Optoelectronică, structuri şi tehnologii

Curs 4

2013/2014

Orar

- Curs
  - marti, 17-20, P4
  - 2C ⇨ 3C
    - 14*2/3≈9.33
    - 9÷10 C

Fotometrie şi radiometrie

Capitolul 4

Parametri, dependenta de mediu

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\Omega$$

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8 \ m/s$$

$n = 1$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\lambda_0 = \frac{2\pi}{\beta} = \frac{c_0}{f}$$

$$\eta = \frac{\eta_0}{n}$$

$$c = \frac{c_0}{n}$$

$n = \sqrt{\varepsilon_r}$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\lambda = \frac{c_0}{n \cdot f} = \frac{\lambda_0}{n}$$

λ=f(n) !!

ITU G.692

"the allowed channel frequencies are based on a 50 GHz grid with the reference frequency at 193.10 THz"

SI

"a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz"

Fotometrie şi radiometrie –

- **Examen!**

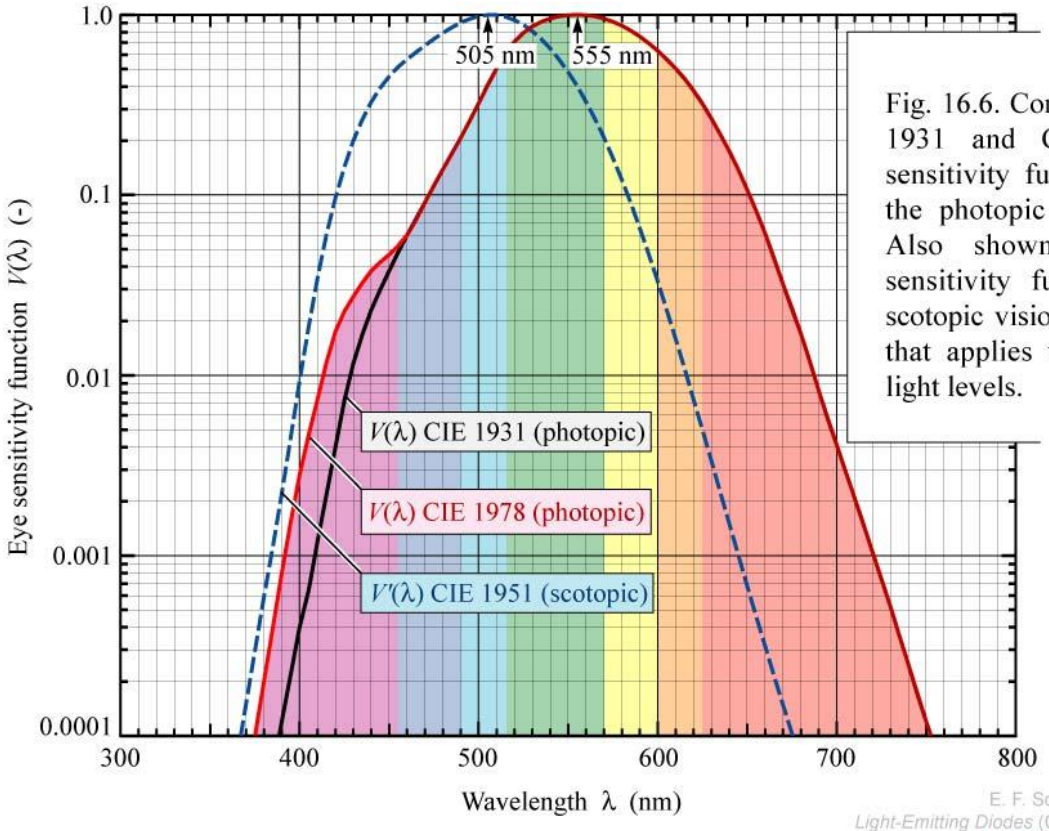


Fig. 16.6. Comparison of CIE 1931 and CIE 1978 eye sensitivity function $V(\lambda)$ for the photopic vision regime. Also shown is the eye sensitivity function for the scotopic vision regime, $V'(\lambda)$, that applies to low ambient light levels.

