Optoelectronică, structuri şi tehnologii

Curs 6

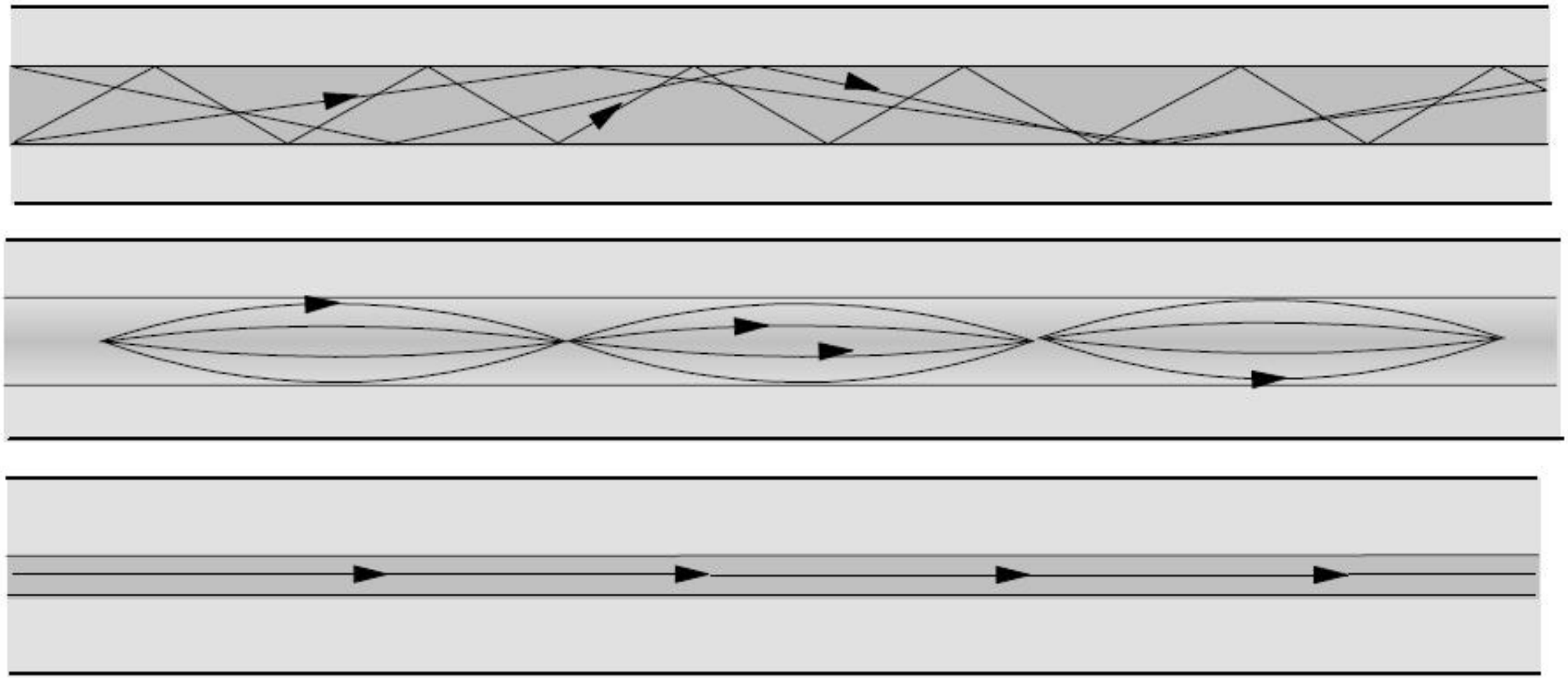
2011/2012

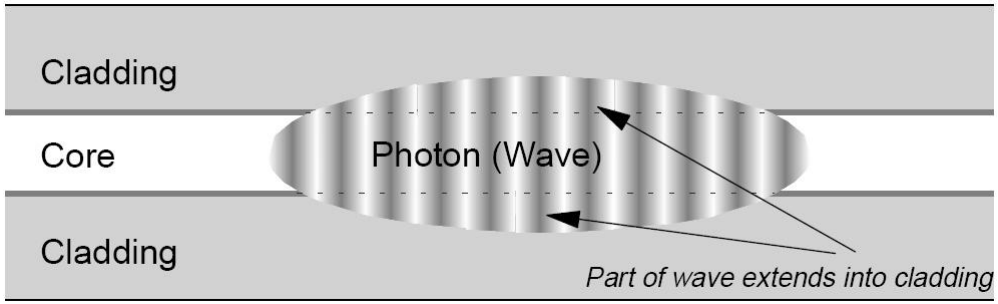
Fibra optică

Capitolul 5

Recapitulare

Fibre




Cladding
Core
Photon (Wave)
Cladding
Part of wave extends into cladding

ATENUAREA

- Macrocurburi
- Microcurburi
- Imprastiere
- Absorbtie

$$\text{Pierderi} = \frac{P_{out}}{P_{in}}$$

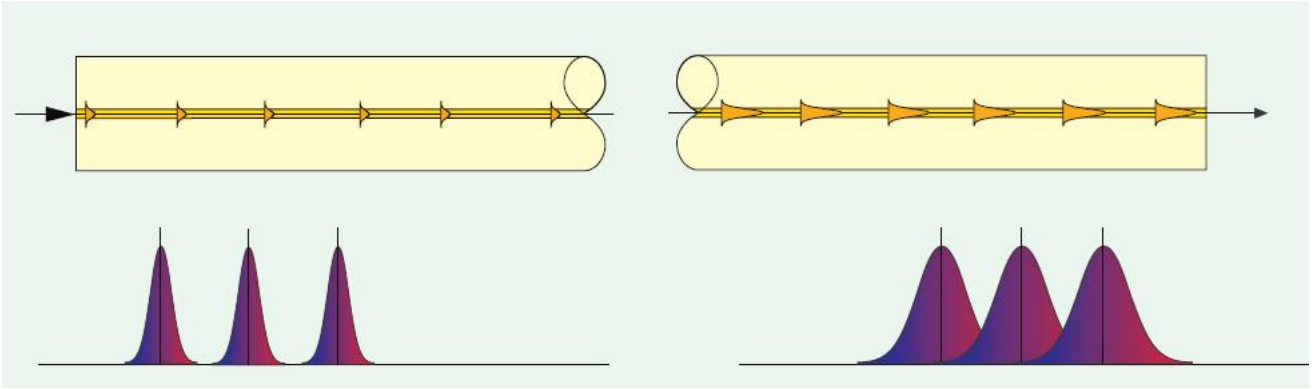
$$\text{Pierderi}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

$$\text{Atenuare}[\text{dB/km}] = \frac{\text{Pierderi}[\text{dB}]}{\text{lungime}[\text{km}]}$$

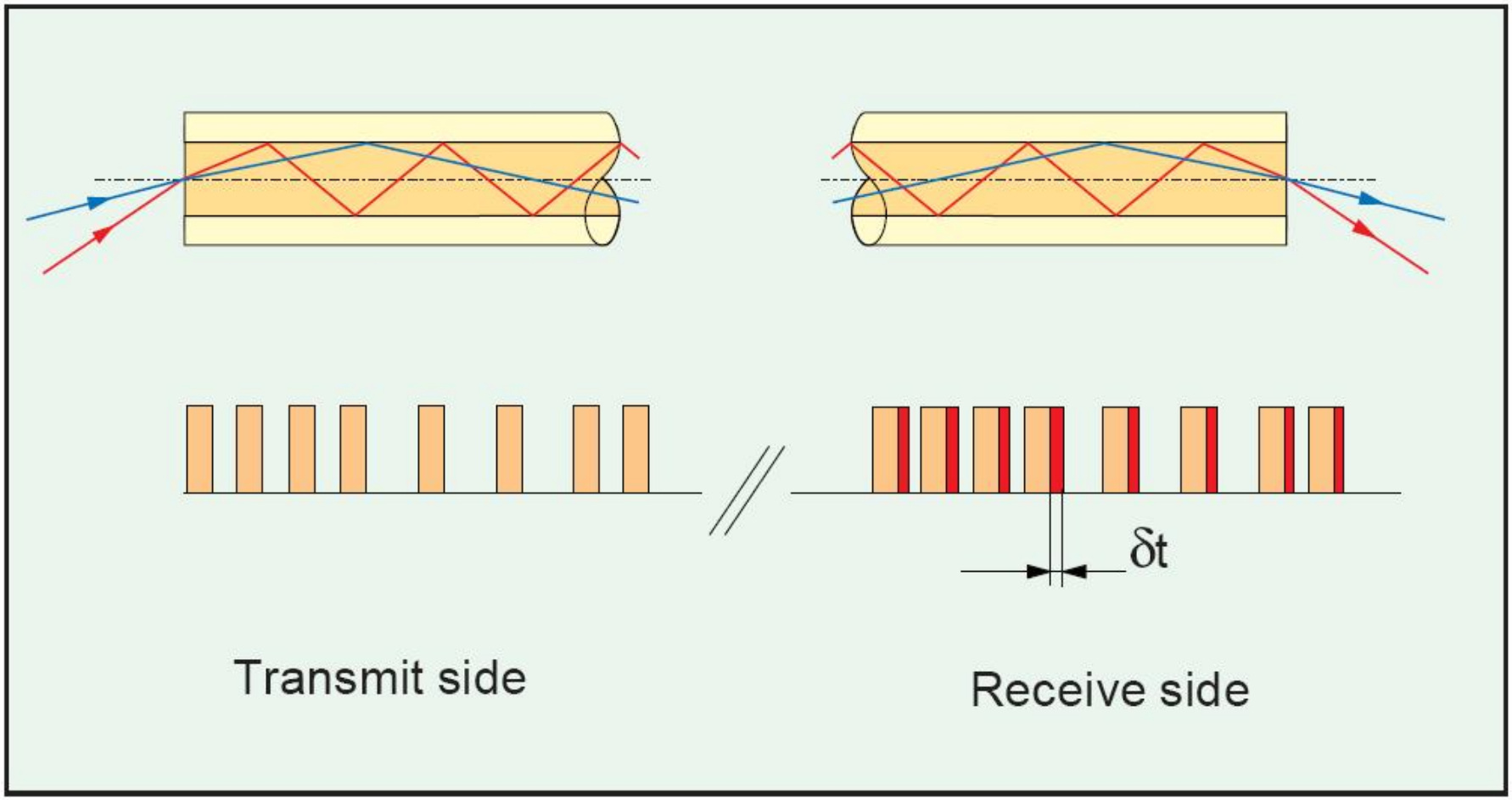
Dispersie

Dispersia

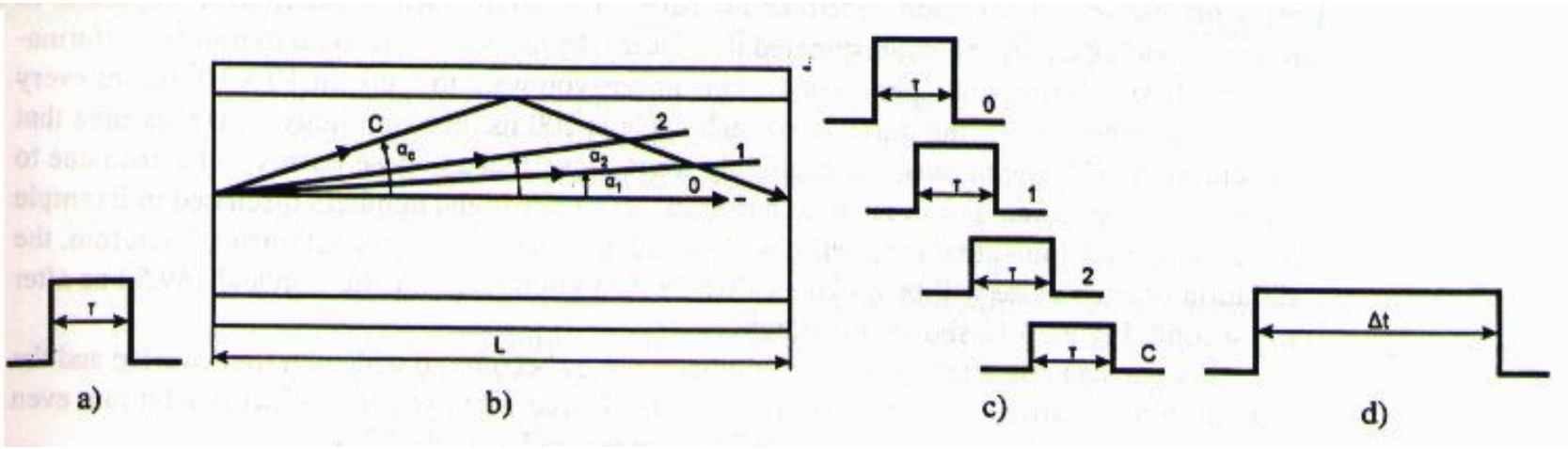
- intermodala (modala – depinde de prezenta modurilor)
- intramodala (cromatica – depinde de lungimea de unda)
  - de material
  - de ghid



Dispersia modala



Dispersia modala



$$t_0 = L/v \qquad t_C = L/(v\cos\alpha_C)$$

$$\Delta t_{SI} = t_C - t_0 = \frac{Ln_1}{c}\left(\frac{n_1 - n_2}{n_2}\right)$$

$$\Delta t_{SI} = t_C - t_0 = (Ln_1/c)\Delta \qquad \Delta t_{SI} = t_C - t_0 \approx \frac{L}{2cn_1}(NA)^2$$

Dispersia modala

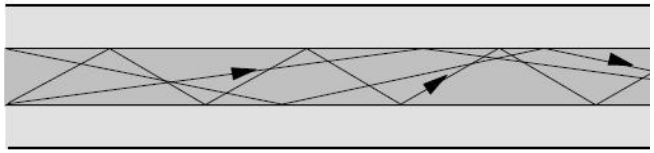
- salt de indice

$$dt = \frac{L \cdot n_1^2}{c \cdot n_2}\left(\frac{n_1 - n_2}{n_1}\right) \approx \frac{L \cdot NA^2}{2 \cdot c \cdot n_1}$$

intarzierea intre moduri cand $\Delta = \frac{n_1 - n_2}{n_2} << 1$

$$\Delta\tau_{\text{mod}}^2 = \frac{1}{3}\left(\frac{dt}{2}\right)^2$$

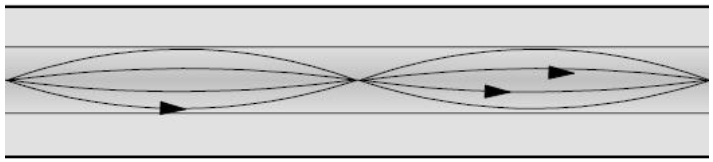
$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_1 \cdot \Delta}{2\sqrt{3} \cdot c} \approx \frac{L \cdot NA^2}{4\sqrt{3} \cdot c \cdot n_1}$$



