Optoelectronică

Curs 8

2022/2023

Disciplina 2022/2023

- 2C/1L Optoelectronică OPTO
- **Minim** 7 prezente curs + laborator
- Curs – conf. Radu Damian
  - an IV μE
  - Joi 08(:10)–10:00, C1
  - E – 70% din nota (50%+20%)
    - **20% test (VP) la curs**, saptamana 4–6?
  - probleme + (2p prez. curs)
  - toate materialele permise
- Laborator – sl. Daniel Matasaru
  - an IV μE
    - Luni 18–20, Miercuri 11–15 par
    - Max. 7 prezente
  - L – 30% din nota (+Caiet de laborator)

Cuprins

- **Lumina ca undă electromagnetică*** (ecuaţiile lui Maxwell, ecuaţia undelor, parametrii de propagare)
- **Elemente de fotometrie şi radiometrie*** (mărimi energetice/luminoase)
- **Fibra optică** (realizare, principiu de funcţionare, atenuare, dispersie, banda de frecvenţă)
- **Cabluri optice** (tehnologie, conectori, lipire – splice)
- **Proiectare sistemică a legăturii pe fibra optică** (bandă de frecvenţă, balanţa puterilor)
- **Emiţătoare optice** (LED şi dioda laser – realizare fizică şi functionare)
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- **Amplificatoare transimpedanţă** (parametri, scheme tipice, TIA în buclă deschisă, cu reacţie, diferenţiale, control automat al câştigului)
- **Realizarea circuitelor pentru controlul emiţătoarelor optice** (parametri, scheme tipice, controlul puterii, multiplexoare)
- **Dispozitive de captare a energiei solare** (principiu de functionare, utilizare, proiectare)

*** – VP**

Bibliografie

- http://rf-opto.etti.tuiasi.ro
- Irinel Casian-Botez, "Structuri Optoelectronice", Ed. "CANOVA", Iasi 2001, ISBN 973-96099-2-9
- Behzad Razavi – Design of Integrated Circuits for Optical Communications, Mc Graw Hill
- John Powers – An Introduction to Fiber Optic Systems
- IBM – Understanding Optical Communications: on-line http://www.redbooks.ibm.com
- Radu Damian, I Casian, D Matăsaru – „Comunicatii Optice” , Indrumar de laborator, 2005
- MIT Course – Fundamentals of Photovoltaics, https://ocw.mit.edu

Fotografii

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente

Finantare	Buget
Bursa	Fara Bursa

Observatii

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5244

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente

Finantare	Buget
Bursa	Bursa de Studii

Observatii

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Acceseaza ca acest student

Note obtinute

Disci...	Tip	Data	Descriere	Nota	P...	Obs.
TW	Tehnolo... Web					
	N	17/01/2014	Nota finala	10	-	
	A	17/01/2014	Colocviu Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9		

Bonus

Disciplina: Optoelectronica, structuri, tehnologii, circuite
An: 2015/2016

Bonus-uri care se aplica la nota de la teza obtinute prin:
- prezenta la curs (0.5p / 3pr)
- 3 miniteste aplicate la curs (max. 3 X 1.5p)
- contributie la site rf-opto (foto <C5=1p, >C5=0.5p)

Nr.	Student	Grupa	Prezente curs	Bonus prezenta	Bonus foto	Bonus T1	Bonus T2	Bonus T3	Total Bonus	Obs.
1	CIOLPAN OCTAVIAN	5306	3	0.5					0.5	-
2	NITA COSTEL-CATALIN	5307	4	0.5	1				1.5	-
3	BARON BOGDAN-IONUT	5405	12	2	1	0.5		0.75	4.25	-

Prezenta

Curs
Laborator

Liste

Studenti care nu pot intra in examen
Bonus-uri acumulate

- **Minim** 7 prezente
- 0.5p/3(2)prez
- 3 teste
- foto <C3/<C5

Reprezentare logaritmică

$dB = 10 \cdot \log_{10}(P_2 / P_1)$

$dBm = 10 \cdot \log_{10}(P / 1\ mW)$

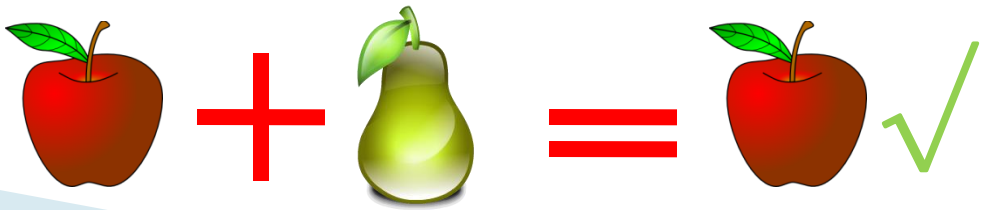
0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
−3 dB	= 0.5
−10 dB	= 0.1
−20 dB	= 0.01
−30 dB	= 0.001

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
−3 dBm	= 0.5 mW
−10 dBm	= 100 μW
−30 dBm	= 1 μW
−60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]



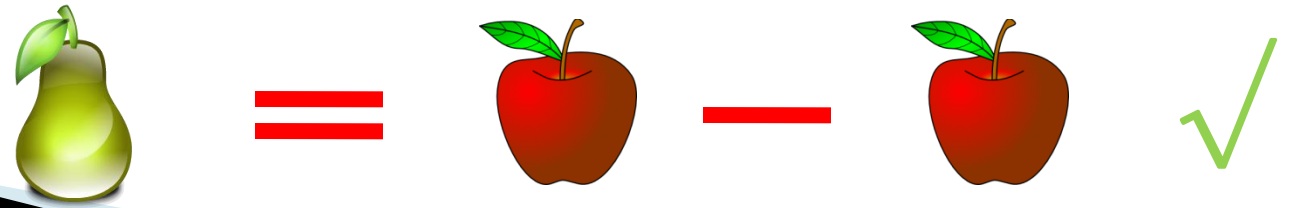
Calculul atenuarii/amplificarii

$$\text{Atenuare/Amplificare} = \frac{P_{out}}{P_{in}}$$

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

$$\text{Atenuare}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_0} \cdot \frac{P_0}{P_{in}}\right) = [-]10 \cdot \left[\log_{10}\left(\frac{P_{out}}{P_0}\right) - \log_{10}\left(\frac{P_{in}}{P_0}\right)\right]$$

$$\text{Pierderi}[\text{dB}] = [-]\left(P_{out}[\text{dBm}] - P_{in}[\text{dBm}]\right)$$



Online

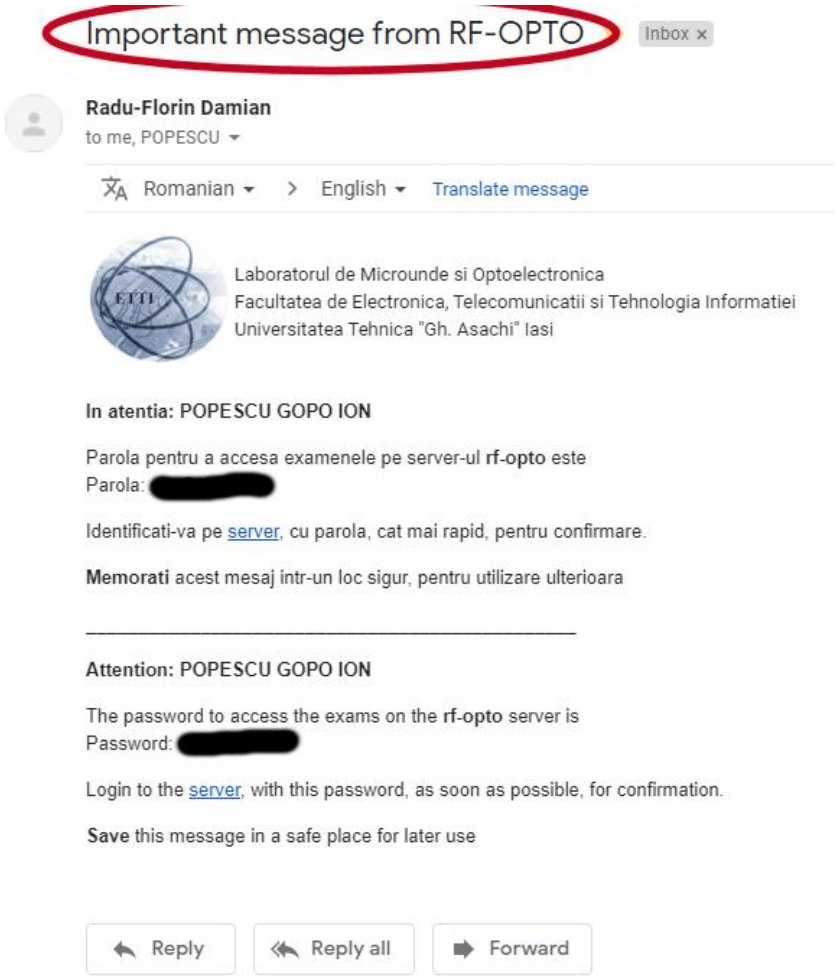
- acces la examene necesita parola primita prin email

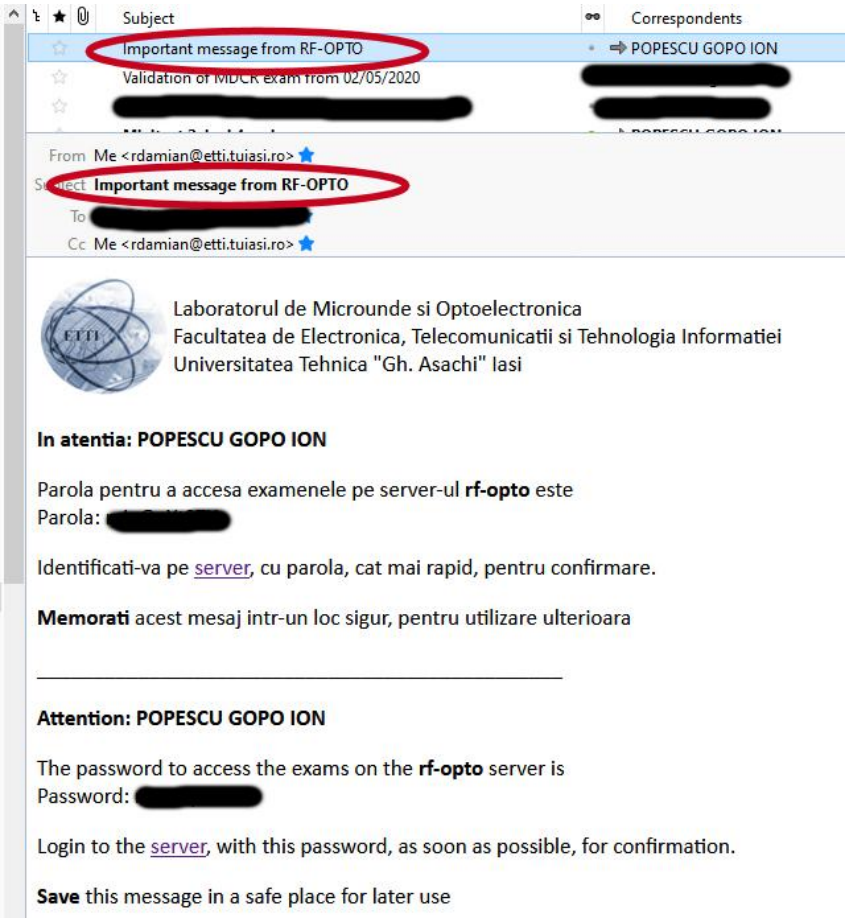
Online

- acces email/parola

Parola

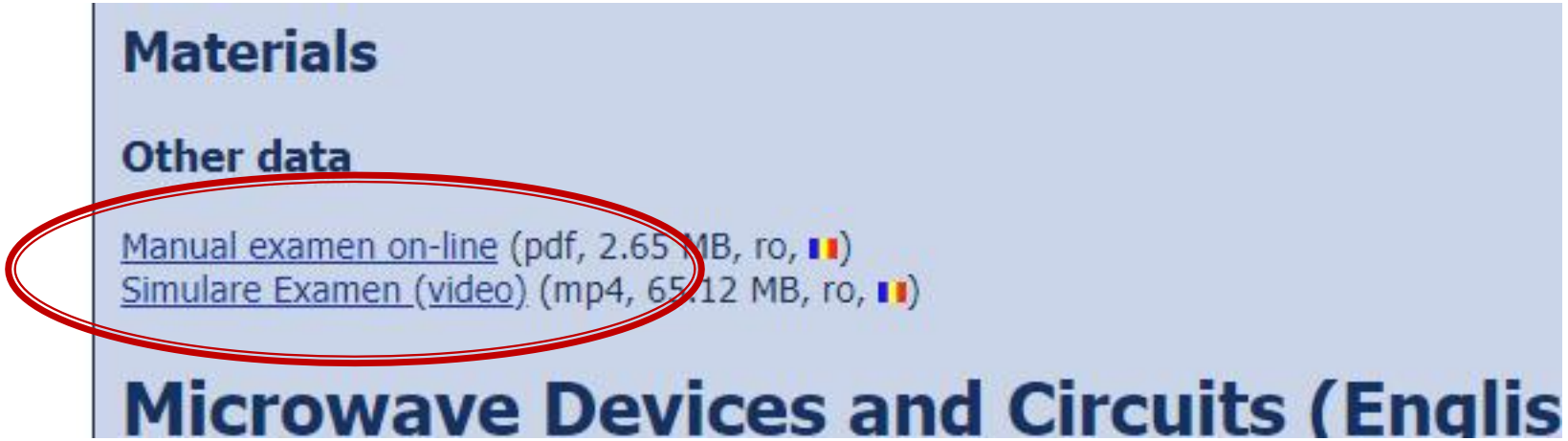
- primita prin email





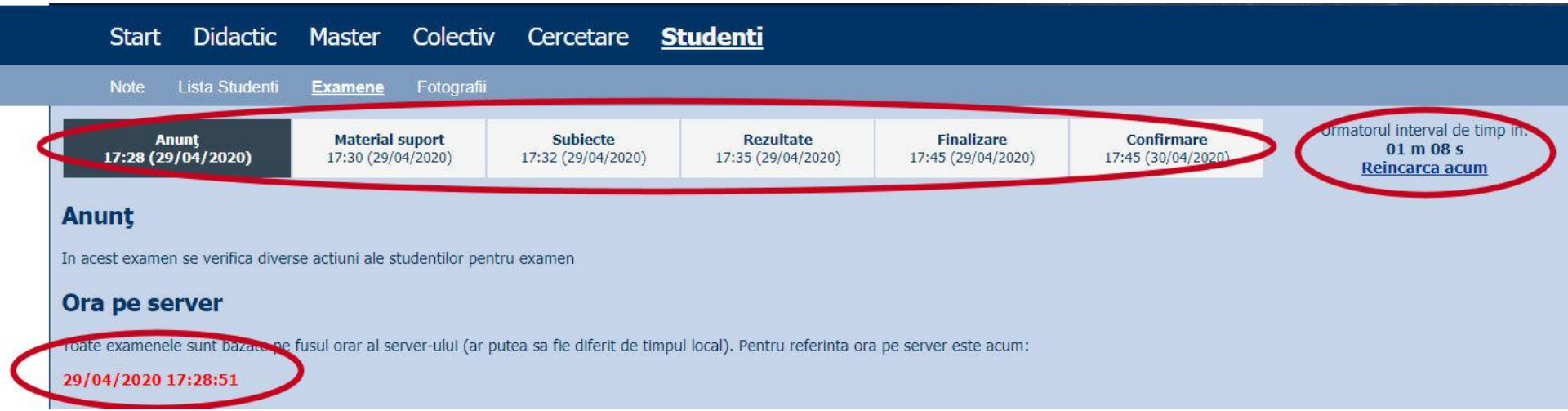
Manual examen online

- Aplicatia de examen online utilizata intens la:
  - curs (prezenta)
  - miniteste
  - examen



Examen online

- intotdeauna **contratimp**
  - perioada lunga (prezenta curs/rezultate laborator)
  - perioada scurta (teste: 15min, examen: 2h)



Fibra optică

Capitolul 4

Aplicatii majore

- Comunicatii
  - Infrarosu (InGaAsP)
- Vizibil
  - Spectru vizibil (GaAlAs)
- Iluminare
  - Putere ridicata, lumina alba (GaInN)
- Energie solara
  - Efect fotovoltaic (Si)

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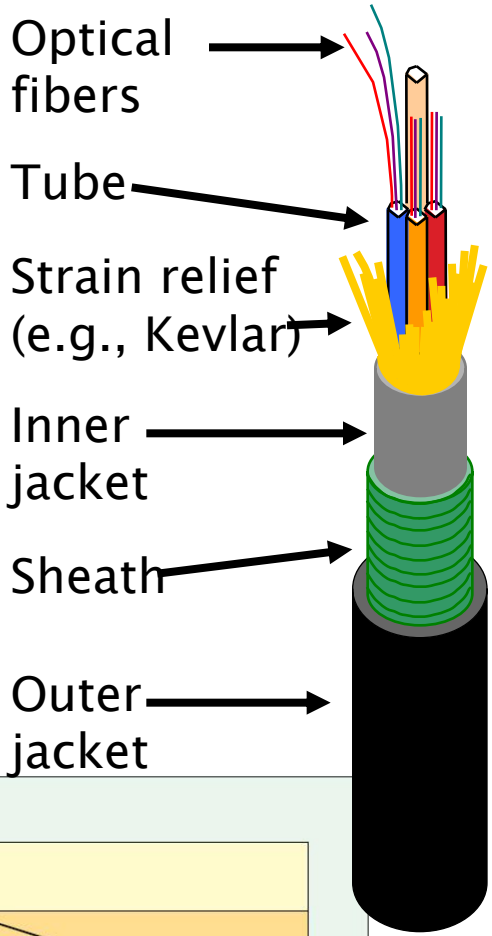
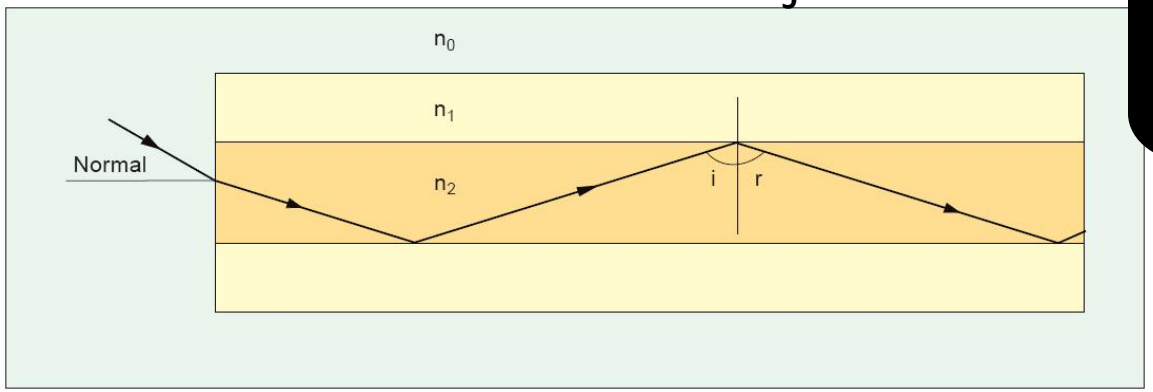
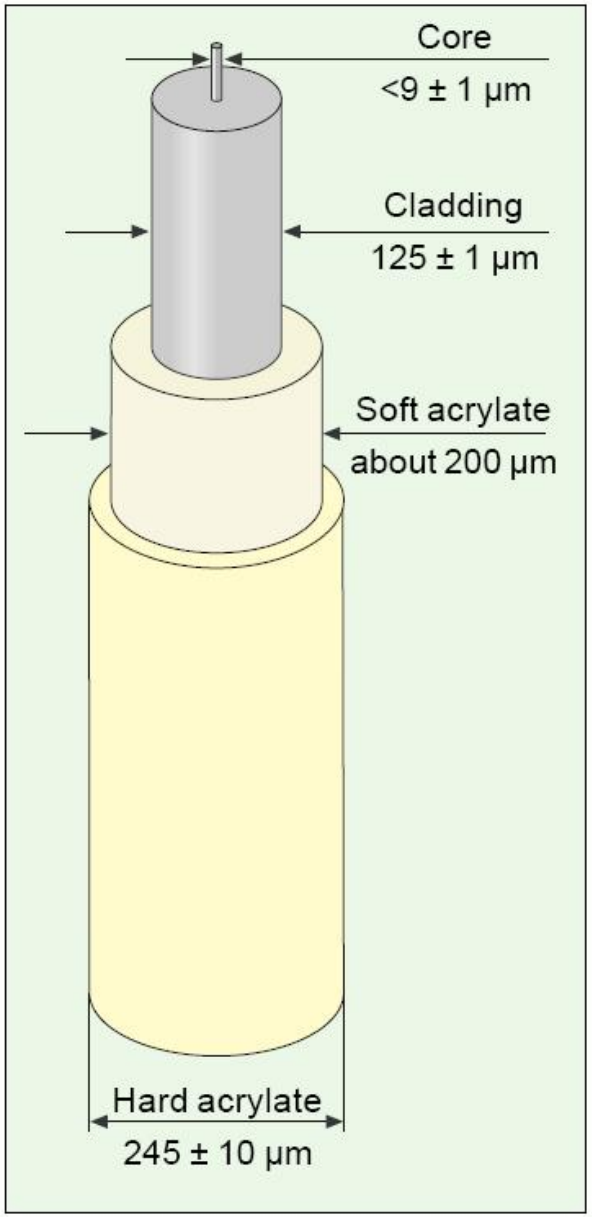
Fibra optica

- un ghid de unda dielectric
  - miez
  - teaca

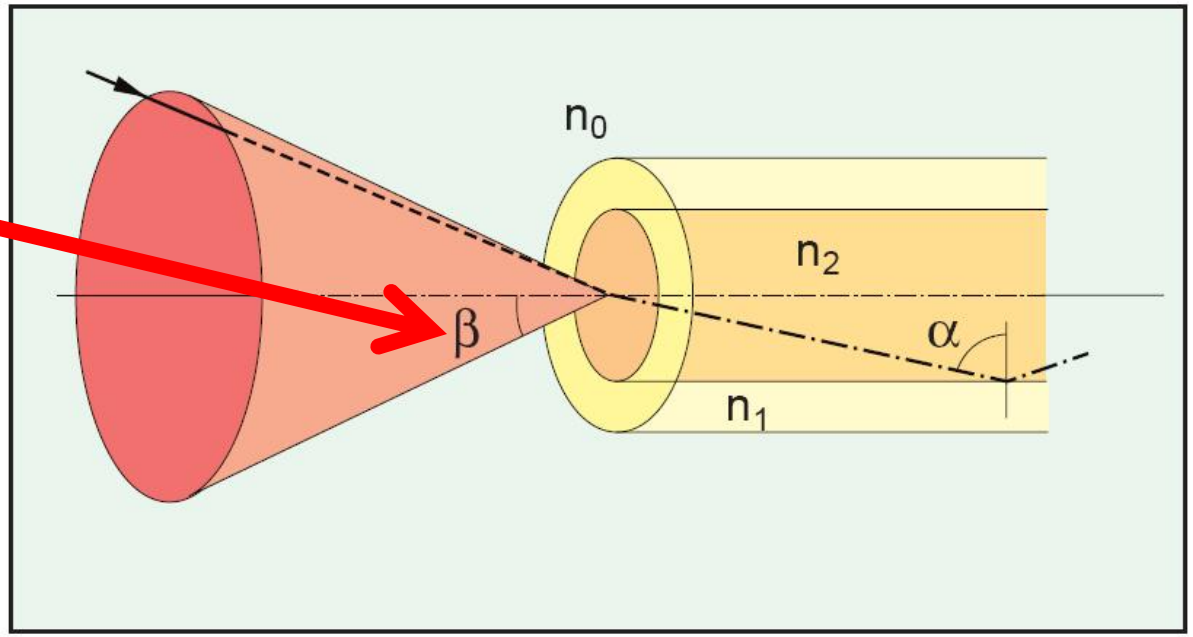






Unghi de acceptanta, apertura numerica

- Unghi de acceptanta



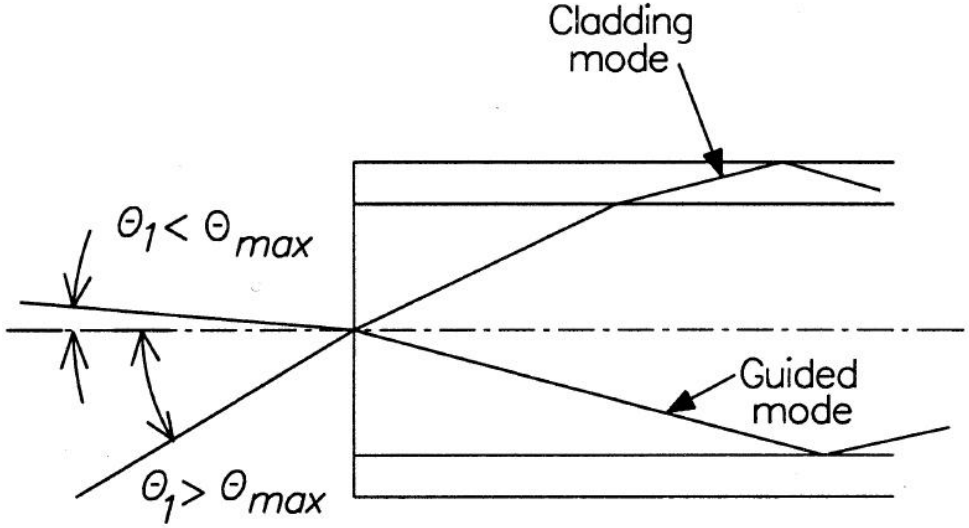
$$n_0 \cdot \sin\theta_{ACC} = n_2 \cdot \sin\phi_c$$

- **Apertura numerica**

$$NA = n_0 \cdot \sin\theta_{ACC}$$

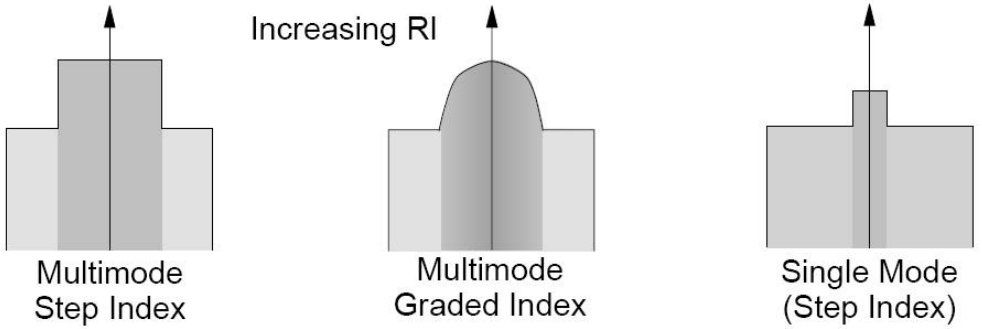
$$NA = n_2\sqrt{\frac{n_2^2 - n_1^2}{n_2^2}} = \sqrt{n_2^2 - n_1^2}$$

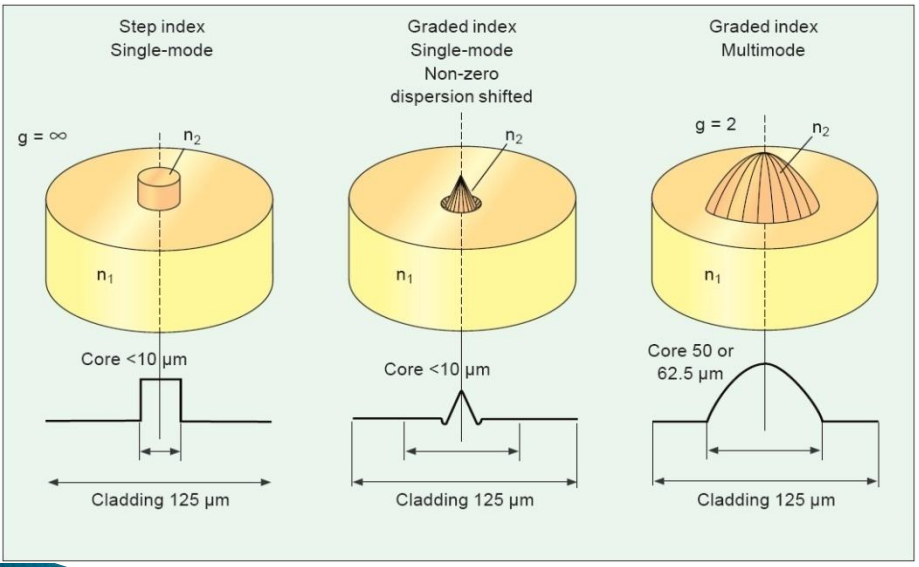
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

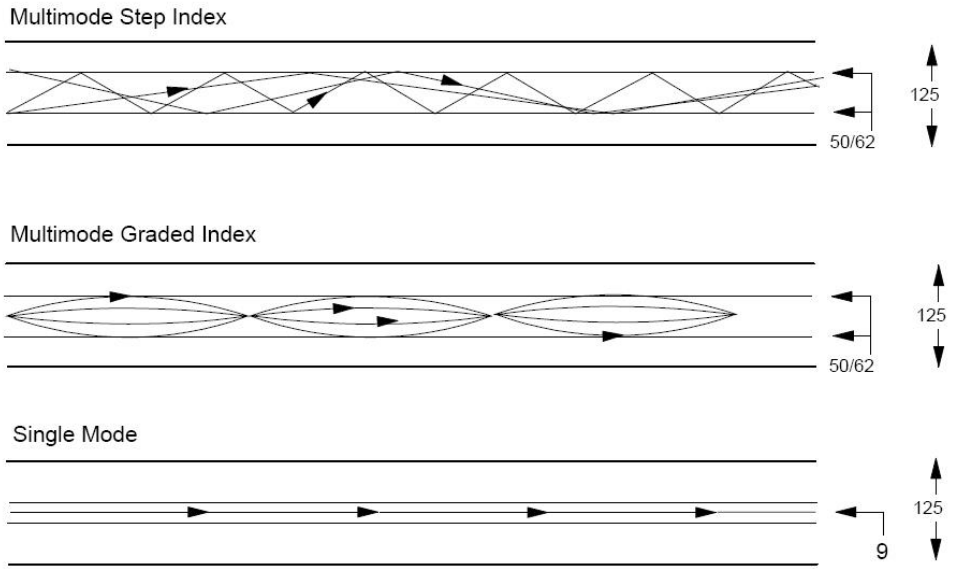


Tipuri de fibra

- Monomod
- Multimod
  - cu salt de indice
  - cu indice gradat







Fenomene de interes

- Cat de departe pot transmite semnalul luminos pe fibra
  - **atenuare**
- Cat de rapid pot transmite informația
  - dispersie