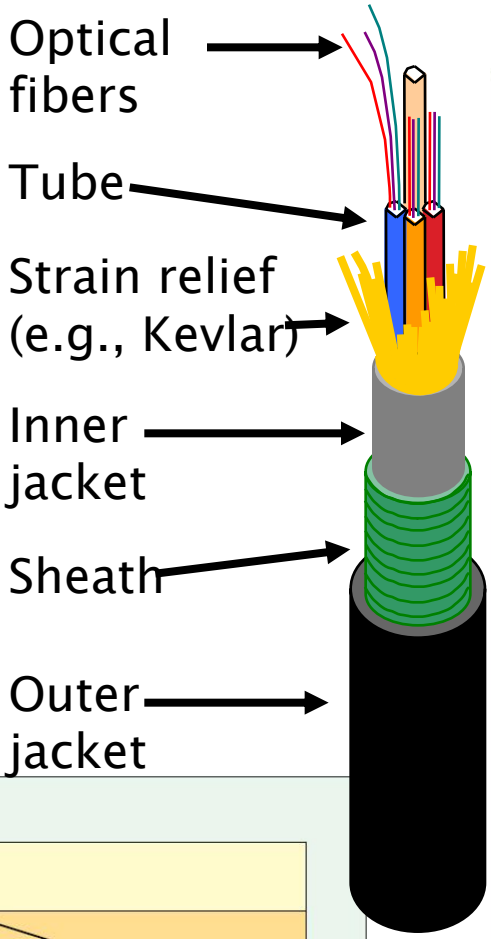
Fibra optică

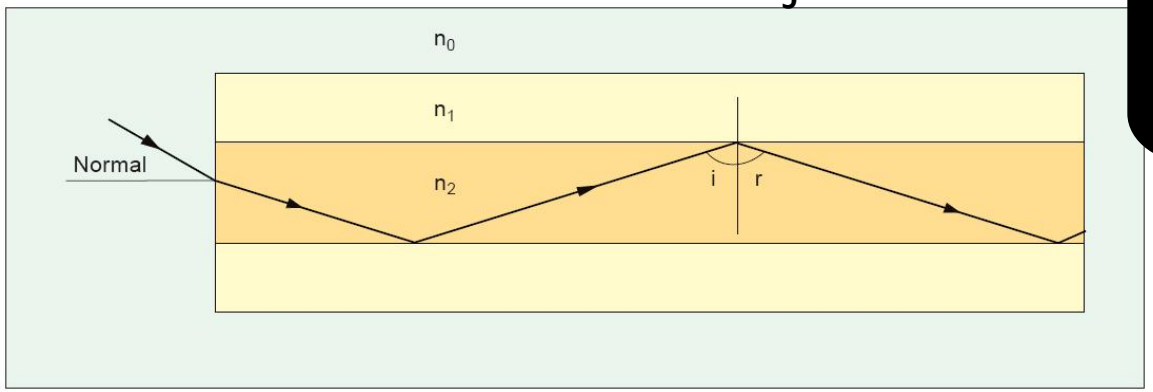
Capitolul 5

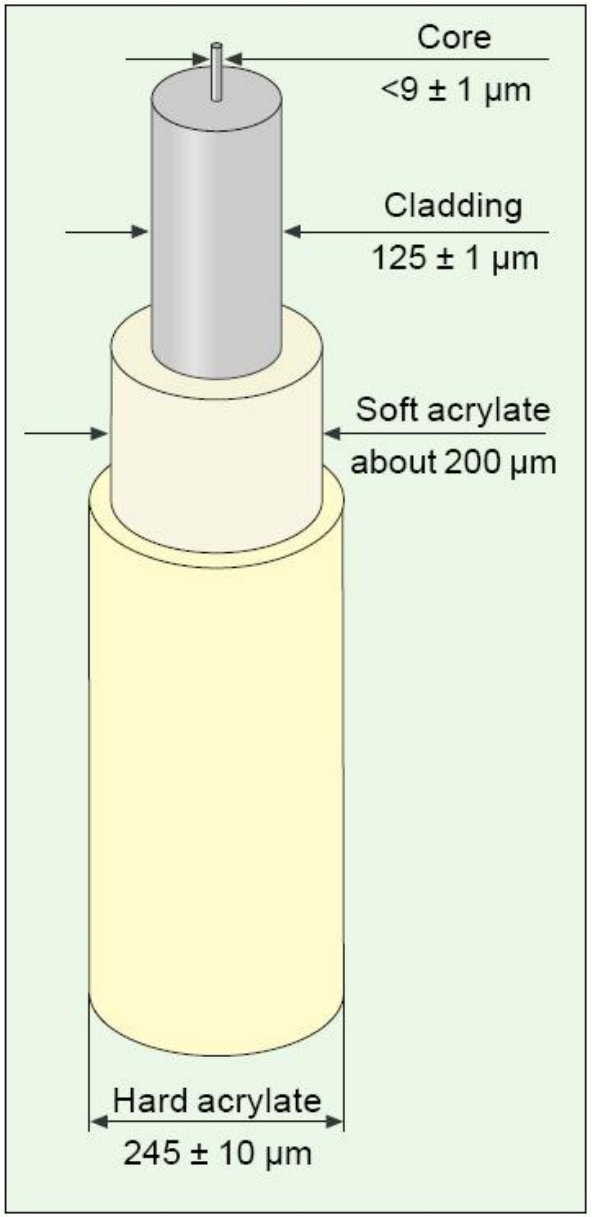
Recapitulare

Fibra optica

- un ghid de unda dielectric
  - miez
  - teaca







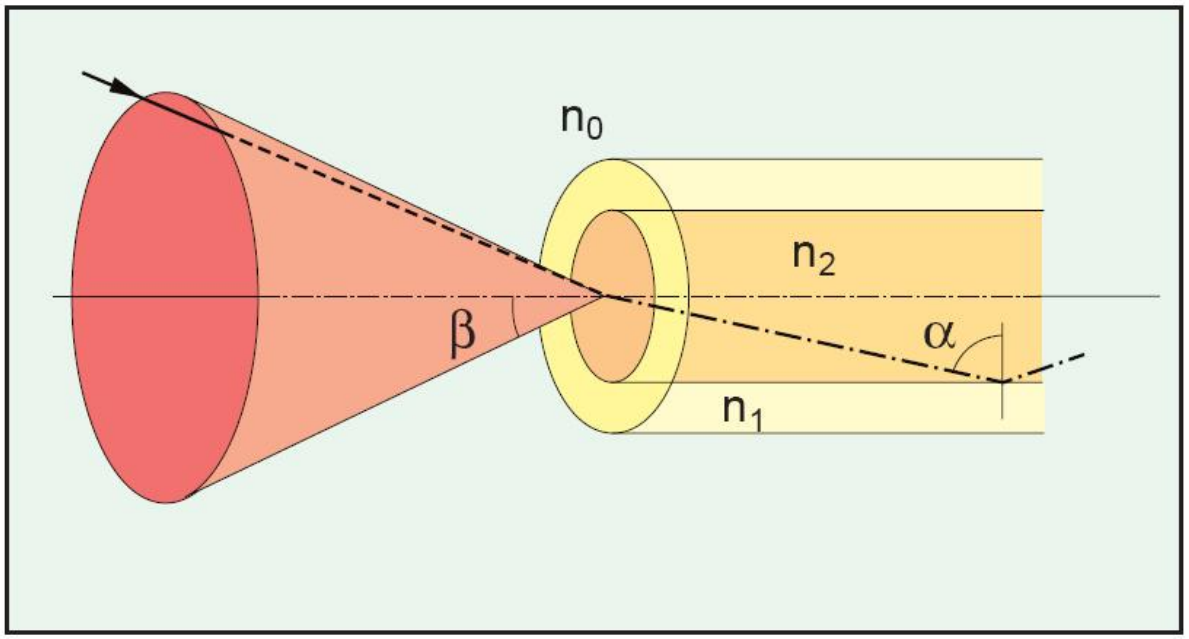
Unghi de acceptanta, apertura numerica

- Unghi de acceptanta

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

- Apertura numerica

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

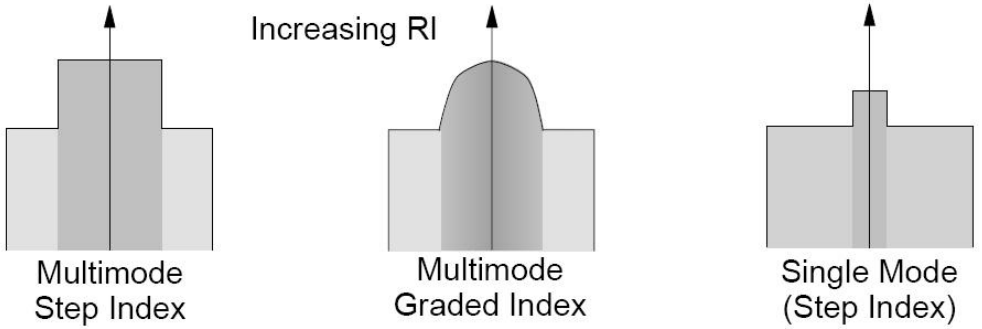


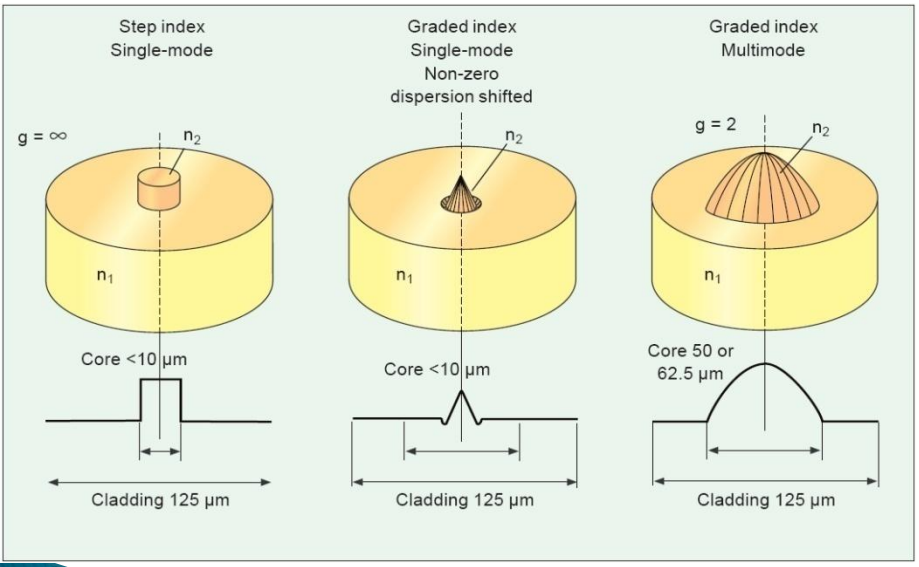
$$NA = n_2\sqrt{\frac{n_2^2 - n_1^2}{n_2^2}} = \sqrt{n_2^2 - n_1^2}$$

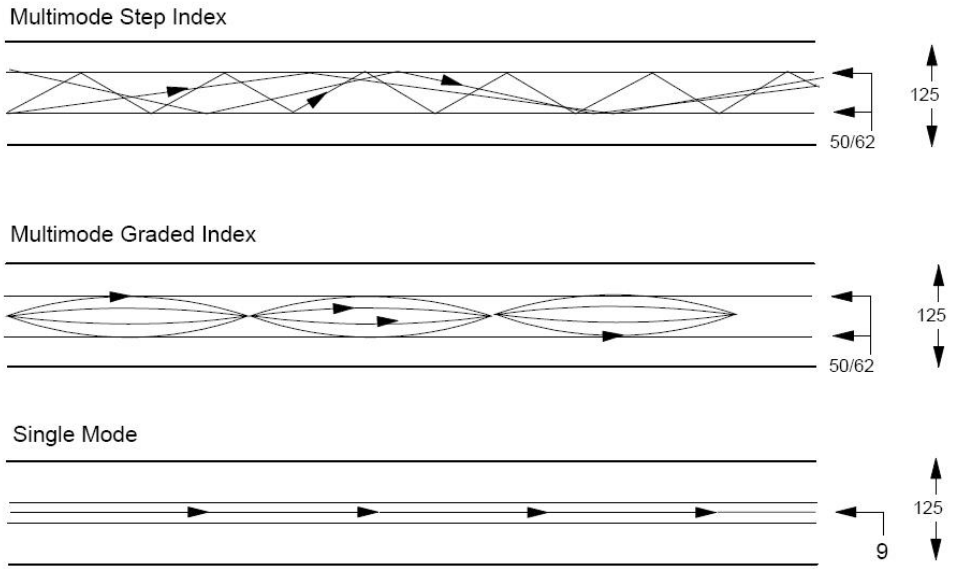
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

Tipuri de fibra

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







Frecventa normalizata

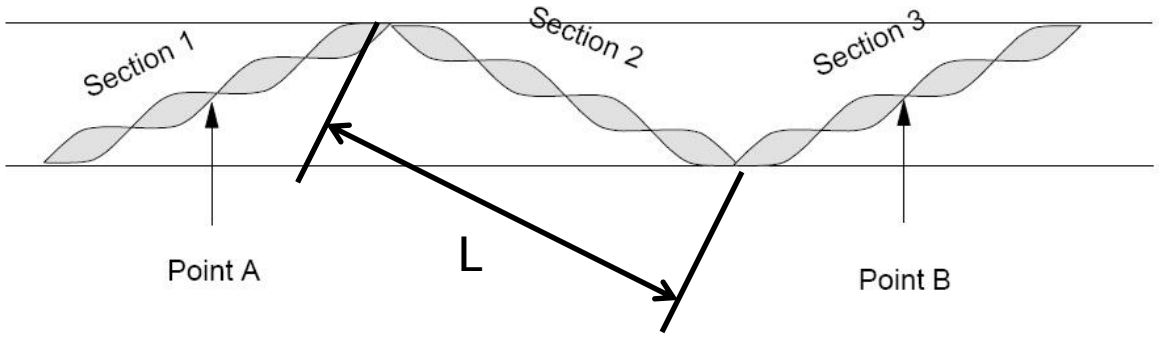
- Frecventa normalizata

$$V = 2\pi \frac{a}{\lambda} NA = k \cdot a \cdot NA$$

a – raza miezului

$$k = \frac{2\pi}{\lambda}$$

- Numar de moduri

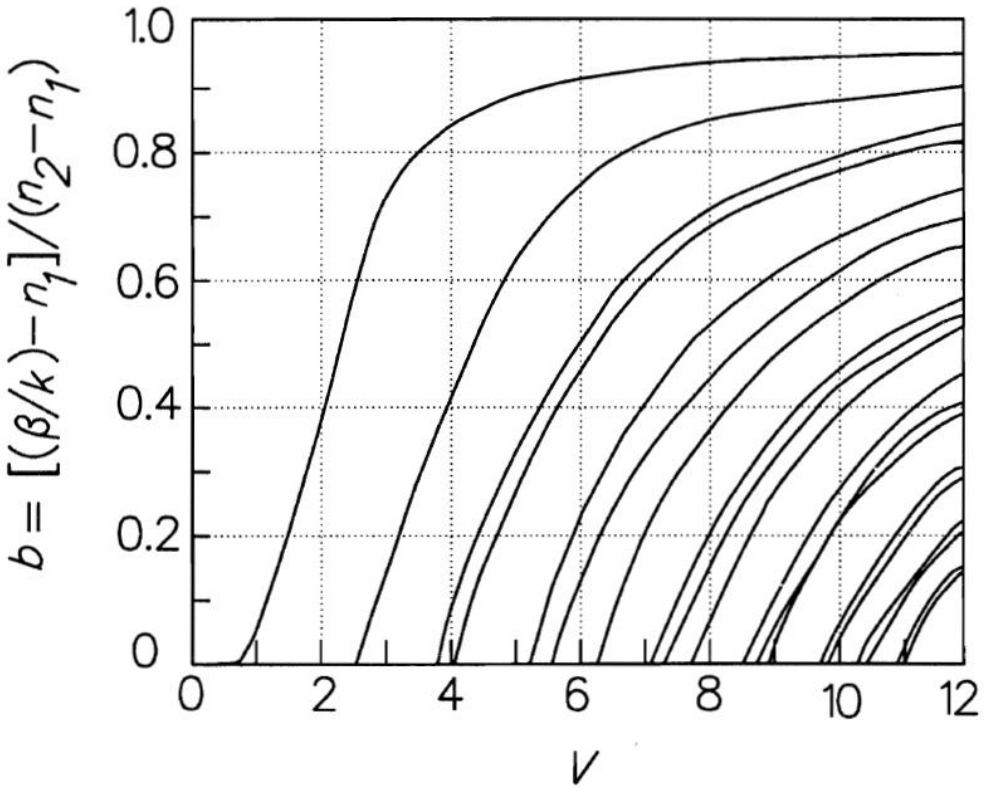


$$L = m \cdot \lambda$$

$$N \approx \frac{V^2}{2} \cdot \frac{g}{g+2}$$

Frecventa normalizata – monomod

- Fibre monomod



b – coeficient de propagare modal relativ

$$V \le V_C = 2.405$$

exista un singur mod (solutii fc. Bessel)

$$\lambda \ge \lambda_C = \pi \frac{2a}{V_C} NA = \pi \frac{2a}{2.405} NA$$

Exemplu:

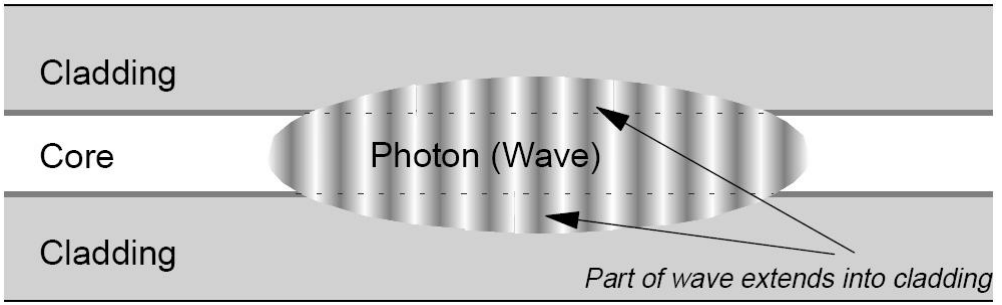
$2a = 8.5\mu m$

$NA = 0.11$

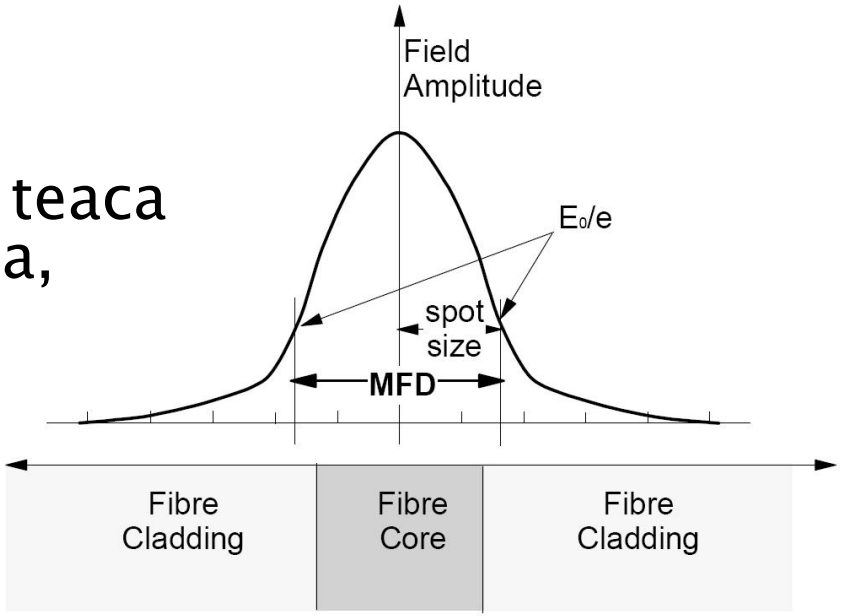
$$\lambda_C = \pi \frac{8.5}{2.405} 0.11 = 1210 nm$$

Propagarea in fibra monomod

- Propagarea luminii poate fi explicata doar prin teoria electromagnetica



- Energia campului se extinde in teaca (diametrul efectiv al spotului luminos – MFD, Mode Field Diameter)
- MFD > 2a
- Adancimea de patrundere in teaca depinde de lungimea de unda, generand dispersia de ghid