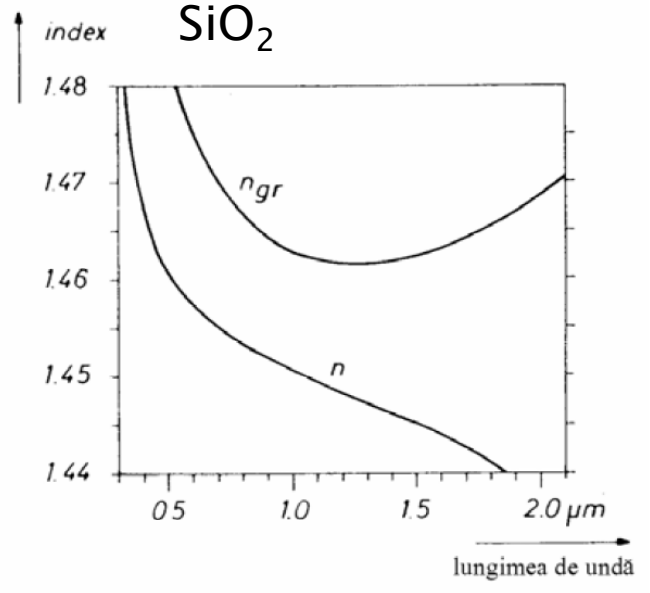
- indice gradat

$$dt = \frac{L \cdot n_1 \cdot \Delta^2}{2c} \approx \frac{L \cdot NA^4}{8 \cdot c \cdot n_1^3}$$

$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_1 \cdot \Delta^2}{4\sqrt{3} \cdot c}$$

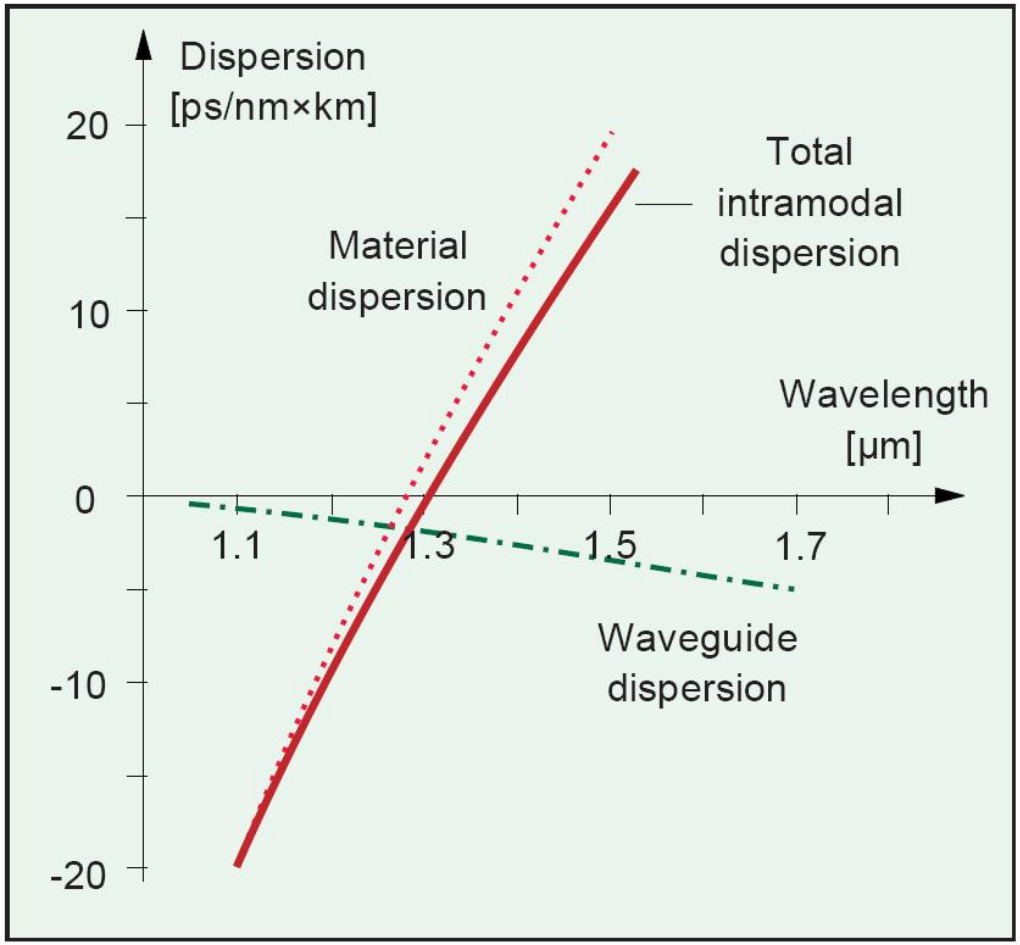


Dispersia de material



$$n_{gr} = n - \lambda \frac{dn}{d\lambda}$$

$$\Delta\tau_{mat} = \frac{L \cdot \lambda \cdot \Delta\lambda}{c} \cdot \frac{d^2 n}{d\lambda^2}$$

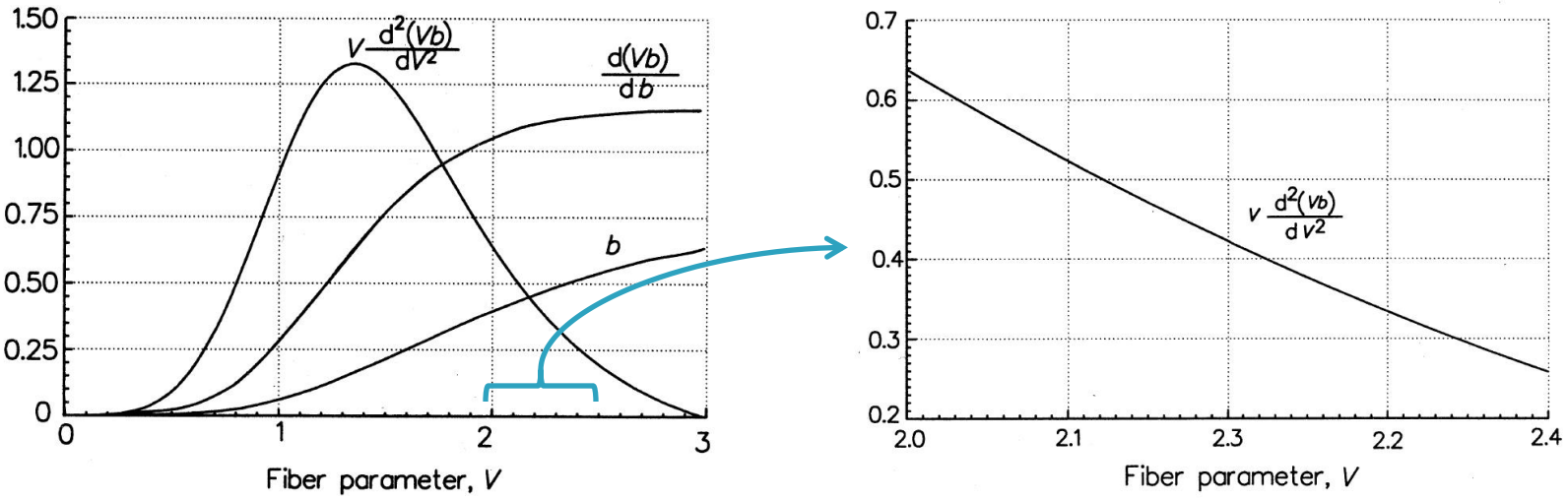


Dispersia de ghid

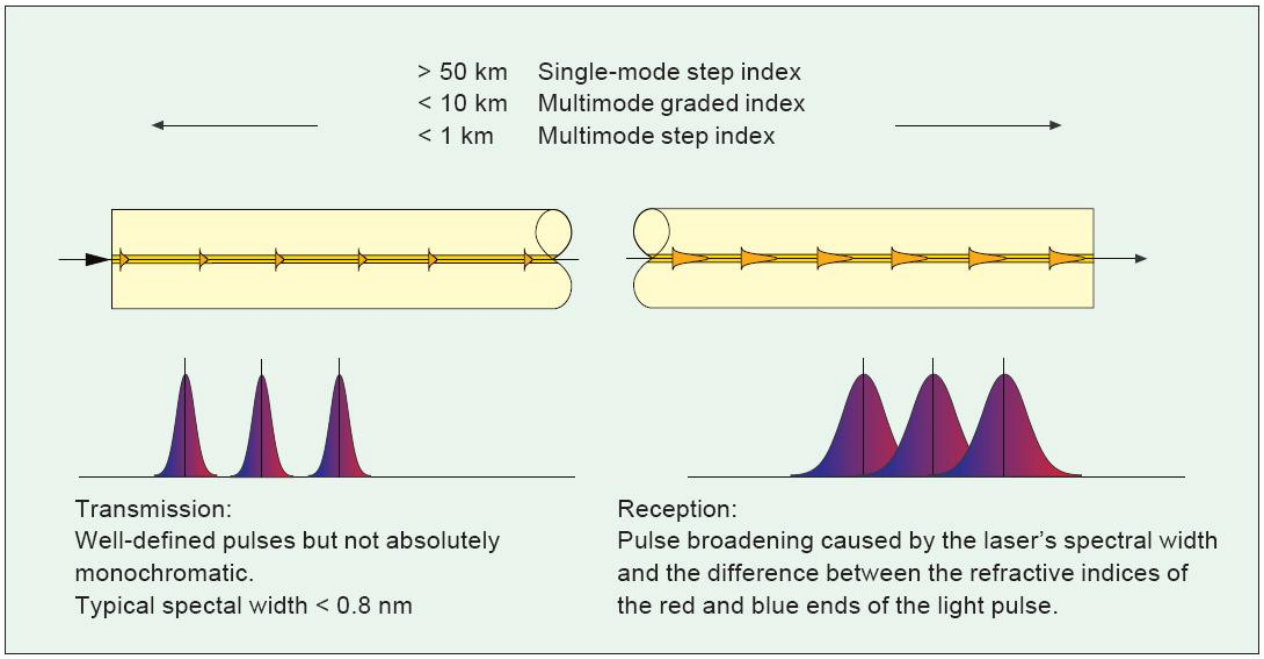
- Neglijabila in fibrele multimod fata de dispersia modala

$$\Delta\tau_{mat} = \frac{n \cdot L \cdot \Delta}{c} \cdot \frac{\Delta\lambda}{\lambda} \cdot \left(V \frac{d^2(Vb)}{dV^2} \right)$$

b – constanta de propagare normalizata



Dispersia cromatica



$$\Delta\tau_{cr} = D(\lambda)\cdot\Delta\lambda\cdot L$$

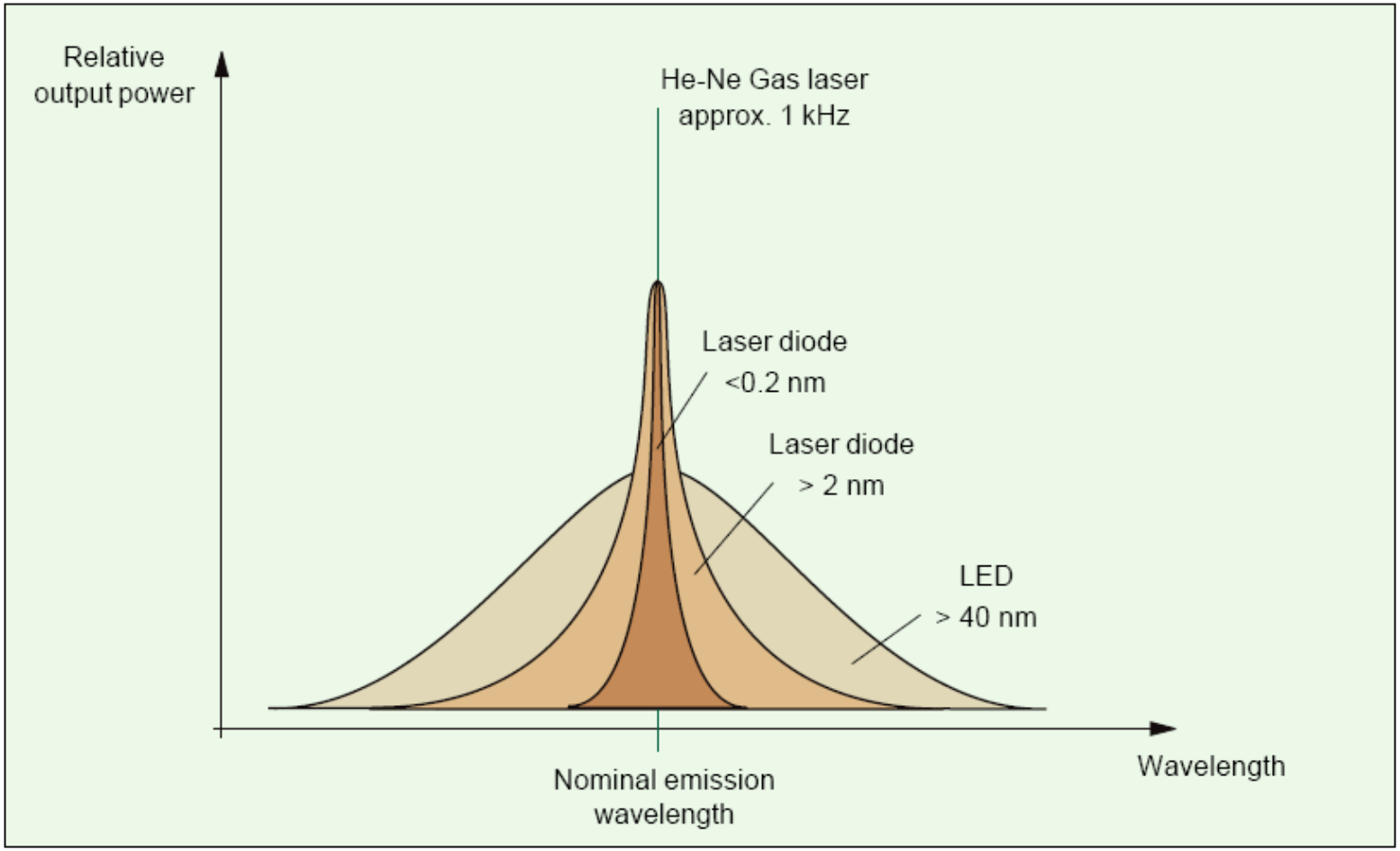
$$D(\lambda) = \frac{S_0}{4}\cdot\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