Reprezentare logaritmică

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

$$\text{P}[\text{dBm}] = 10 \cdot \log_{10}\left(\frac{P}{P_0}\right) = 10 \cdot \log_{10}\left(\frac{P}{1mW}\right)$$

dB = 10 · $\log_{10}$ (P_2 / P_1)

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
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−30 dBm	= 1 μW
−60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]

Calculul atenuarii

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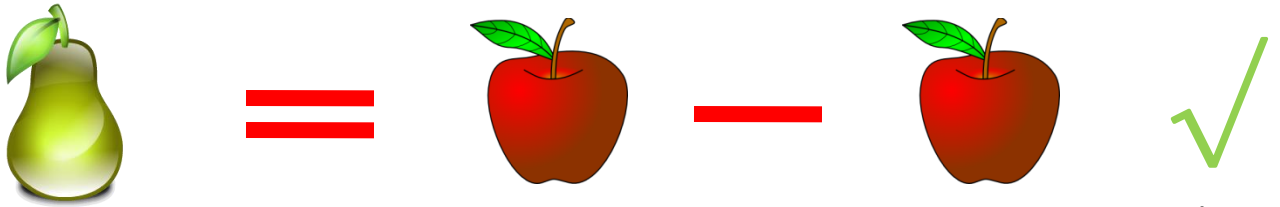
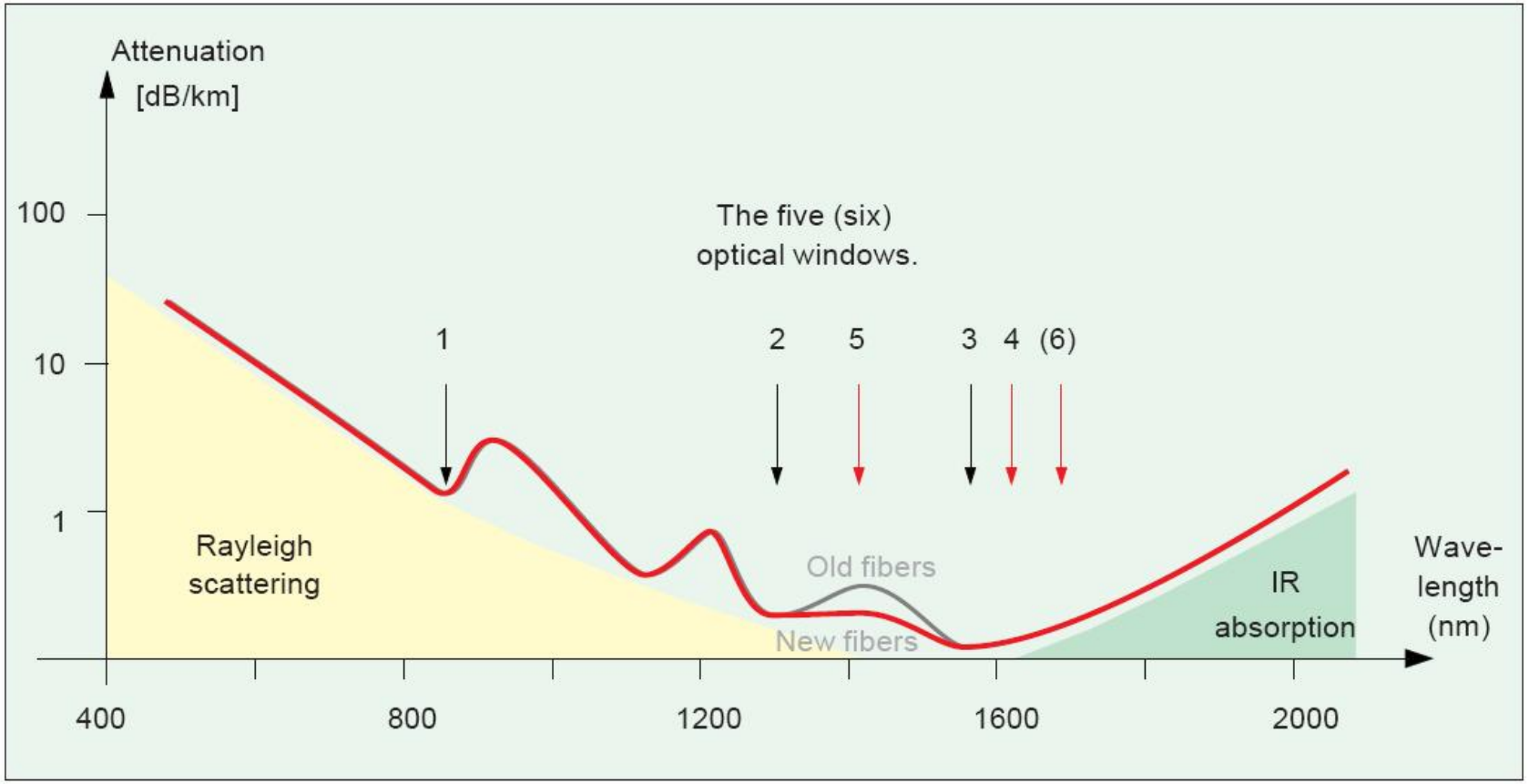


$$\text{Atenuare}[\text{dB/km}] = \frac{\text{Pierderi}[\text{dB}]}{\text{lungime}[\text{km}]}$$

Atenuare

- Macrocurburi
  - utilizator, **localizat**, dB
- Discontinuitate in fibra
  - utilizator, **localizat**, dB
- Microcurburi
  - **distribuit**, tehnologie, dB/km
- Imprastiere
  - **distribuit**, tehnologie, dB/km
- Absorbtie
  - **distribuit**, material, dB/km

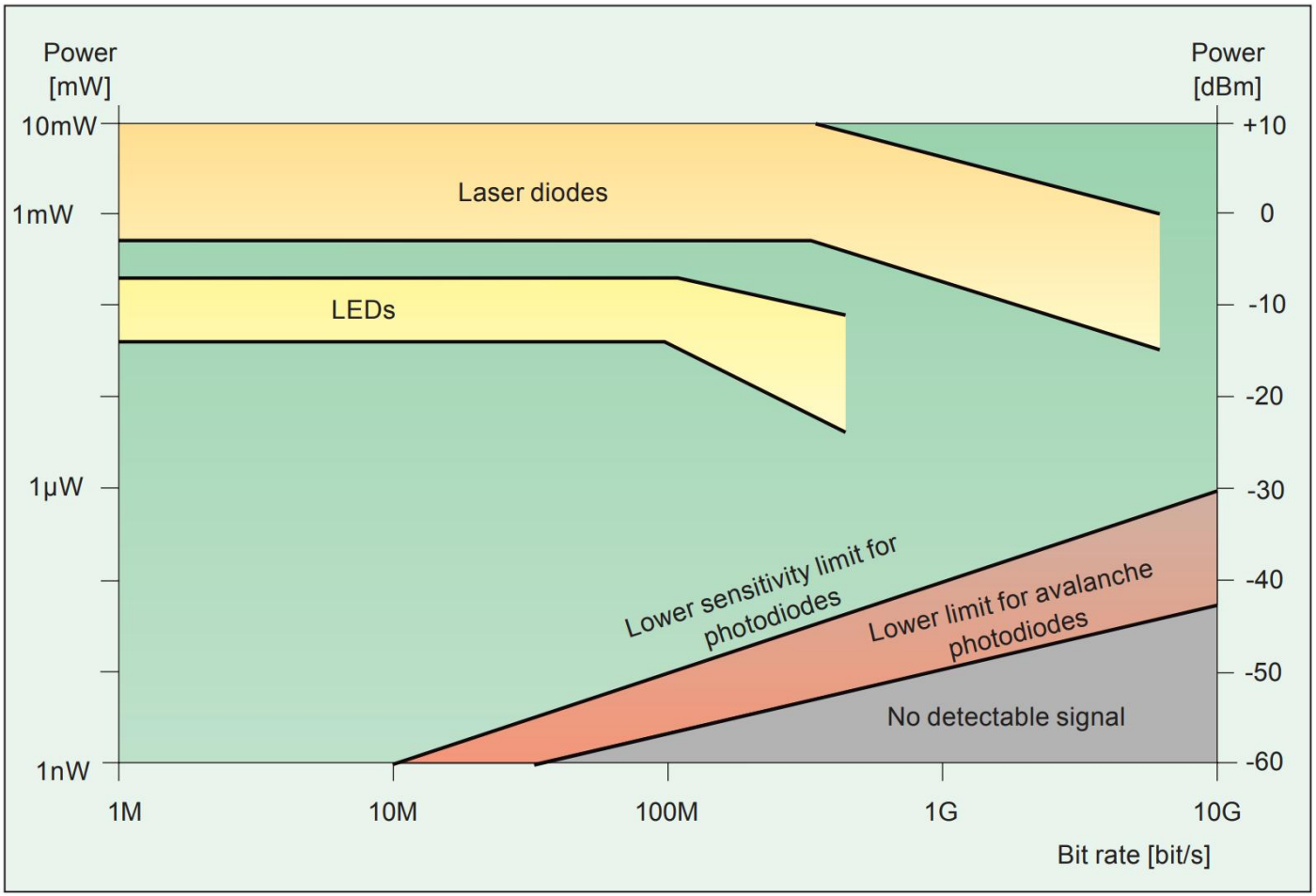
Absorbtie



distribuit, material, **dB/km**

$$A[dB] = A_i[dB/km] \cdot L[km]$$

Limite putere/bandă a dispozitivelor optoelectronice

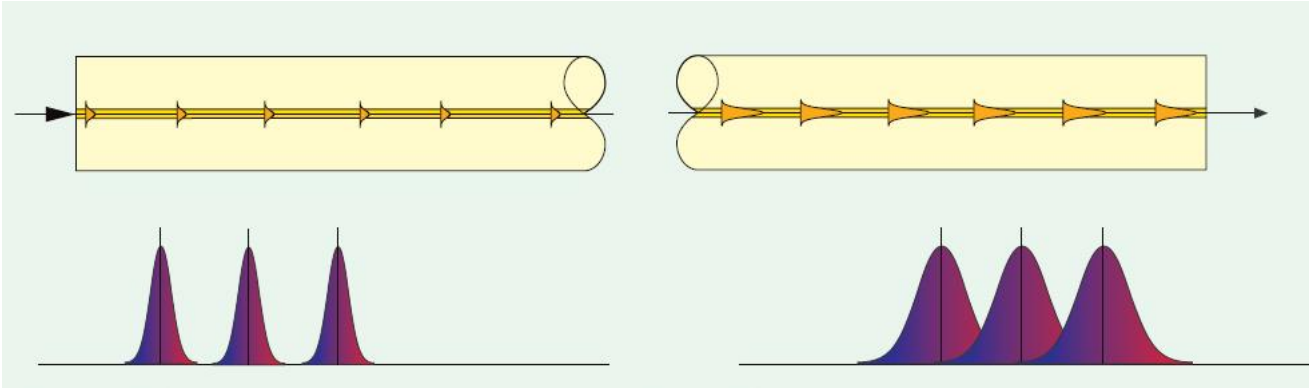


Fenomene de interes

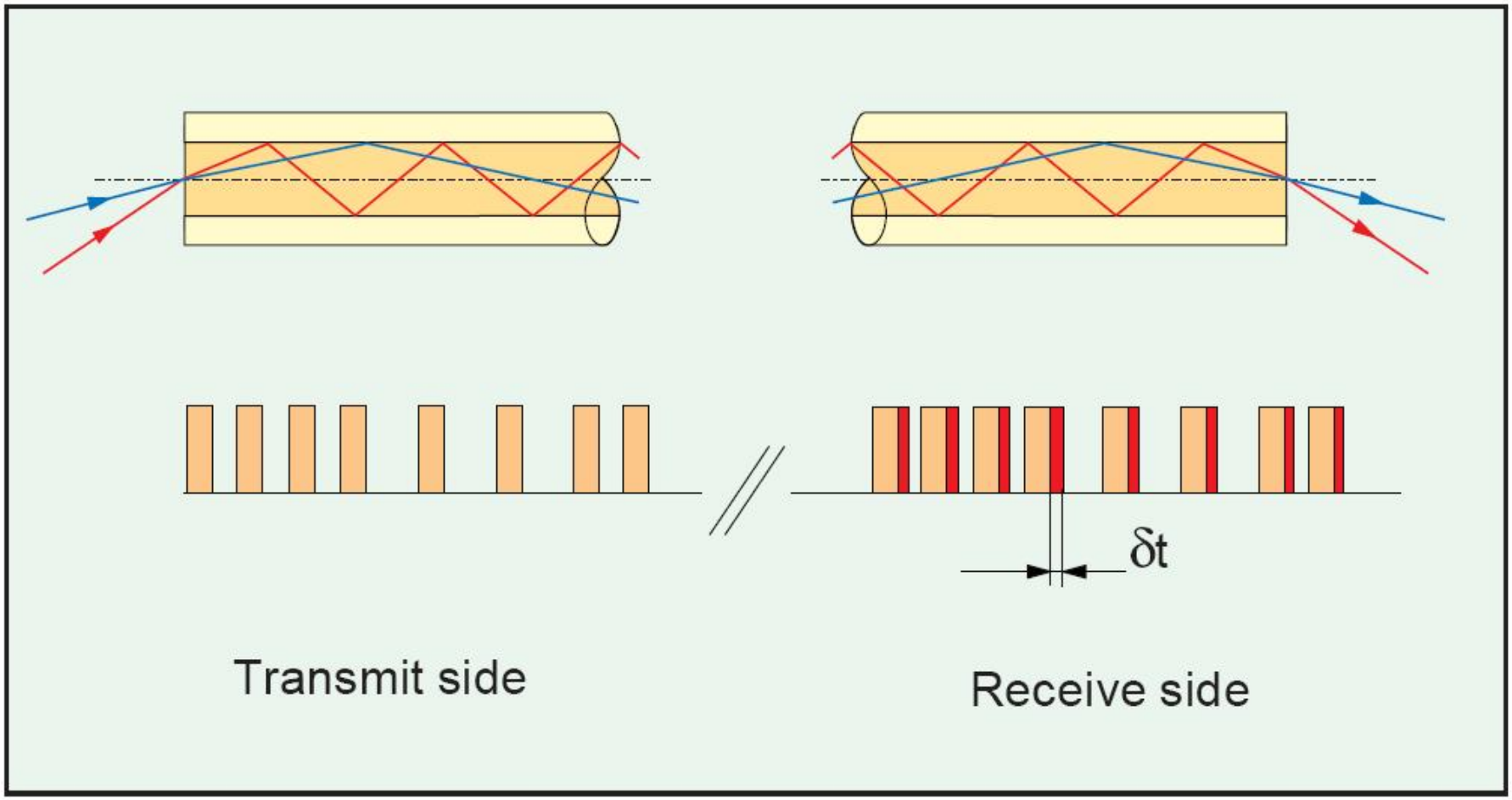
- Cat de departe pot transmite semnalul luminos pe fibra
  - atenuare
- Cat de rapid pot transmite informația
  - **dispersie**

Dispersia

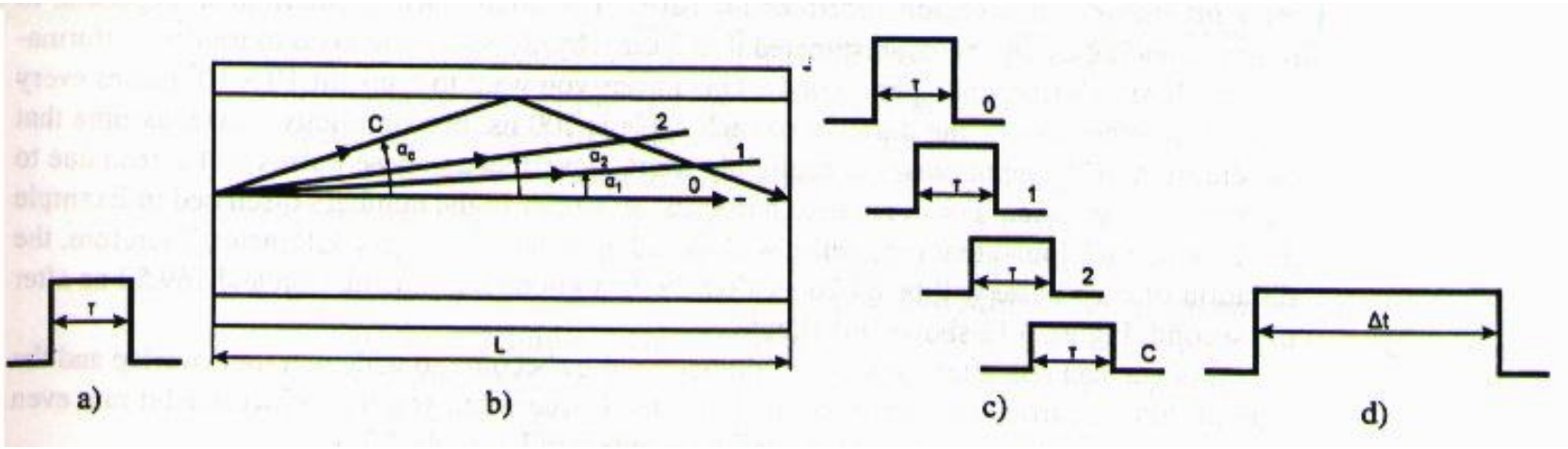
- Propagarea cu viteze diferite a radiatiilor cu trasee/lungimi de unda diferite
  - intermodala (**modala** – depinde de prezenta modurilor)
  - intramodala (**cromatica** – depinde de lungimea de unda)
    - de material
    - de ghid



Dispersia modala



Dispersia modala



$$t_0 = \frac{L}{v} \qquad t_C = \frac{L}{v \cdot \cos\alpha_C} \qquad v = \frac{c}{n_2} \qquad \cos\alpha_C = NA$$

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

$$\Delta = \frac{n_2 - n_1}{n_1} << 1 \qquad \Delta t_{SI} = t_C - t_0 \approx \frac{L}{2 \cdot c \cdot n_2} \cdot (NA)^2$$

$$\Delta t_{SI} \to dt$$

Dispersia modala

- salt de indice

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

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

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

$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_2 \cdot \Delta}{2\sqrt{3} \cdot c} \approx \frac{L \cdot NA^2}{4\sqrt{3} \cdot c \cdot n_2}$$

- indice gradat

$$dt = \frac{L \cdot n_2 \cdot \Delta^2}{2c} \approx \frac{L \cdot NA^4}{8 \cdot c \cdot n_2^3}$$

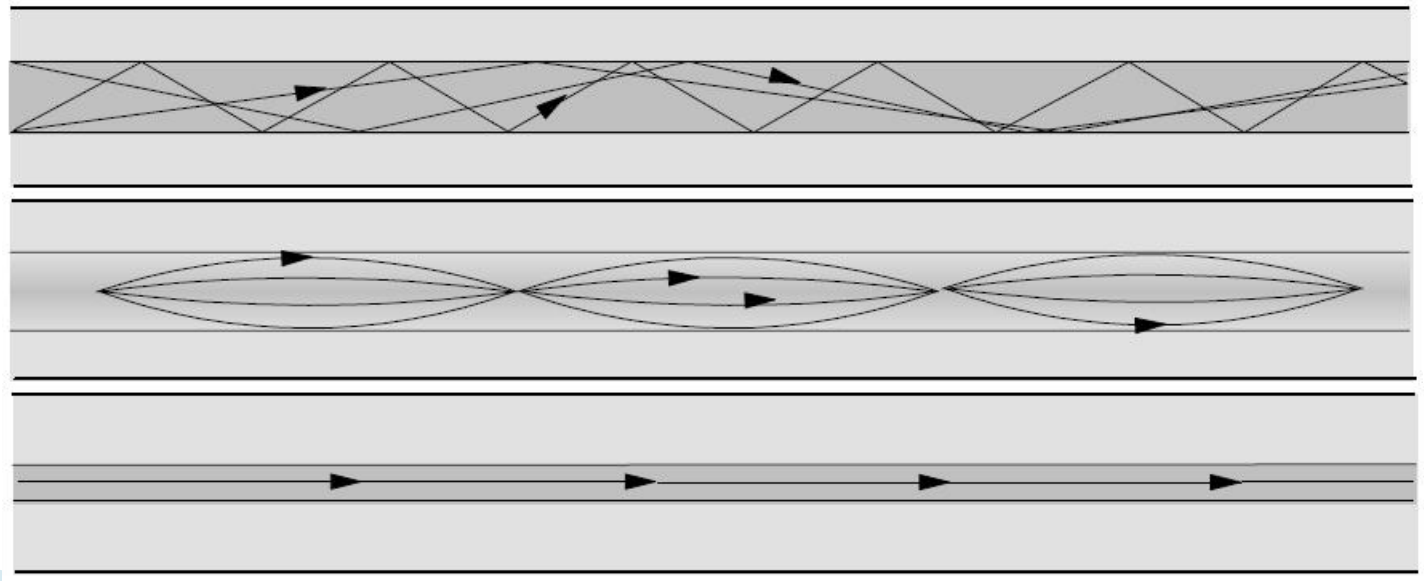
$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_2 \cdot \Delta^2}{4\sqrt{3} \cdot c}$$

$$NA = 0.1 \div 0.2 < 1$$

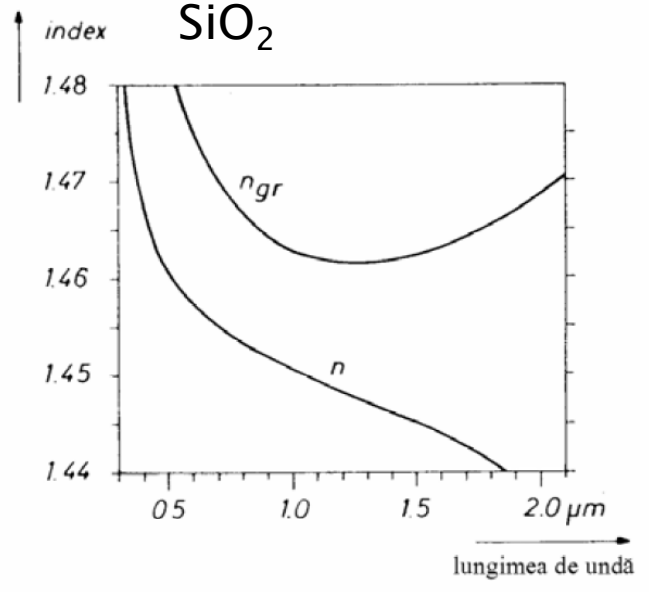
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

Dispersia modala

- Mai mare la fibre multimod cu salt de indice
- Mai mica la fibre multimod cu indice gradat
  - traseele mai lungi trec prin zone cu indice mai mic
- Inexistenta la fibrele monomod