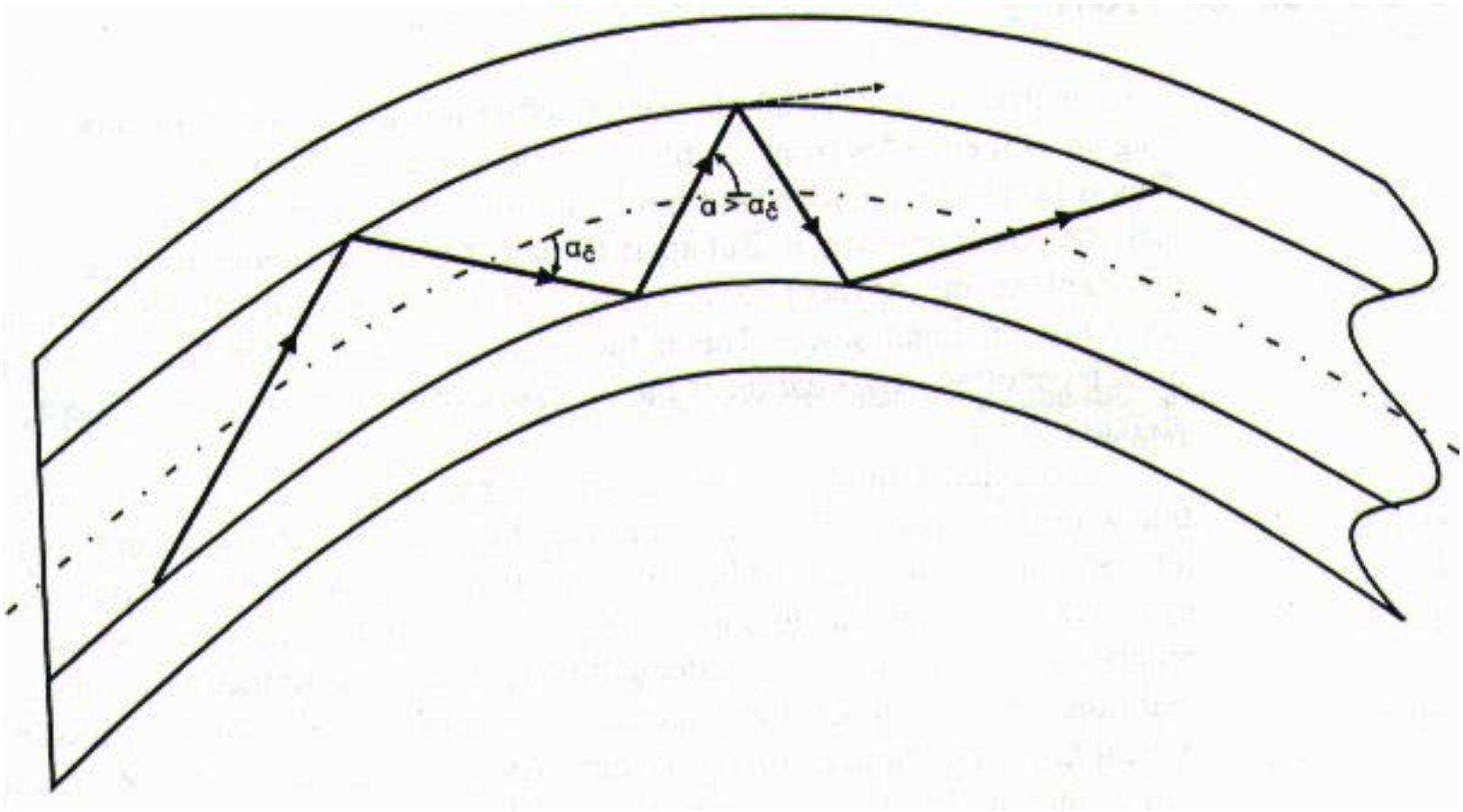


Continuare

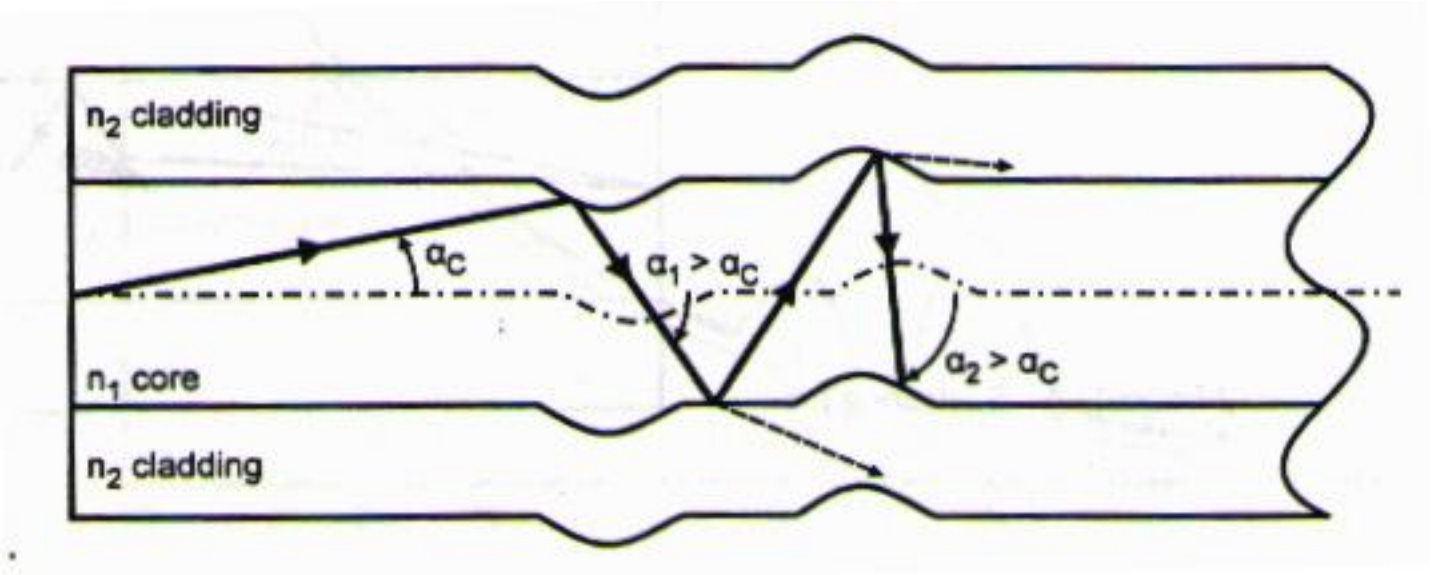
ATENUAREA

- Macrocurburi
- Microcurburi
- Imprastiere
- Absorbtie

Macrocurburi

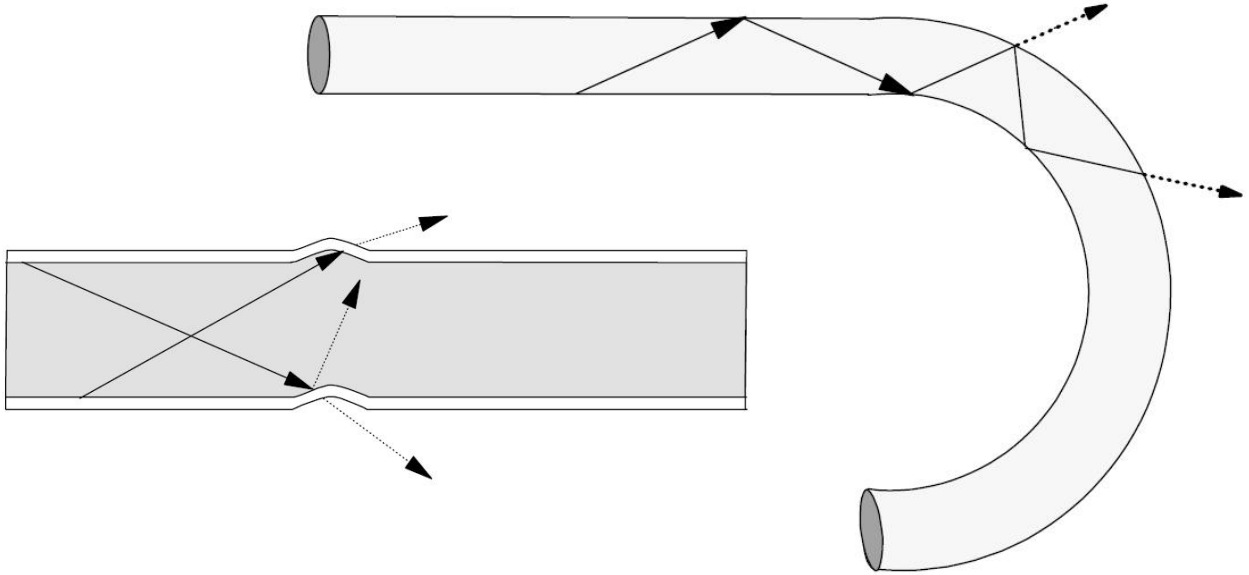


Microcurburi

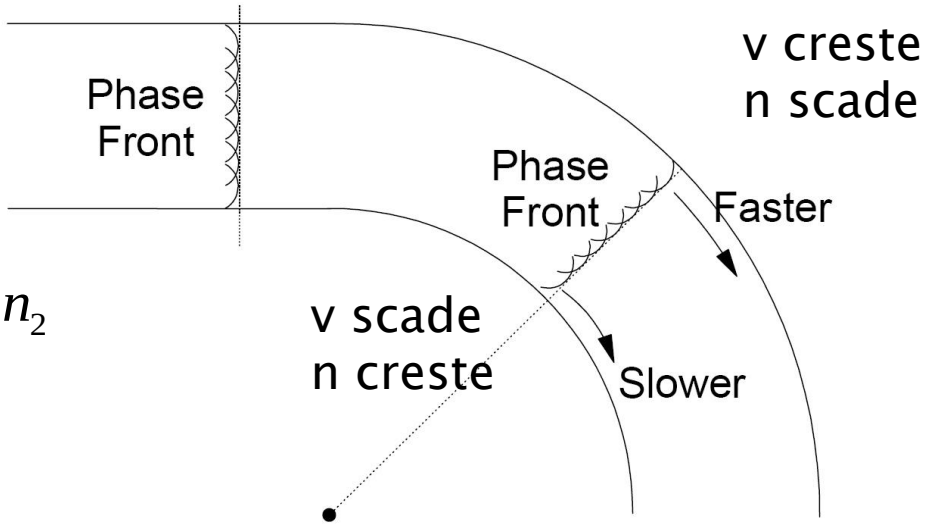


Efectul curburilor

- Multimod

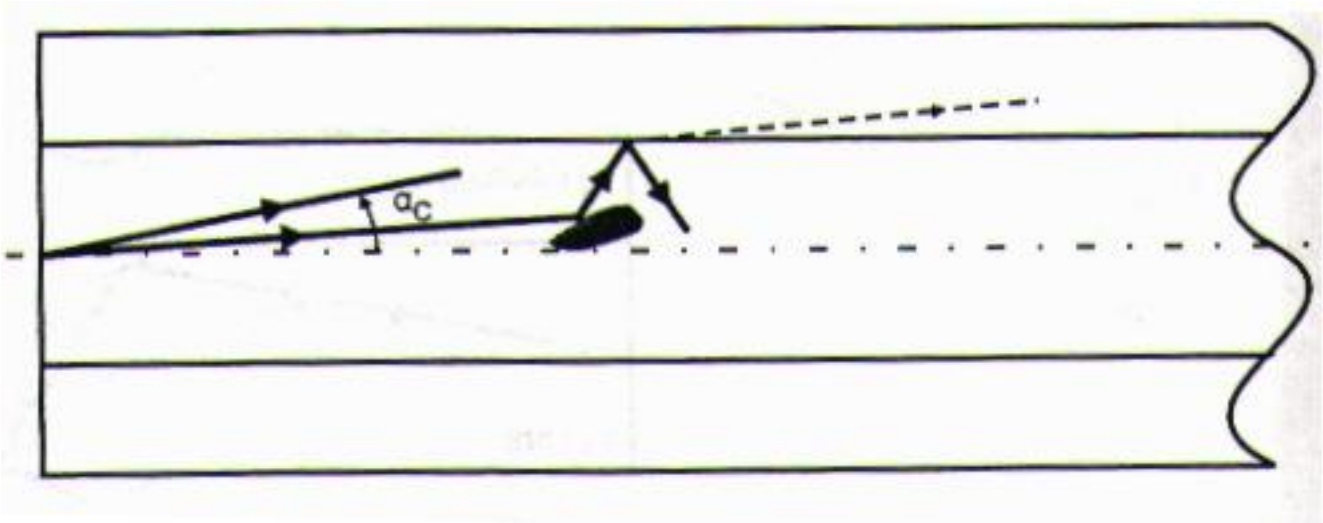


- Monomod

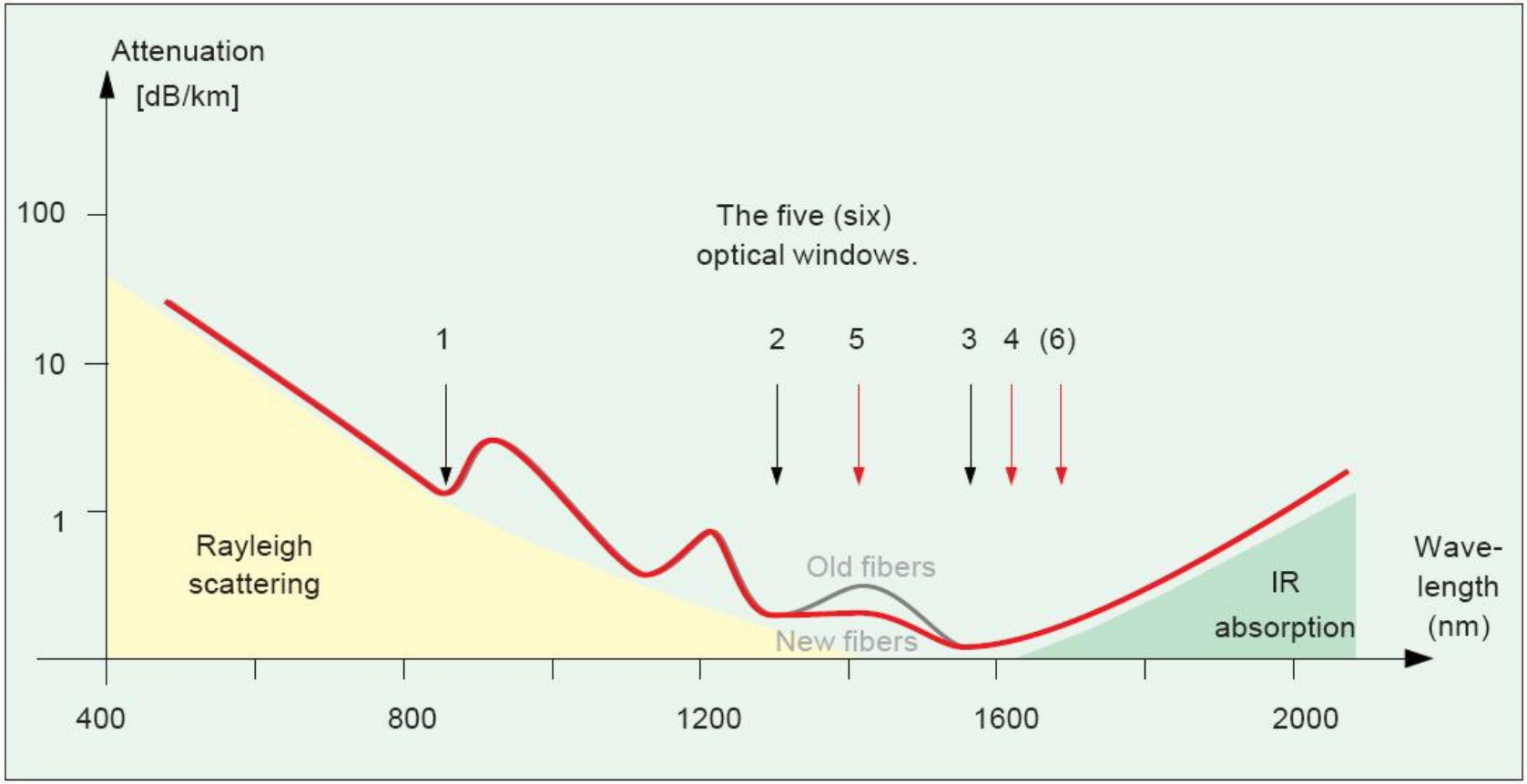


$$R > R_C \quad \Rightarrow \quad n_{1,ext} > n_2$$

Imprastiere

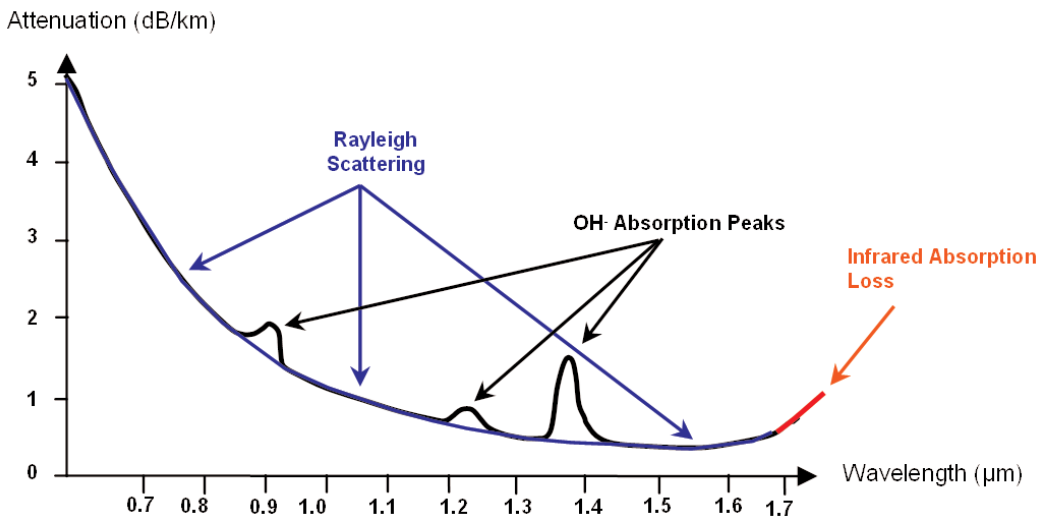


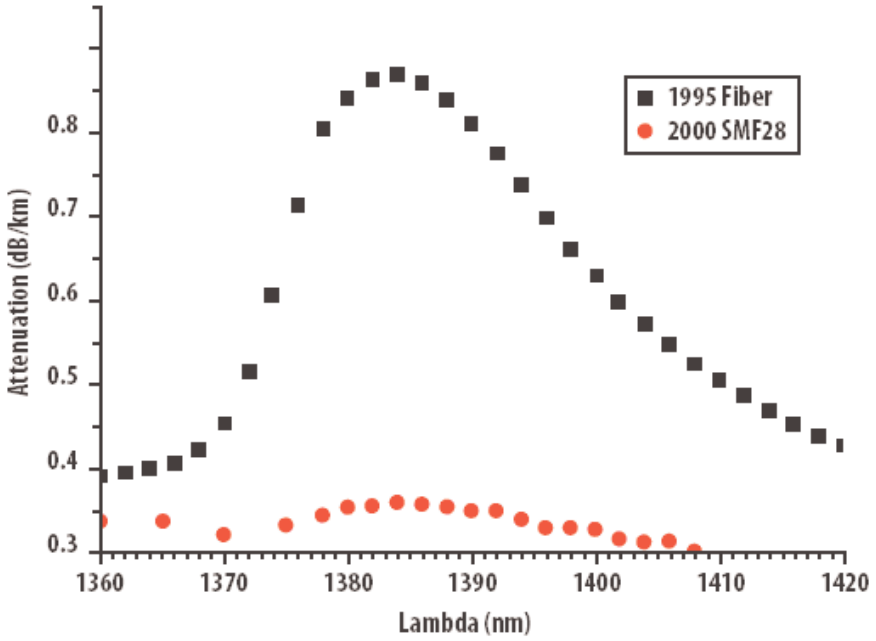
Absorbtie


Attenuation
[dB/km]
100
10
1
The five (six)
optical windows.
1
2
5
3
4
(6)
Rayleigh
scattering
Old fibers
New fibers
IR
absorption
Wave-
length
(nm)
400
800
1200
1600
2000

Absorbtie OH

- Absorbtie
  - 950nm
  - 1244nm
  - 1383nm
- Apa!