S_0 panta dispersiei – $ps/nm^2/km$

- $D(\lambda) \approx 100 + 0.4\,(850 - \lambda)$ [ps/nm/km] pentru $800 < \lambda < 900$ nm
- $D(\lambda) \leq 3{,}5$ ps/nm/km pentru $1285 < \lambda < 1330$ nm
- $D(\lambda) \leq 17$ ps/nm/km pentru $1525 < \lambda < 1575$ nm

$$D(\lambda) = \frac{S_0}{4}\cdot\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

Calitatea spectrală a emiţătorilor optici



Banda

- Dispersia totala

$$\Delta\tau_{tot} = \sqrt{\Delta\tau_{cr}^2 + \Delta\tau_{\text{mod}}^2}$$

- Banda

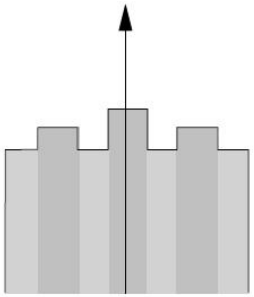
$$B_{opt} = \frac{0.44}{\Delta\tau_{tot}[ns]} \quad [GHz] \qquad\qquad B_{opt} = \sqrt{2}B_{el}$$

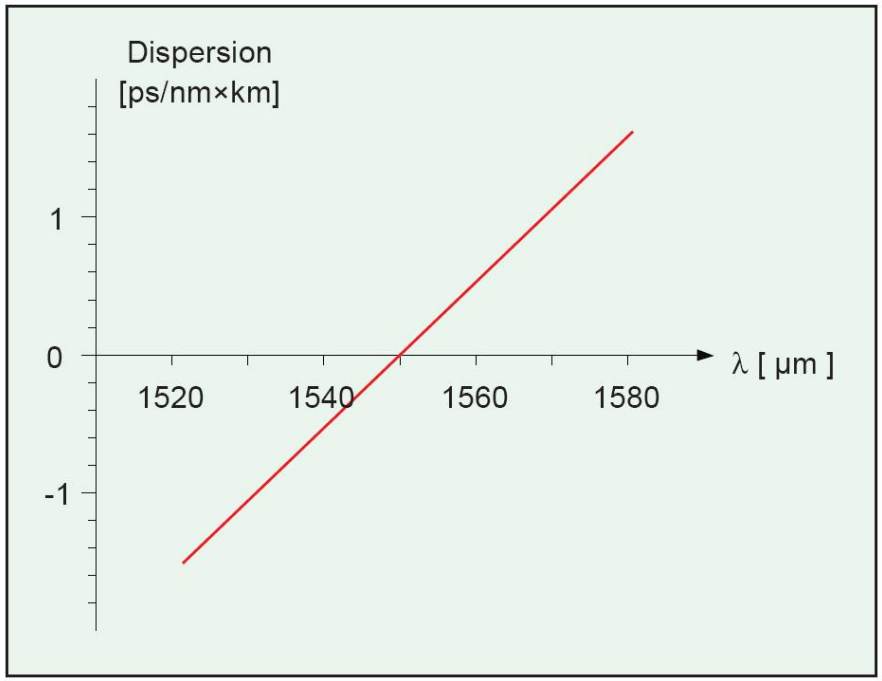
- Banda optica la 3 dB corespunde unei benzi electrice la 6 dB
  - $P_{opt} \sim I; \quad P_{el} \sim I^2$
- Viteza legaturii

$$V[Gb/s] \cong 2 \cdot B_{el}$$

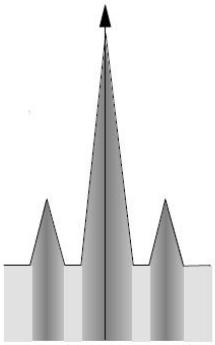
Dispersion shifted fibers

- Atenuarea e mai mica la 1550 nm
- EDFA (Erbium doped fibre amplifiers) opereaza in banda aceasta
- Sistemele WDM (Wavelength division Multiplexing) necestia banda larga amplificata

