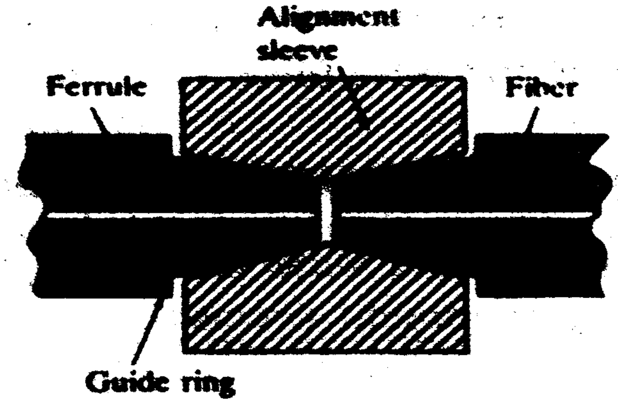
3-rods splicing

Konektor

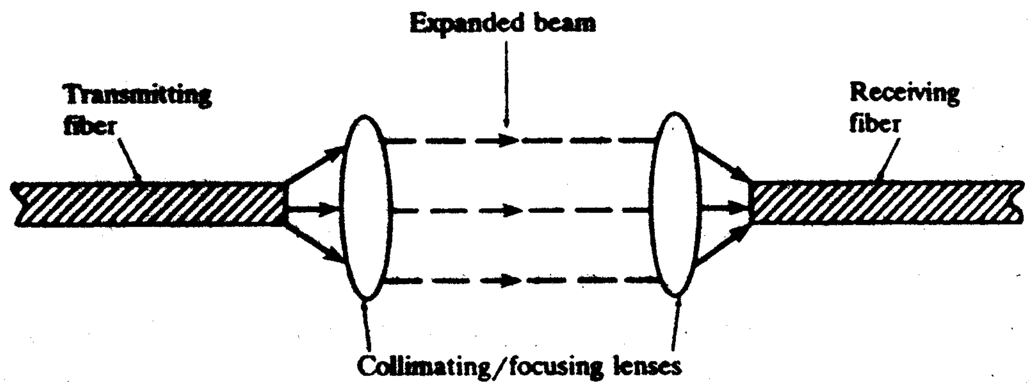
- Persyaratan konektor yg baik :
  - Loss gandengan rendah
  - Interchangeability/compatibility
  - Mudah pemasangan pd fiber
  - Sensitifitas lingkungan rendah
  - Murah dan konstruksi andal
  - Mudah penyambungan (buka-sambung)
- Jenis konektor :
  - **Butt-joint**
    - **Straight sleeve**
    - **Tapered sleeve**
  - **Expanded beam**



(a)