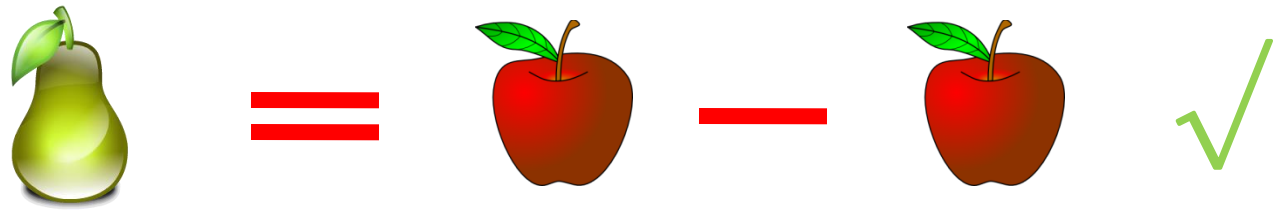
Fiber Attenuation Comparison

Calculul atenuarii

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

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

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

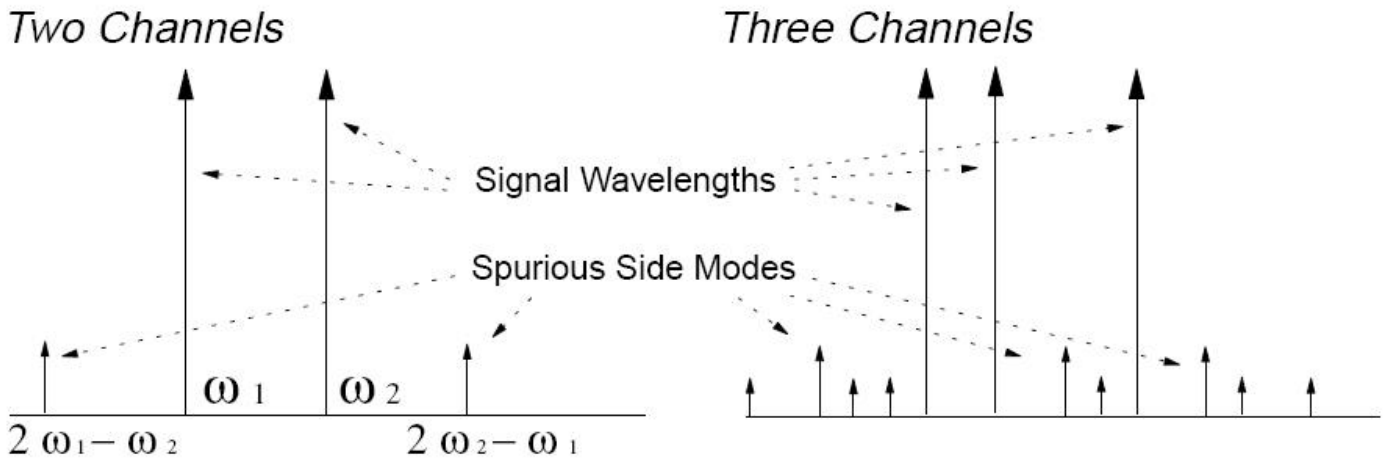


$$\text{Atenuare}[\text{dB/km}] = \frac{\text{Pierderi}[\text{dB}]}{\text{lungime}[\text{km}]}$$

Efecte neliniare in fibra

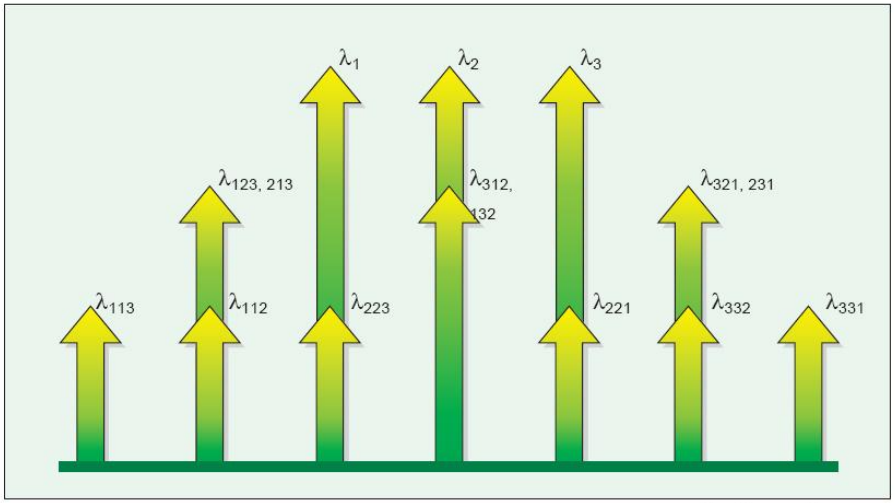
- Stimulated Brillouin Scattering, SBC
  - difractia luminii inspre emitator datorita undelor mecano-acustice generate in fibra
  - 6-10 dBm
- Stimulated Raman Scattering, SRS
  - interactiunea luminii cu vibratiile moleculare
  - 27 dBm (~1W)
- Self Phase Modulation, SPM
  - Frontiera impulsului implica indice de refractie variabil in timp moduland faza impulsului
  - 5 dBm
  - Cross Phase Modulation, CPM
- Four-Wave Mixing, FWM
  - 0 dBm

Four-Wave Mixing, FWM



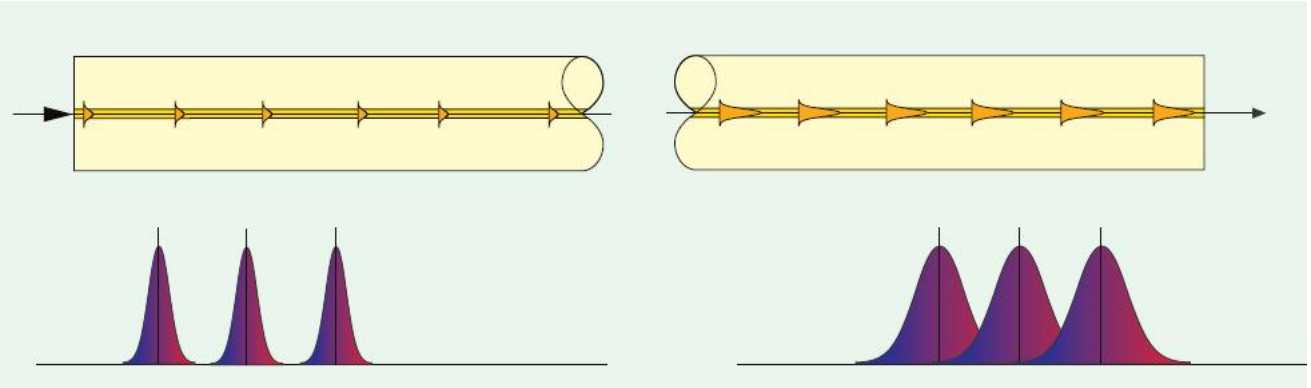
$$NL = \frac{1}{2}\left(N^3 - N^2\right)$$