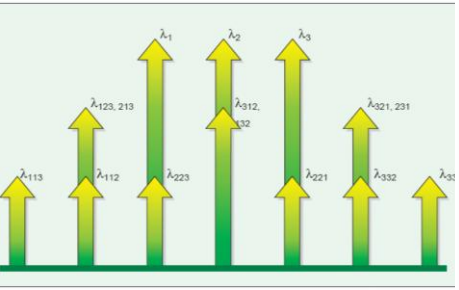


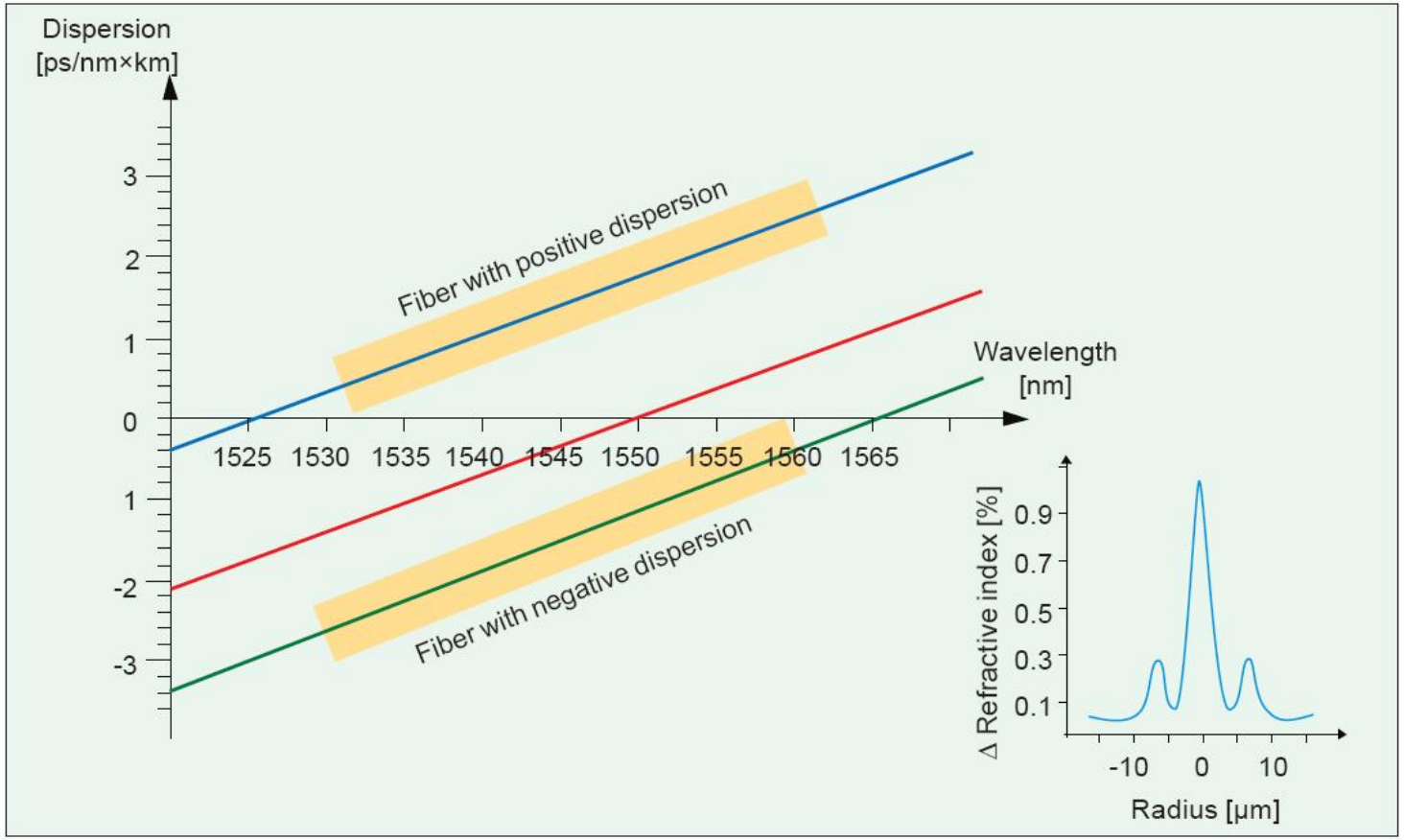


Non-zero Dispersion shifted fibers

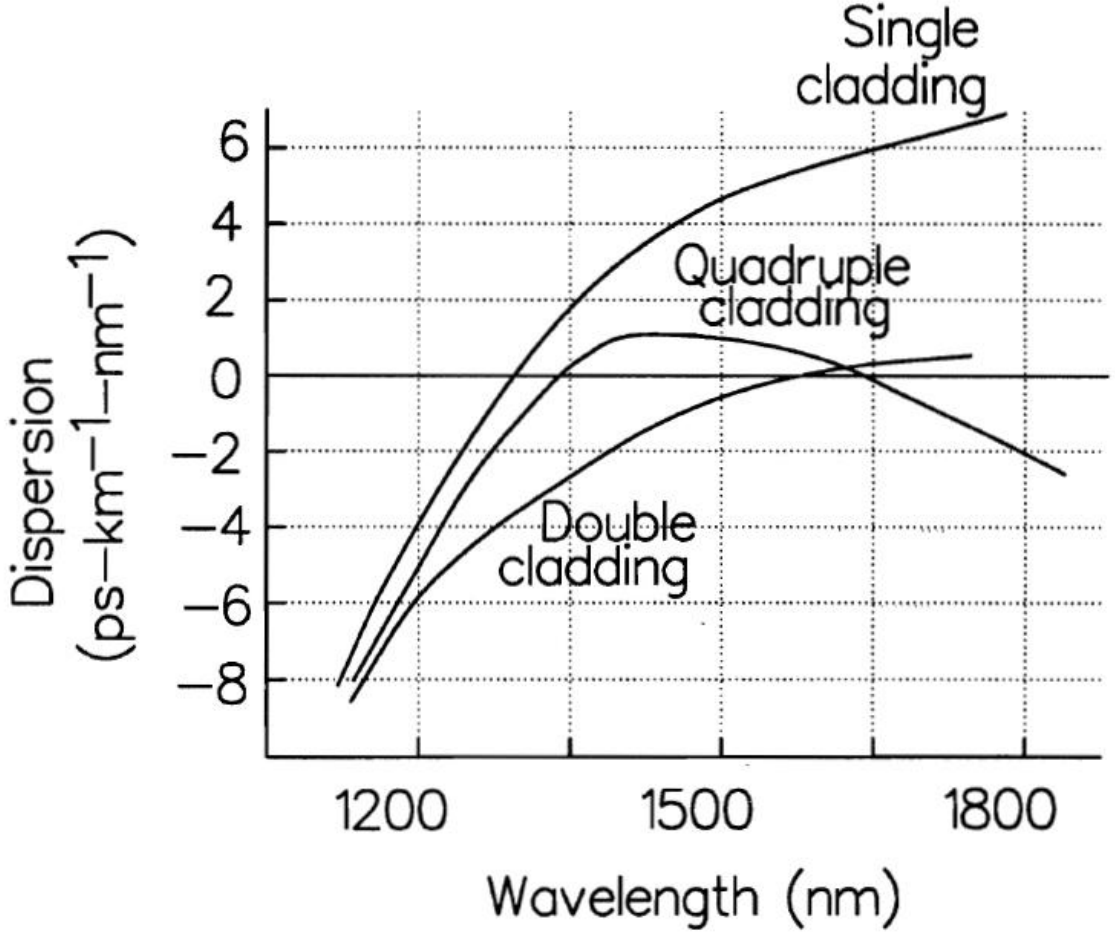


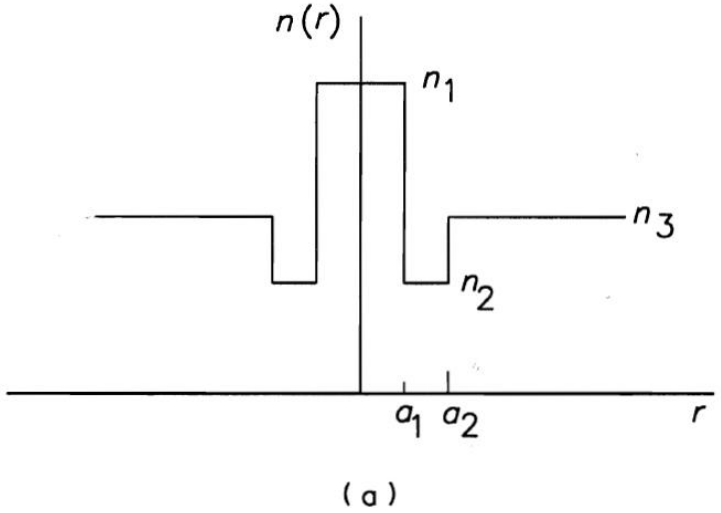
FWM

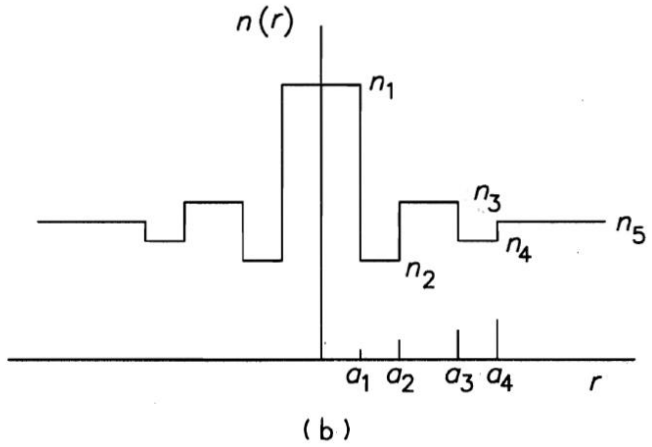




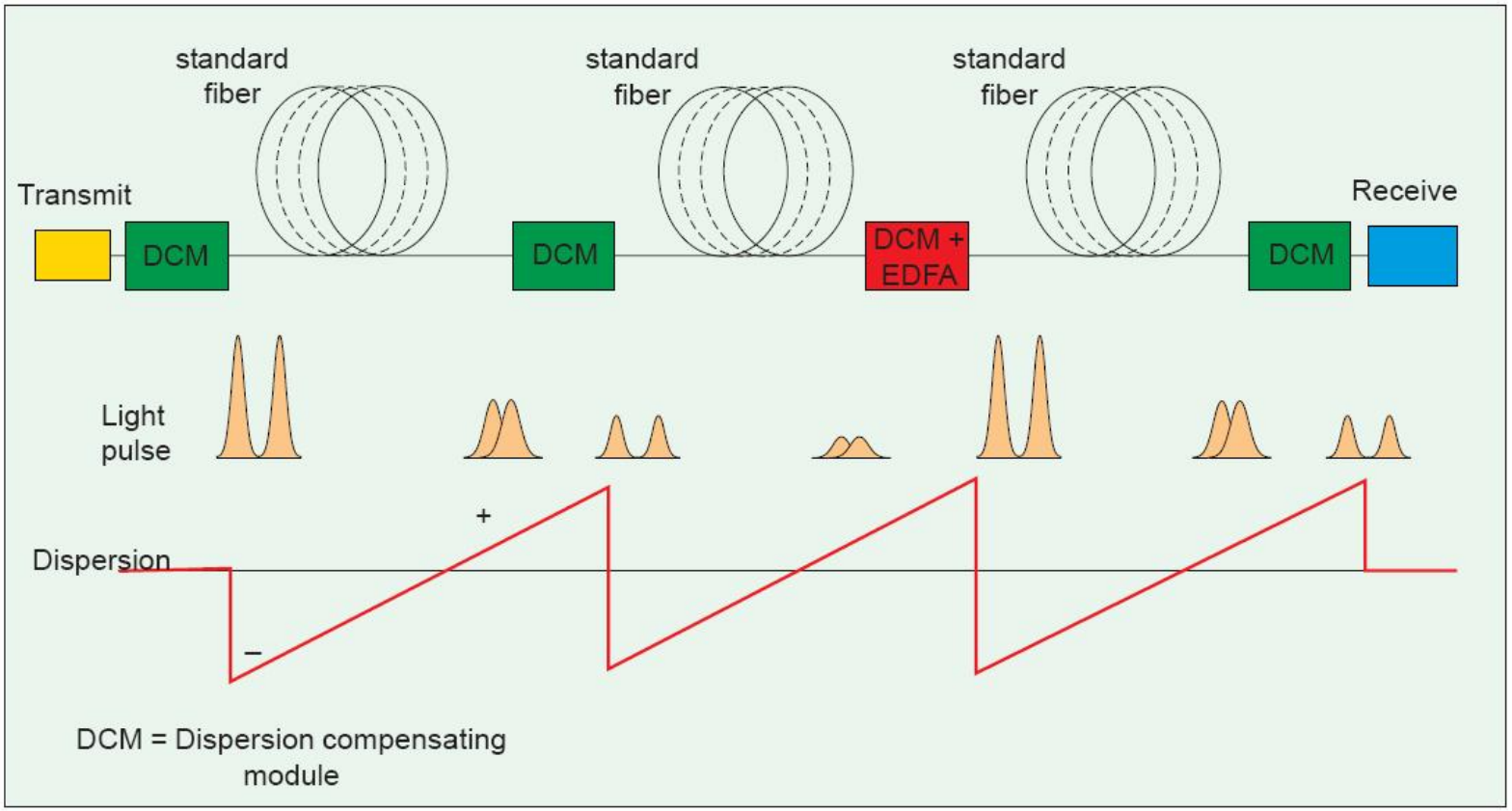
Dispersion shifted fibers







Fibra pentru compensarea dispersiei

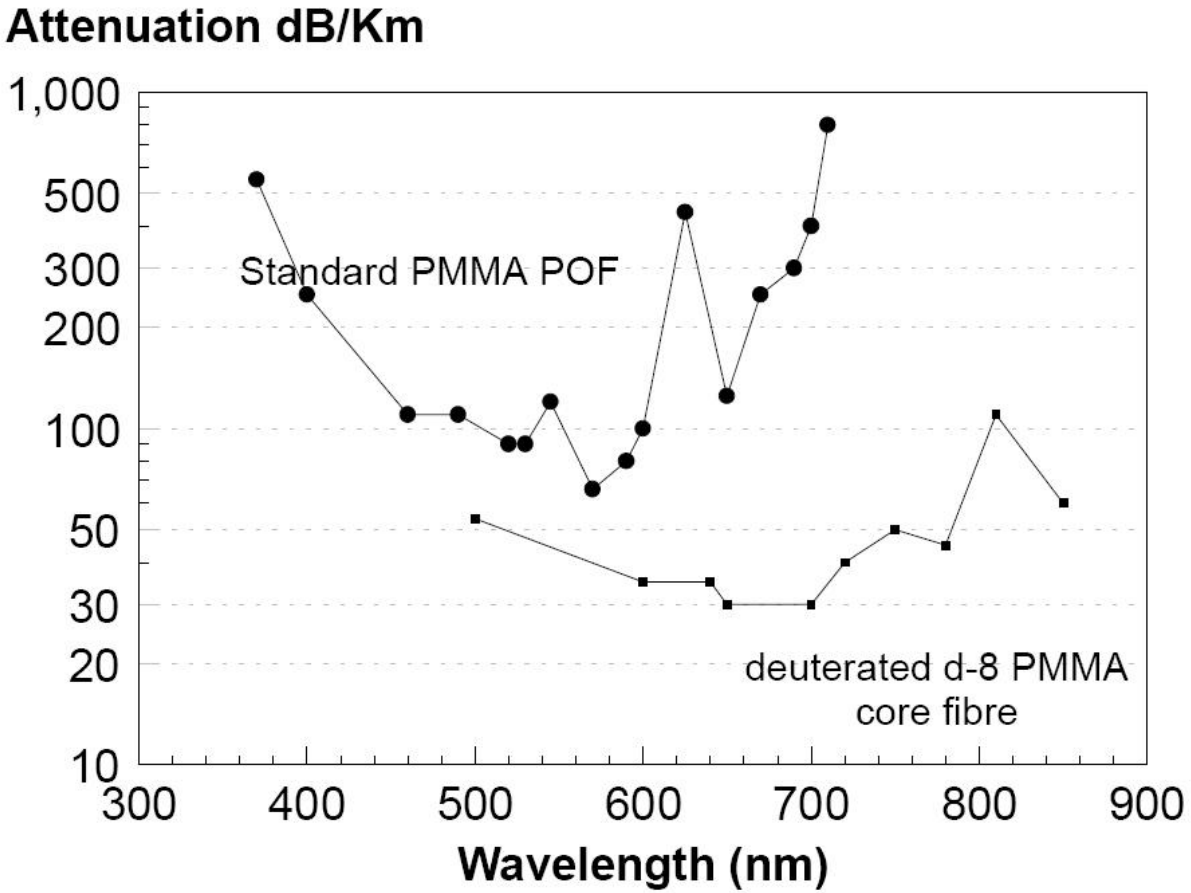


- Dispersie -100 ps/nm/km
- Atenuare 0.5 dB/km

Fibra standard ITU G.652

- Diametru teaca = 125 µm
- MFD = 9÷10 µm la 1300 nm
- λ_C = 1100÷1280 nm
- Pierderi de curbura (la 1550 nm) mai mici de 1 dB pentru 100 spire de fibra rulata pe un mosor cu 7.5 cm diametru
- Dispersia in banda 1300 nm (1285-1330 nm) mai mica de 3.5 ps/nm/km. La 1550 nm dispersia trebuie sa fie mai mica de 20 ps/nm/km
- Viteza de variatie a dispersiei (panta dispersiei S_0) mai mica de 0.095 ps/nm^2/km

Fibra optica din plastic (POF)



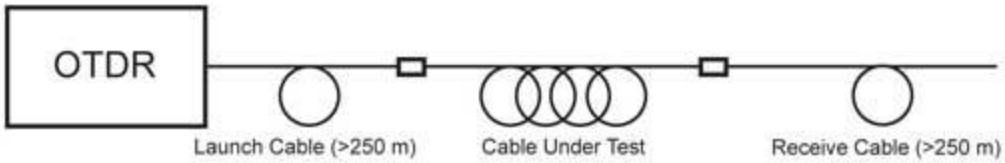
- Atenuare 180 dB/km
- NA = 0.3
- Diametru 1 mm
- Banda 125MHz (100m)

Fibra optică – Tehnologie

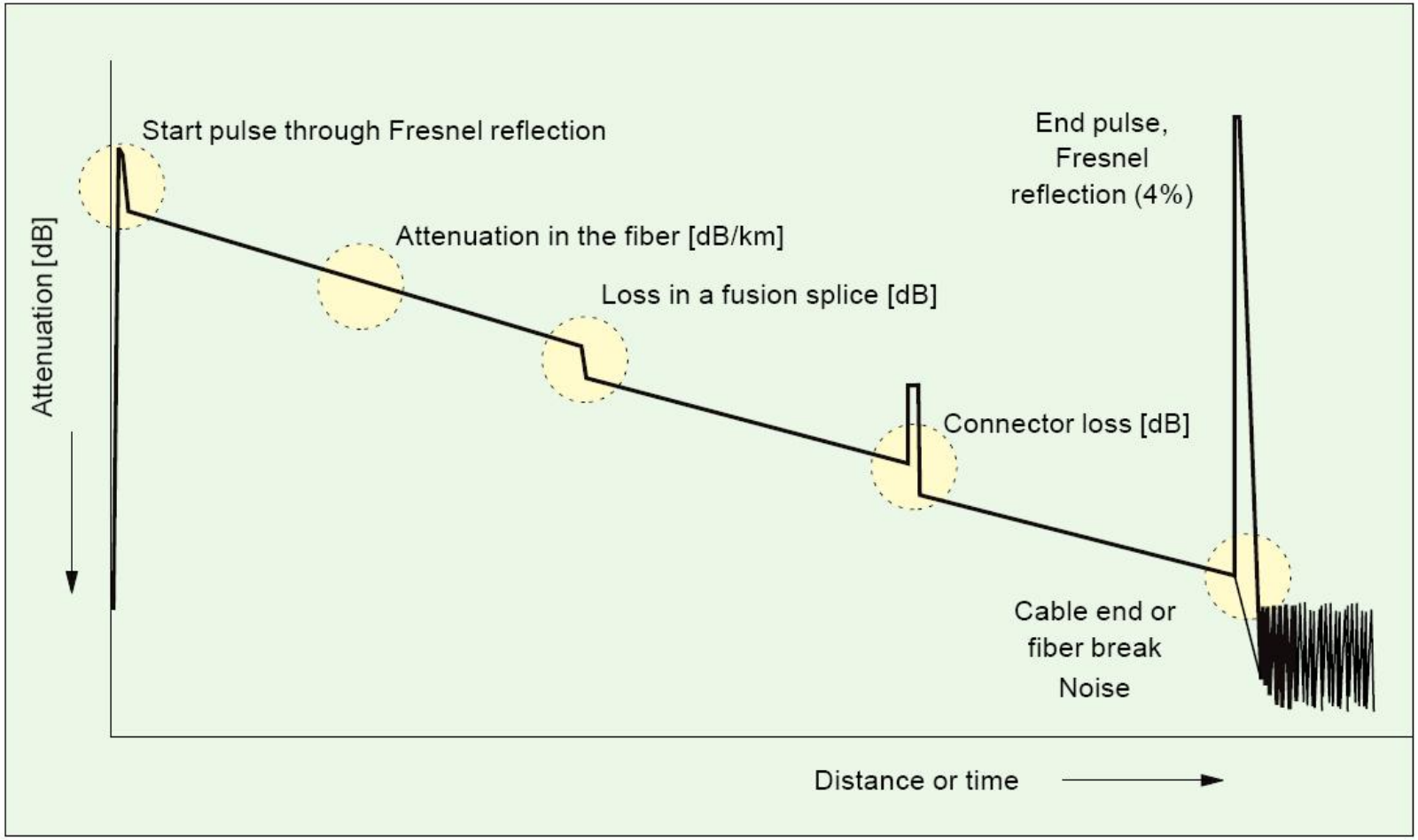
Capitolul 5

OTDR

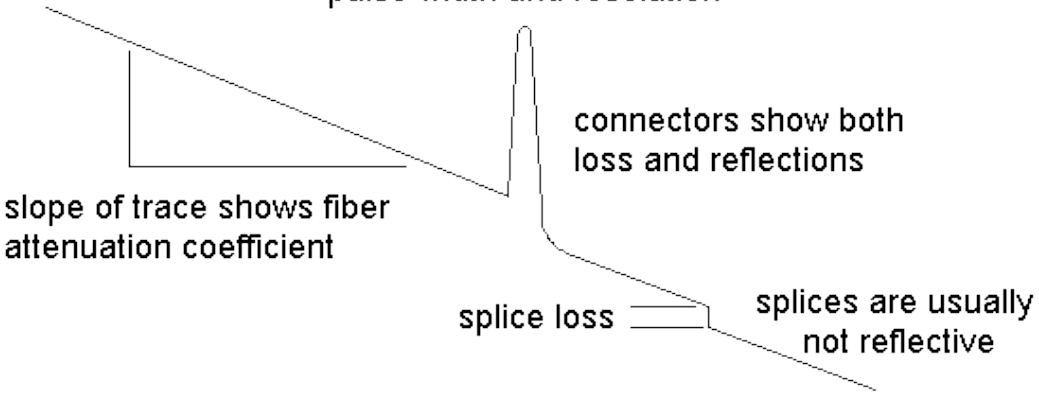
- Optical time-domain reflectometer
- Localizarea defectelor