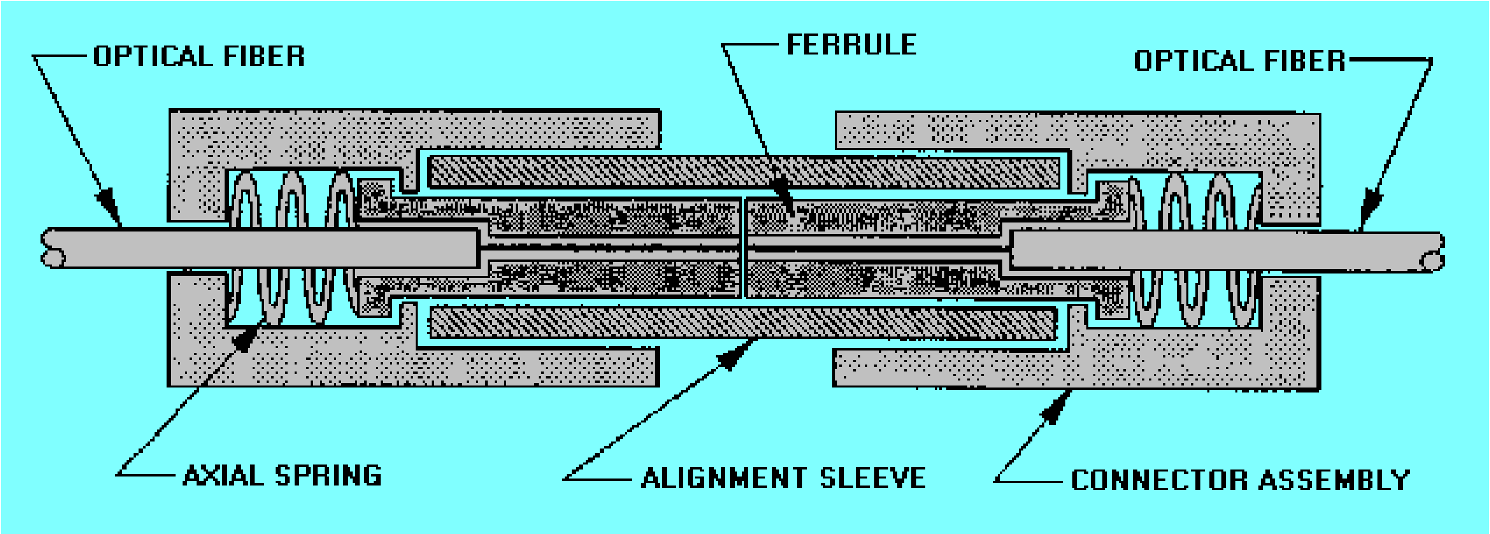


(b)

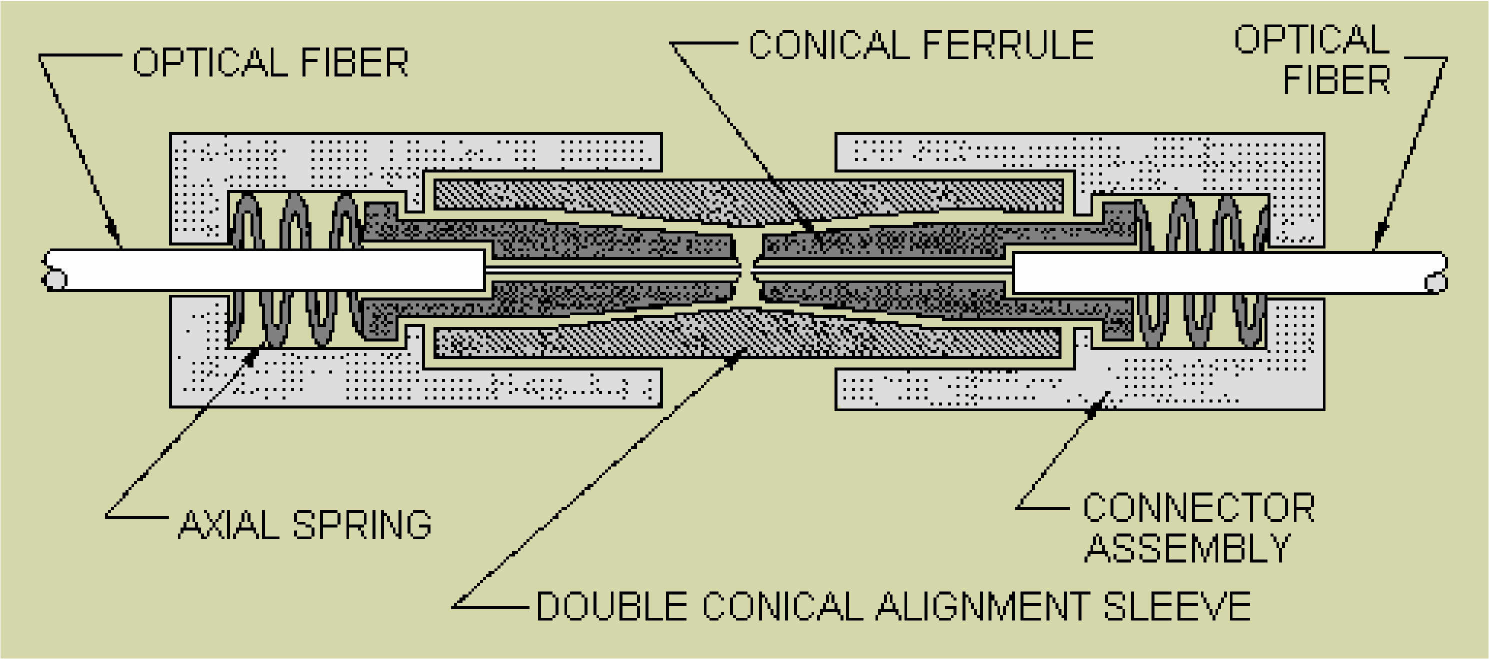


(c)