N = 2, NL = 4
N = 3, NL = 9
N = 16, NL = 1920

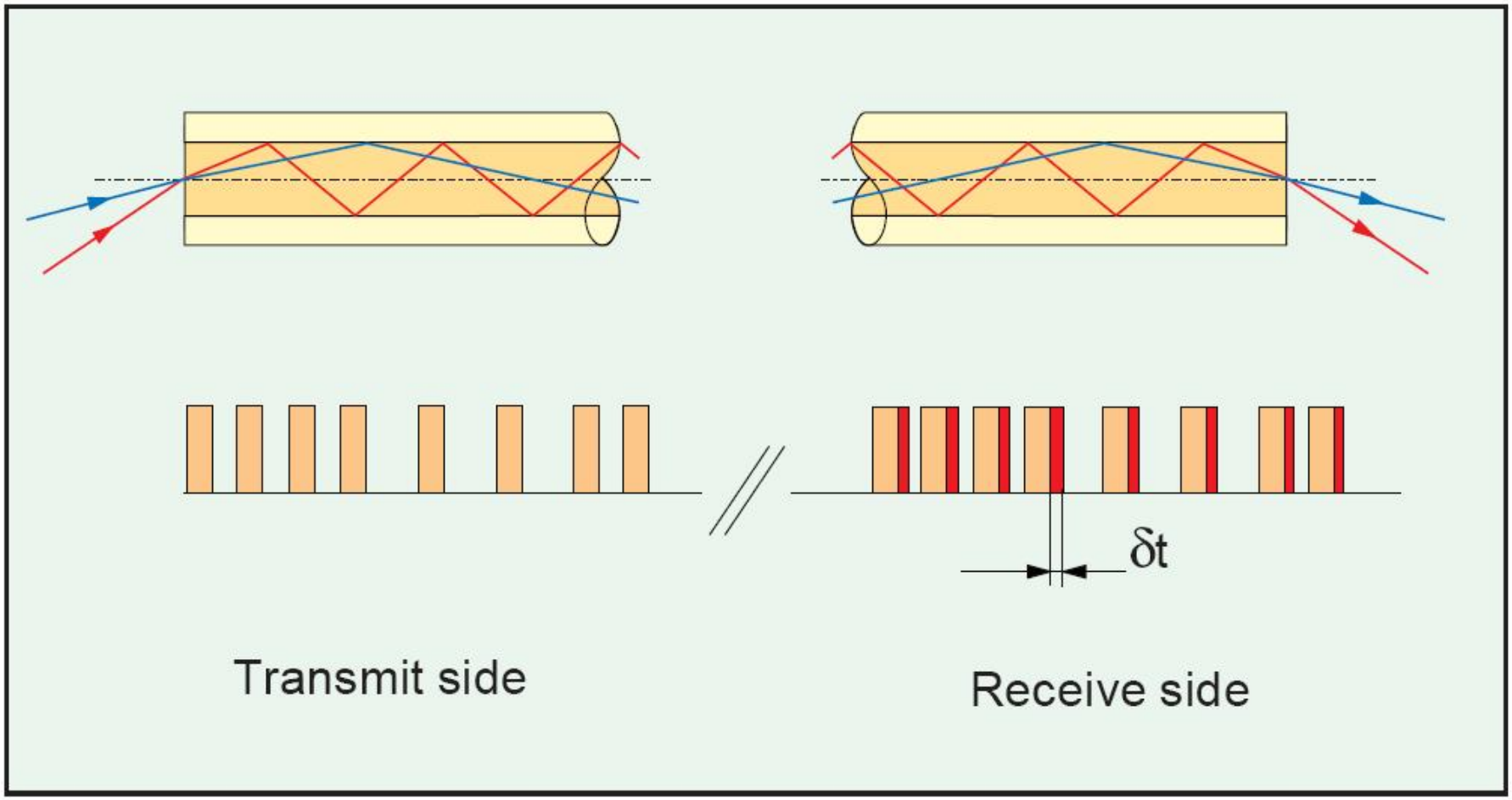


Dispersia

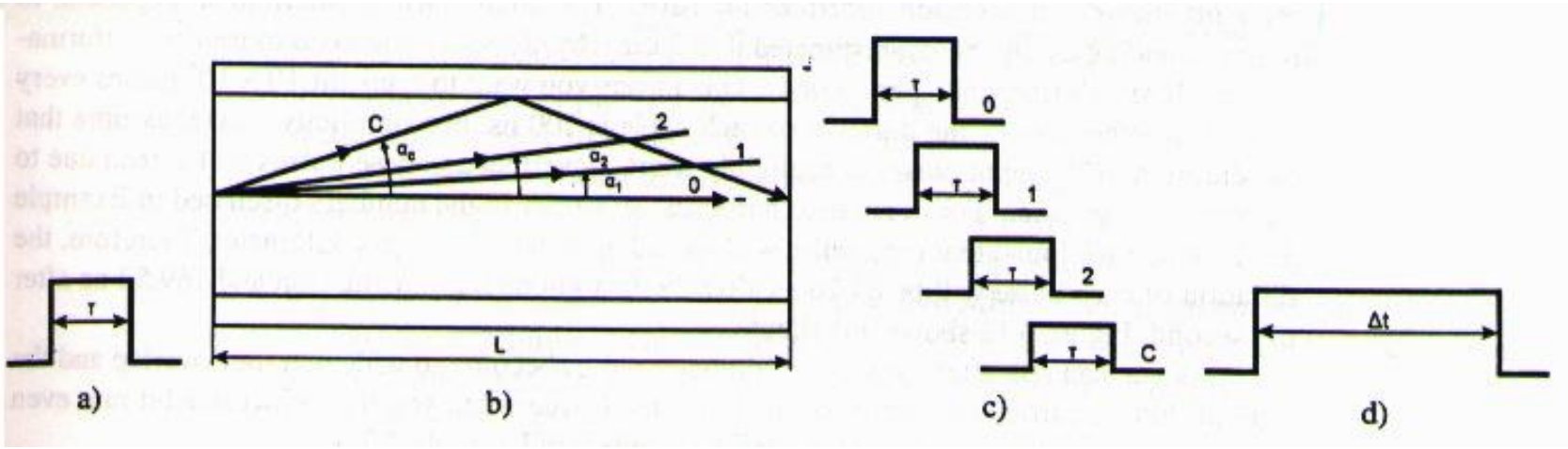
- Propagarea cu viteze diferite a radiatiilor cu lungimi de unda diferite
  - intermodala (modala – depinde de prezenta modurilor)
  - intramodala (cromatica – depinde de lungimea de unda)
    - de material
    - de ghid



Dispersia modala



Dispersia modala



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

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

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

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

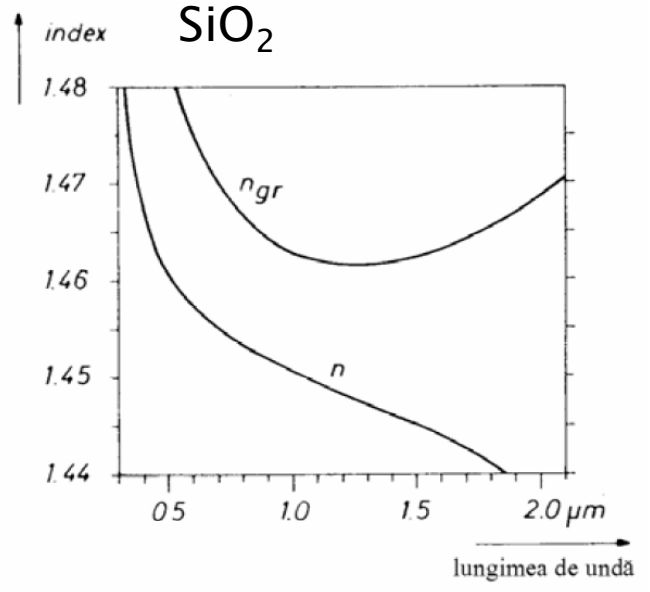
$$dt = \frac{L \cdot n_2 \cdot \Delta^2}{2c} \approx \frac{L \cdot NA^4}{8 \cdot c \cdot n_2^3}$$

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

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

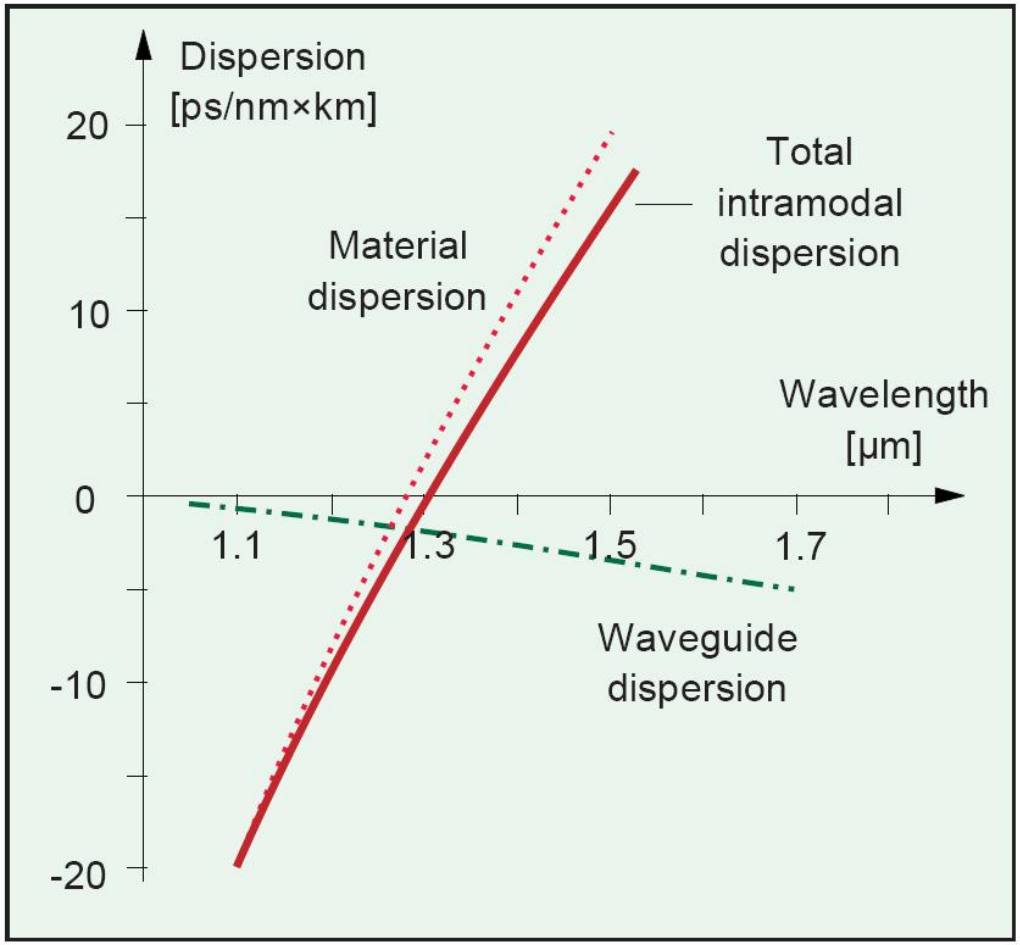
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