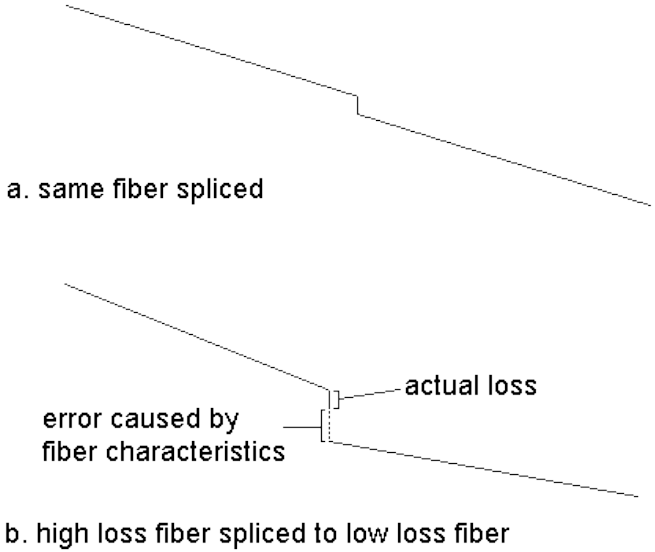


Rezultat grafic al OTDR

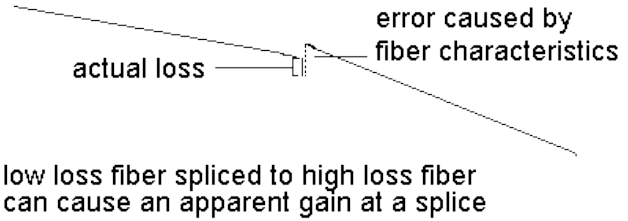


Efecte vizibile OTDR



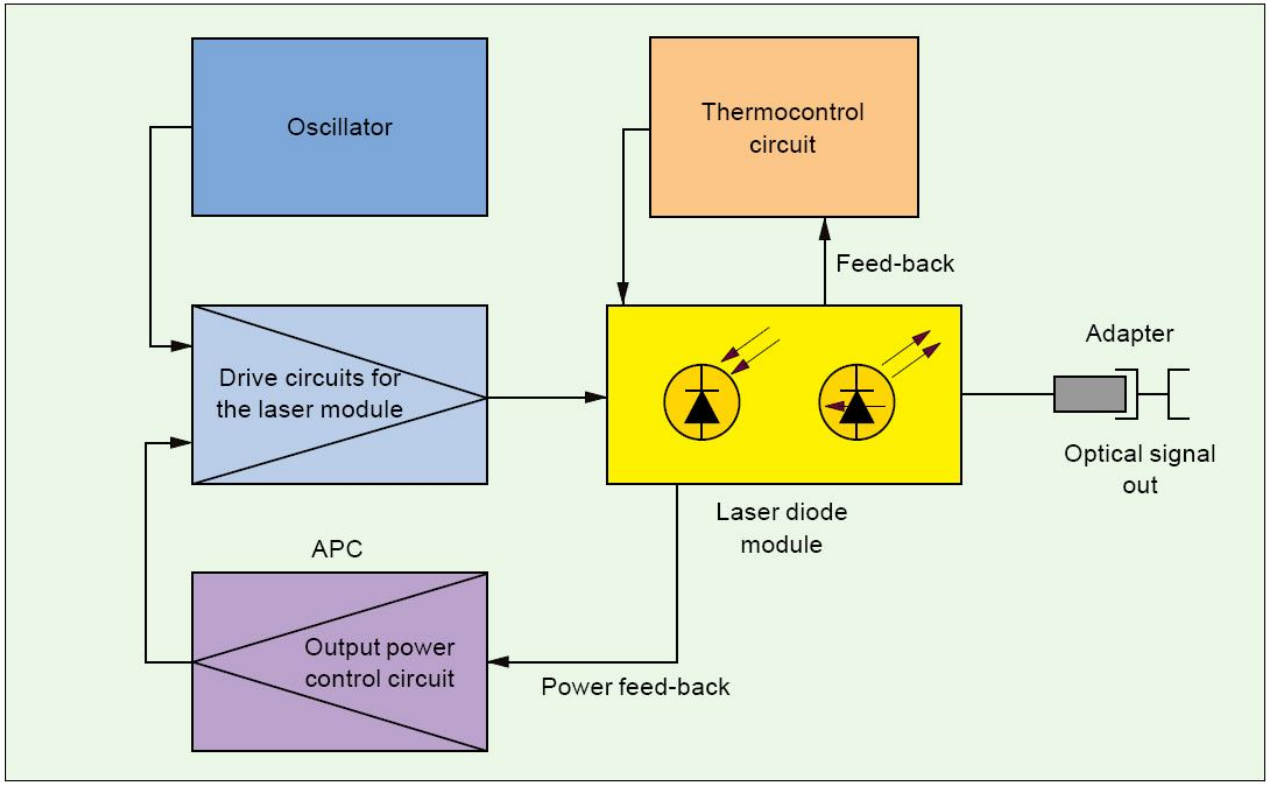


$$Splice\,loss = \frac{Splice\,loss_{A \to B} + Splice\,loss_{B \to A}}{2}$$



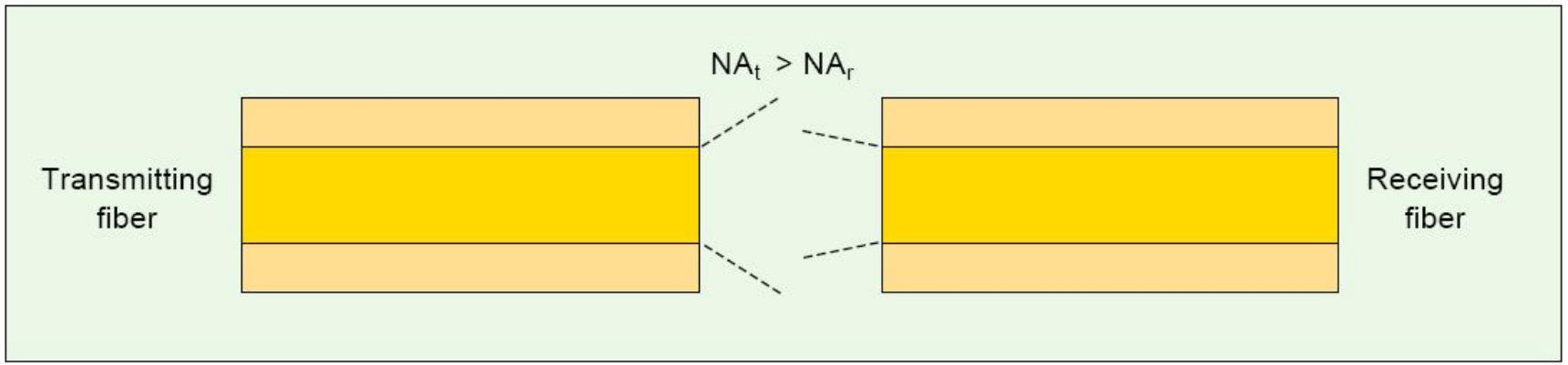
Stabilized light source Optical power meter

- Masurarea puterii si atenuarii



Pierderi – Apertura numerica

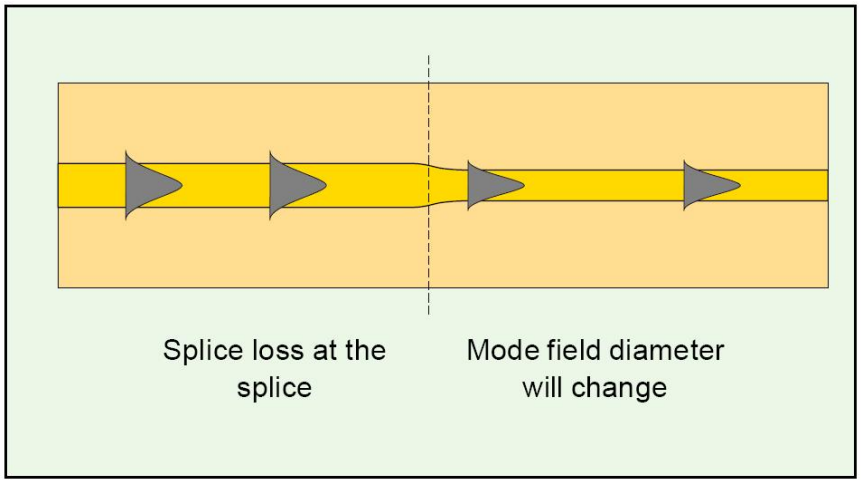
- **Numai** la trecerea de la apertura numerica mai mare la apertura numerica mai mica



$$\text{Attenuation}_{NA} = 10 \log_{10} \left(\frac{NA_r}{NA_t} \right)^2$$

Pierderi – Diametrul miezului

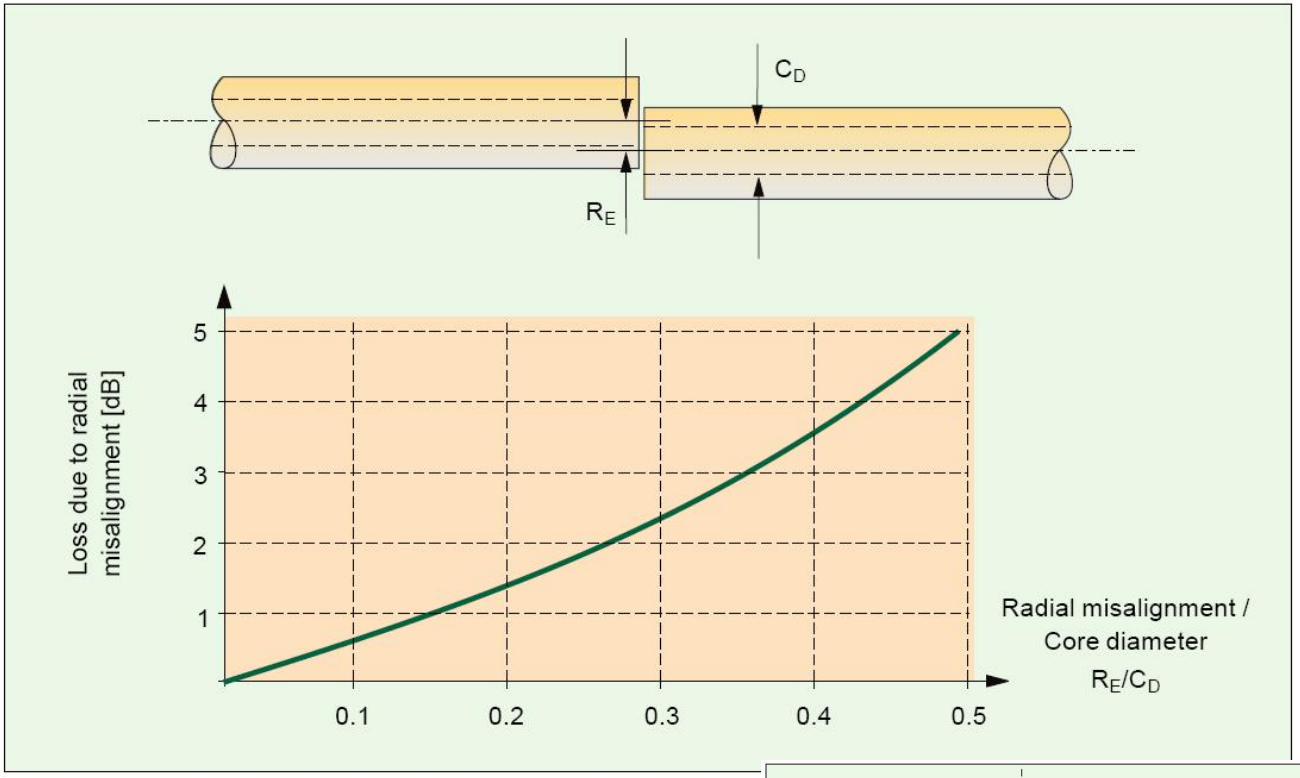
- **Numai** la trecerea de la diametru mai mare la diametru mai mic

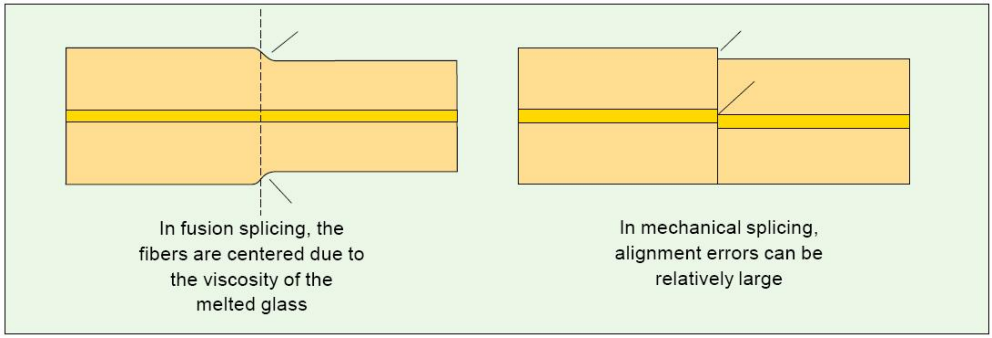


$$\text{Attenuation}_{\varnothing}\,(\text{multimode}) = -10\log_{10}\left(\frac{\varnothing_r}{\varnothing_t}\right)^2$$

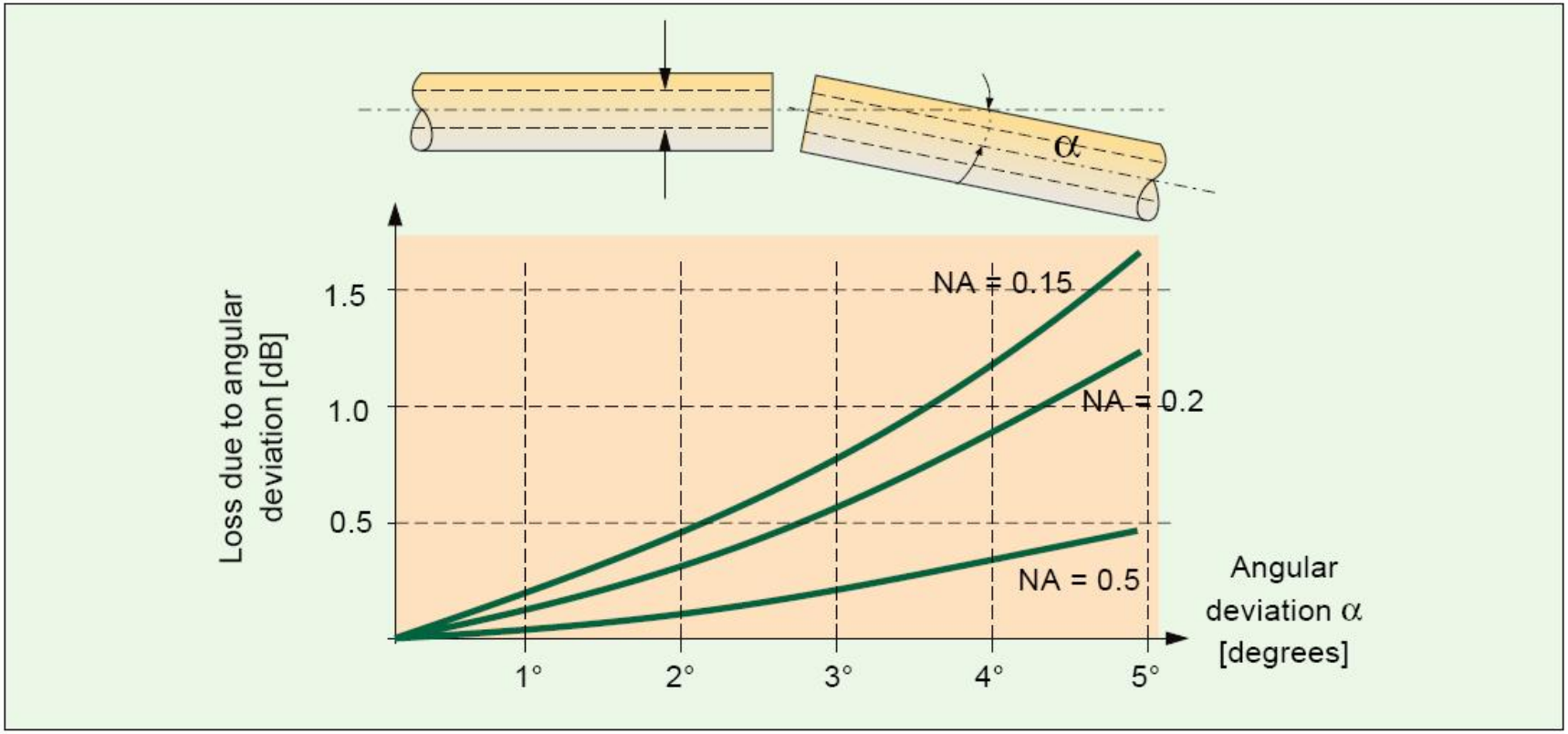
$$\text{Attenuation}_{\varnothing}\,(\text{single-mode}) = -20\log\left(\frac{2\,w_1\,w_2}{w_1^2 + w_2^2}\right)$$