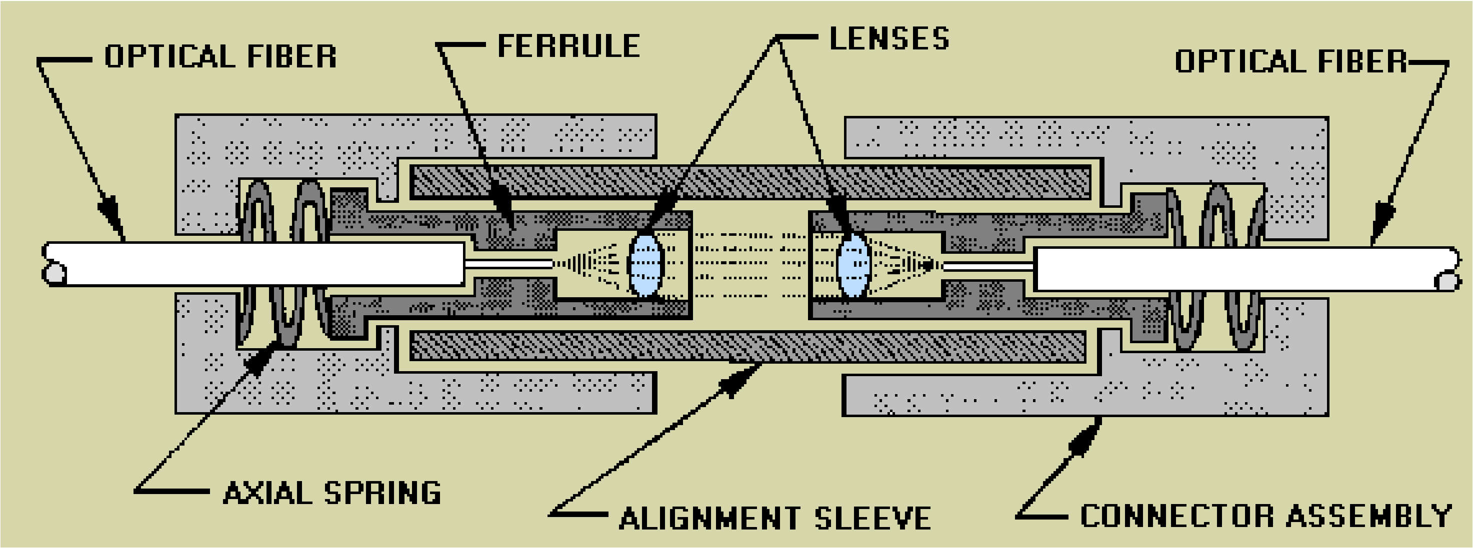
(a) Straight sleeve   (b) Tapered sleeve   (c) Expanded beam



Ferrule connector



Biconical connector



Expanded beam connector

Efisiensi gandengan konektor SM fiber :

$$\eta_{SM,ff} = \frac{16 n_1^2 n_3^2}{(n_1 + n_3)} \frac{4\sigma}{q} e^{-(\rho u / q)}$$

$$u = (\sigma + 1) F^2 + 2\sigma FG \sin\theta + \sigma \left(G^2 + \sigma + 1 \right) \sin^2\theta$$