Dispersia de material



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

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

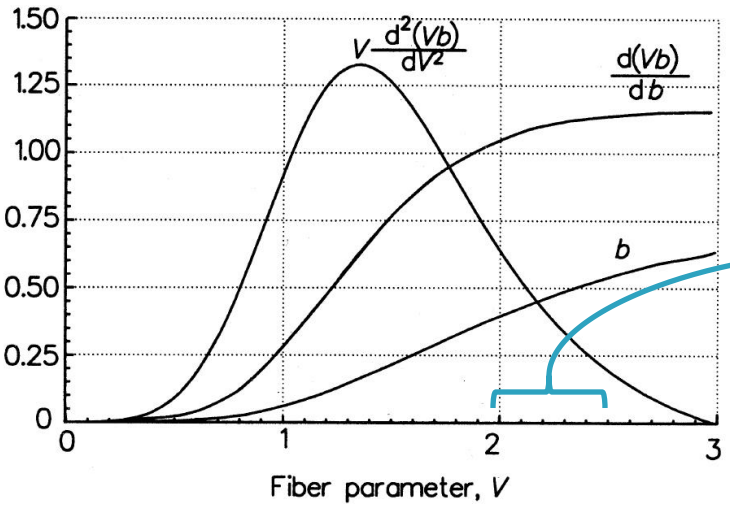


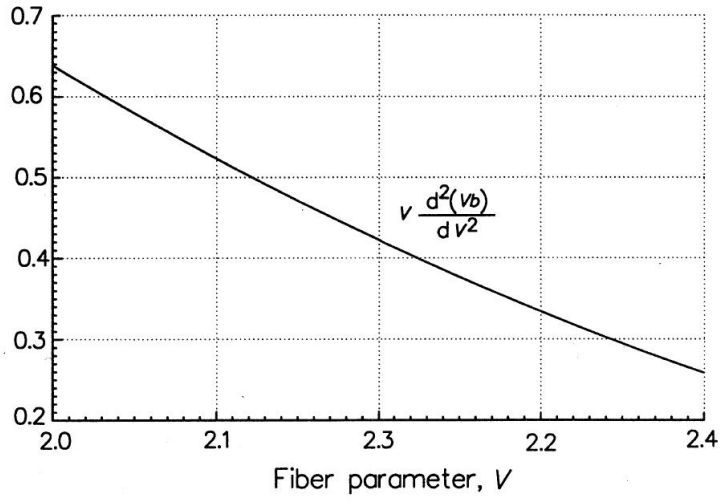
Dispersia de ghid

- Neglijabila in fibrele multimod fata de dispersia modala

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

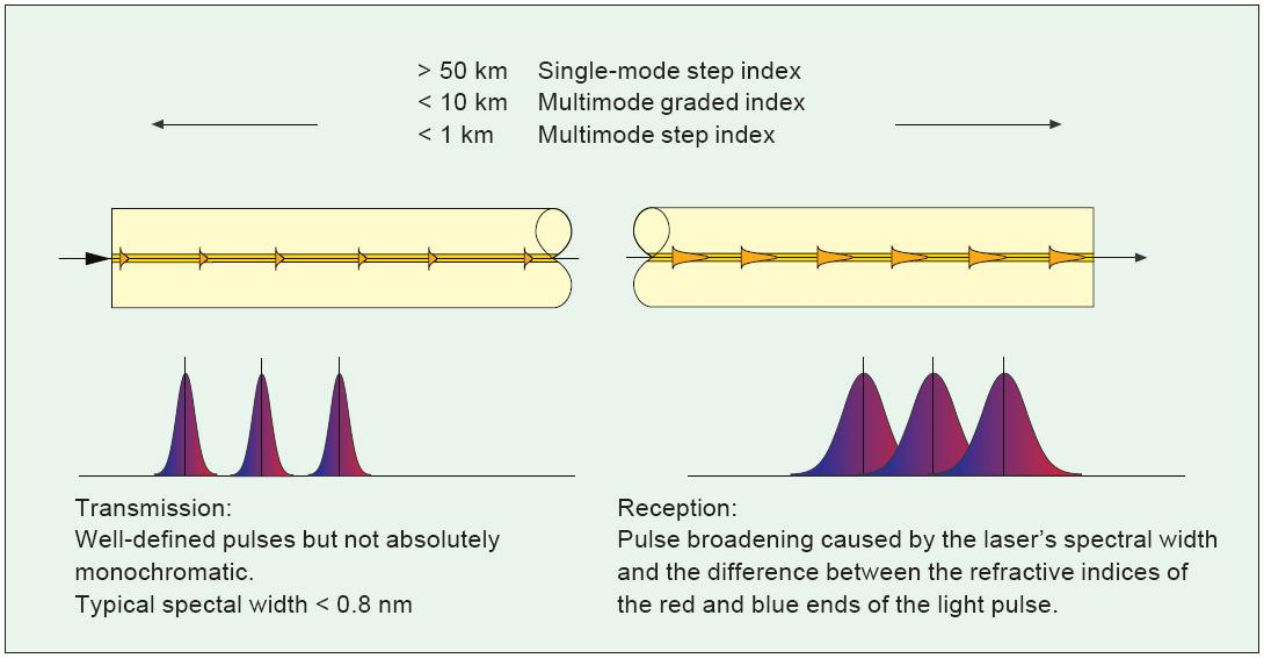
b – constanta de propagare normalizata





$$V \le V_C = 2.405$$

Dispersia cromatica (gh+mat)



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

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

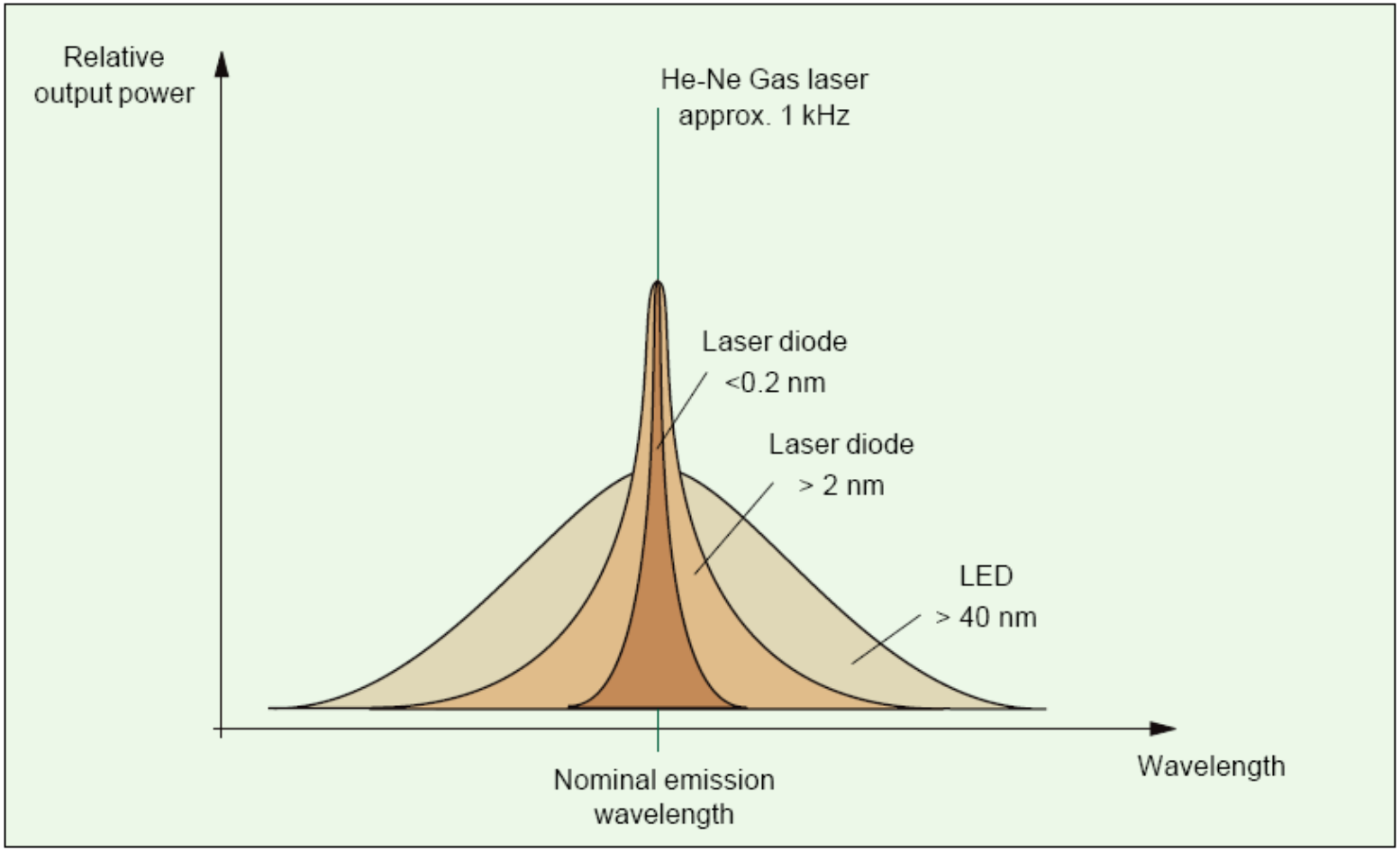
S_0 panta dispersiei – $ps/nm^2/km$

$$D(\lambda_0) = 0$$

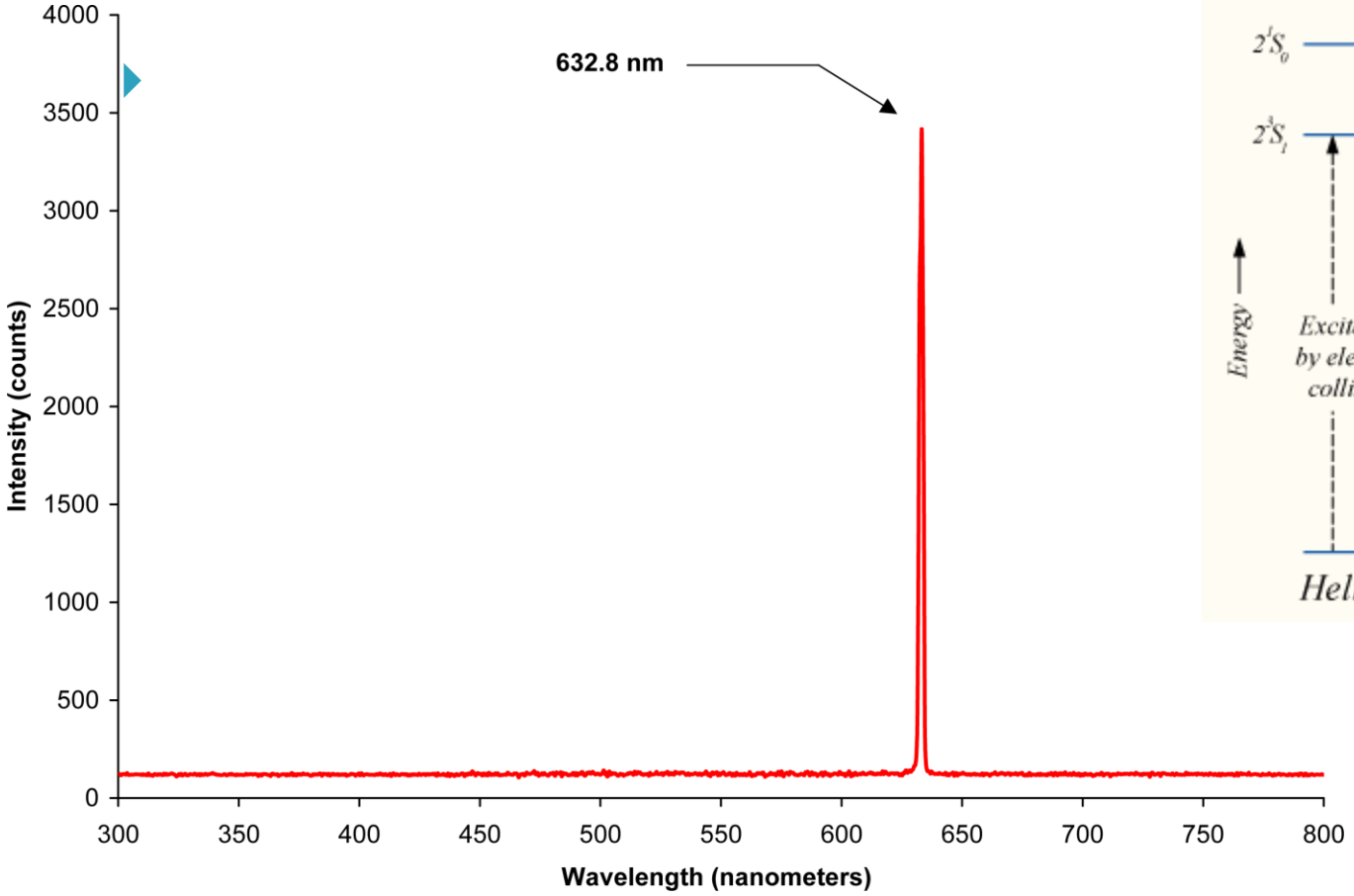
- $D(\lambda) \approx 100 + 0.4\,(850 - \lambda)$ [ps/nm/km] pentru $800 < \lambda < 900$ nm
- $D(\lambda) \leq 3{,}5$ ps/nm/km pentru $1285 < \lambda < 1330$ nm
- $D(\lambda) \leq 17$ ps/nm/km pentru $1525 < \lambda < 1575$ nm

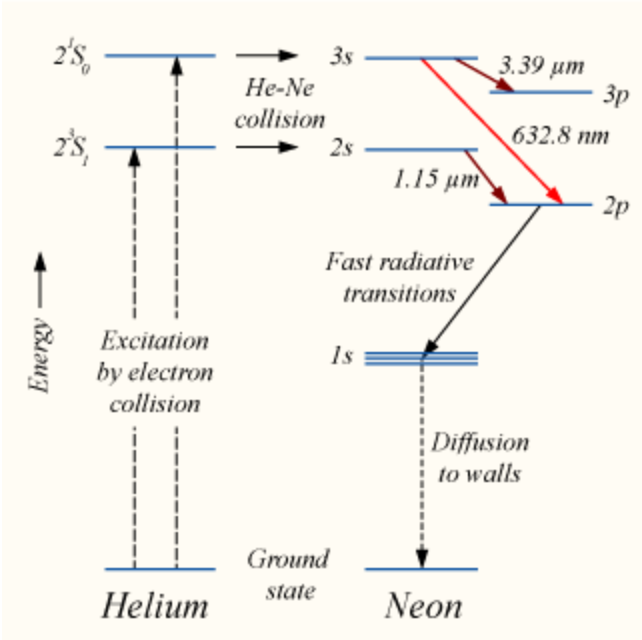
$$D(\lambda) = \frac{S_0}{4}\cdot\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