Pierderi – Nealinierea axelor



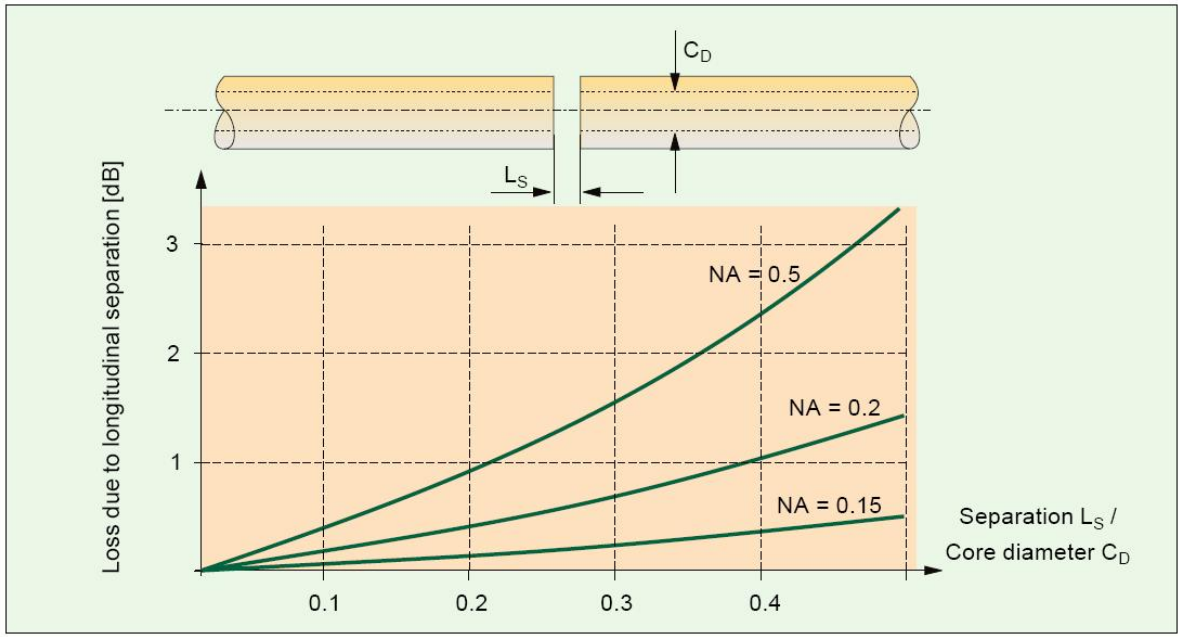


Pierderi – unghi



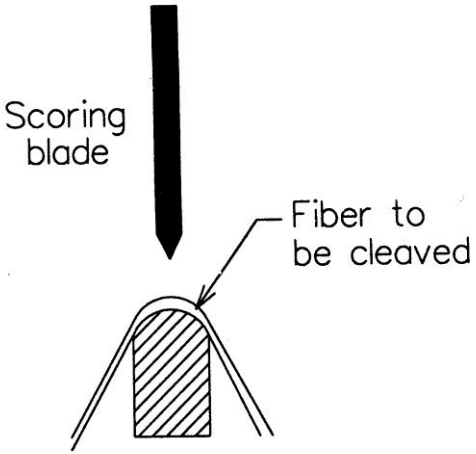
Pierderi – distanta

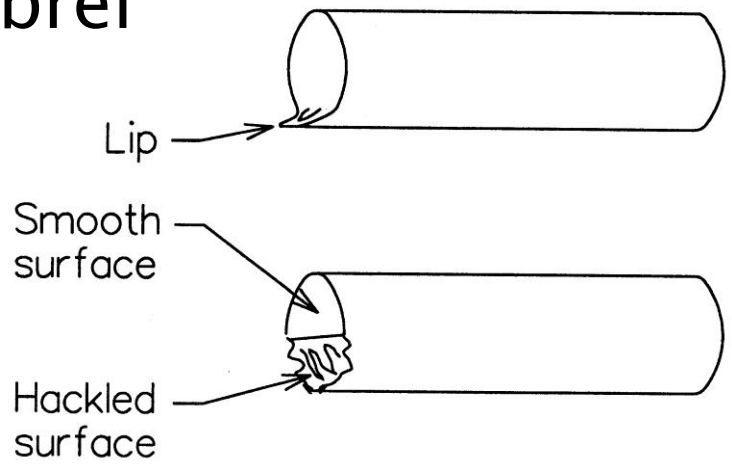
- Se foloseste un gel cu indice de refractie egal cu al fibrelor
- Se aduna pierderile generate de reflexie pe o lamela (pana la 16%)



Taiere – Cleaving

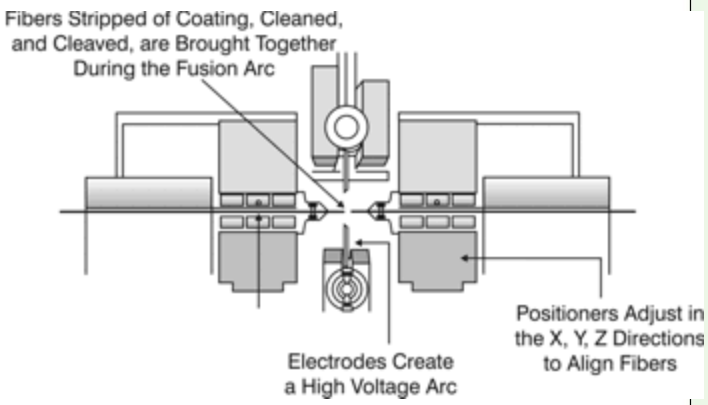
- Tehnici necesare pentru a asigura o taiere perpendiculara pe axa fibrei