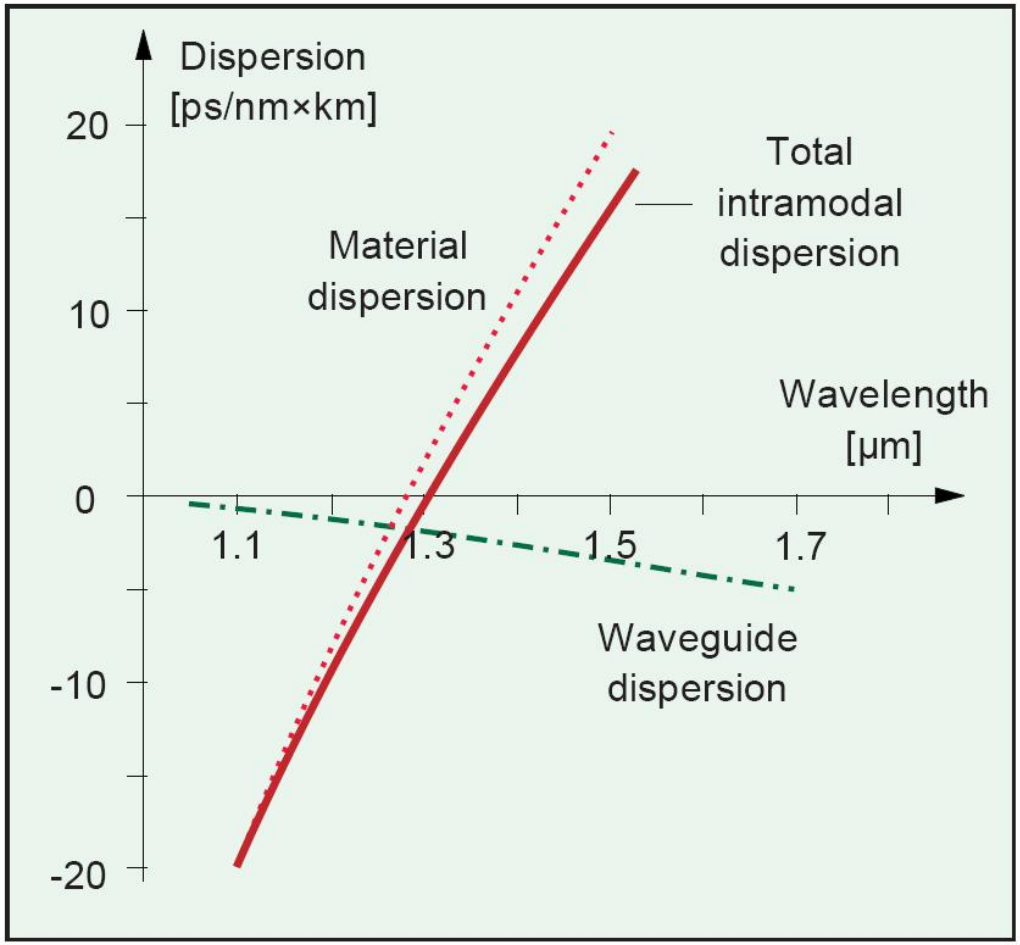


Dispersia de material



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

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

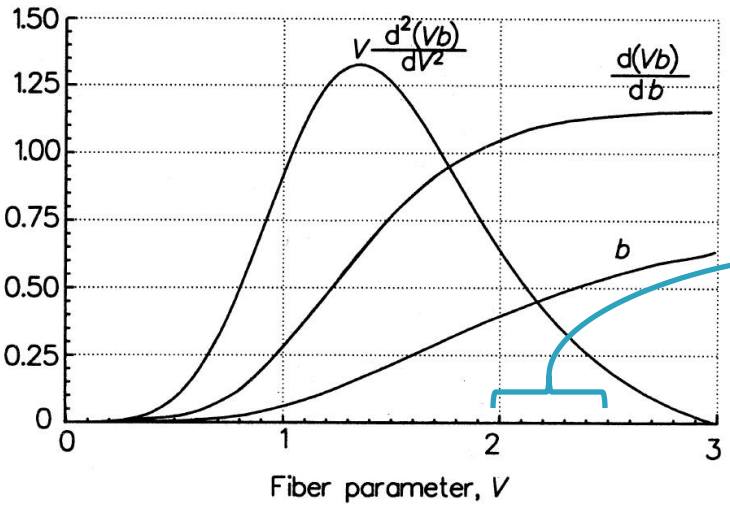


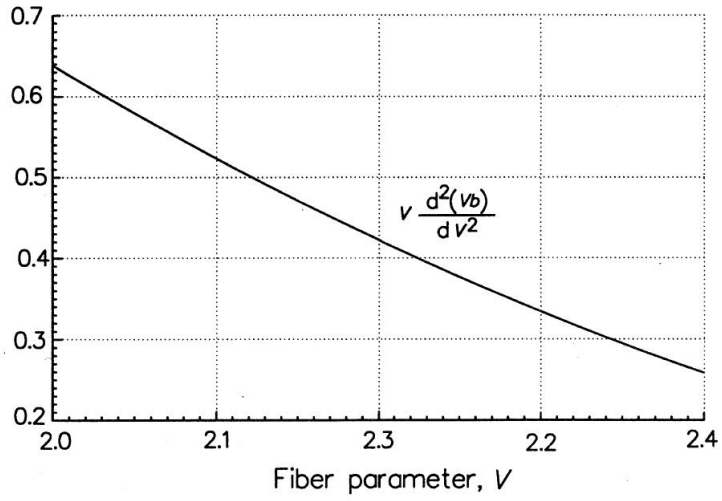
Dispersia de ghid

- Neglijabila in fibrele multimod fata de dispersia modala

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

b – constanta de propagare normalizata



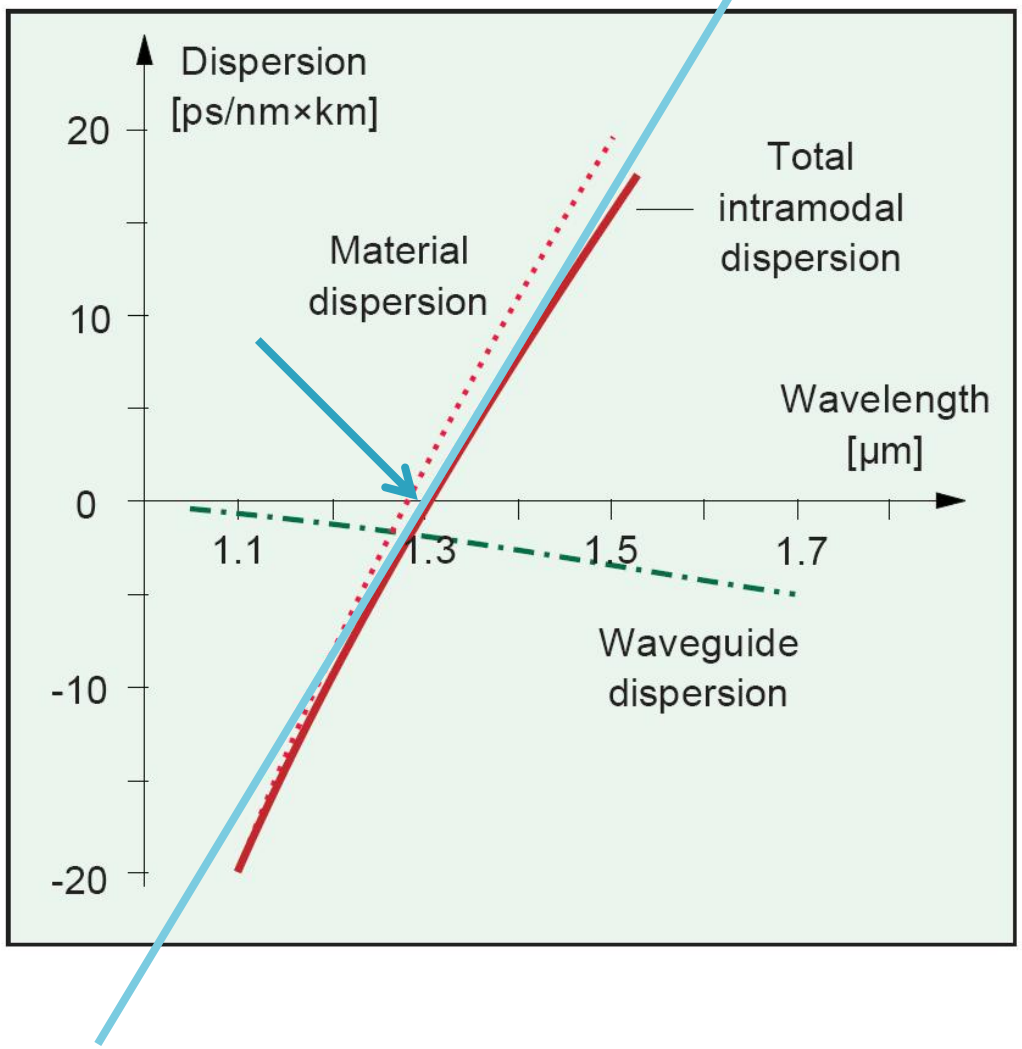


$$V \le V_C = 2.405$$

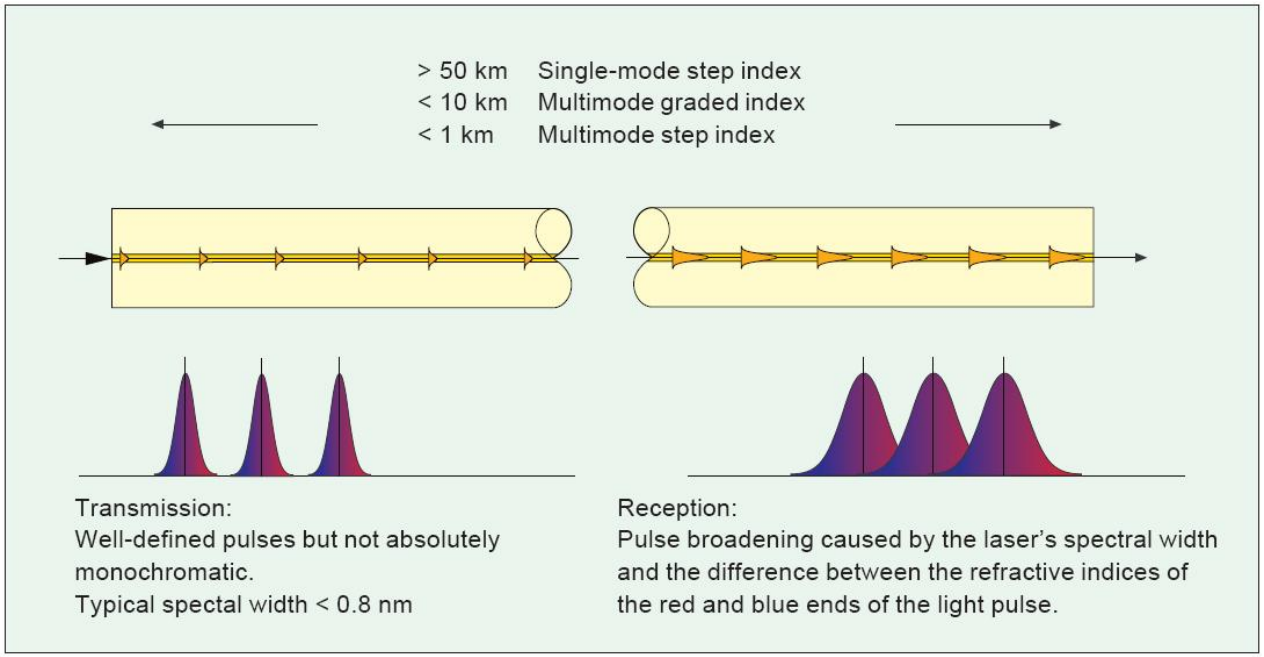
Dispersia cromatica (gh+mat)

- Variatie aproximativ liniara
- Caracterizata de panta si punctul de trecere prin 0

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



Dispersia cromatica (gh+mat)



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

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

S_0 panta dispersiei – $ps/nm^2/km$

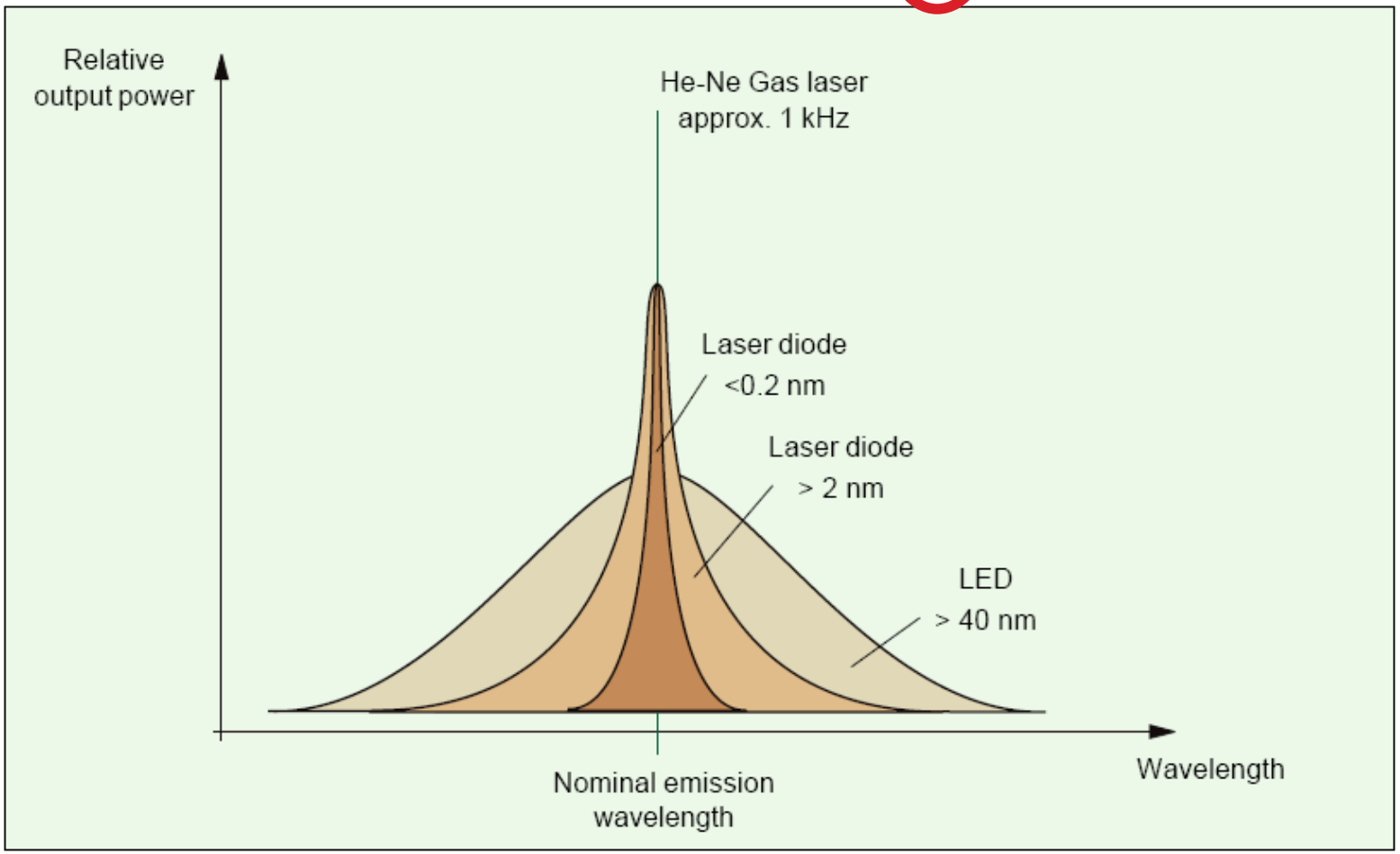
$$D(\lambda_0) = 0$$

- $D(\lambda) \approx 100 + 0.4\,(850 - \lambda)$ [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

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

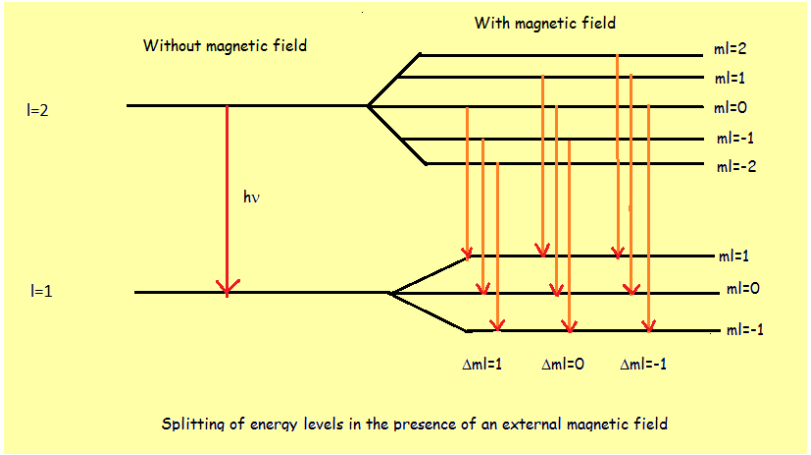
Calitatea spectrală a emiţătorilor optici

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

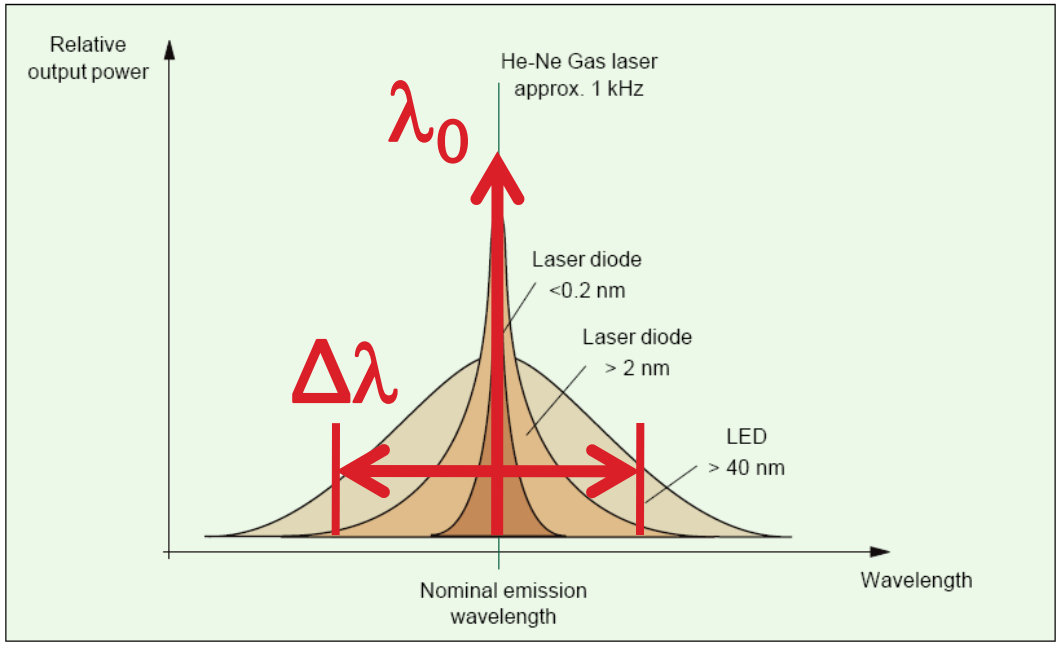


Calitatea spectrală a emiţătorilor optici

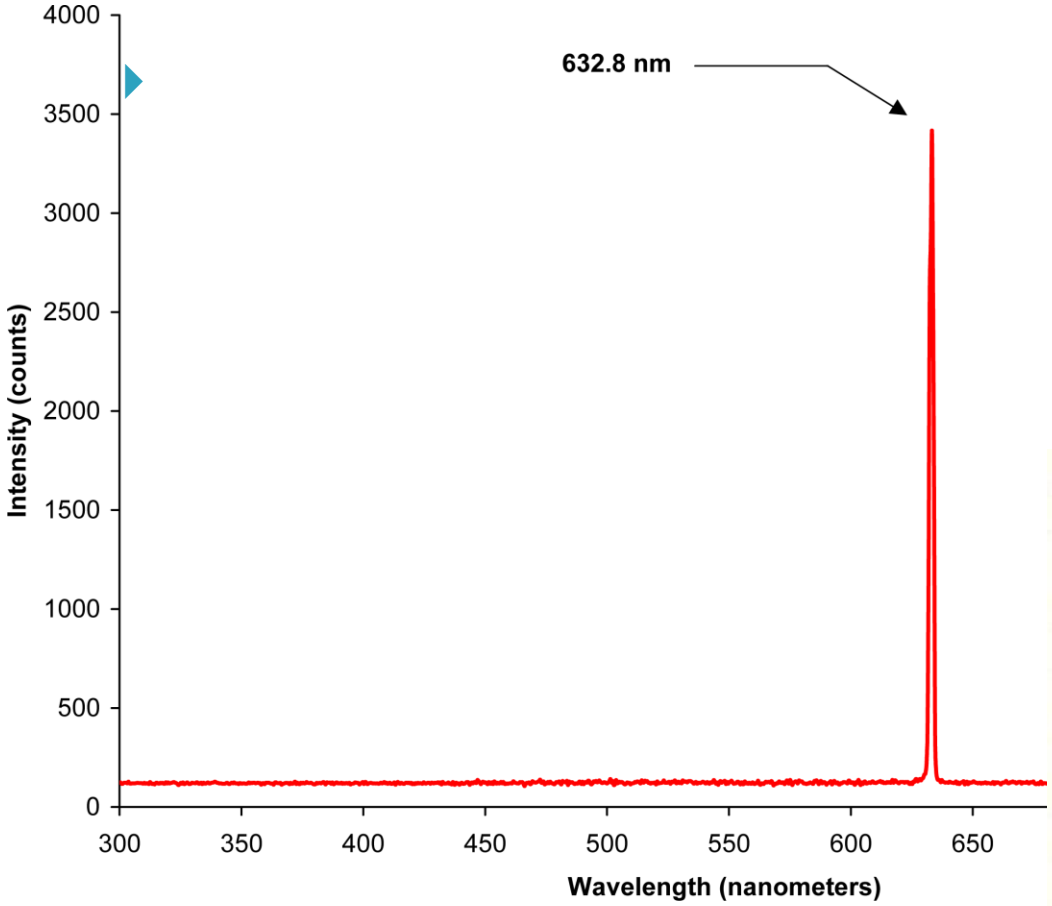
- degenerarea nivelelor energetice duce la aparitia benzilor energetice
- Multitudinea de tranzitii posibile intre cate doua nivele situate in benzi energetice diferite duce la largirea caracteristicii spectrale a surselor

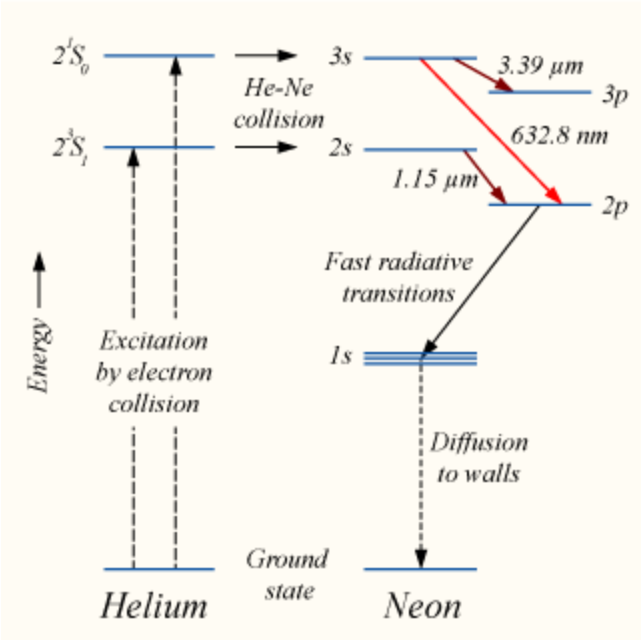


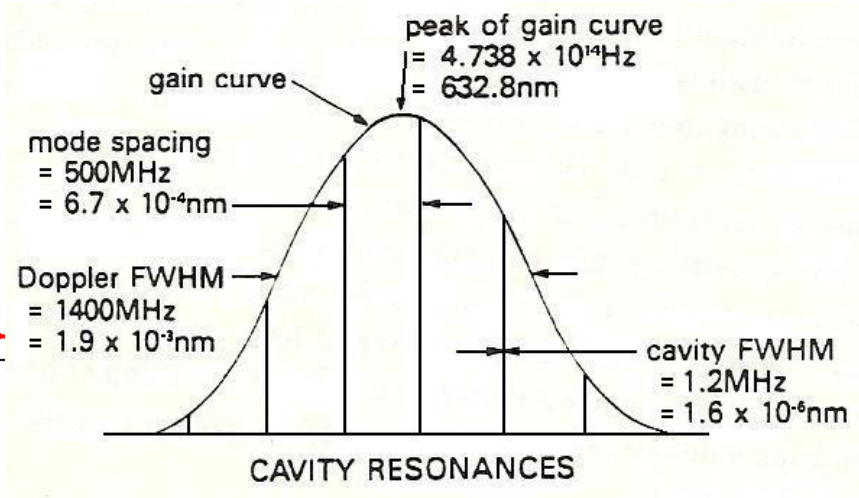
$$\lambda_0 \rightarrow \left[\lambda_0 - \frac{\Delta\lambda}{2}, \lambda_0 + \frac{\Delta\lambda}{2}\right]$$



He-Ne Laser

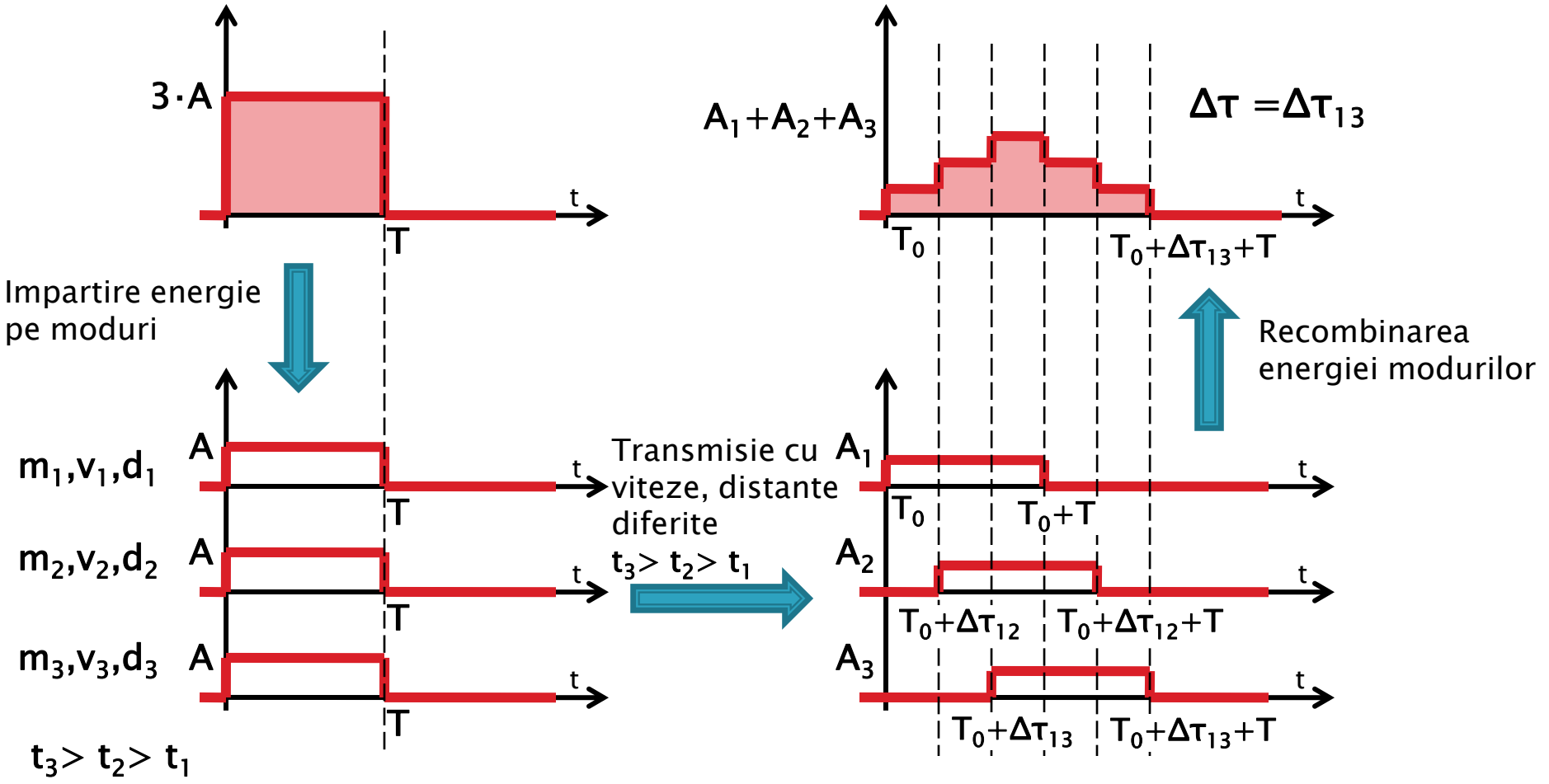






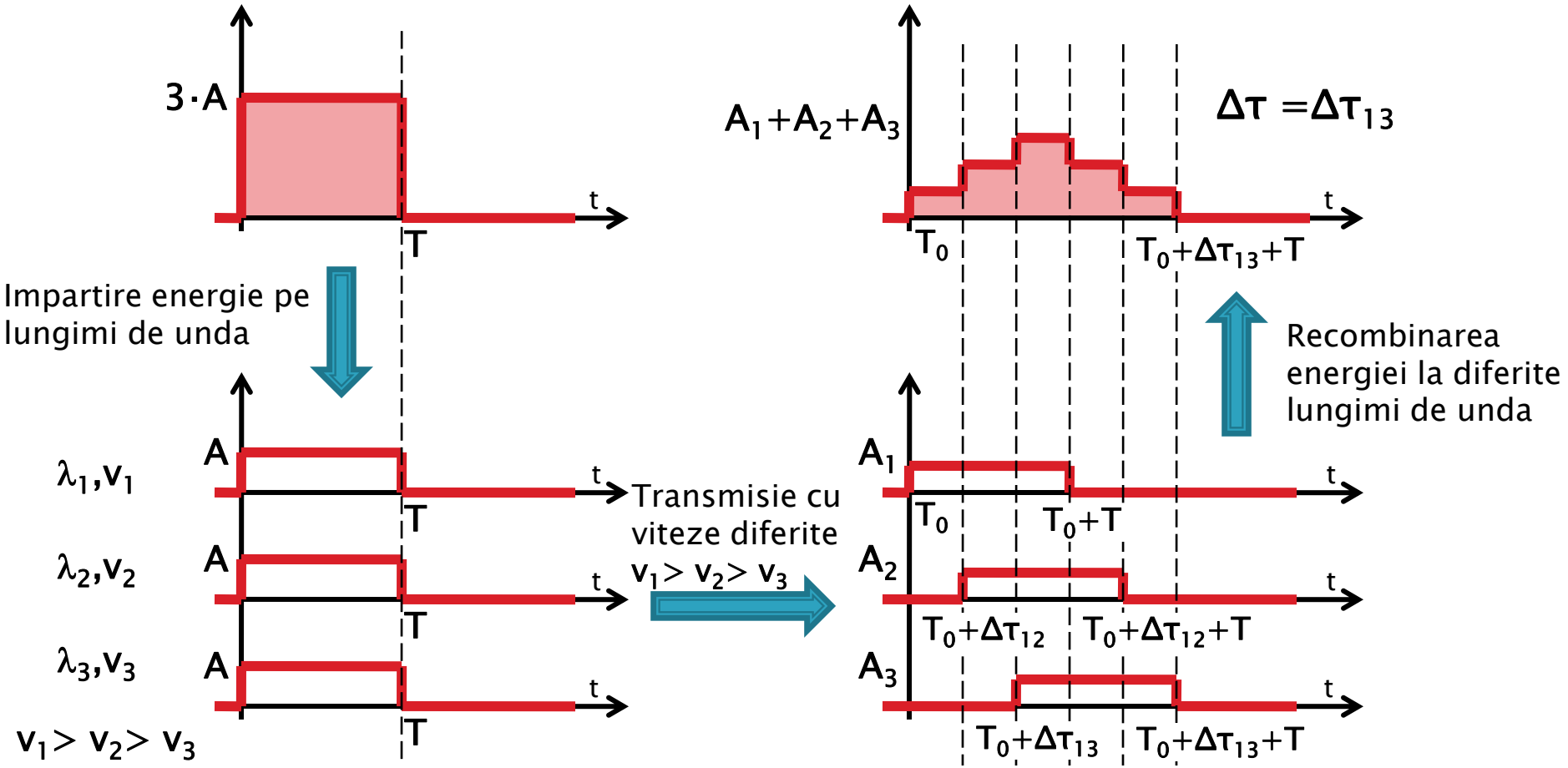
$$\Delta\lambda = 0.002\ nm$$

Dispersia modala



Conceptual→ $f(t)=\int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$

Dispersia cromatica (gh+mat)

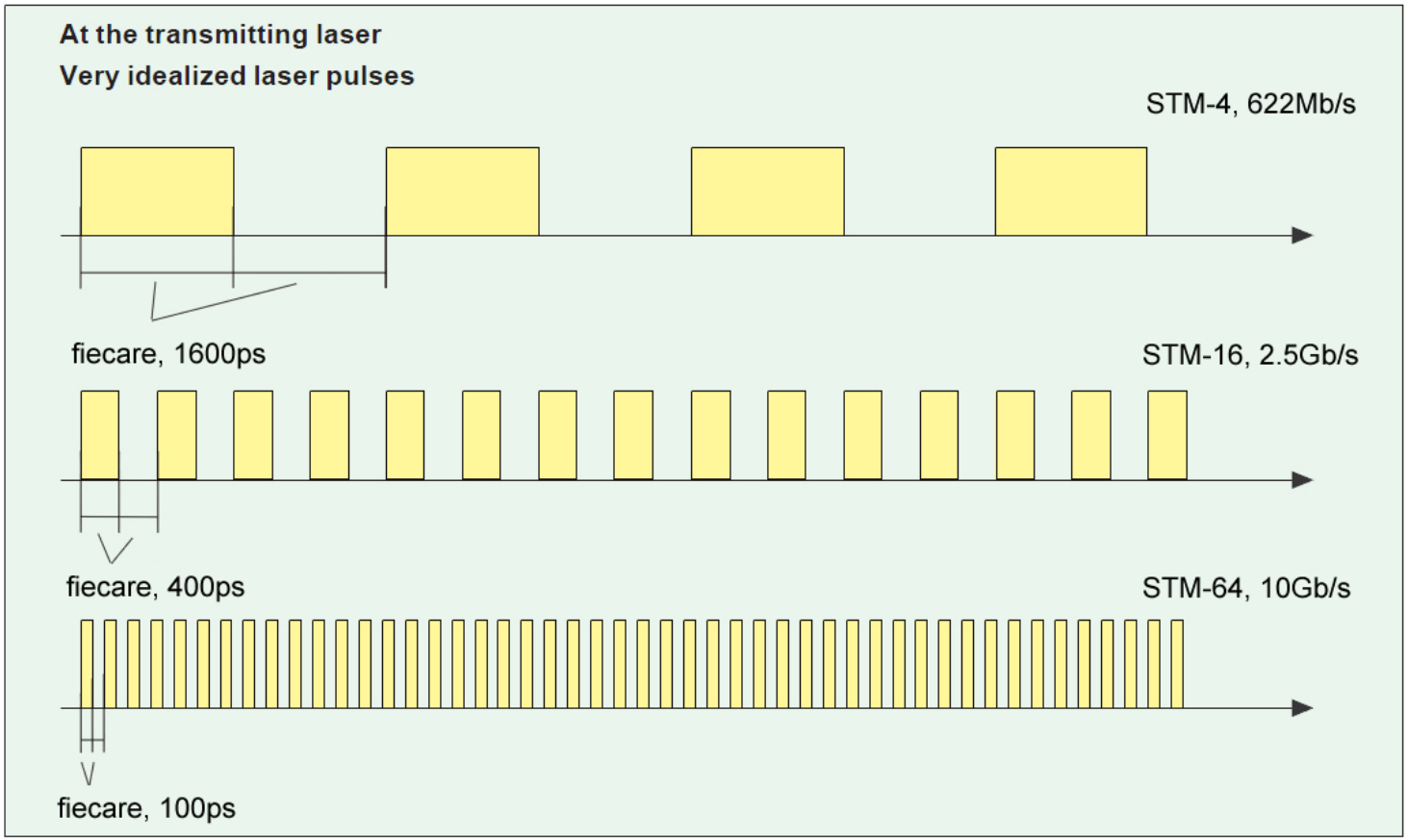


Efectiv→ $f(t)=\int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$

Dispersie exemplu – 1

- transmisii cu viteze diferite

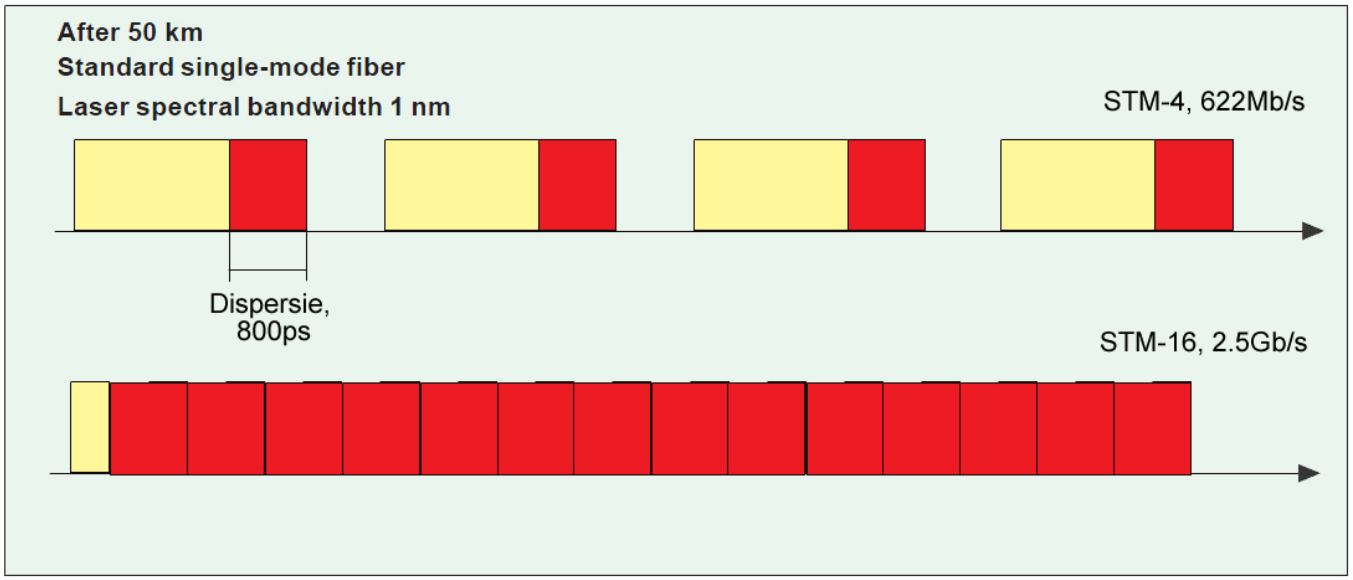
$$\Delta\tau_{cr} = D(\lambda)\cdot\Delta\lambda\cdot L$$