$$\rho = (kW_1)^2$$

$$q = G^2 + (\sigma + 1)^2$$

$$F = d / kW_1^2$$

$$G = s / kW_2^2$$

$$\sigma = (W_2 / W_1)^2$$

$$k = 2\pi n_3 / \lambda$$

n_1 = indeks bias inti

n_3 = indeks bias media antar fiber

λ = panjang gel sumber

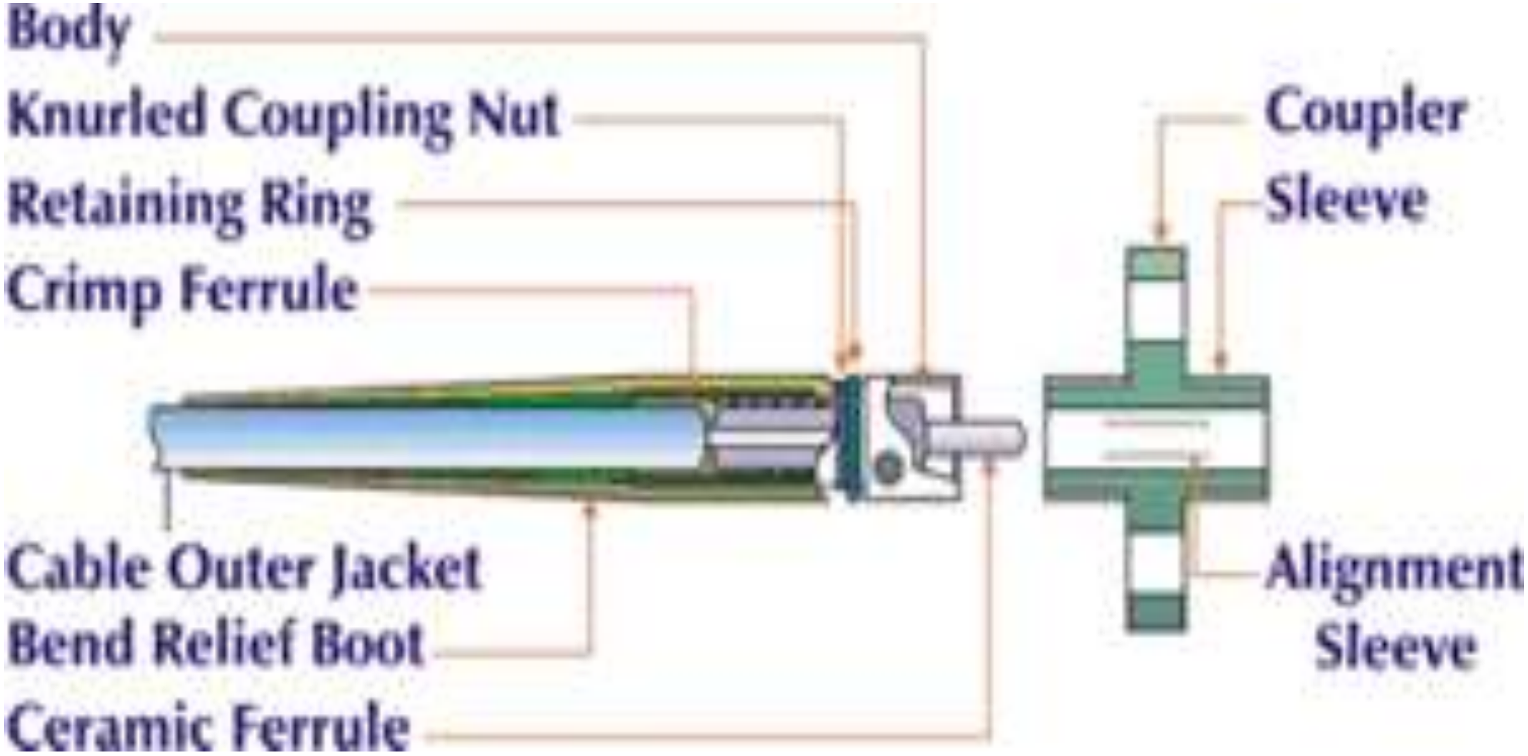
d = lateral offset

s = longitudinal missaligment

θ = angular missalignment

W_1 = 1/e mode-field radius dr fiber kirim

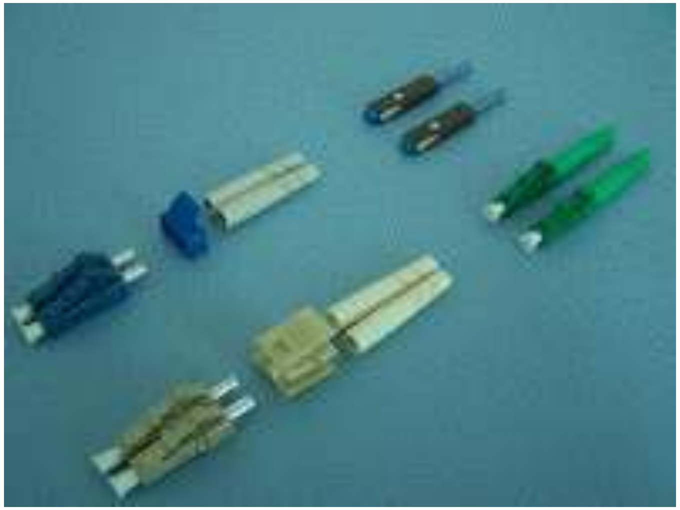
W_2 = 1/e mode-field radius dr fiber terima

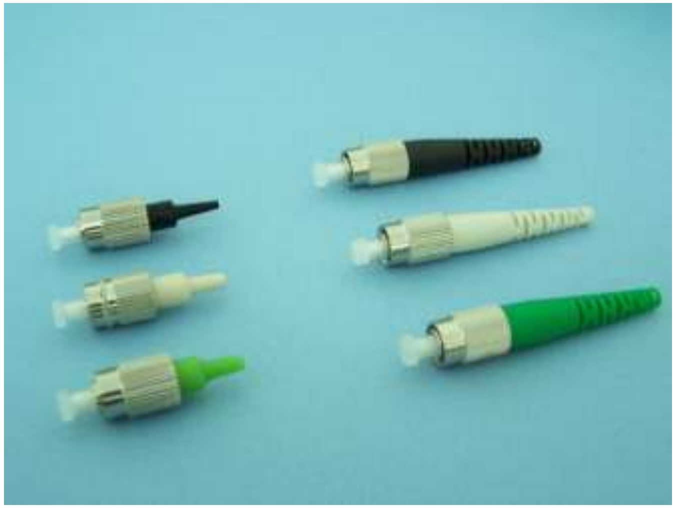


Parts of a Fiber Optic Connector

Konektor Multimode

Konektor Singlemode





Konektor SFF

Konektor FC