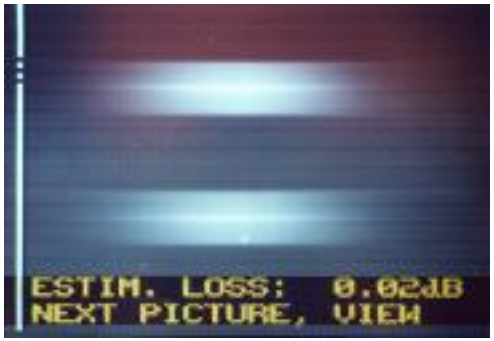


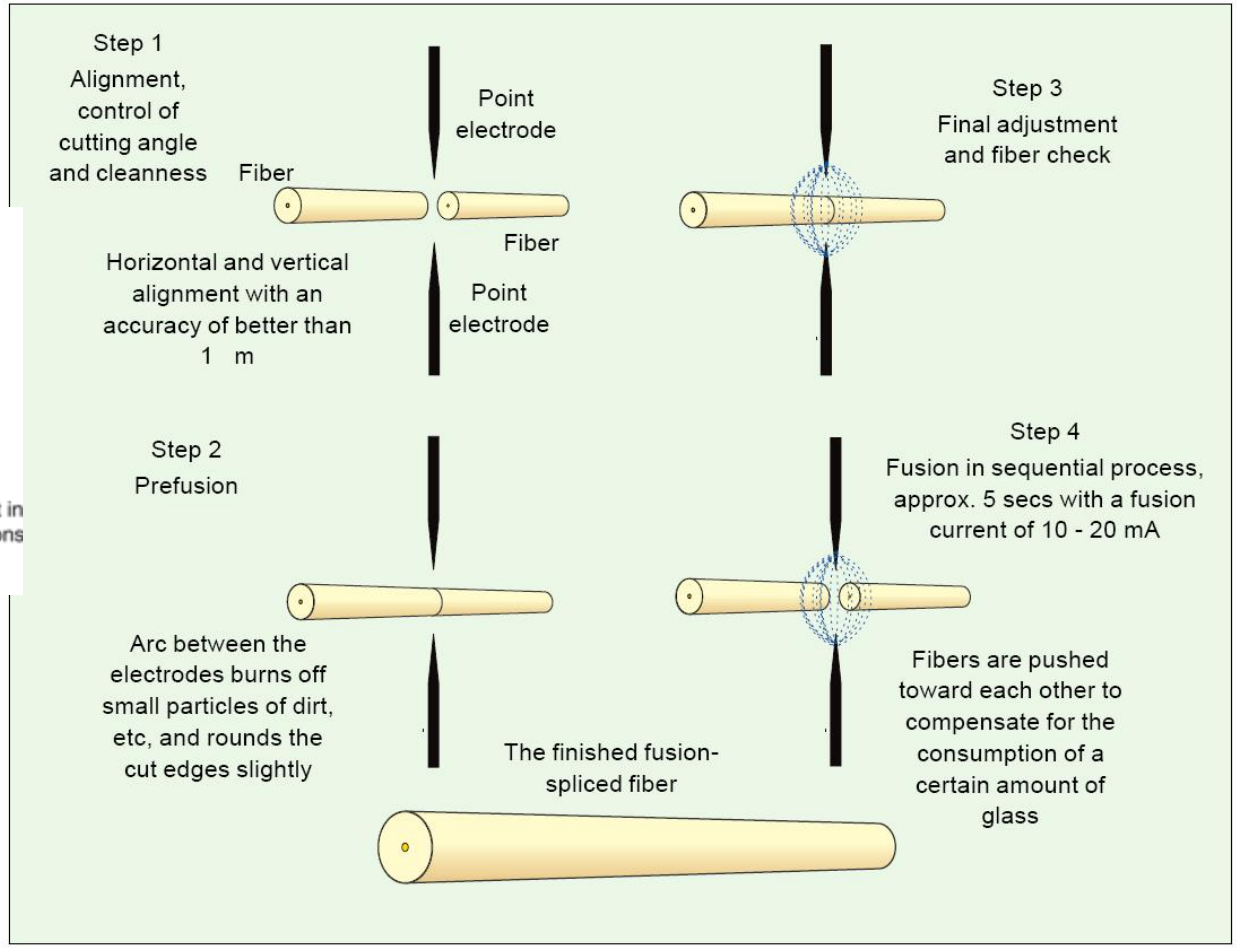


Lipire prin fuziune

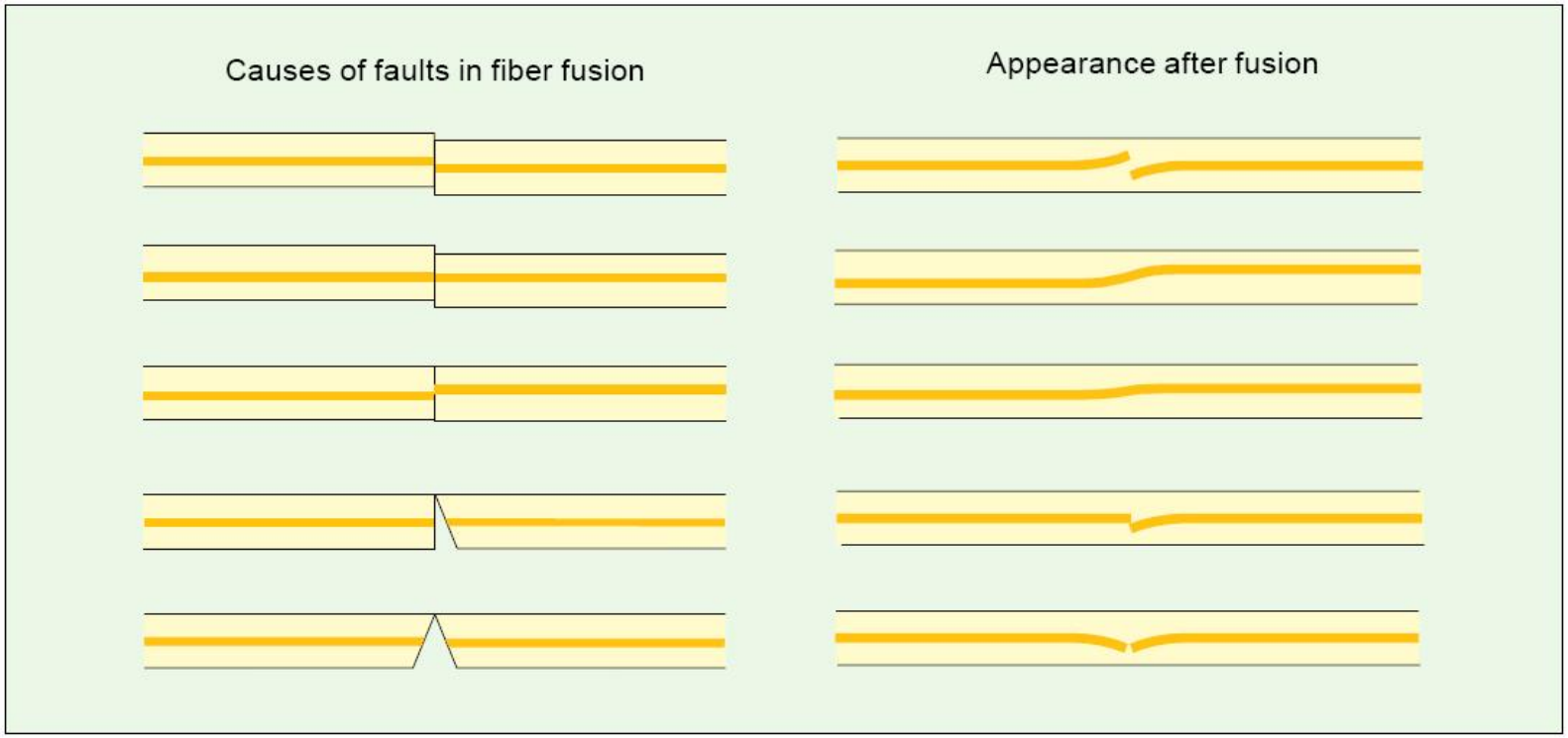
Splice prin fuziune



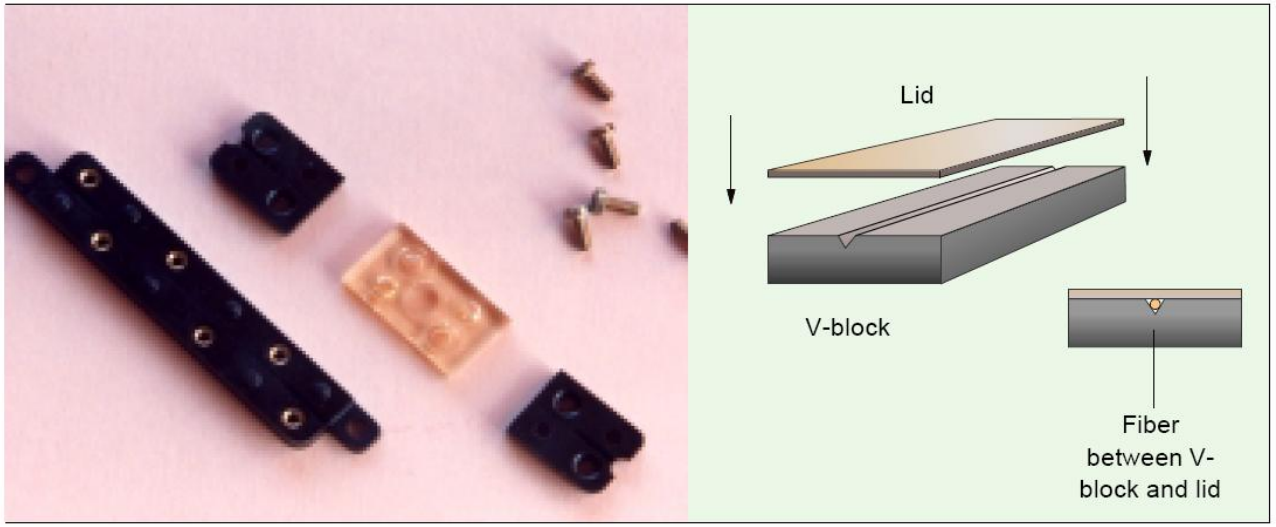


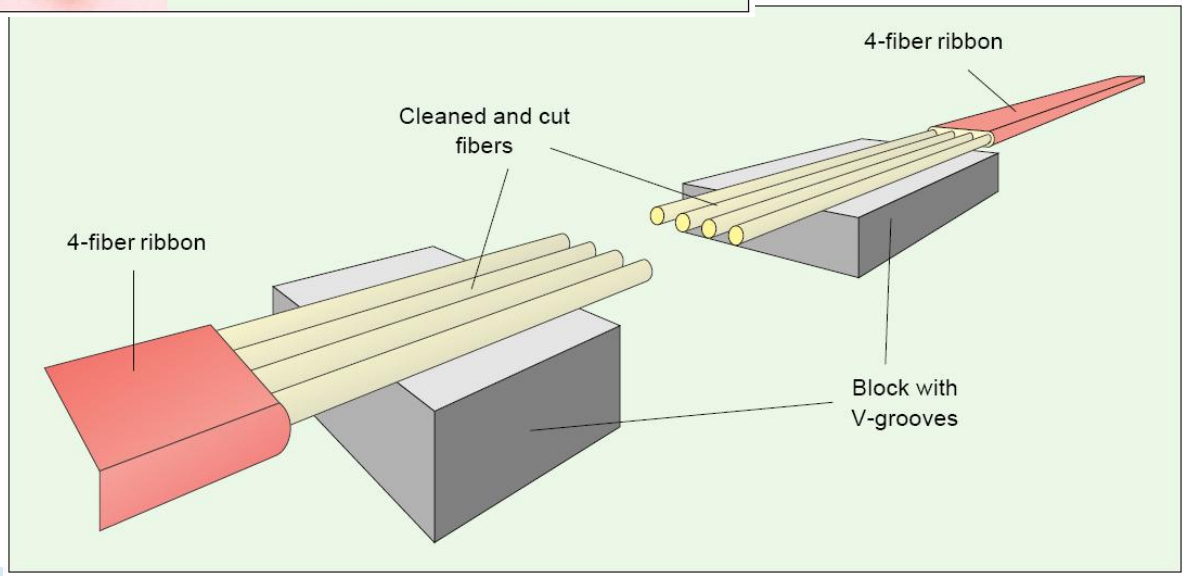


Splice prin fuziune

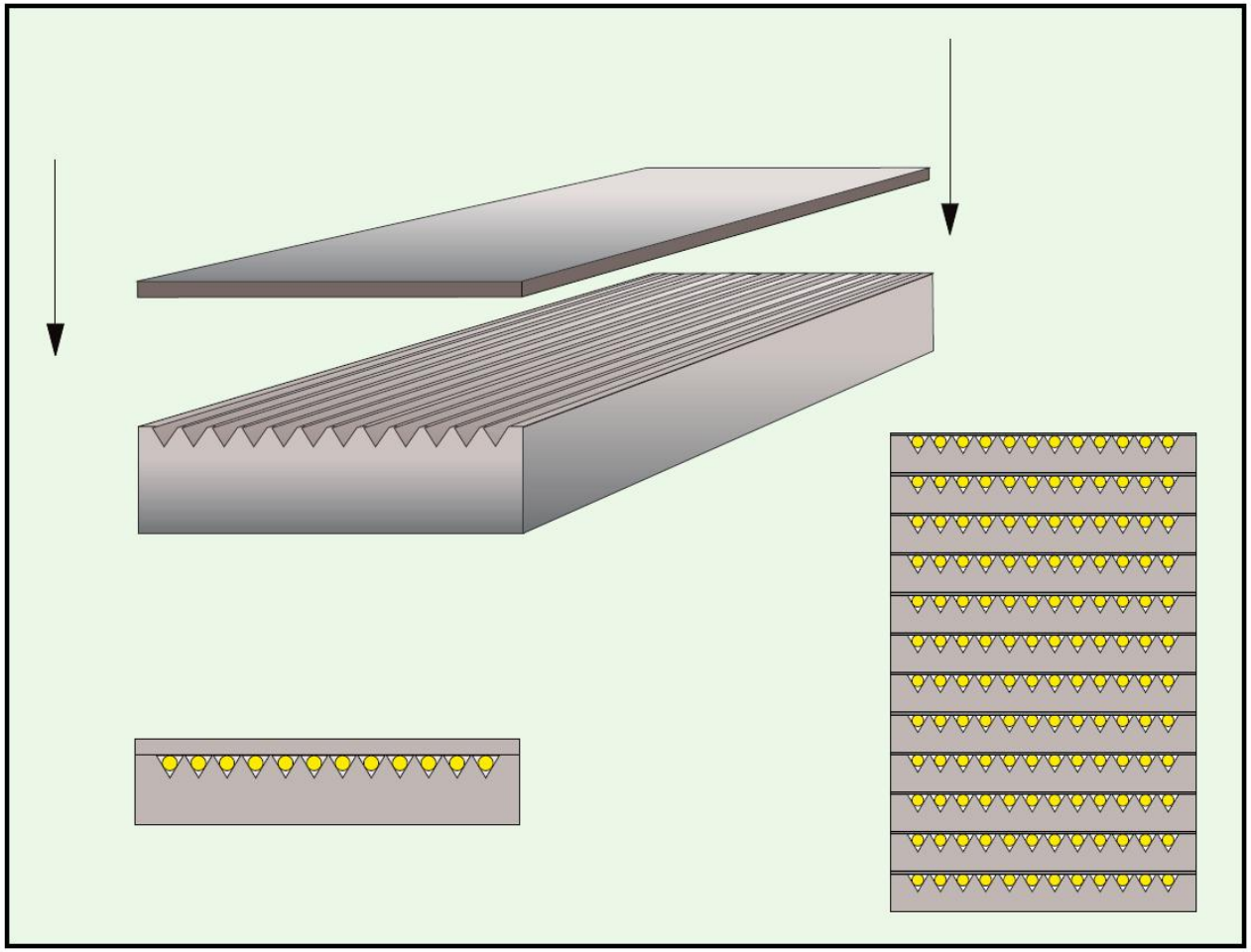


Splice mecanic – bloc V

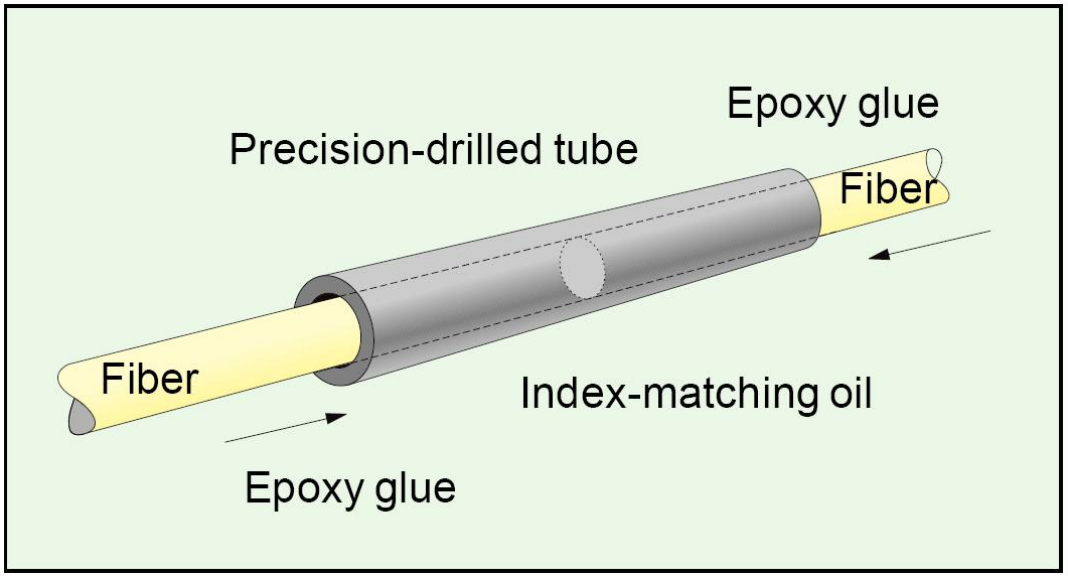


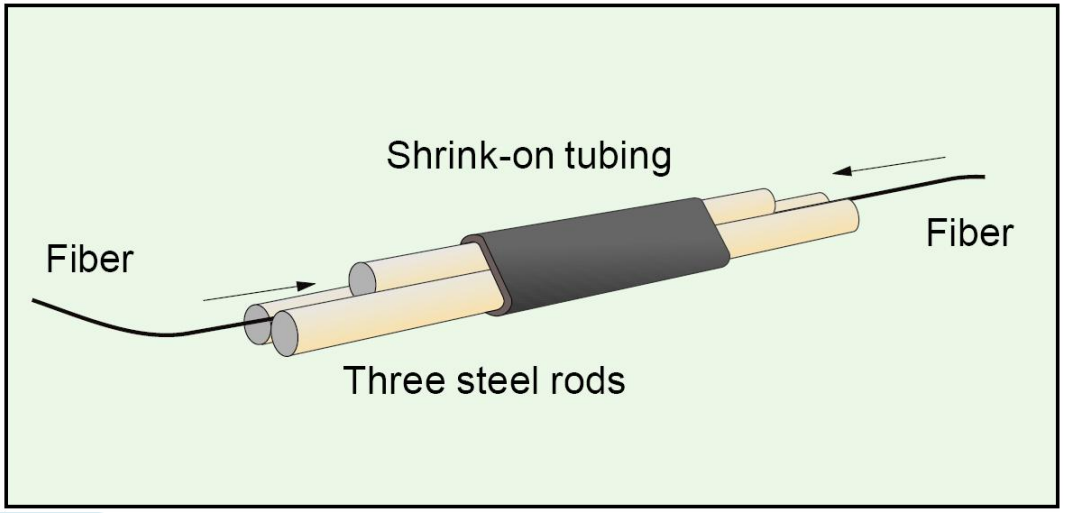


Splice mecanic – bloc V



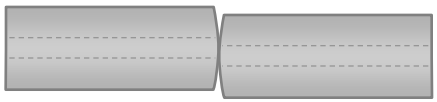
Splice mecanic



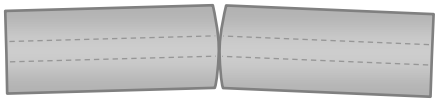


Probleme Fibre/Conectori

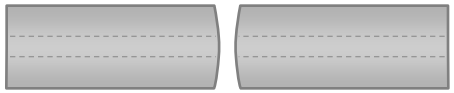
Offset



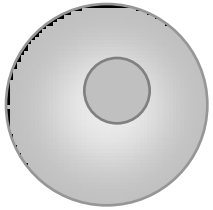
Angular Misalignment



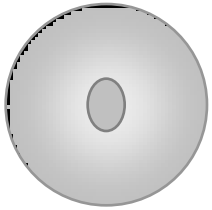
Separation



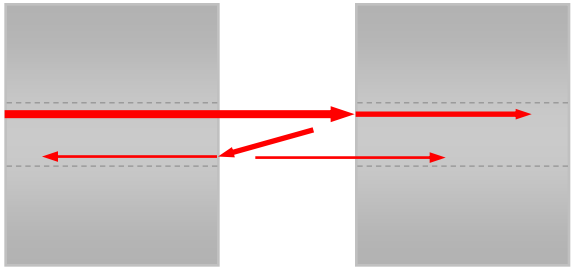
Core Eccentricity



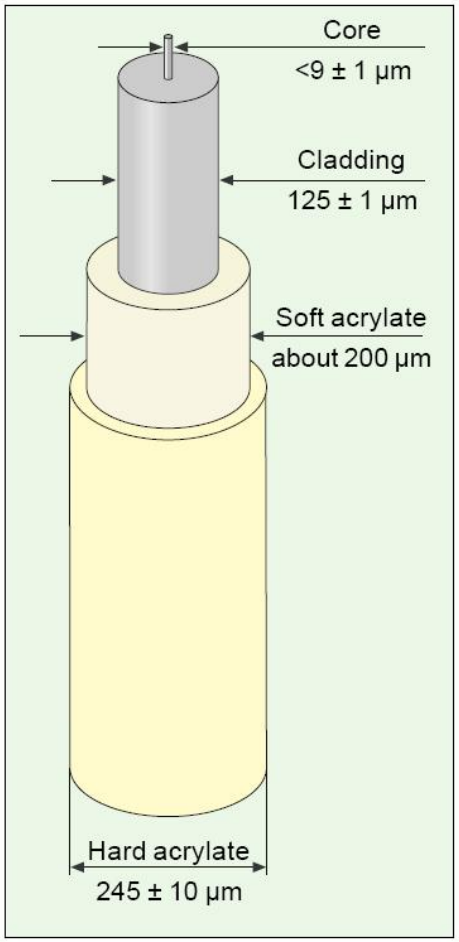
Core Ellipticity

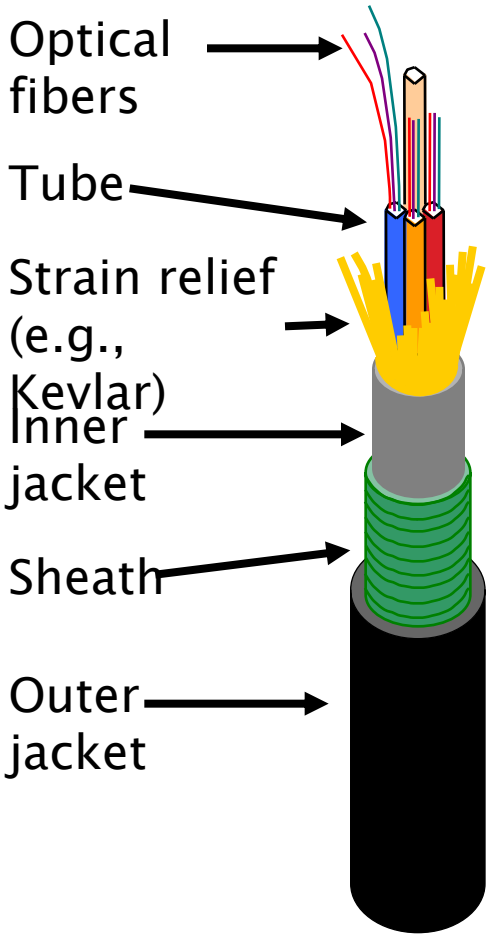


Reflections & Interference