Dispersie exemplu – 2

- 1550nm
- Efectul **sursei**
  - fibra monomod cu dispersia 16ps/nm/km@1550
  - latimea spectrala a sursei Δλ=1nm
  - 50km

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



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

$$\Delta\tau_{cr} = 16\cdot 1\cdot 50\,ps = 800\,ps$$

$$[\Delta\tau_{cr}] = \frac{ps}{nm\cdot km}\cdot nm\cdot km = ps$$

100<400<800<1600

Dispersie exemplu – 3

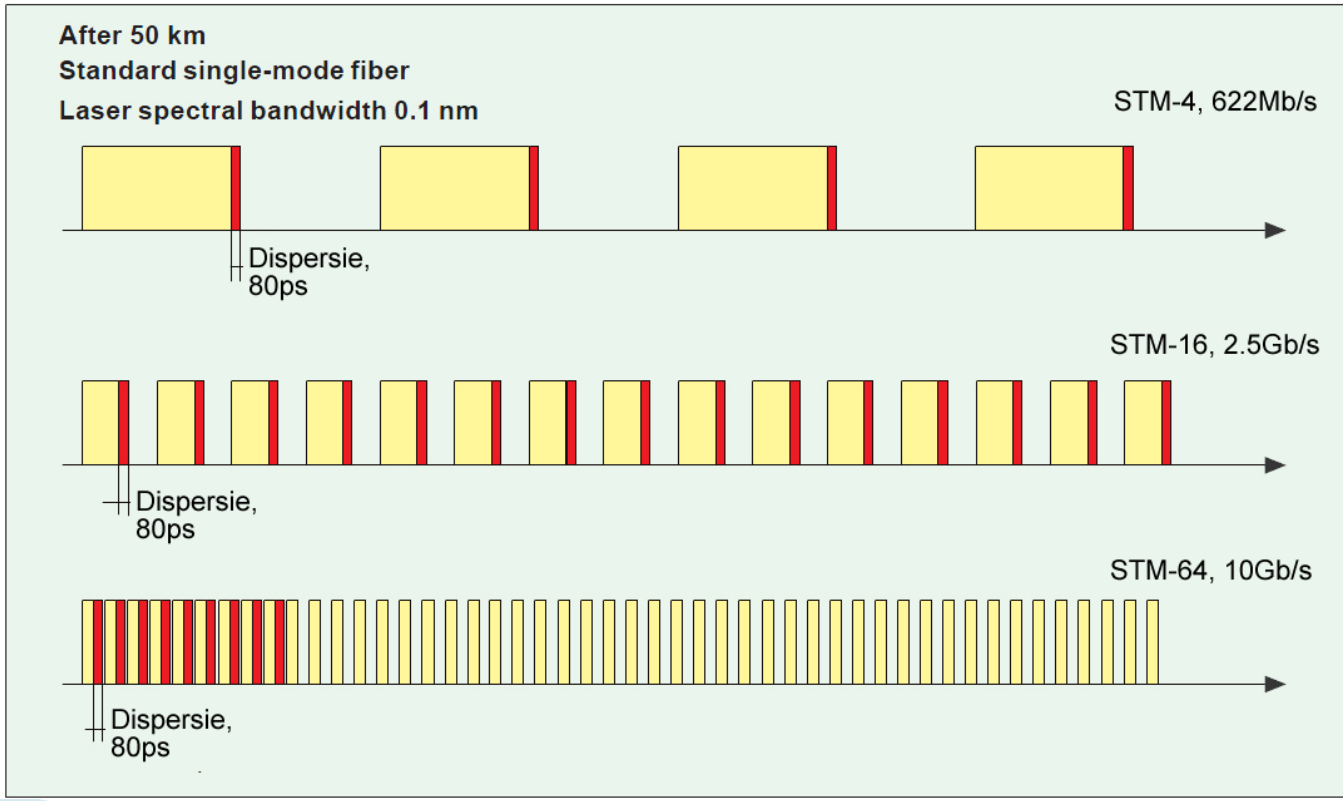
- 1550nm
- Efectul **sursei**
  - fibra monomod cu dispersia 16ps/nm/km@1550
  - latimea spectrala a sursei **Δλ=0.1nm**
  - 50km

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

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

$$\Delta\tau_{cr} = 16\cdot 0.1\cdot 50\,ps = 80\,ps$$

$$[\Delta\tau_{cr}] = \frac{ps}{nm\cdot km}\cdot nm\cdot km = ps$$



$100 \approx 80 < 400 < 1600$

Dispersie exemplu – 4

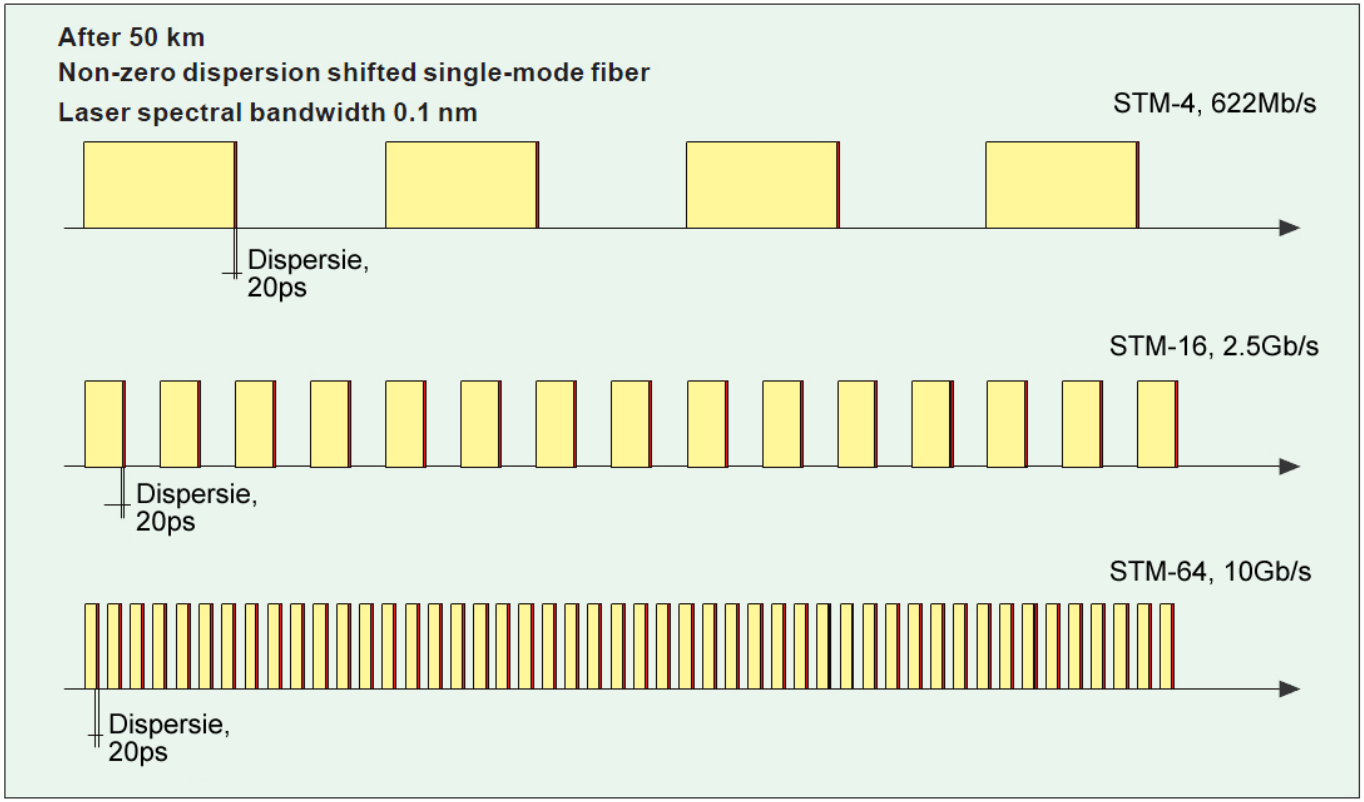
$$\Delta\tau_{cr} = D(\lambda)\cdot\Delta\lambda\cdot L$$

- Efectul **fibrei**
  - fibra cu dipersie deplasata: **4ps**/nm/km@1550
  - latimea spectrala a sursei Δλ=0.1nm
  - 50km

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

$$\Delta\tau_{cr} = 4\cdot 0.1\cdot 50\,ps = 20\,ps$$

$$[\Delta\tau_{cr}] = \frac{ps}{nm\cdot km}\cdot nm\cdot km = ps$$



20<100<400<1600

Dispersie exemplu – 5

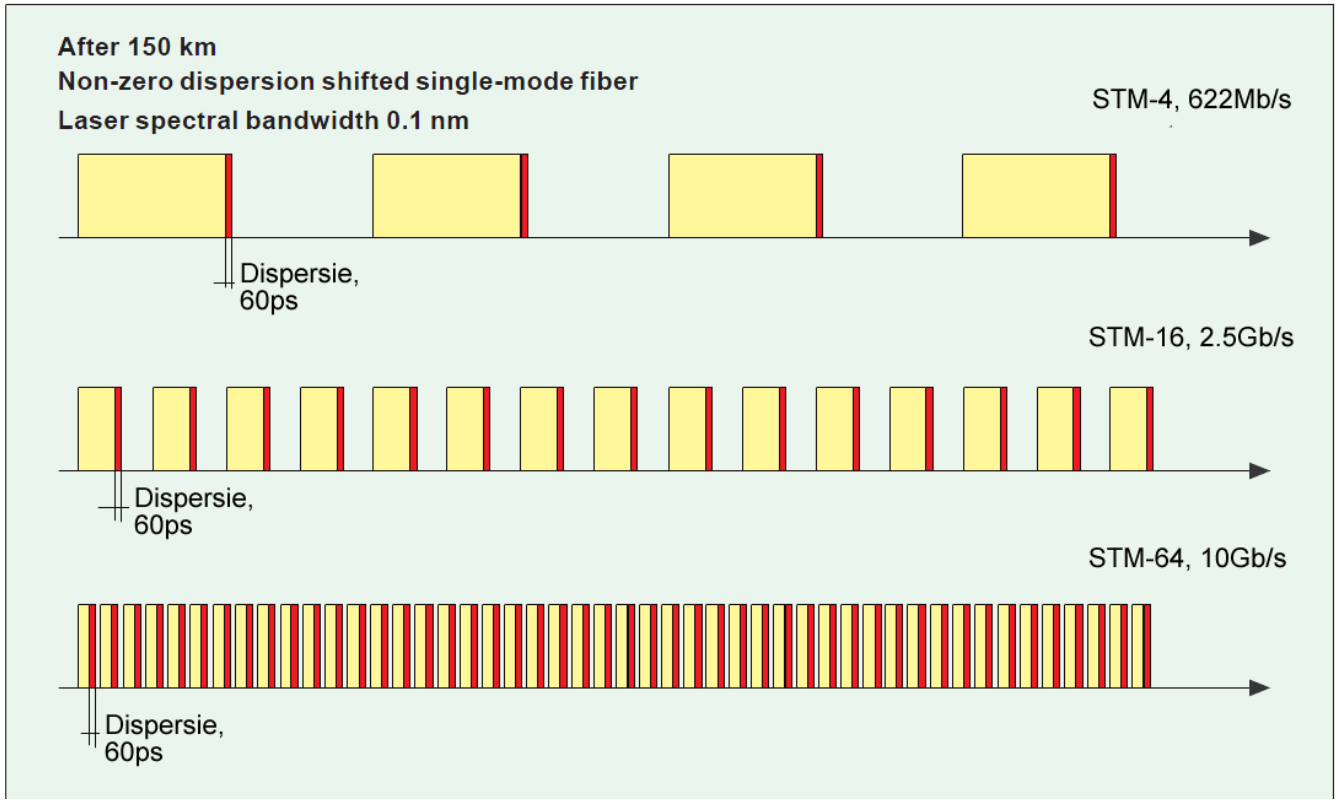
$$\Delta\tau_{cr} = D(\lambda)\cdot\Delta\lambda\cdot L$$

- Efectul **fibrei**
  - fibra cu dipersie deplasata: 4ps/nm/km@1550
  - latimea spectrala a sursei Δλ=0.1nm
  - **150km**

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

$$\Delta\tau_{cr} = 4\cdot 0.1\cdot 150\,ps = 60\,ps$$

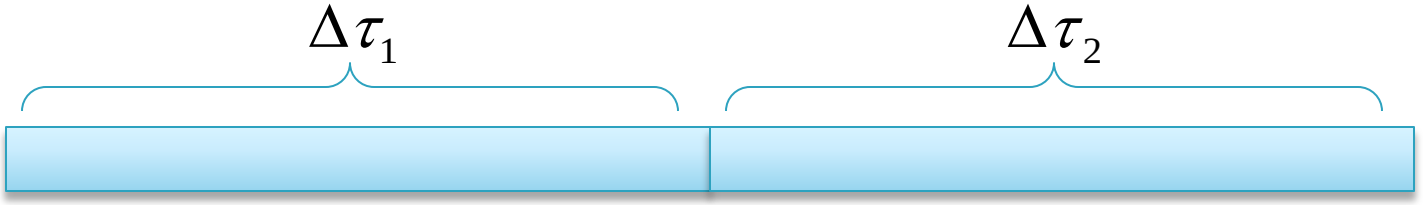
$$[\Delta\tau_{cr}] = \frac{ps}{nm\cdot km}\cdot nm\cdot km = ps$$



60<100<400<1600

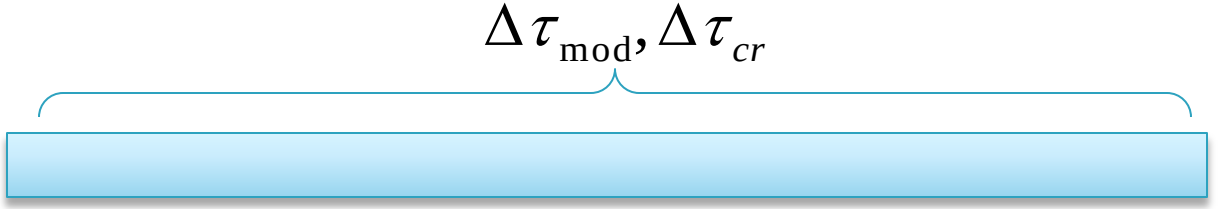
Sumarea efectelor

- efecte **succesive** se adună liniar



$$\Delta\tau_{tot} = \Delta\tau_1 + \Delta\tau_2$$

- efecte **simultane** se adună pătratic



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

Dispersia

- Dispersia modala
  - salt de indice

$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_2 \cdot \Delta}{2\sqrt{3} \cdot c} \approx \frac{L \cdot NA^2}{4\sqrt{3} \cdot c \cdot n_2}$$

  - indice gradat

$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_2 \cdot \Delta^2}{4\sqrt{3} \cdot c} \cong \frac{L \cdot NA^4}{16\sqrt{3} \cdot c \cdot n_2^3}$$

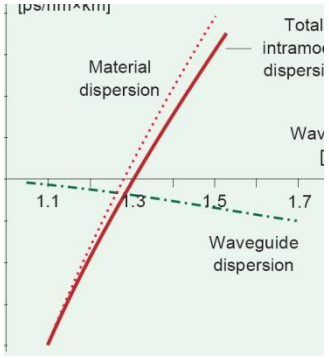
$$\Delta = 0.01 \div 0.02 << 1$$

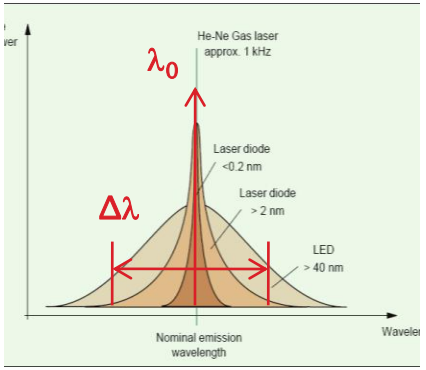
$$NA = 0.1 \div 0.2 < 1$$

- Dispersia cromatica

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

$$\mathrm{D}(\lambda) = \frac{\mathrm{S}_0}{4} \cdot \left(\lambda - \frac{\lambda_0^4}{\lambda^3} \right)$$





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

Banda

- Dispersia totala

$$\Delta\tau_{tot} = \sqrt{\Delta\tau_{cr}^2 + \Delta\tau_{\text{mod}}^2} \quad \text{sau} \quad \Delta\tau_{tot} = \Delta\tau_1 + \Delta\tau_2$$

- Banda

$$B_{opt} \cong \frac{0.44}{\Delta\tau_{tot}[ns]} \quad [GHz]$$

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

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

Produs Banda · Distanta

$$\Delta\tau_{\text{mod}} \cong \frac{L \cdot n_2 \cdot \Delta}{2\sqrt{3} \cdot c} \approx \frac{L \cdot NA^2}{4\sqrt{3} \cdot c \cdot n_2}$$

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

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

$$\Delta\tau_{tot} = const \cdot L$$

$$B_{opt} = \frac{0.44}{\Delta\tau_{tot}[ns]} \quad [GHz] \qquad B_{opt} = \sqrt{2} B_{el} \qquad V[Gb/s] \cong 2 \cdot B_{el}$$

$$V[Gb/s] \cong \frac{const}{L}$$

$$V[Gb/s] \cdot L[km] \cong const$$

Produs Banda · Distanta

$$\Delta\tau_{\text{mod}} \sim L \qquad \Delta\tau_{cr} \sim L \qquad \Delta\tau_{tot} \sim L$$

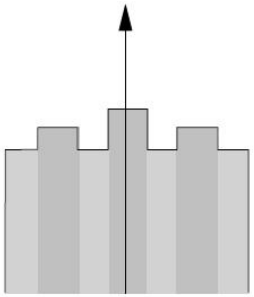
$$V[Gb/s] \sim B_{el}[GHz] \sim \frac{1}{\Delta\tau_{tot}} \sim \frac{1}{L[km]}$$

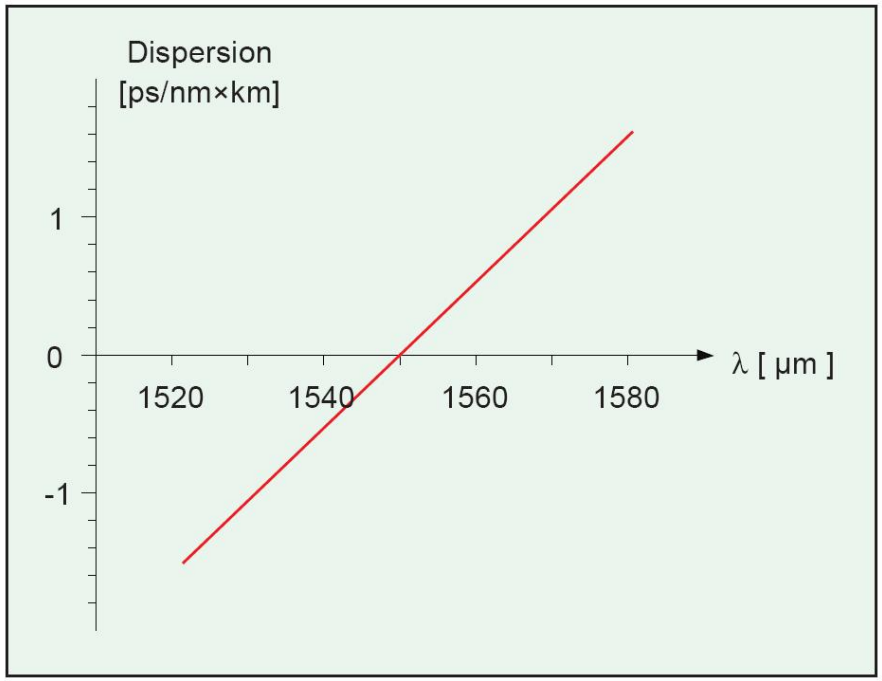
$$V[Gb/s] \times L[km] = \text{ct.}$$

$$B_{el}[MHz] \times L[km] = \text{ct.}$$

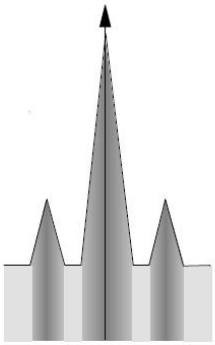
Dispersion shifted fibers

- Sticla are (nativ) dispersie cromatica 0 la 1310nm
- Atenuarea e mai mica la 1550 nm
- EDFA (Erbium doped fibre amplifiers) opereaza in banda 1550nm
- Sistemele WDM (Wavelength division Multiplexing) necesita banda larga amplificata

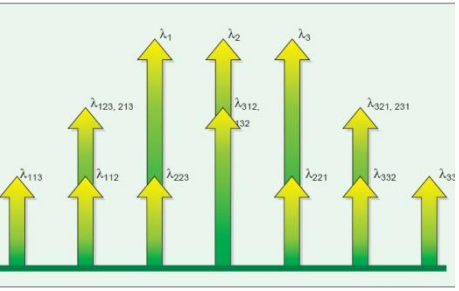


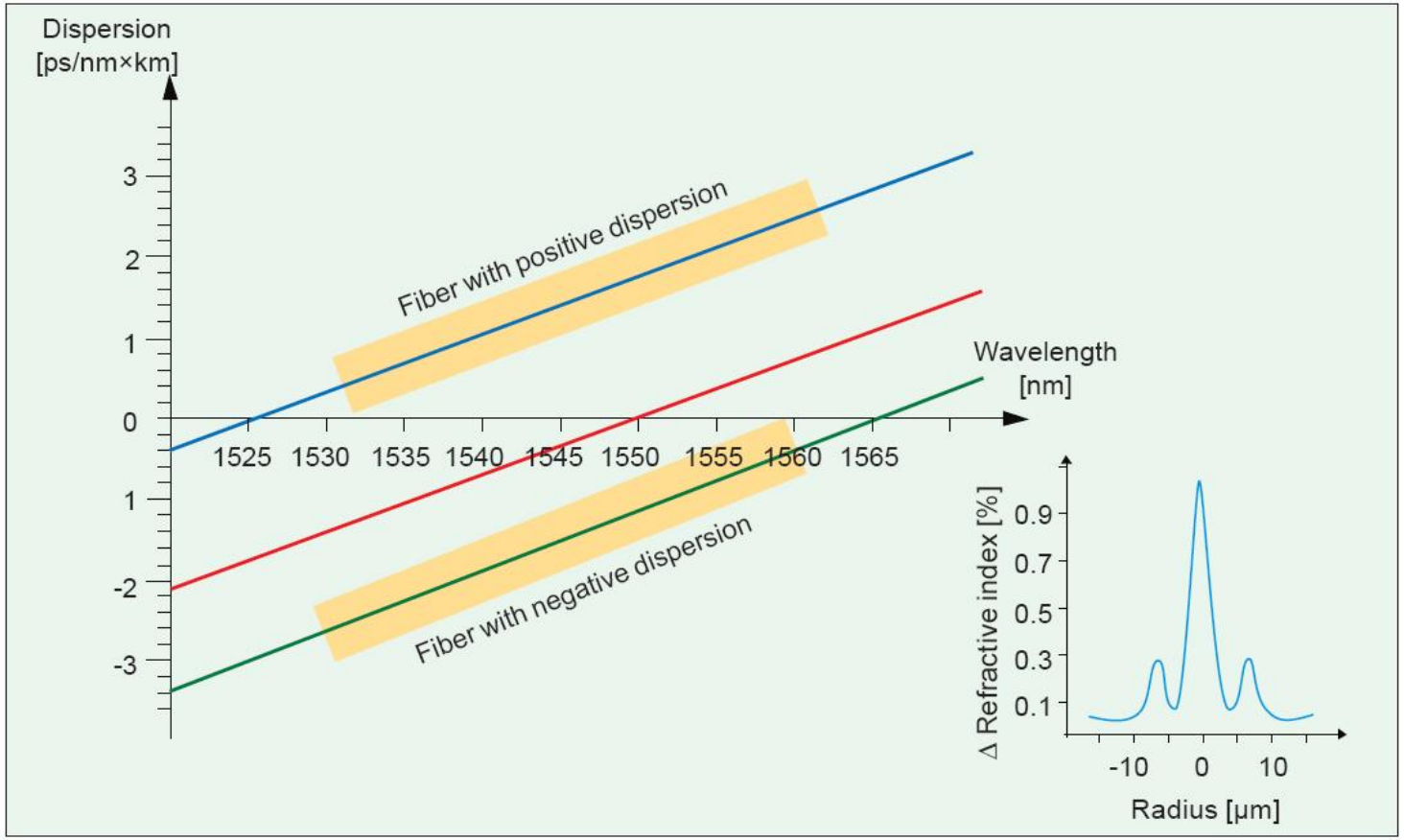


Non-zero Dispersion shifted fibers

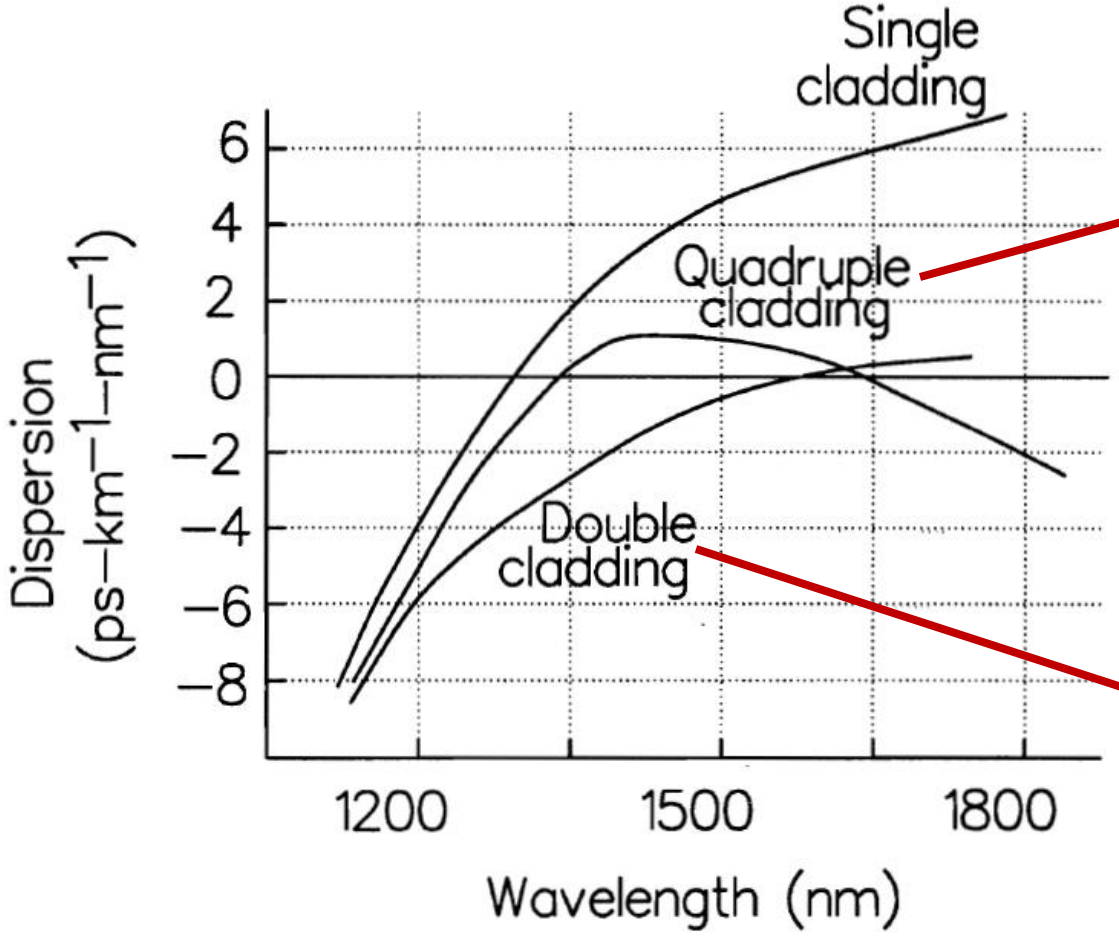


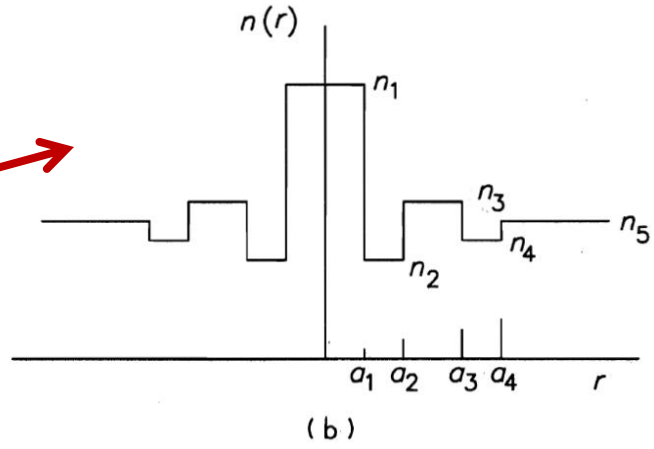
FWM

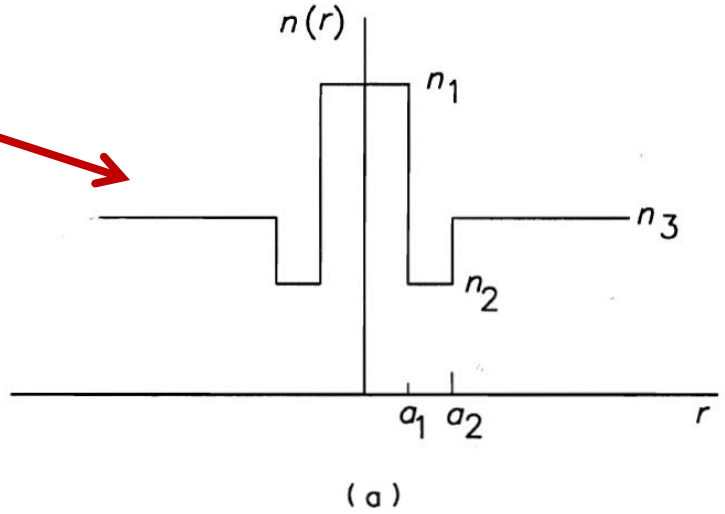




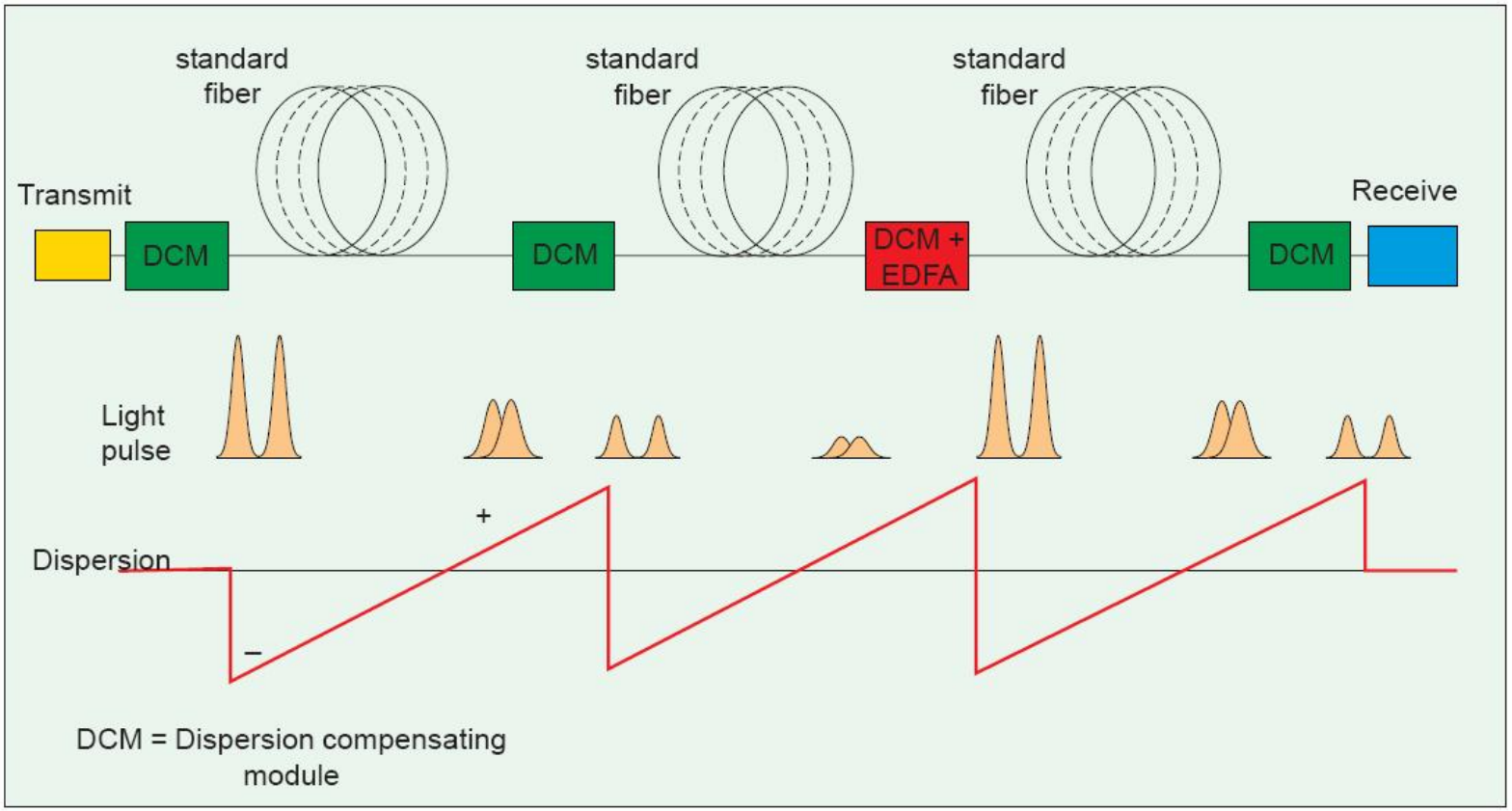
Dispersion shifted fibers







Fibra pentru compensarea dispersiei



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

Catalog – monomod

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

How to Order

Contact your sales representative, or call the Optical Fiber Customer Service Department:
Ph: 607-248-2000 (U.S. and Canada)
+44-1244-287-437 (Europe)
Email: opticalfibers@corning.com
Please specify the fiber type, attenuation and quantity when ordering.

Mechanical Specifications

Proof Test
The entire fiber length is subjected to a tensile stress ≥100 kpsi (0.7 GPa)*.
*Higher proof test levels available.

Length
Fiber lengths available up to 50.4* km/spool.
*Longer spliced lengths available.

Performance Characterizations

Characterized parameters are typical values.

Core Diameter	8.2 µm
Numerical Aperture	0.14 *NA is measured at the one percent power level of a one-dimensional far-field scan at 1310 nm.*
Zero Dispersion Wavelength (λ_0)	1317 nm
Zero Dispersion Slope (S_0)	0.088 ps/(nm²•km)
Effective Group Index of Refraction (N_{eff})	1310 nm: 1.4670 1550 nm: 1.4765
Fatigue Resistance Parameter (N_d)	20
Coating Strip Force	Dry: 0.6 lbs. (3N) Wet, 14-day room temperature: 0.6 lbs. (3N)
Rayleigh Backscatter Coefficient (for 1 ns Pulse Width)	1310 nm: -77 dB 1550 nm: -82 dB
Stimulated Brillouin Scattering Threshold	20 dBm[1]

Notes:
(1) When characterized with a transmitter specifying 17 dBm SBS threshold over standard single-mode fiber. While absolute SBS threshold is a function of distance and signal format, NexCor fiber offers a 3 dB improvement over standard single-mode fiber independent of these variables.

Formulas

Dispersion

$$\text{Dispersion} = D(\lambda) = \frac{S_0}{4}\left[\lambda - \frac{\lambda_0^4}{\lambda^3}\right] \text{ ps/(nm•km)}$$

for 1200 nm ≤ λ ≤ 1625 nm

λ = Operating Wavelength

Cladding Non-Circularity

$$\text{Cladding Non-Circularity} = \left[1 - \frac{\text{Min. Cladding Diameter}}{\text{Max. Cladding Diameter}}\right] \times 100$$

Corning Incorporated
www.corning.com/opticalfiber
One Riverfront Plaza
Corning, NY 14831
U.S.A.
Ph: 800-525-2524 (U.S. and Canada)
607-786-8125 (International)
Fx: 800-539-3632 (U.S. and Canada)
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Indonesia
Ph: 001-803-015-721-1261
Fx: 001-803-015-721-1262
Malaysia
Ph: 1-800-80-3156
Fx: 1-800-80-3155
Philippines
Ph: 1-800-1-116-0338
Fx: 1-800-1-116-0339
Singapore
Ph: 800-1300-955
Fx: 800-1300-956
Thailand
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Fx: 001-800-1-3-721-1264

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Fx: 000817-762-4996
Mexico
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Fx: 001-800-339-1472
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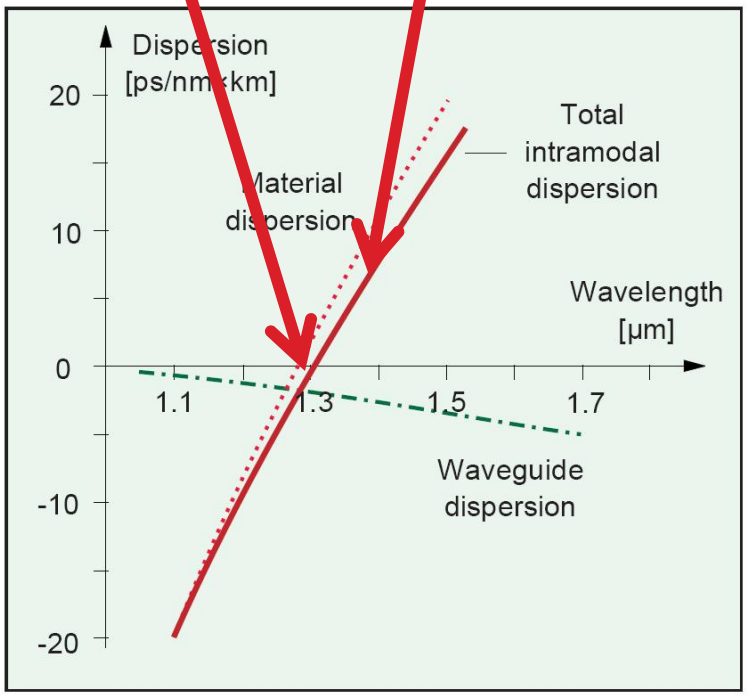
Fx: (852) 2807-2152
Shanghai
Ph: (86) 21-3222-4668
Fx: (86) 21-6288-1575
Taiwan
Ph: (886) 2-2716-0338
Fx: (886) 2-2716-0339

far-field scan at 1310 nm.

Zero Dispersion Wavelength (λ_0)	1317 nm
Zero Dispersion Slope (S_0)	0.088 ps/(nm²•km)
Effective Group Index	1310 nm: 1.4670



Catalog – multimod

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

+

Bandwidth

Standard Bandwidth Cells
850/1300 nm (MHz•km)
400/400
400/600
400/1200
500/500
600/600
600/1000

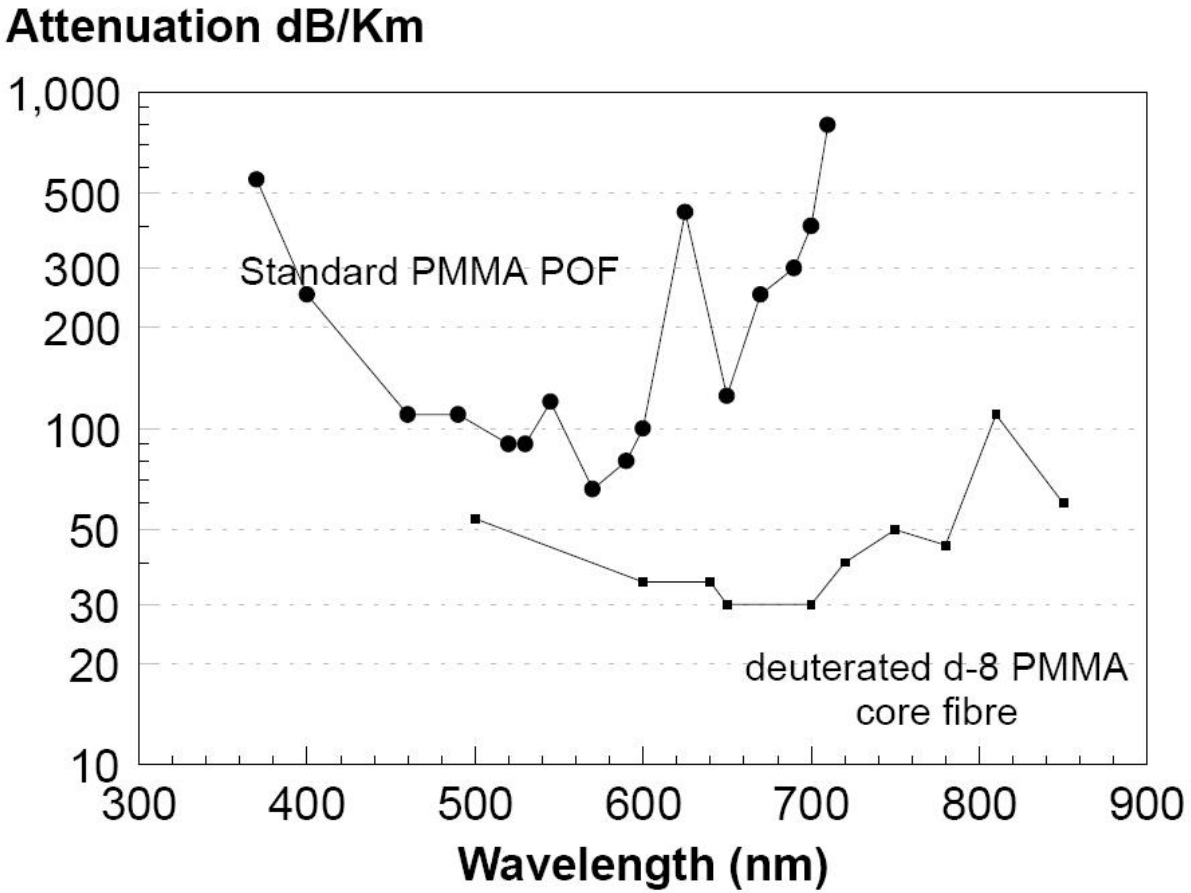
Other bandwidth cells available upon request.

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

ITU (International Telecommunication Union) is the United Nations specialized agency for information and communication technologies – ICTs

Fibra optica din plastic (POF)



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

Fibra optică – Tehnologie

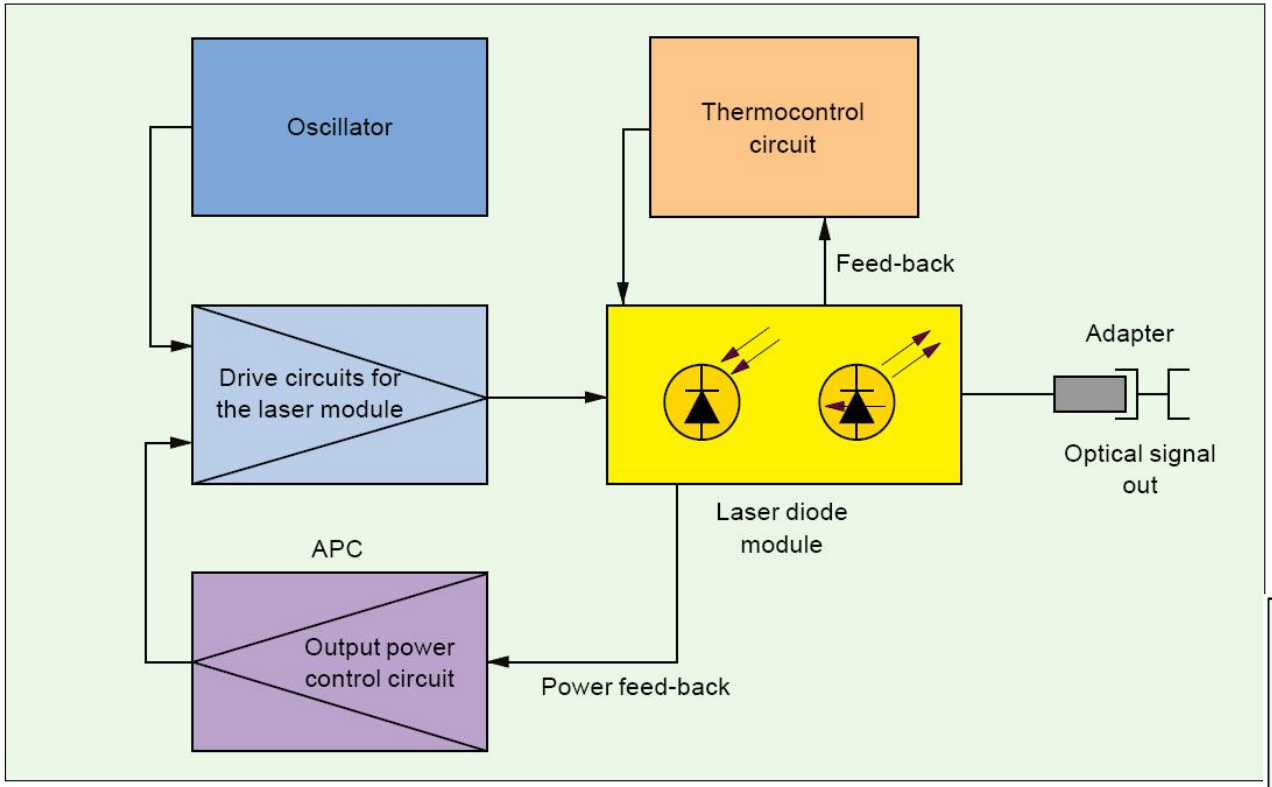
Capitolul 5

Cuprins

- **Lumina ca undă electromagnetică** (ecuaţiile lui Maxwell, ecuaţia undelor, parametrii de propagare)
- **Elemente de fotometrie şi radiometrie** (mărimi energetice/luminoase)
- **Fibra optică** (realizare, principiu de funcţionare, atenuare, dispersie, banda de frecvenţă)
- Cabluri optice (tehnologie, conectori, lipire – splice)
- **Proiectare sistemică a legăturii pe fibra optică** (bandă de frecvenţă, balanţa puterilor)
- **Emiţătoare optice** (LED şi dioda laser – realizare fizică şi functionare)
- **Receptoare optice** (dioda PIN, dioda cu avalanşă – realizare fizică şi functionare)
- **Amplificatoare transimpedanţă** (parametri, scheme tipice, TIA în buclă deschisă, cu reacţie, diferenţiale, control automat al câştigului)
- **Realizarea circuitelor pentru controlul emiţătoarelor optice (**parametri, scheme tipice, controlul puterii, multiplexoare**)**
- **Dispozitive de captare a energiei solare** (principiu de functionare, utilizare, proiectare)

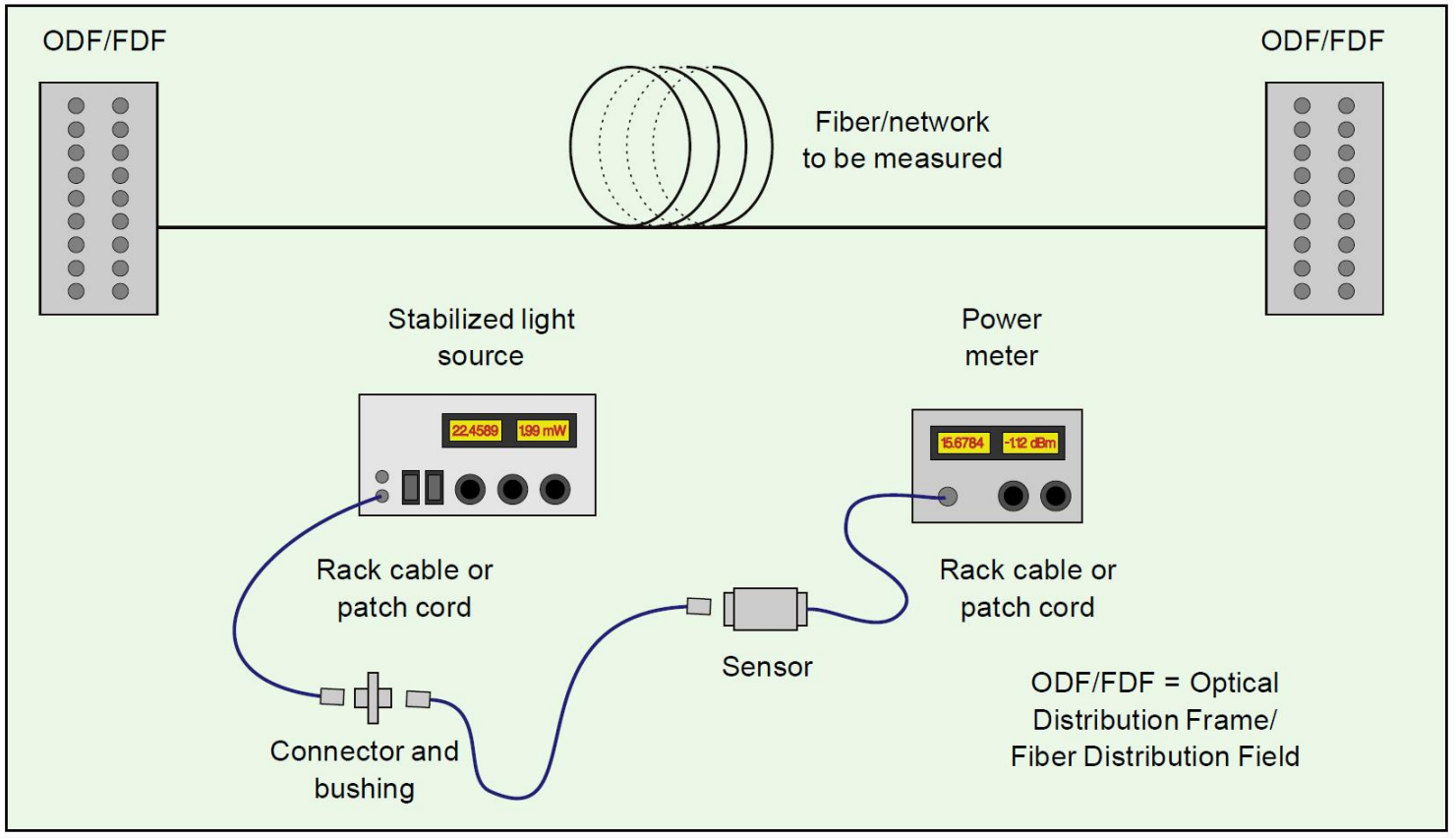
Stabilized light source
Optical power meter