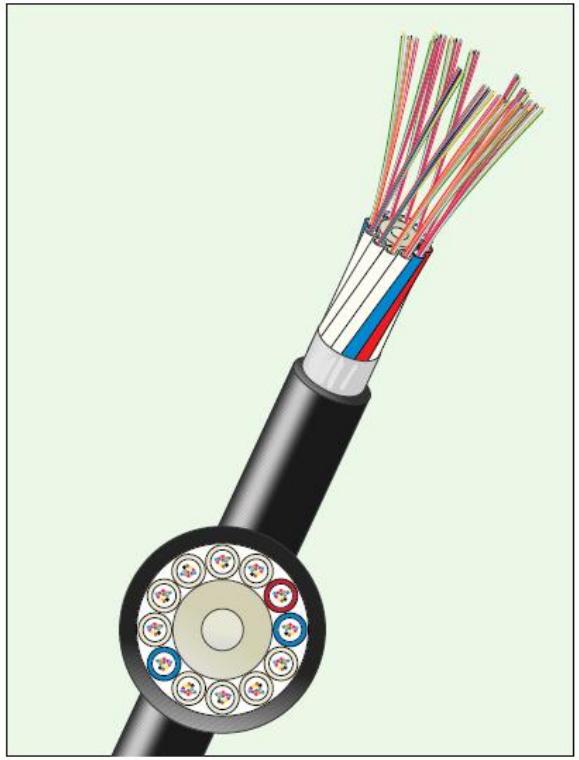


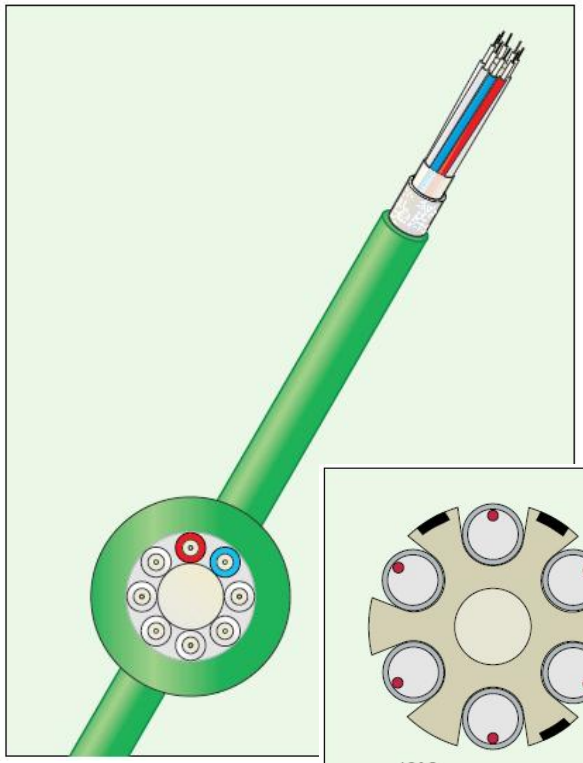
Cabluri

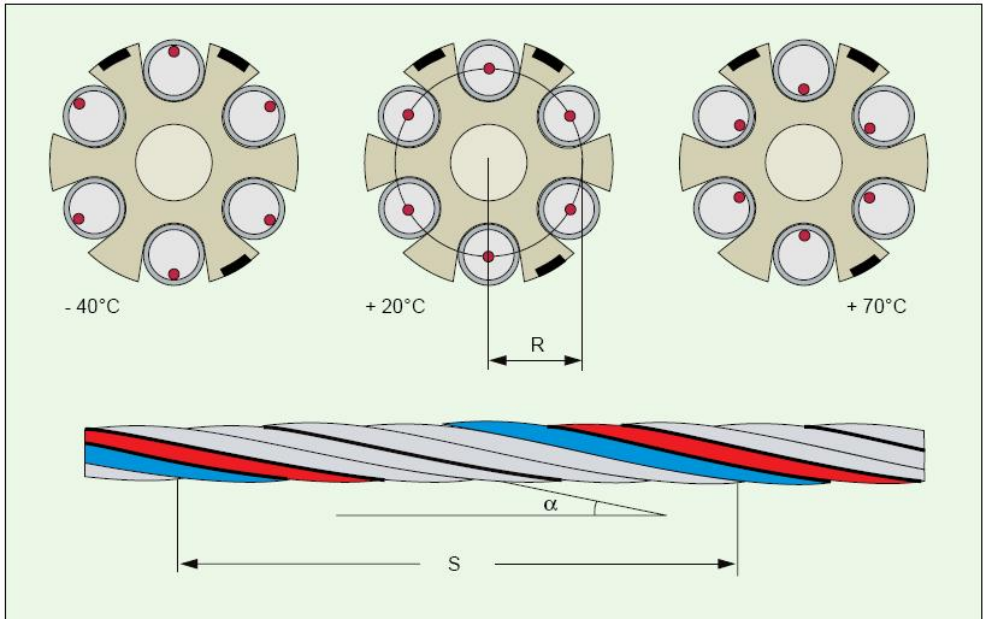

Core
<9 ± 1 µm
Cladding
125 ± 1 µm
Soft acrylate
about 200 µm
Hard acrylate
245 ± 10 µm


Optical fibers
Tube
Strain relief (e.g., Kevlar)
Inner jacket
Sheath
Outer jacket

Cabluri







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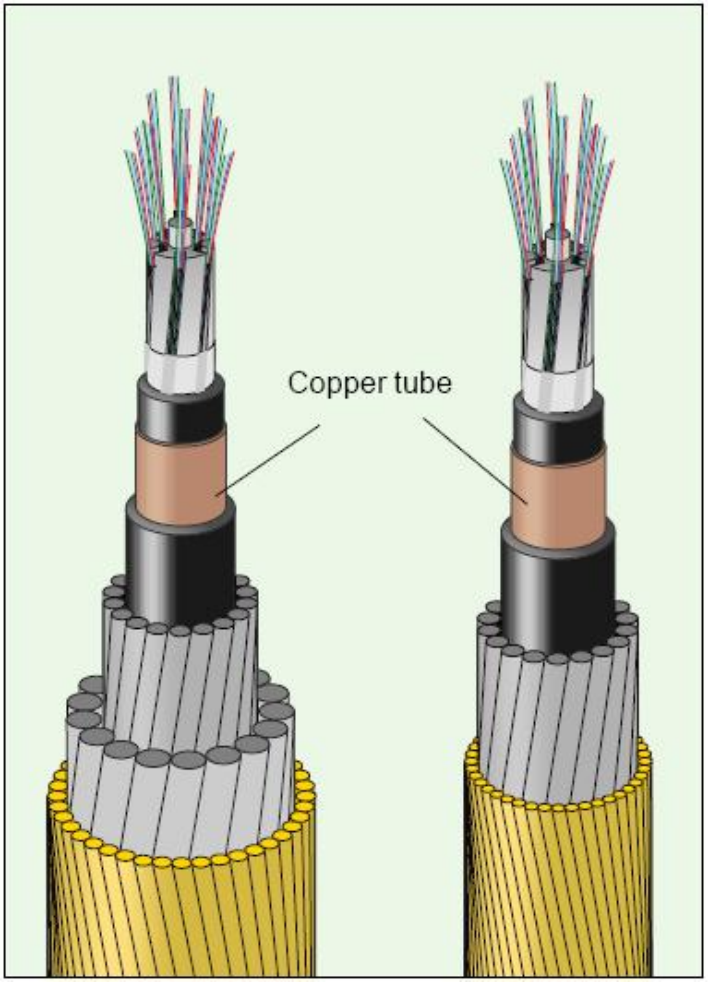
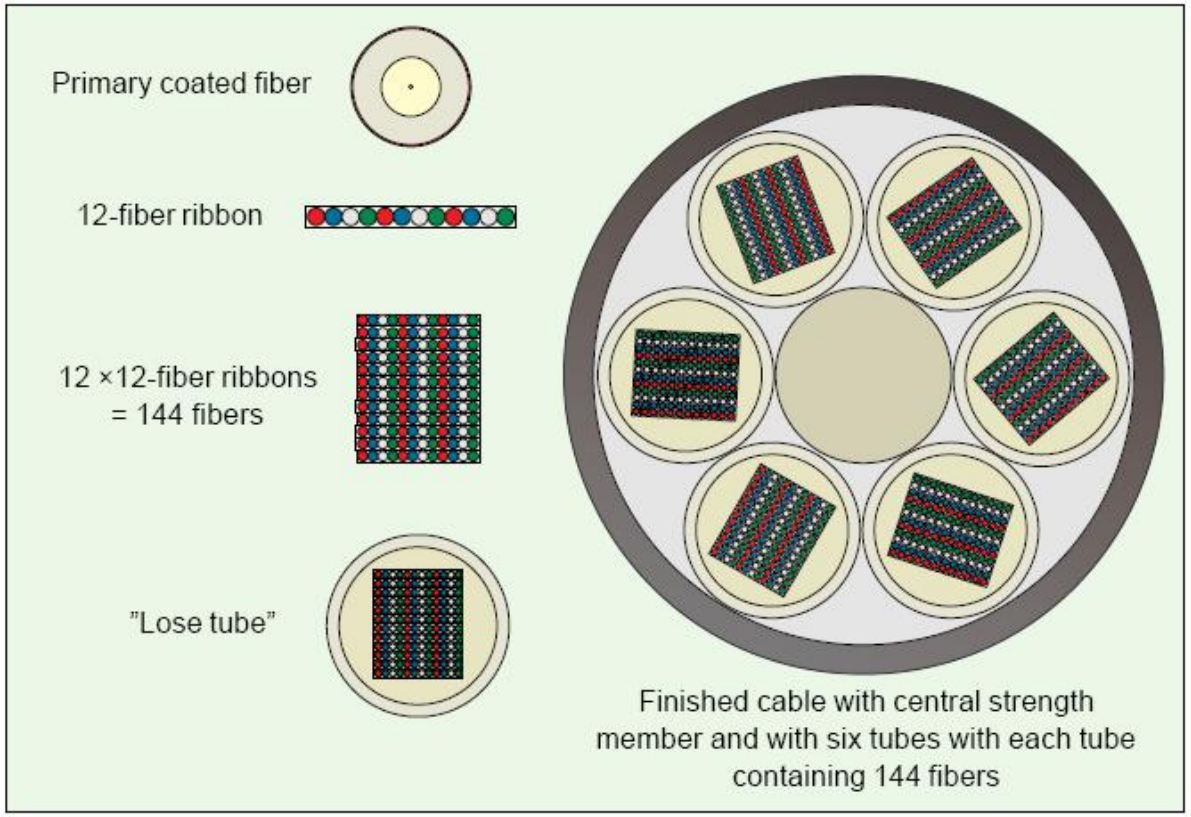

Copper tube


Primary coated fiber
12-fiber ribbon
12 ×12-fiber ribbons
= 144 fibers
"Lose tube"
Finished cable with central strength member and with six tubes with each tube containing 144 fibers

Conectori


FC - PC/PM
FC - APC/PM
DIN - PC
DIN-APC/HRL10
SC - PC
SC - APC
AVIO - PC
AVIO - APC
ST - PC
E2000 - PC
E2000 - APC

Conectori

- Verificati http://rf-opto.etc.tuiasi.ro

Contact

- Laboratorul de microunde si optoelectronica
- http://rf-opto.etti.tuiasi.ro
- rdamian@etti.tuiasi.ro