- Masurarea puterii si atenuarii



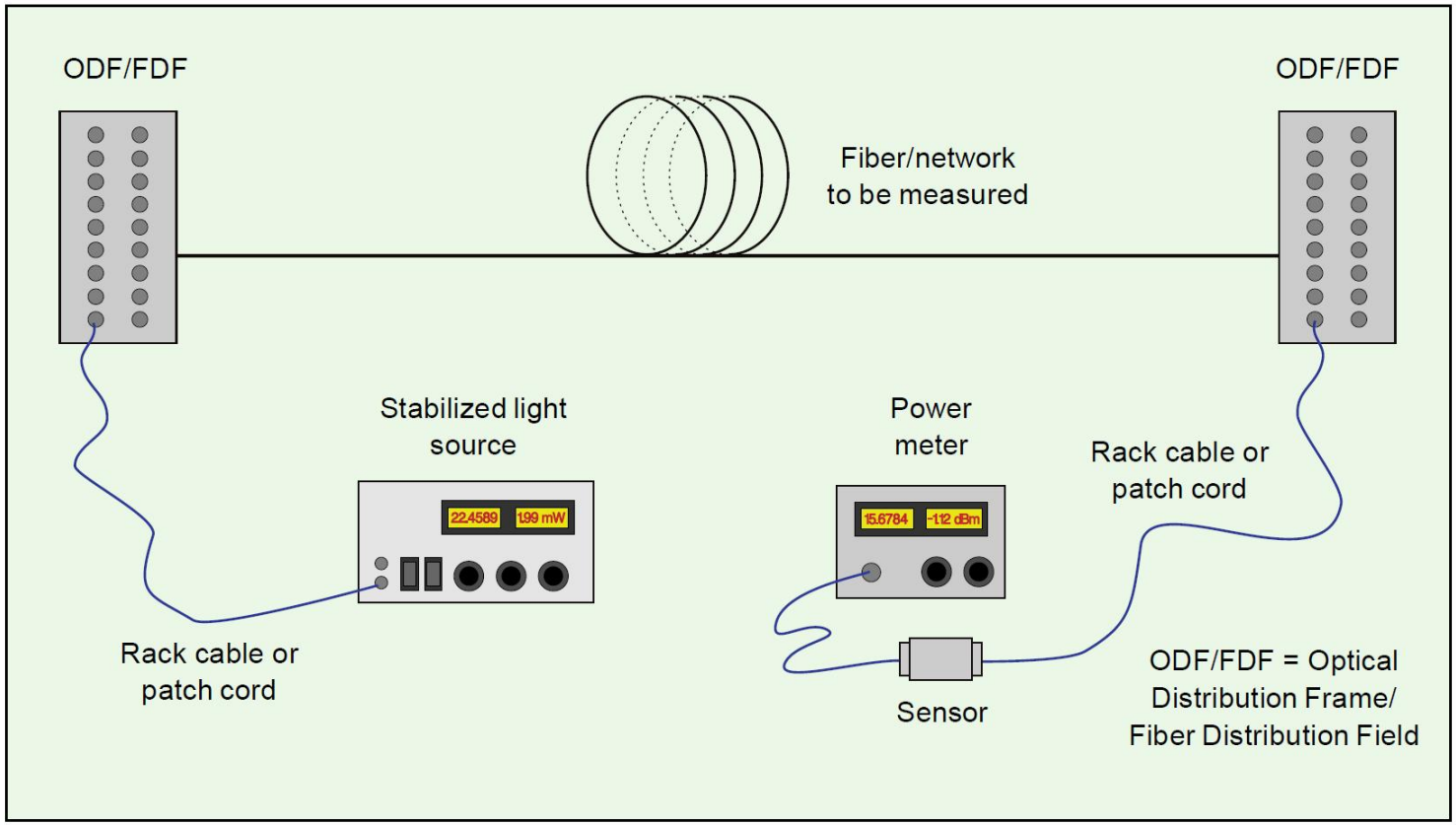
Masurarea puterii si atenuarii

- Masuratoare referinta



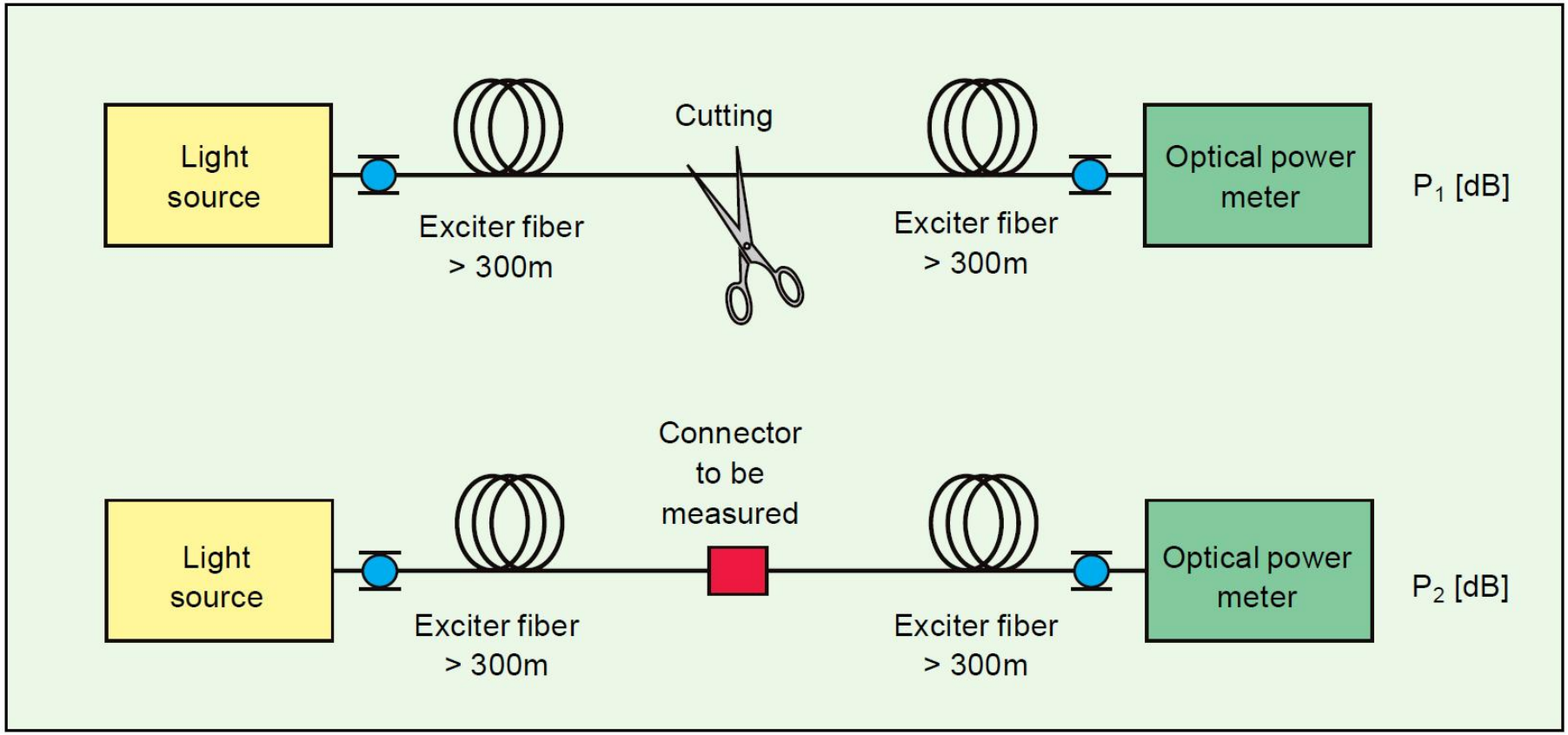
Masurarea puterii si atenuarii

- Masuratoare instalatie



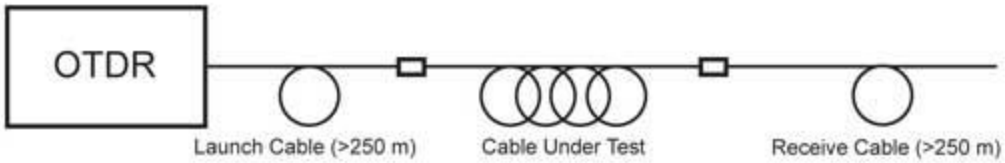
Masurare conectori si splice

- Se elimina efectele fibrei



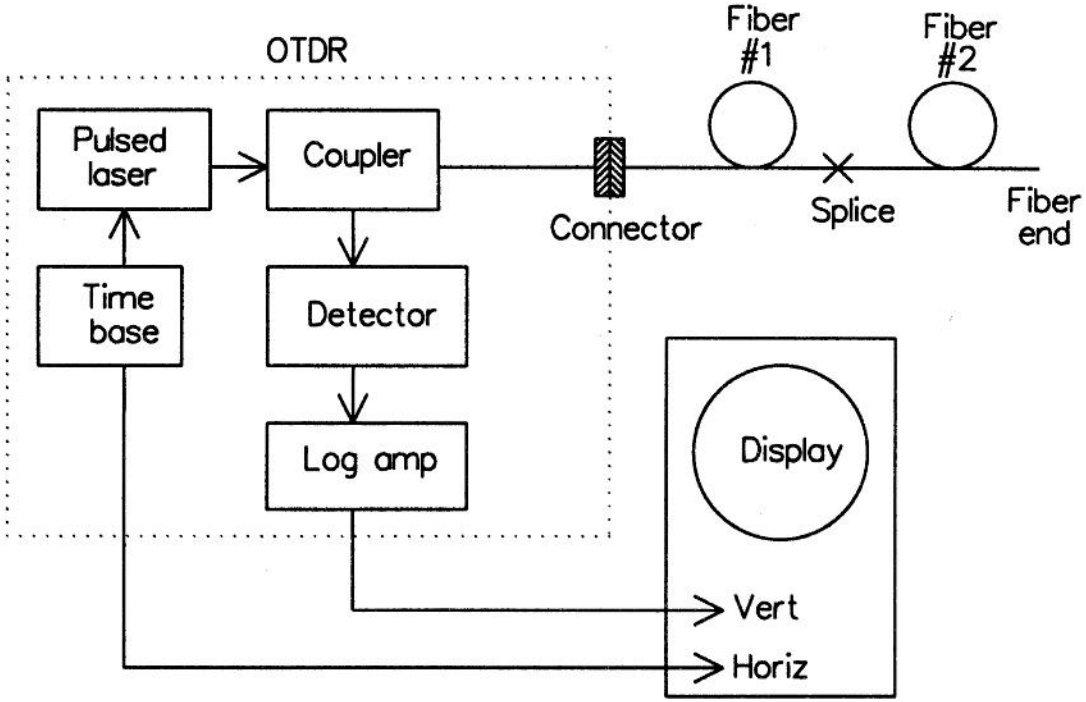
OTDR

- Optical Time-Domain Reflectometer
- Localizarea defectelor

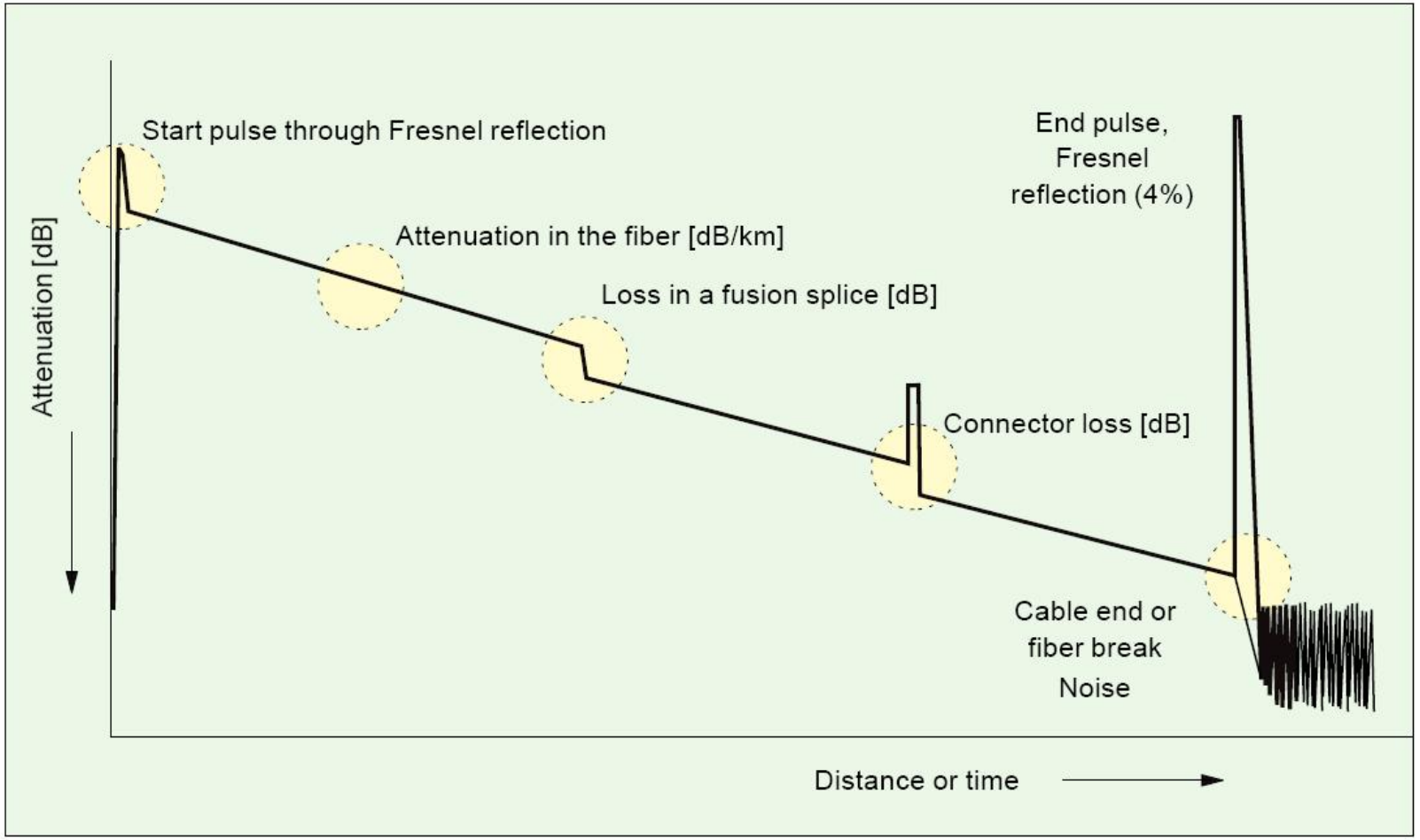


OTDR

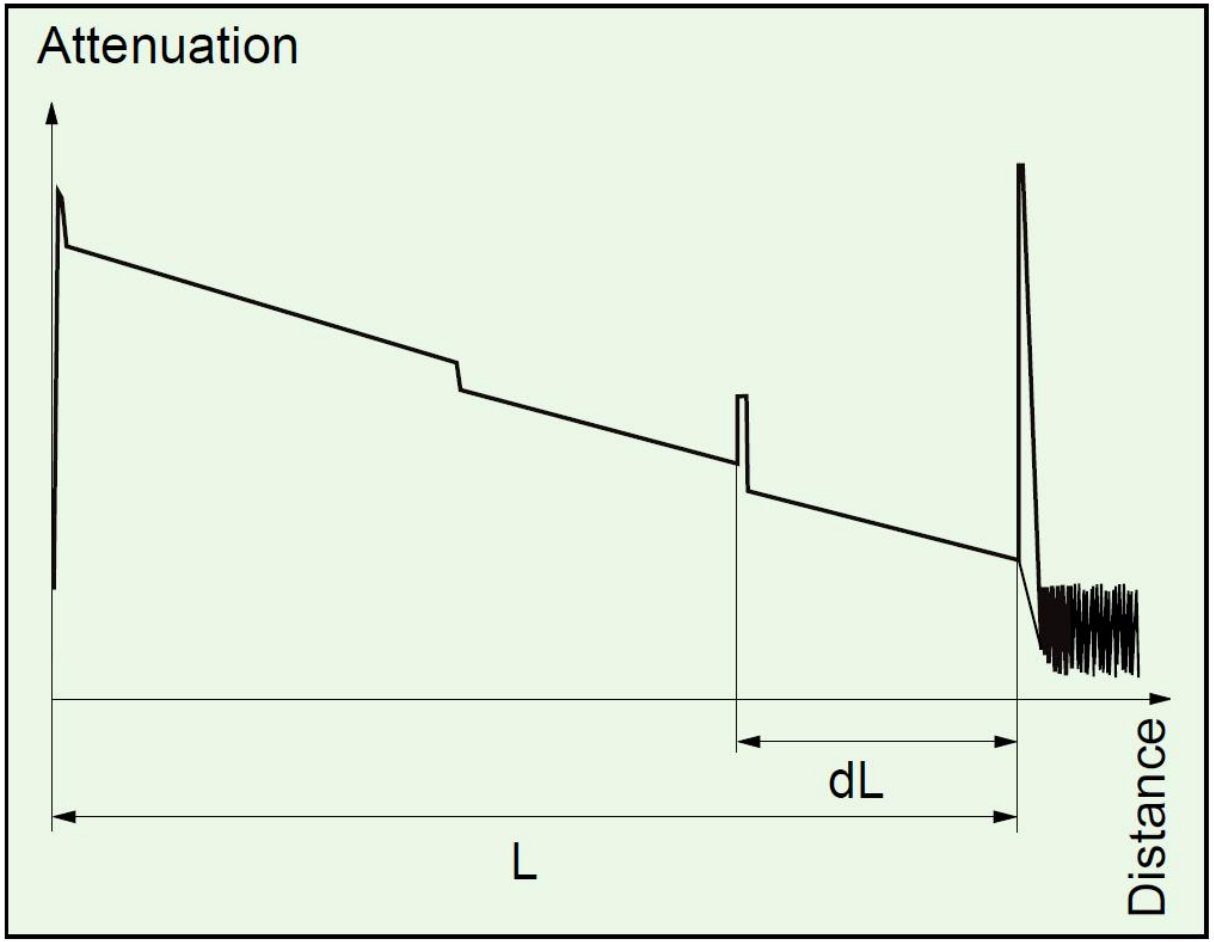
- Optical time-domain reflectometer
- Localizarea defectelor



Rezultat grafic al OTDR



Efecte vizibile OTDR



$$2 \cdot L = c \cdot t$$

$$L = \frac{c_0}{n} \cdot \frac{t}{2}$$

Efecte vizibile OTDR

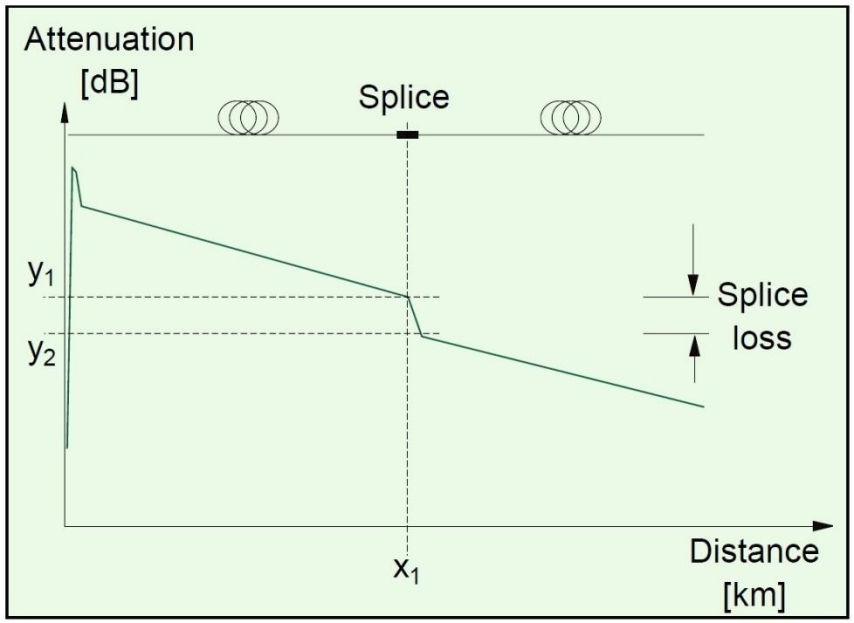
$$A[dB] = \frac{P_1 - P_2}{2}$$

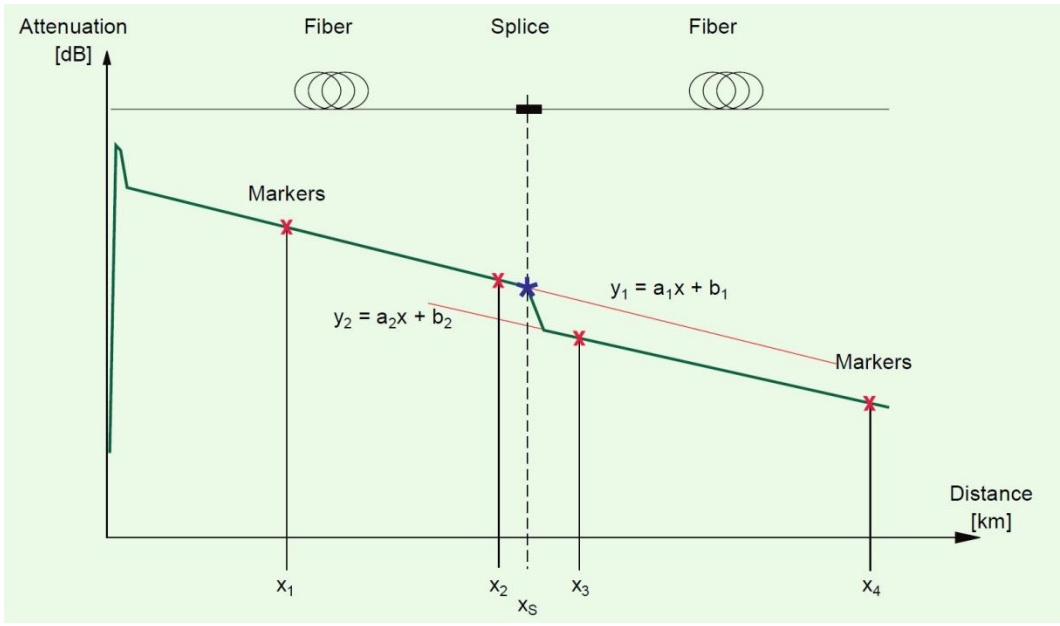
$$A[dB/km] = \frac{P_1 - P_2}{2 \cdot L}$$

panta curbei

Efecte vizibile OTDR – Splice

- splice loss – A(s)

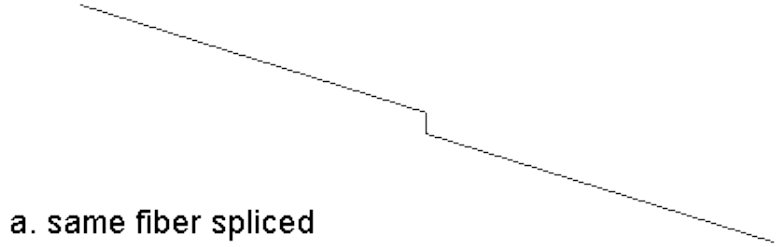




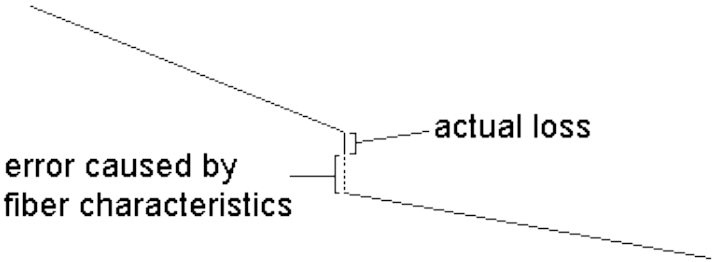
$$A(s) = y_1 - y_2$$

$$A(s) = y_1 - y_2 = x_s \cdot (a_1 - a_2) + (b_1 - b_2)$$

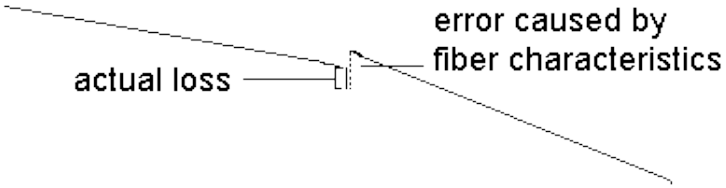
Efecte vizibile OTDR – Splice



a. same fiber spliced



b. high loss fiber spliced to low loss fiber

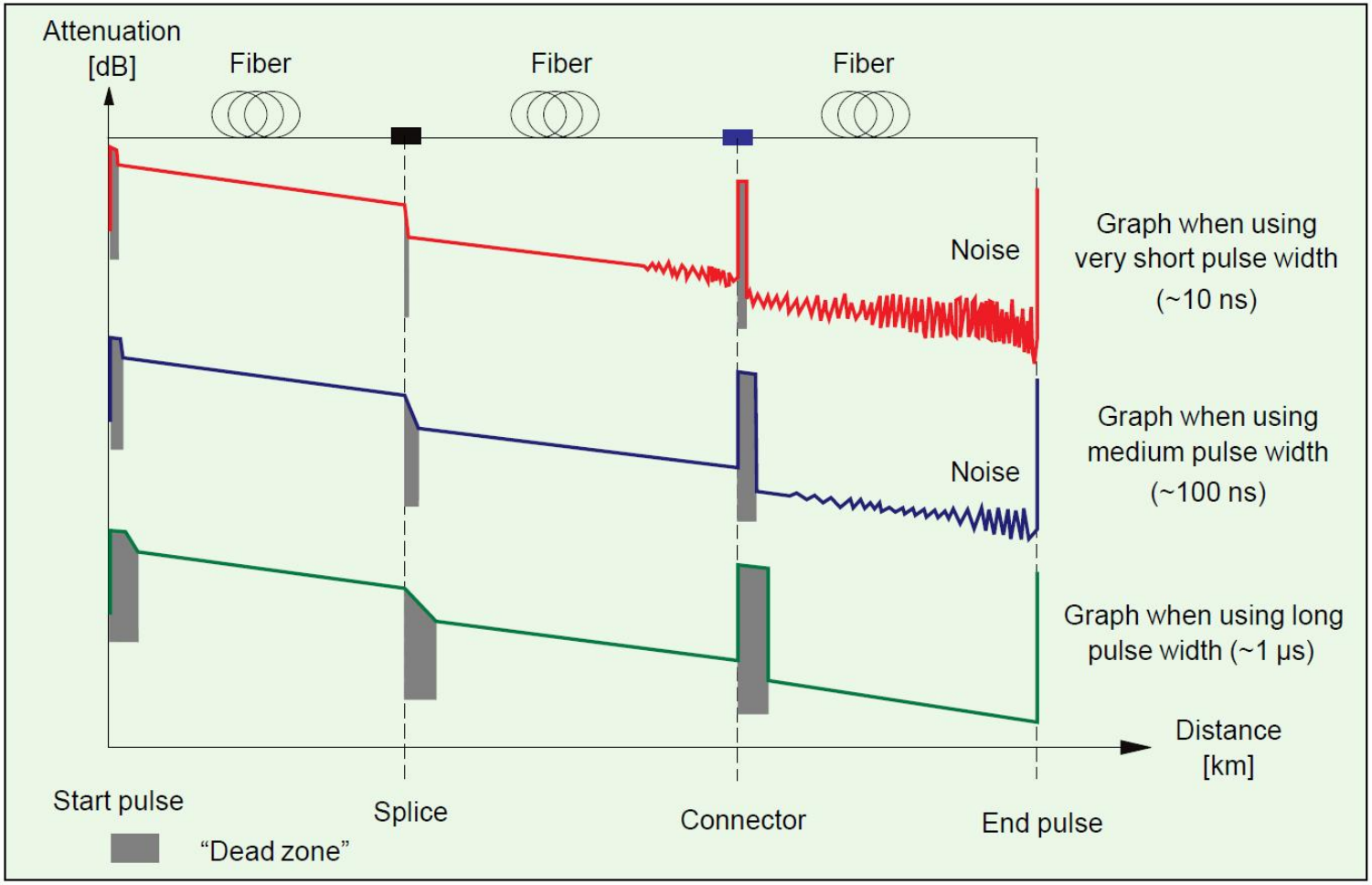


c. low loss fiber spliced to high loss fiber
can cause an apparent gain at a splice

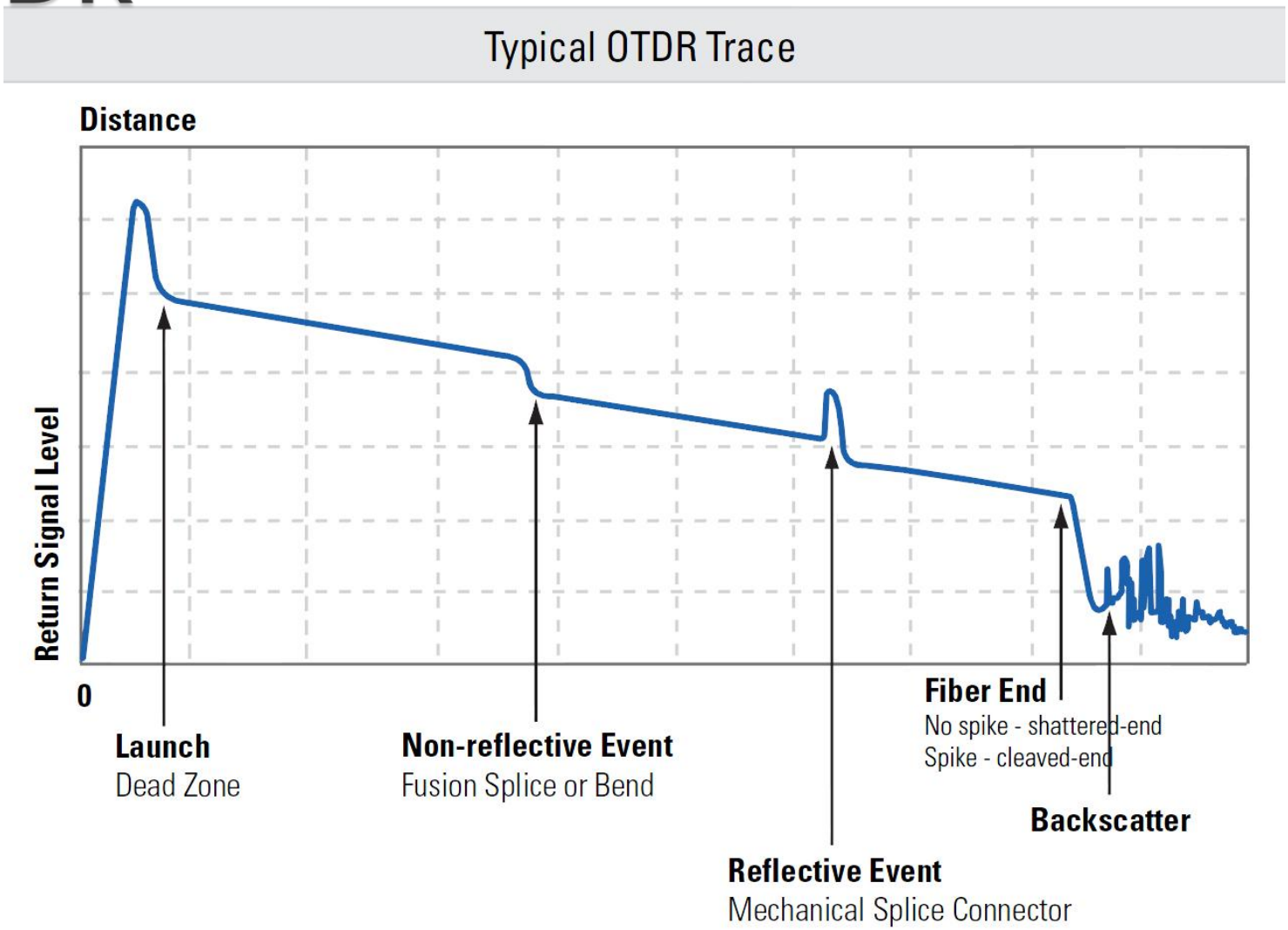
$$A(s) = \frac{A(s)_{A\to B} + A(s)_{B\to A}}{2}$$

Rezultat grafic al OTDR

- latimea pulsurilor luminoase

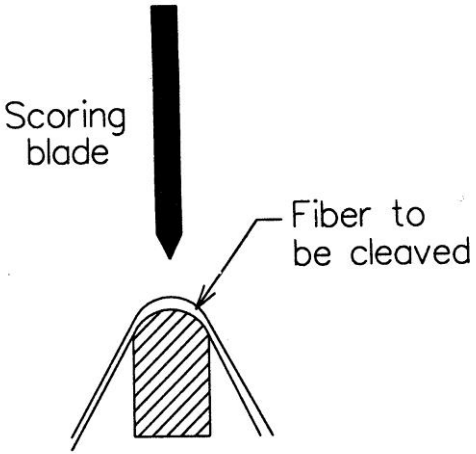


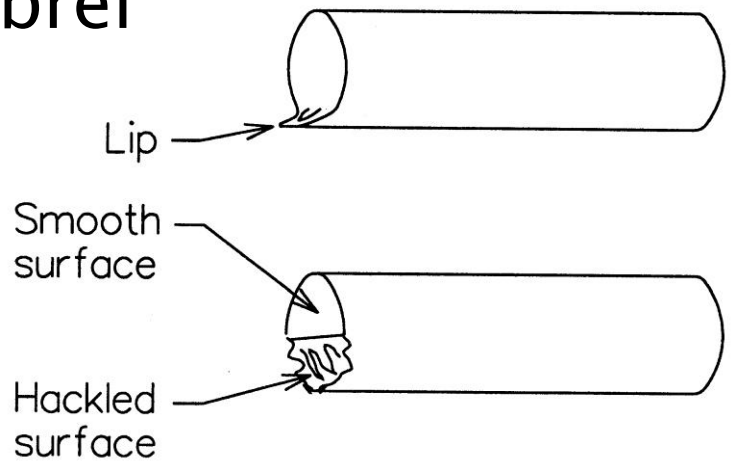
OTDR


Typical OTDR Trace
Distance
Return Signal Level
0
Launch
Dead Zone
Non-reflective Event
Fusion Splice or Bend
Reflective Event
Mechanical Splice Connector
Fiber End
No spike - shattered-end
Spike - cleaved-end
Backscatter

Taiere – Cleaving

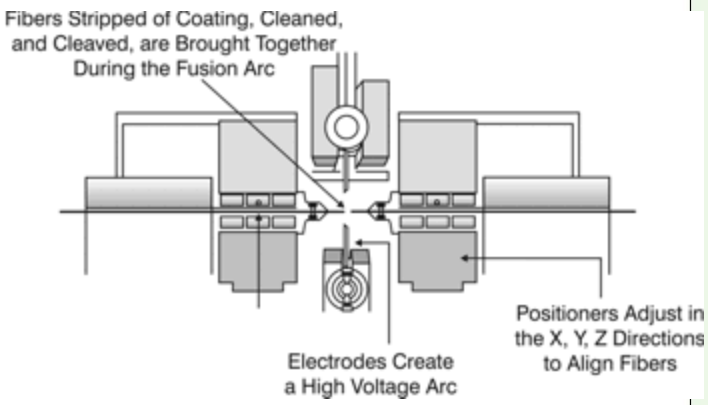
- Tehnici necesare pentru a asigura o taiere perpendiculara pe axa fibrei

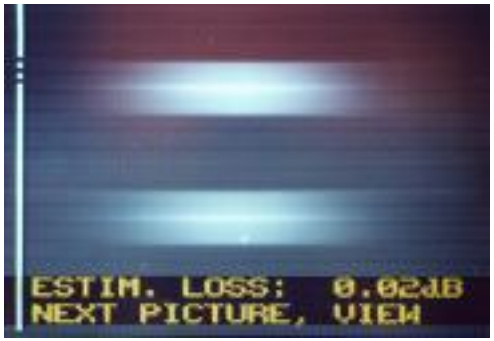


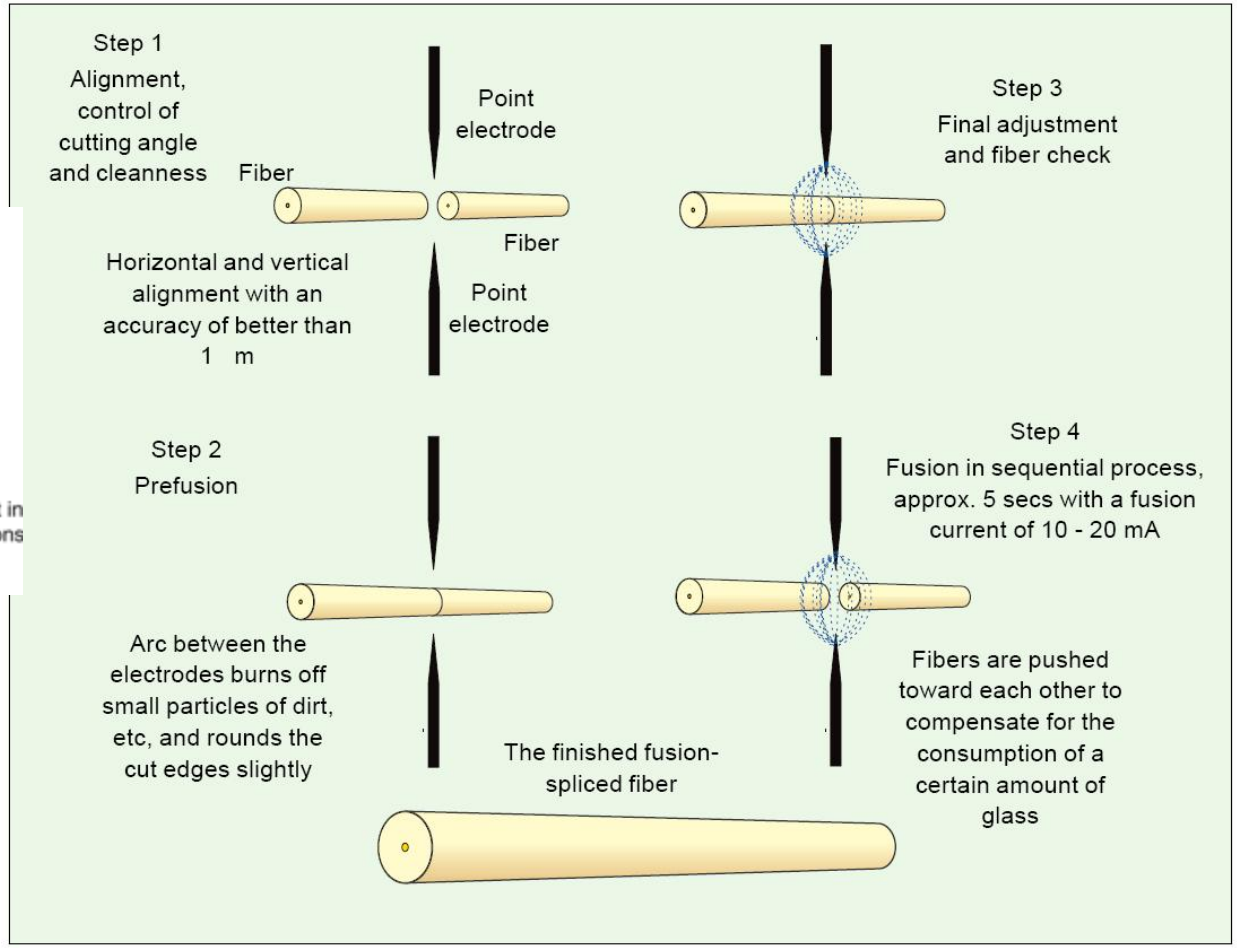


Lipire prin fuziune

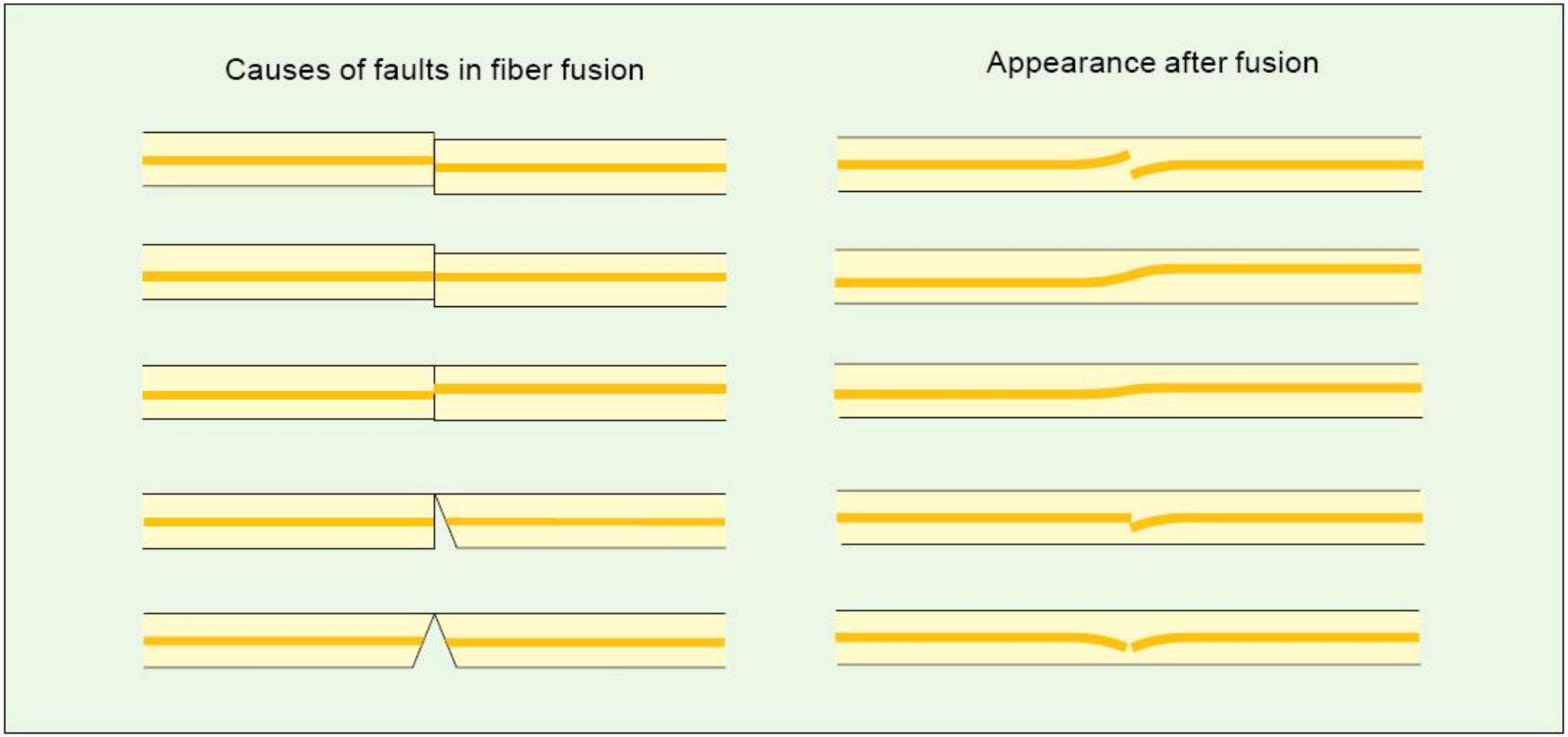
Splice prin fuziune



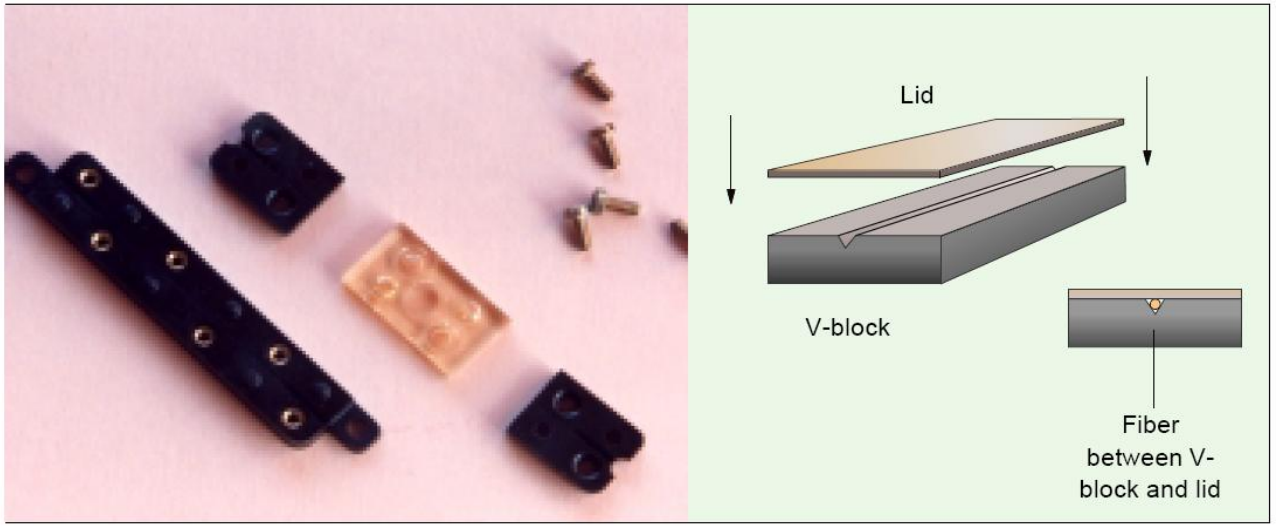


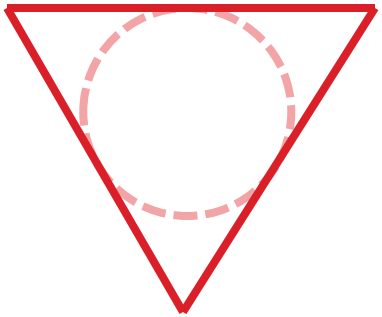


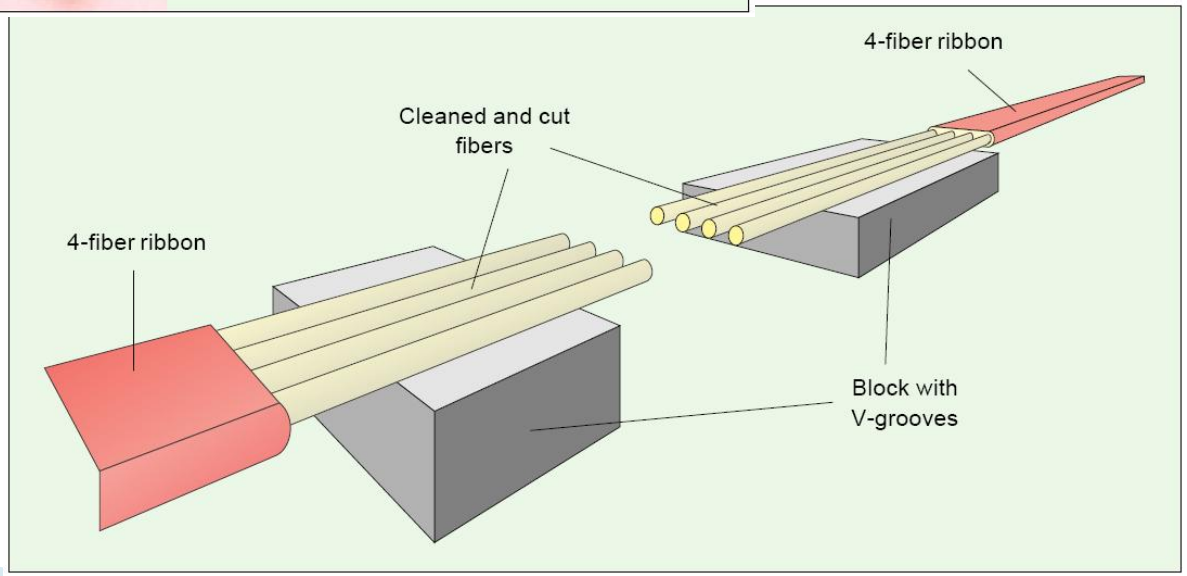
Splice prin fuziune



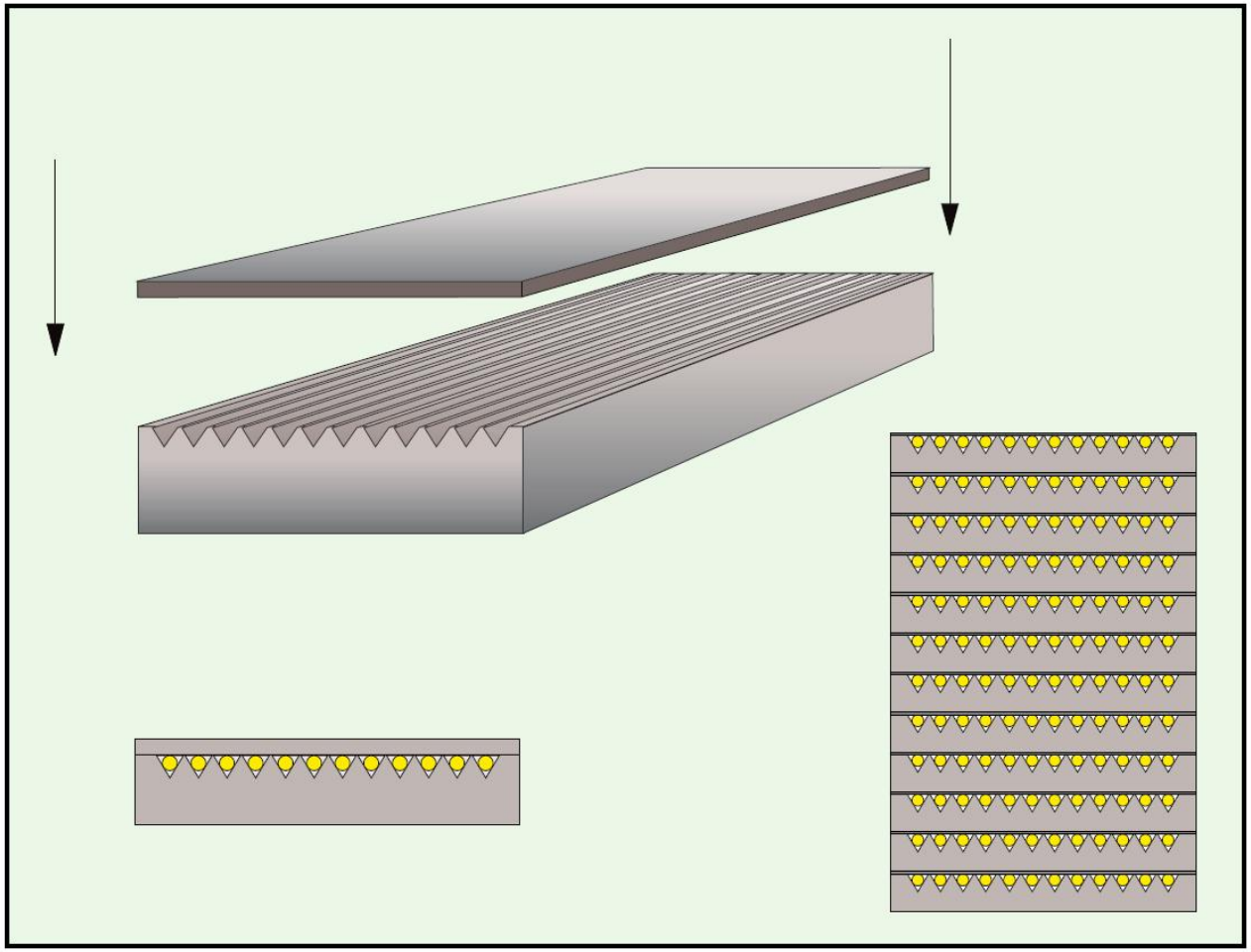
Splice mecanic – bloc V



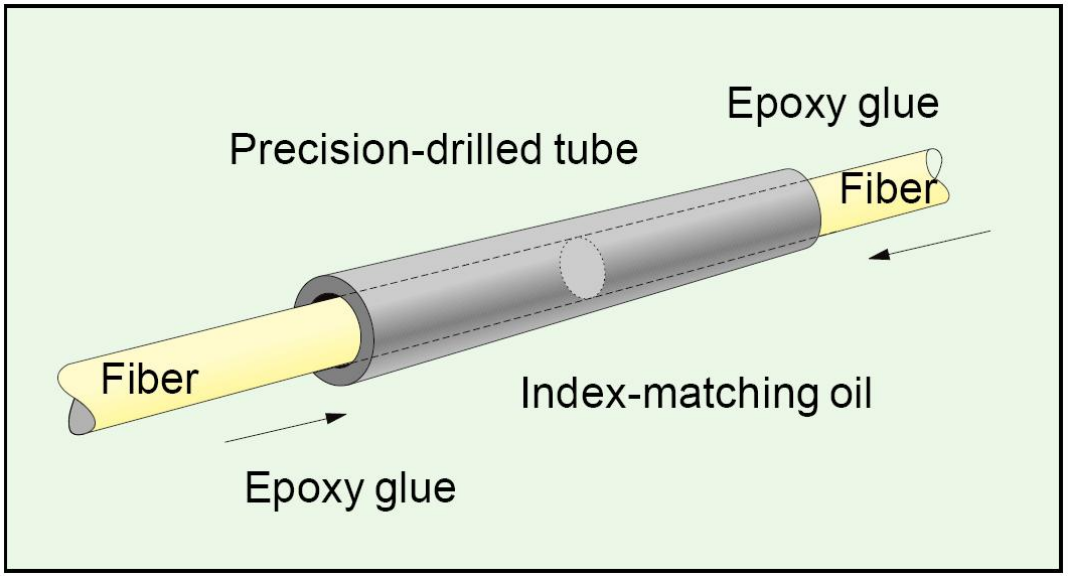


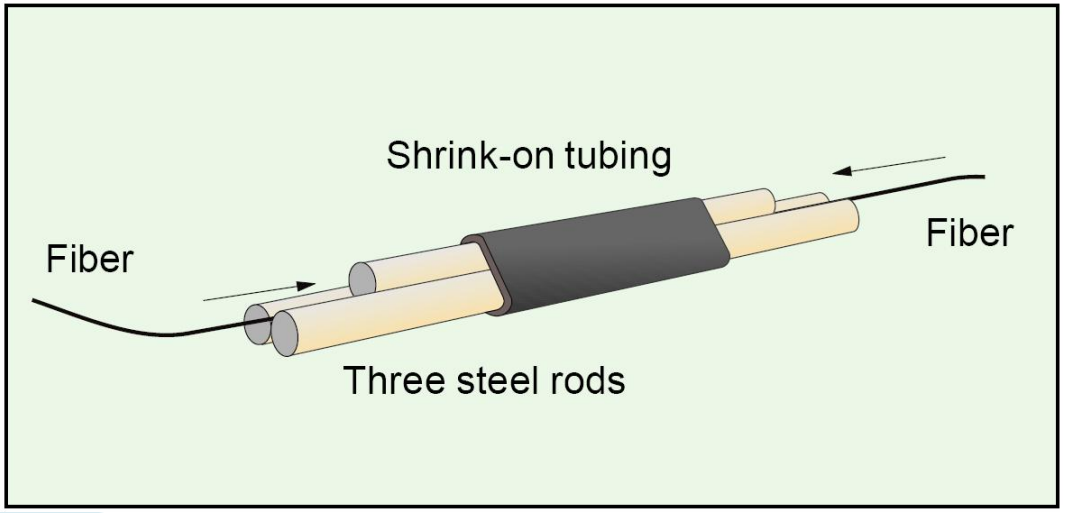


Splice mecanic – bloc V



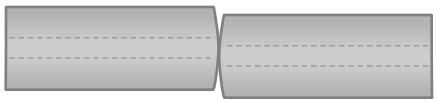
Splice mecanic



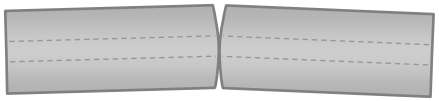


Probleme Fibre/Conectori

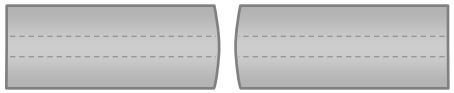
Offset



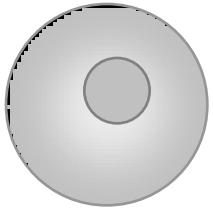
Angular Misalignment



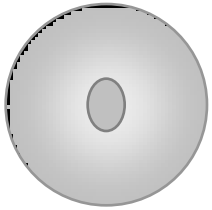
Separation



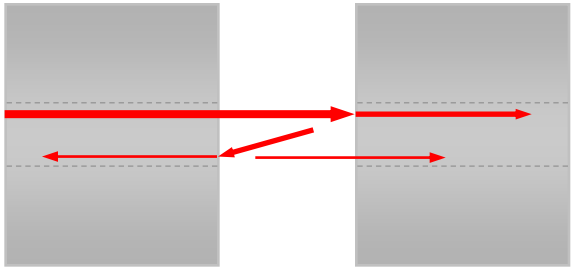
Core Eccentricity



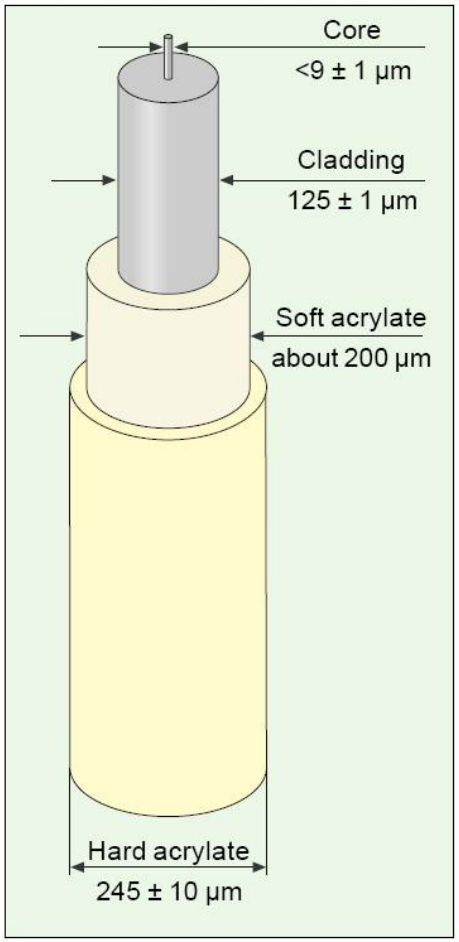
Core Ellipticity

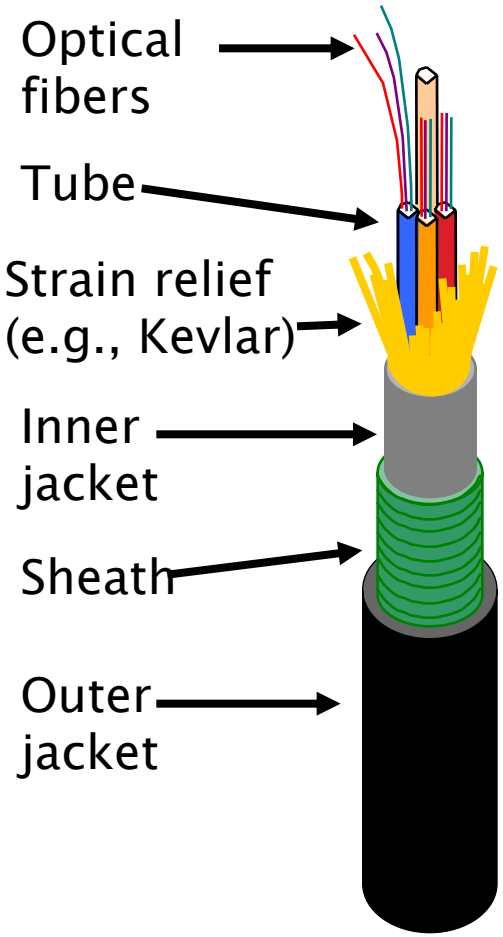


Reflections & Interference

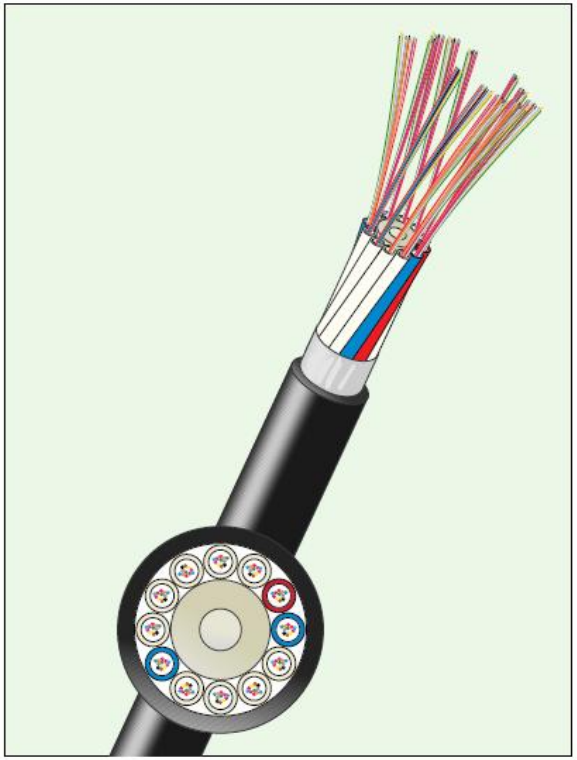


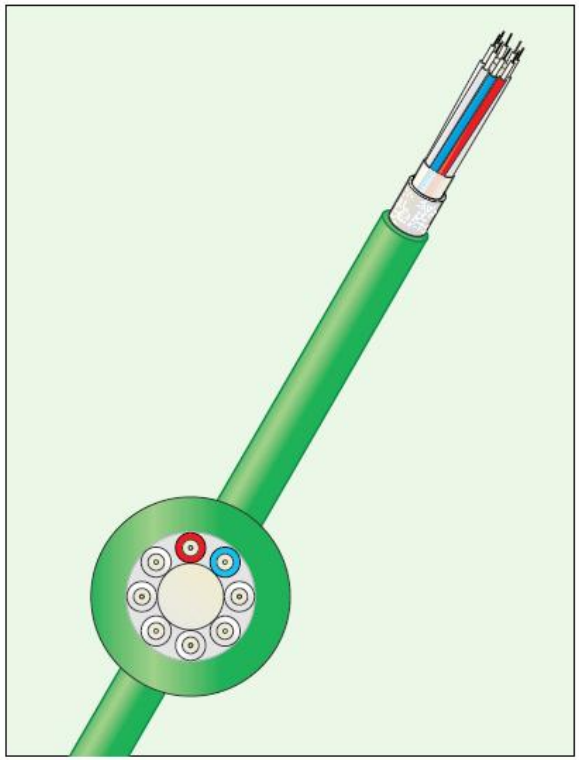
Cabluri

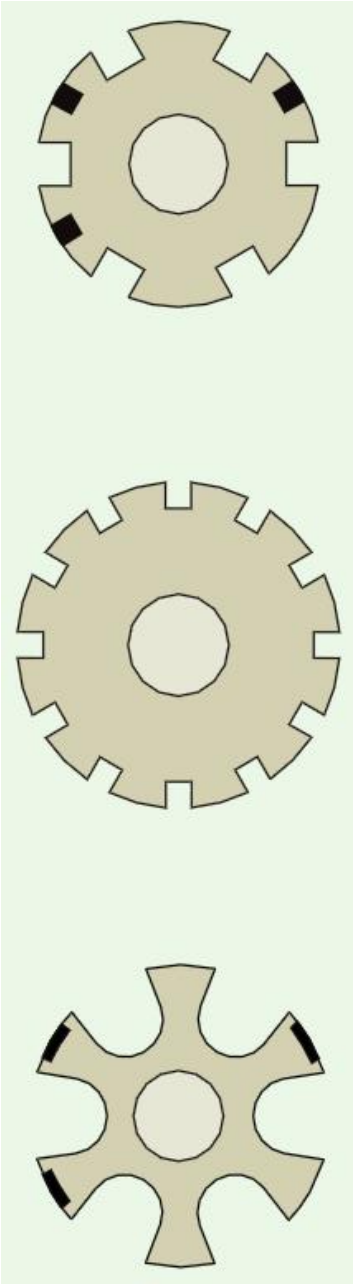

Core
<9 ± 1 µm
Cladding
125 ± 1 µm
Soft acrylate
about 200 µm
Hard acrylate
245 ± 10 µm


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

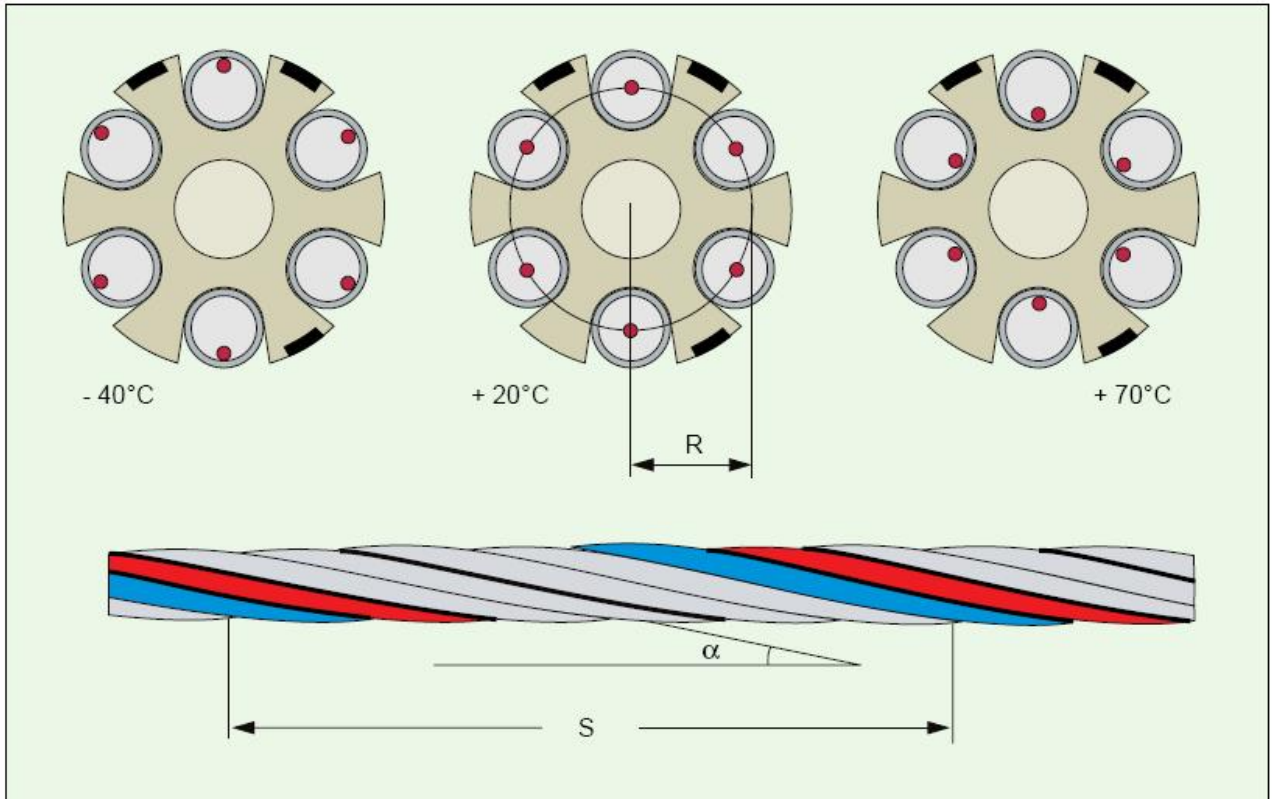
Cabluri

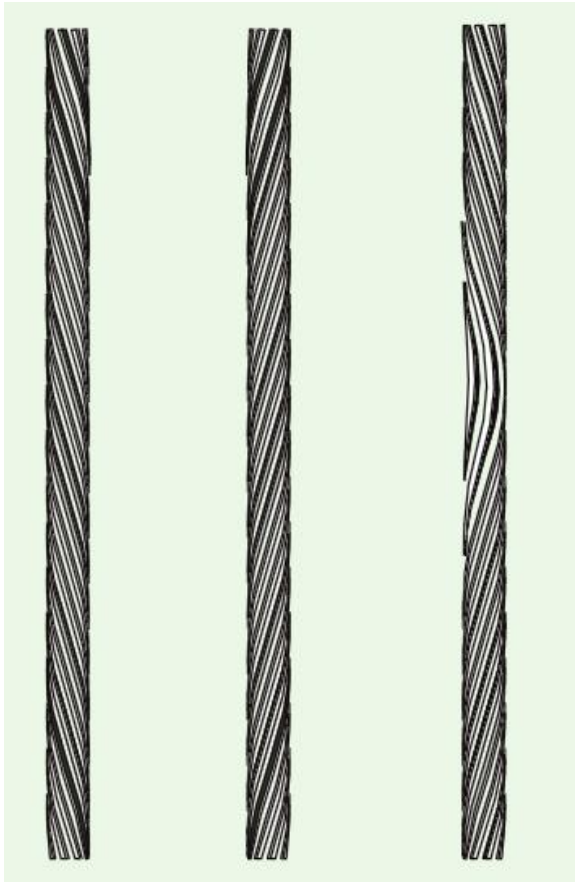






Cabluri

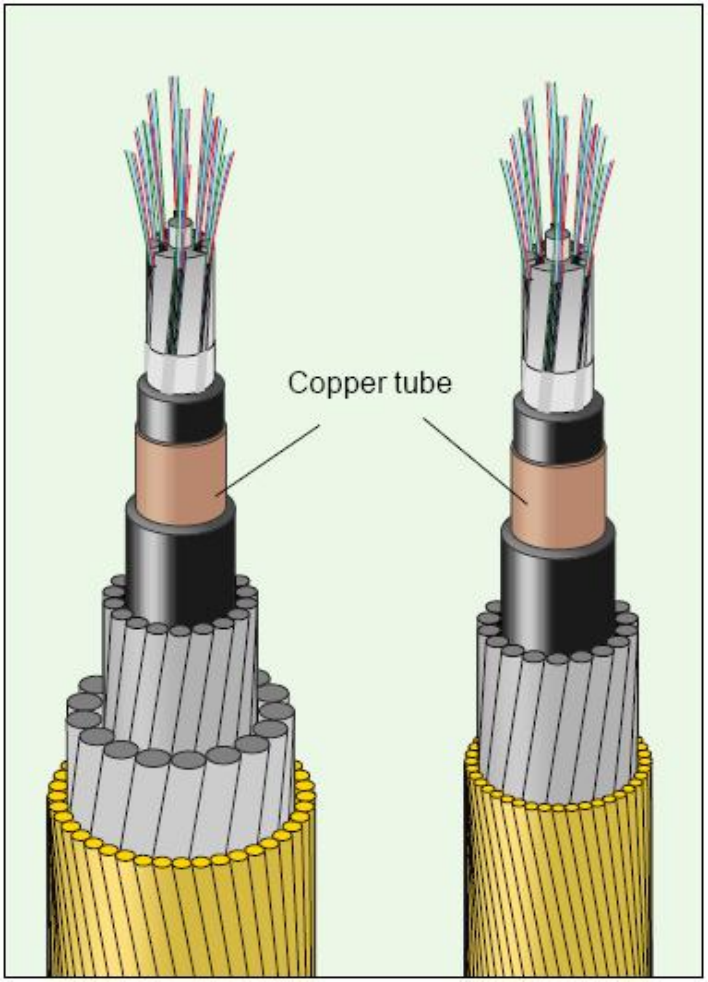


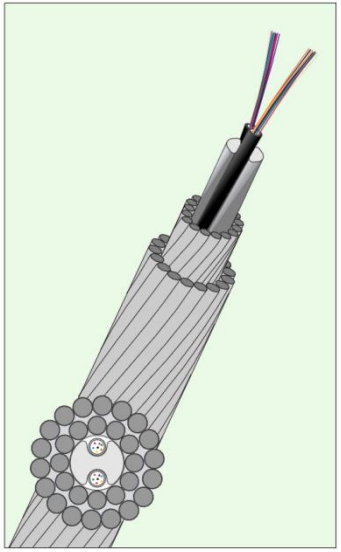


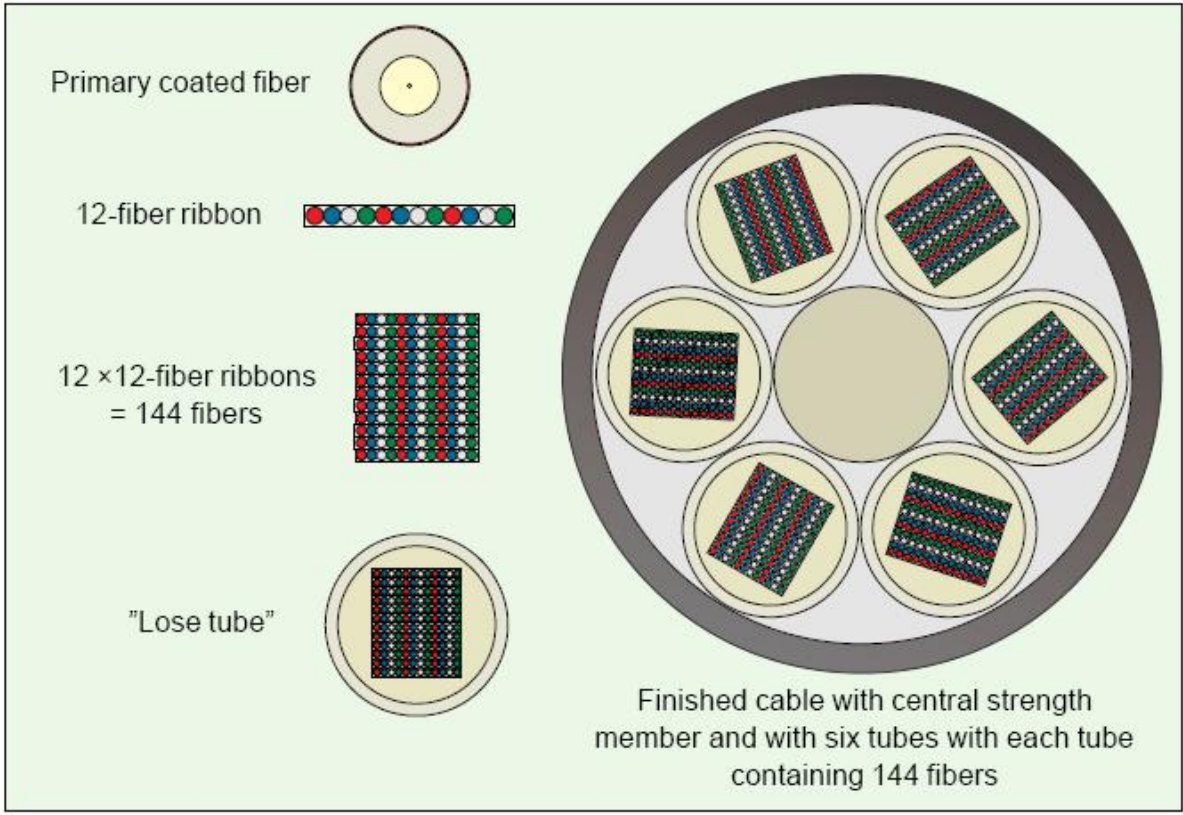
$$S' = S \cdot \sqrt{1 + \left(\frac{2\pi \cdot R}{S}\right)^2}$$

$$\frac{\Delta L}{L_0} = \sqrt{1 + \left(\frac{2\pi \cdot R}{S}\right)^2} - 1$$

Cabluri


Copper tube

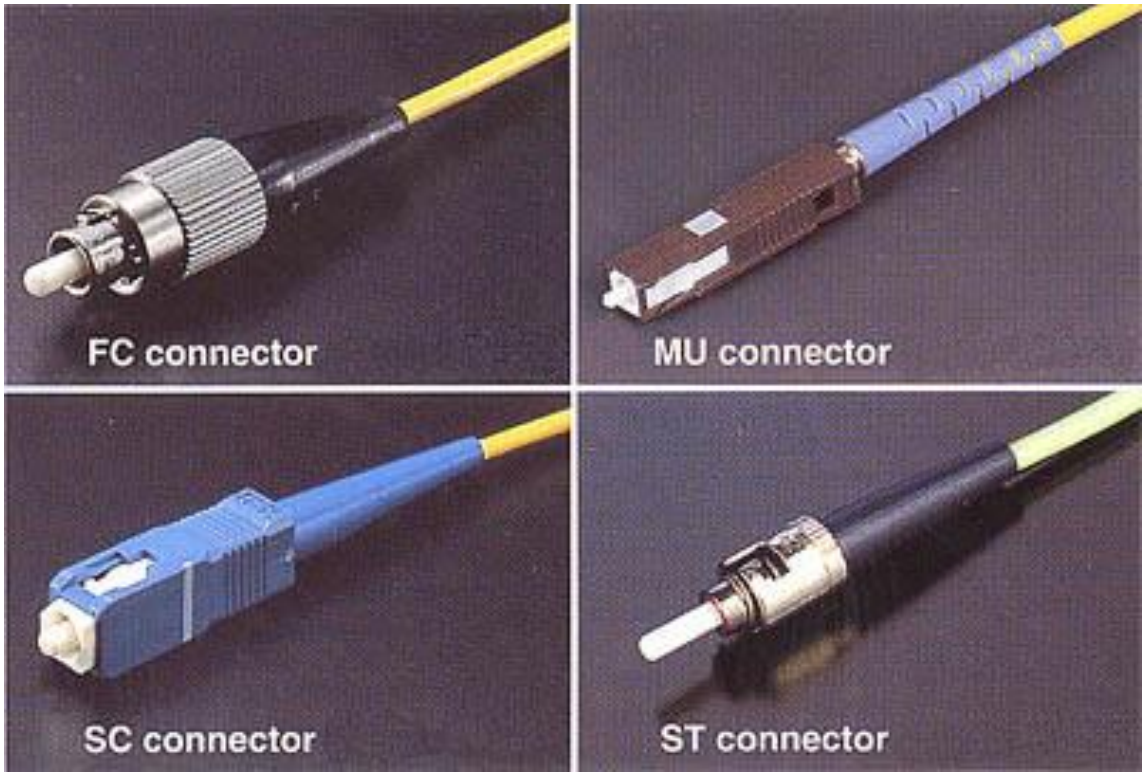



Primary coated fiber
12-fiber ribbon
12 ×12-fiber ribbons
= 144 fibers
"Lose tube"
Finished cable with central strength member and with six tubes with each tube containing 144 fibers

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

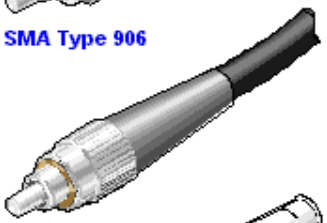


ST

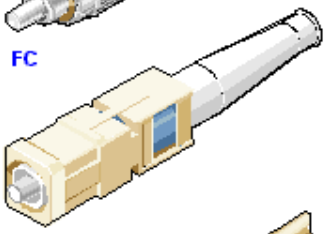
All fiber-optic connectors use ferrules to hold the ends of the fiber and keep them properly aligned.

SMA Type 906

The ST connector uses a half-twist bayonet type of lock, while SMA and FC use threaded connections.



FC

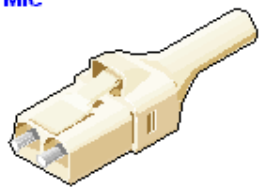


SC

The SC uses a push-pull connector similar to common audio and video plugs and sockets.

MIC

The MIC is the standard FDDI connector.



Fiber Jack

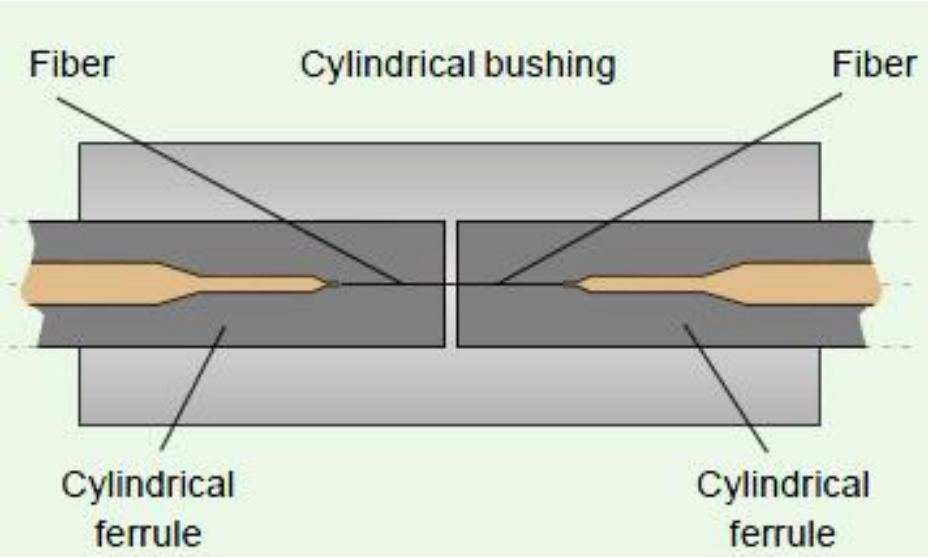
The Fiber Jack connector attaches two fibers in a snap lock connector similar in size and ease of use as an RJ-45 connector.

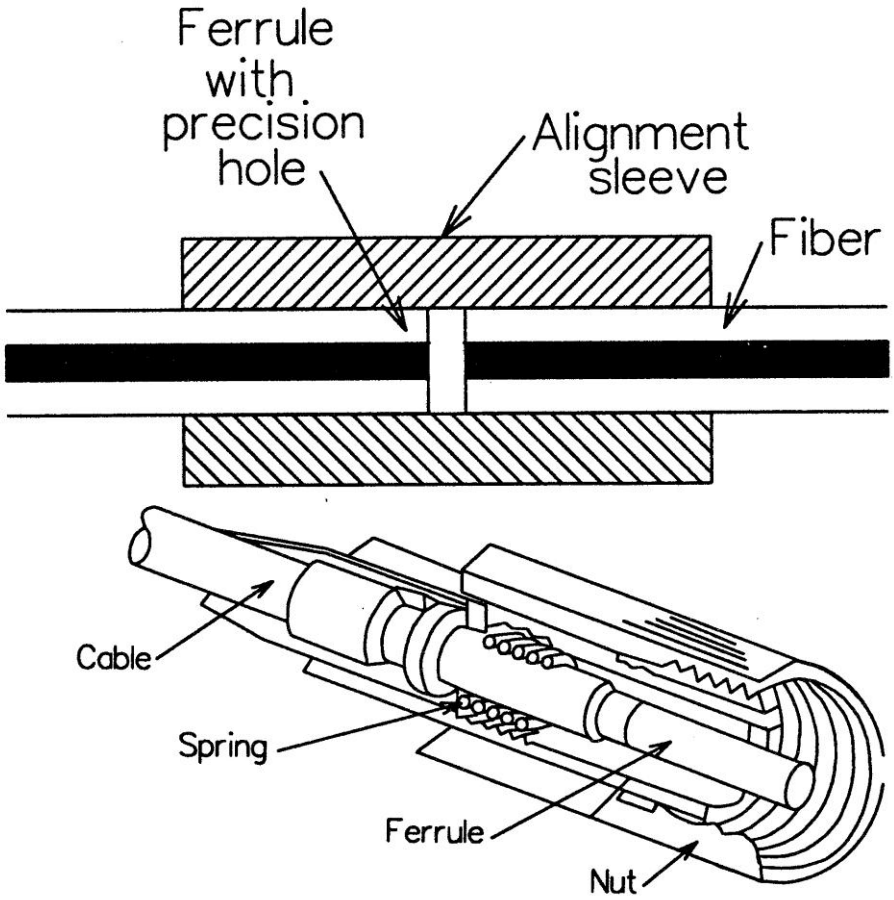
MT-RJ

MT-RJ is a popular connector for two fibers in a very small form factor.

Conectori

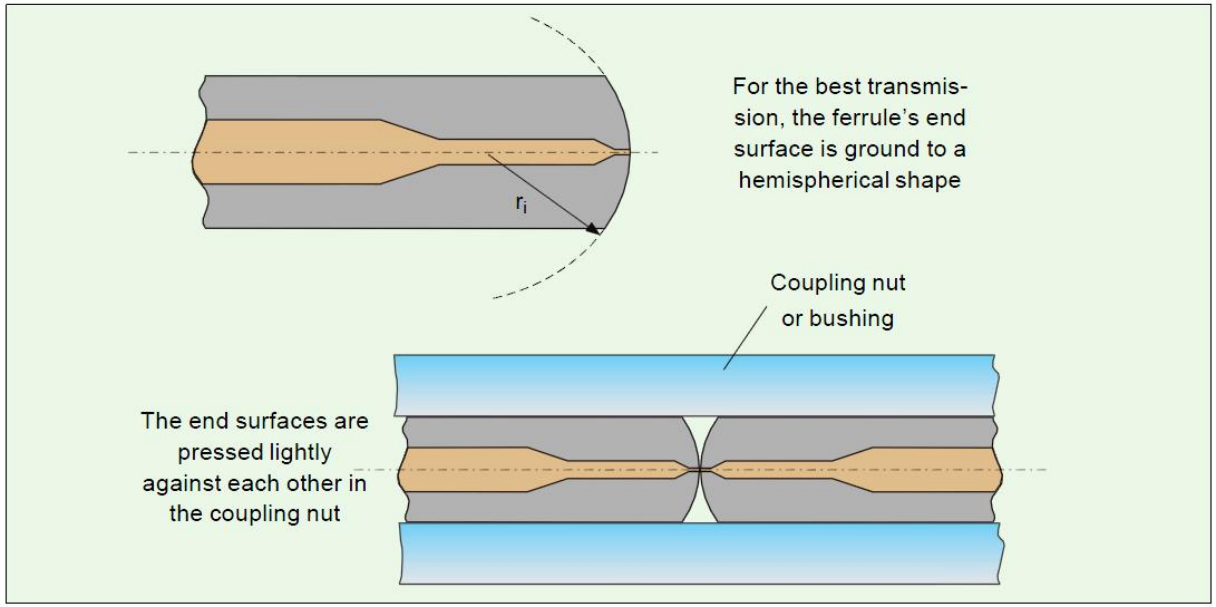
- Verificati http://rf-opto.etti.tuiasi.ro





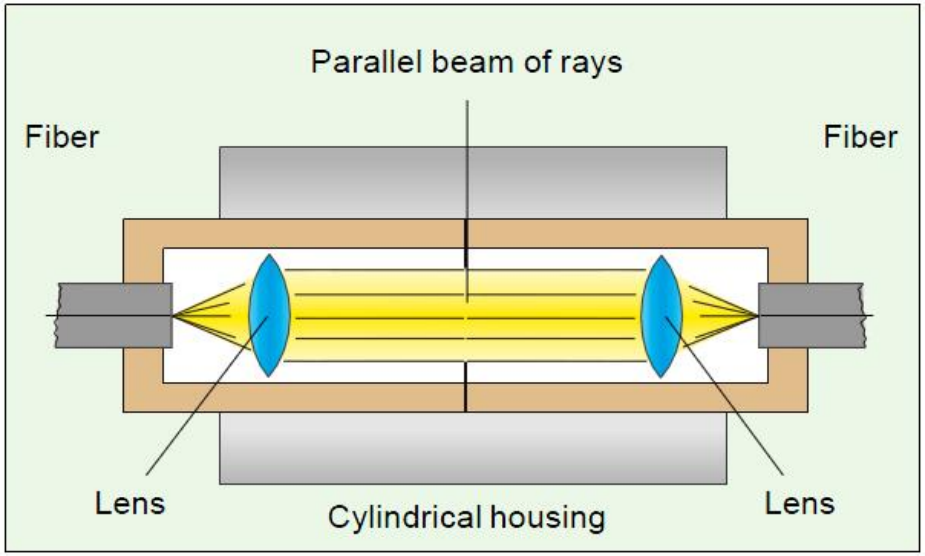
Conectori

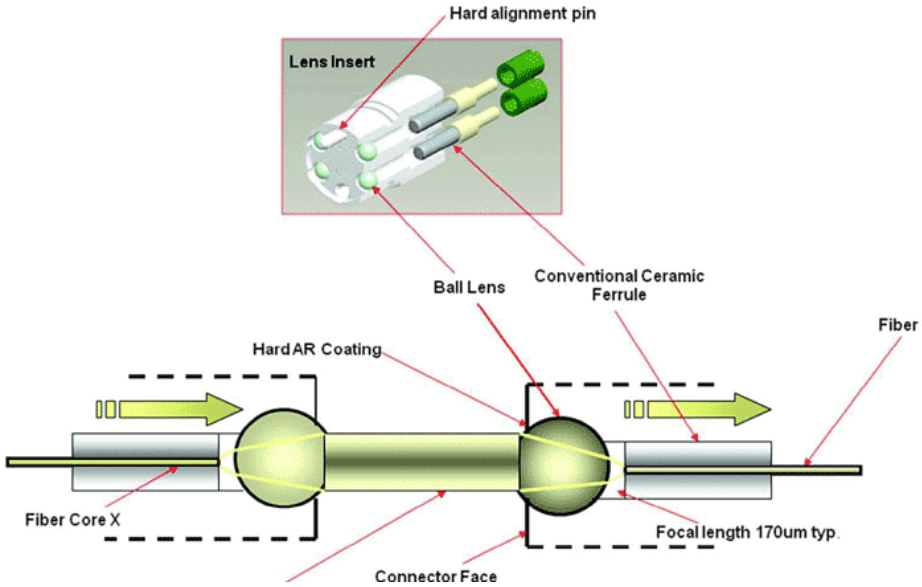
- Ferula semisferica
  - 20mm
  - 60mm



- Conectori multifibra

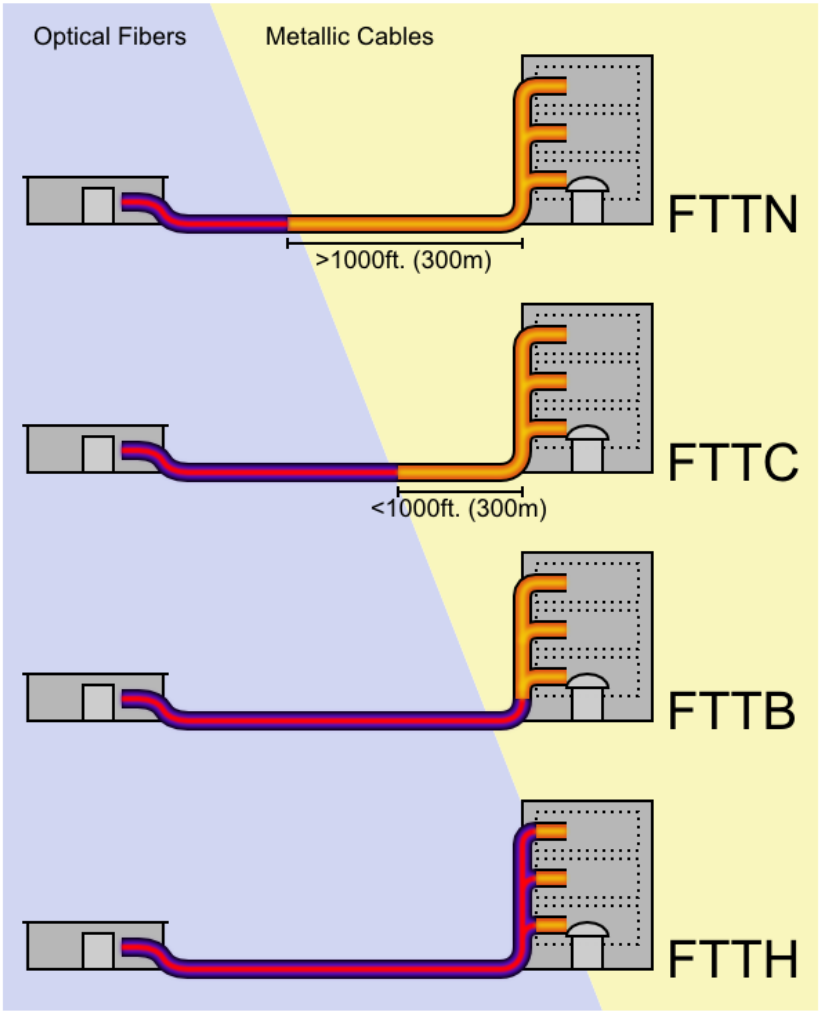
Expanded beam connector





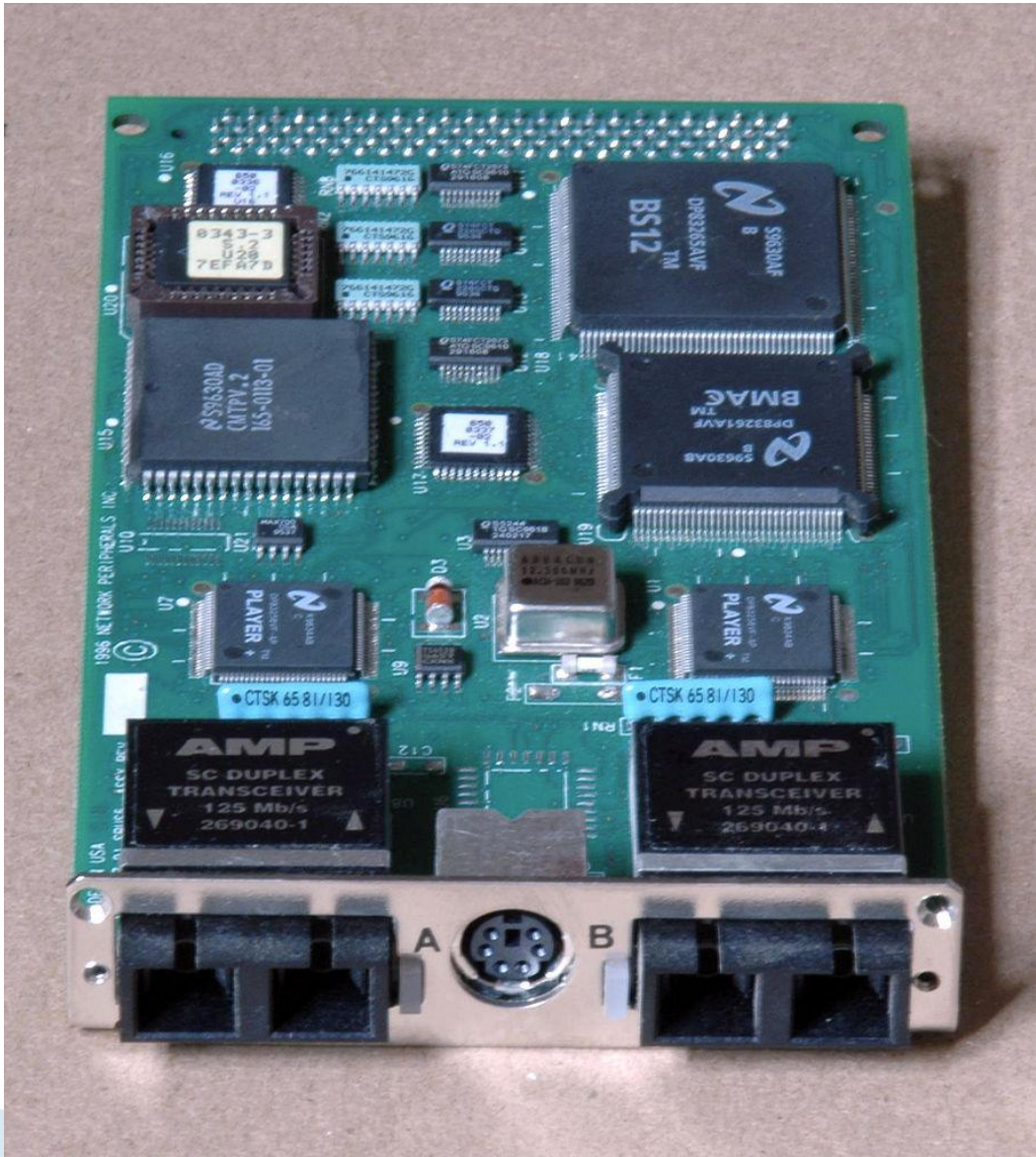
FTTH

- FTTN: Fiber to the node, neighborhood
- FTTC: Fiber to the curb
- FTTB: Fiber to the building
- FTTH: Fiber to the home



FDDI

- Fiber Distributed Data Interface



Cabluri, Conectori, rf-opto

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