Calitatea spectrală a emiţătorilor optici



He-Ne Laser





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

Banda

- Dispersia totala

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

- Banda

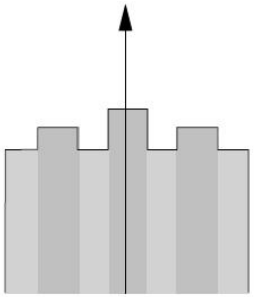
$$B_{opt} = \frac{0.44}{\Delta\tau_{tot}[ns]} \quad [GHz]$$

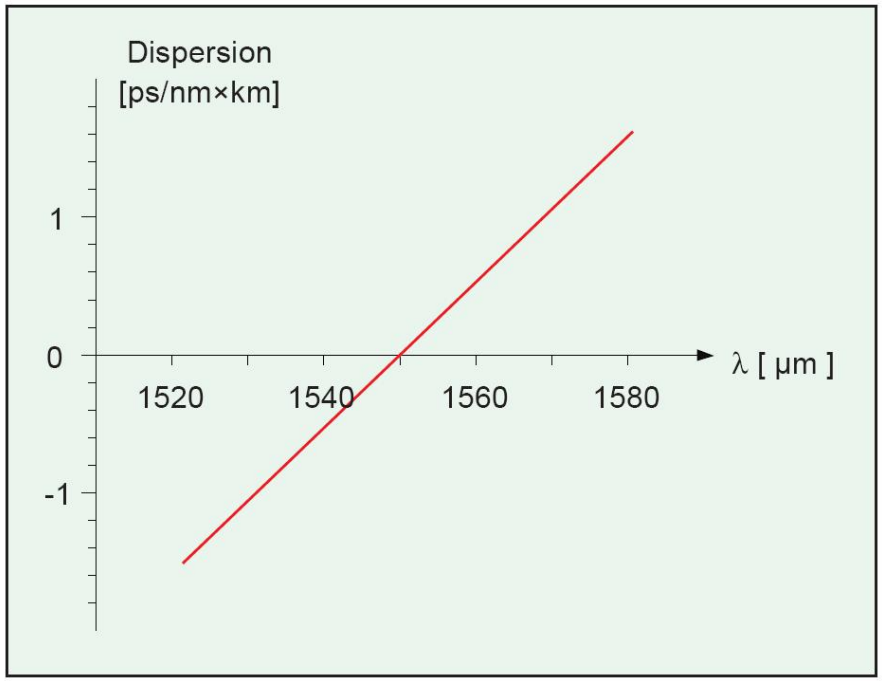
- Banda optica la 3 dB corespunde unei benzi electrice la 6 dB
  - $P_{opt} \sim I; \quad P_{el} \sim I^2$ $\qquad B_{opt} = \sqrt{2} B_{el}$
- Viteza legaturii

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

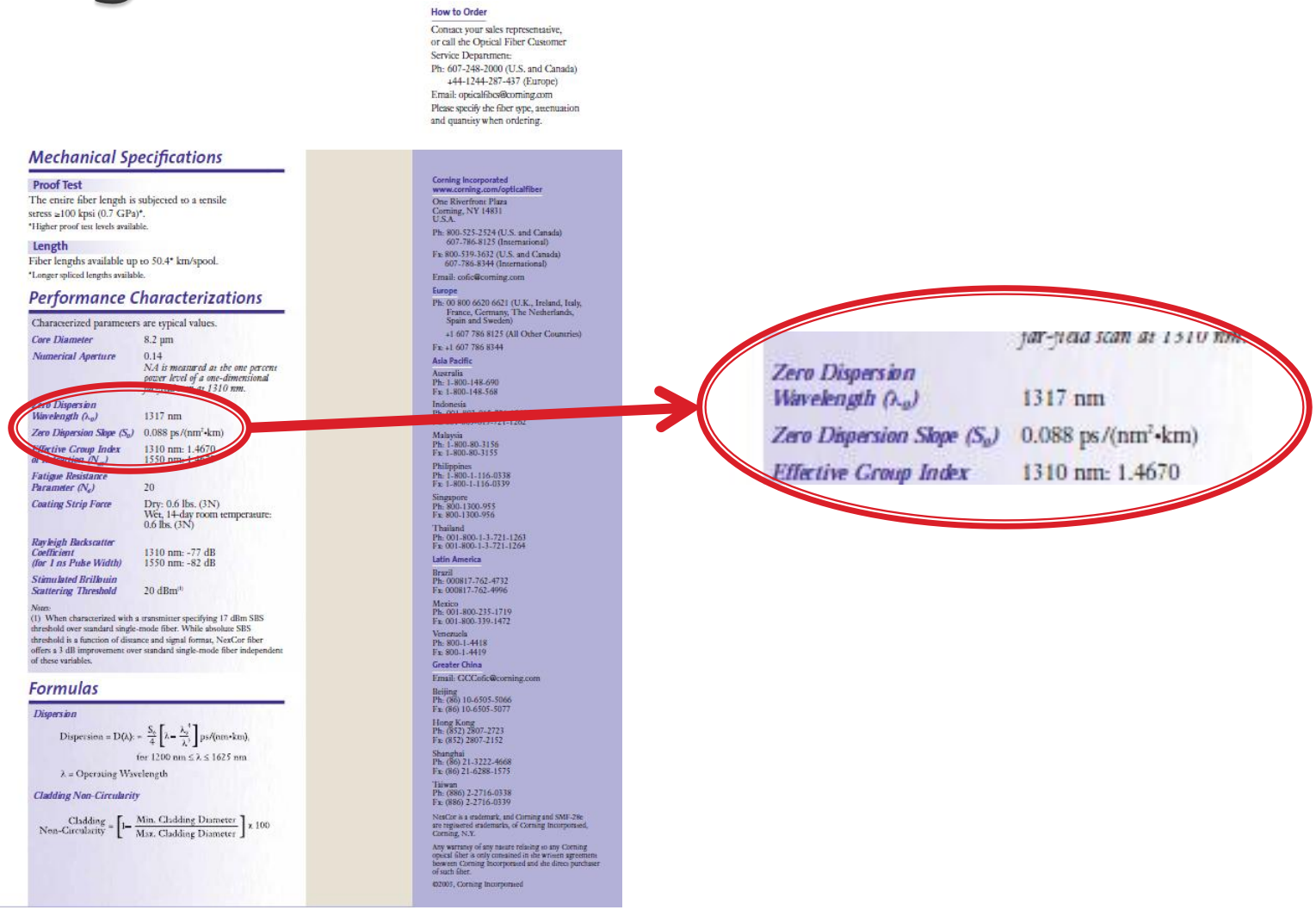
Dispersion shifted fibers

- 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





Catalog



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: 1.4681
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 $1200 \text{ nm} \le \lambda \le 1625 \text{ nm}$

λ = Operating Wavelength

Cladding Non-Circularity

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

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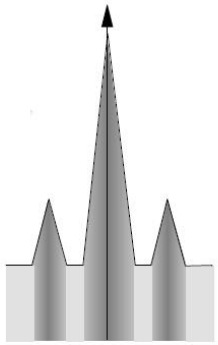
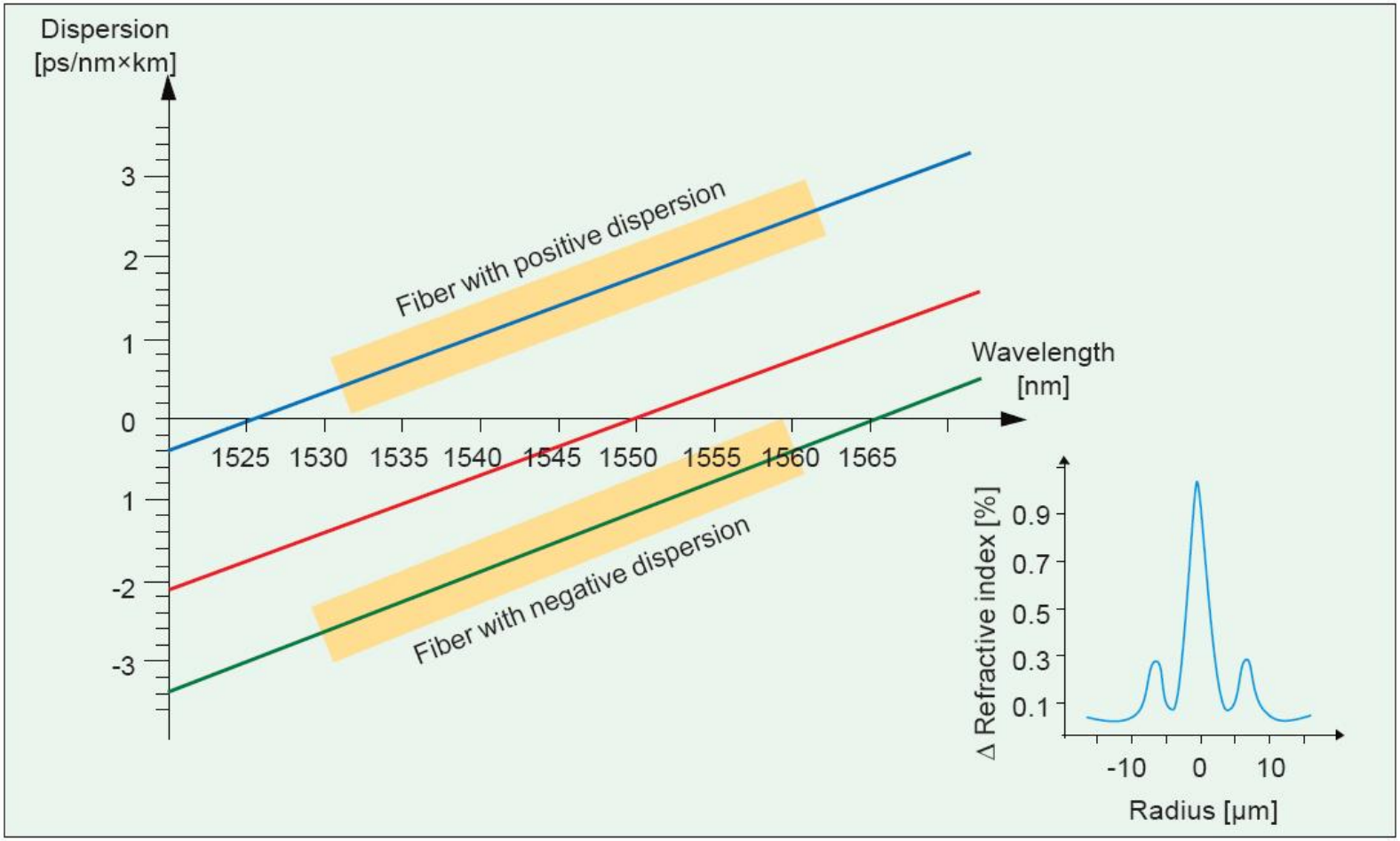
far-field scan at 1310 nm.

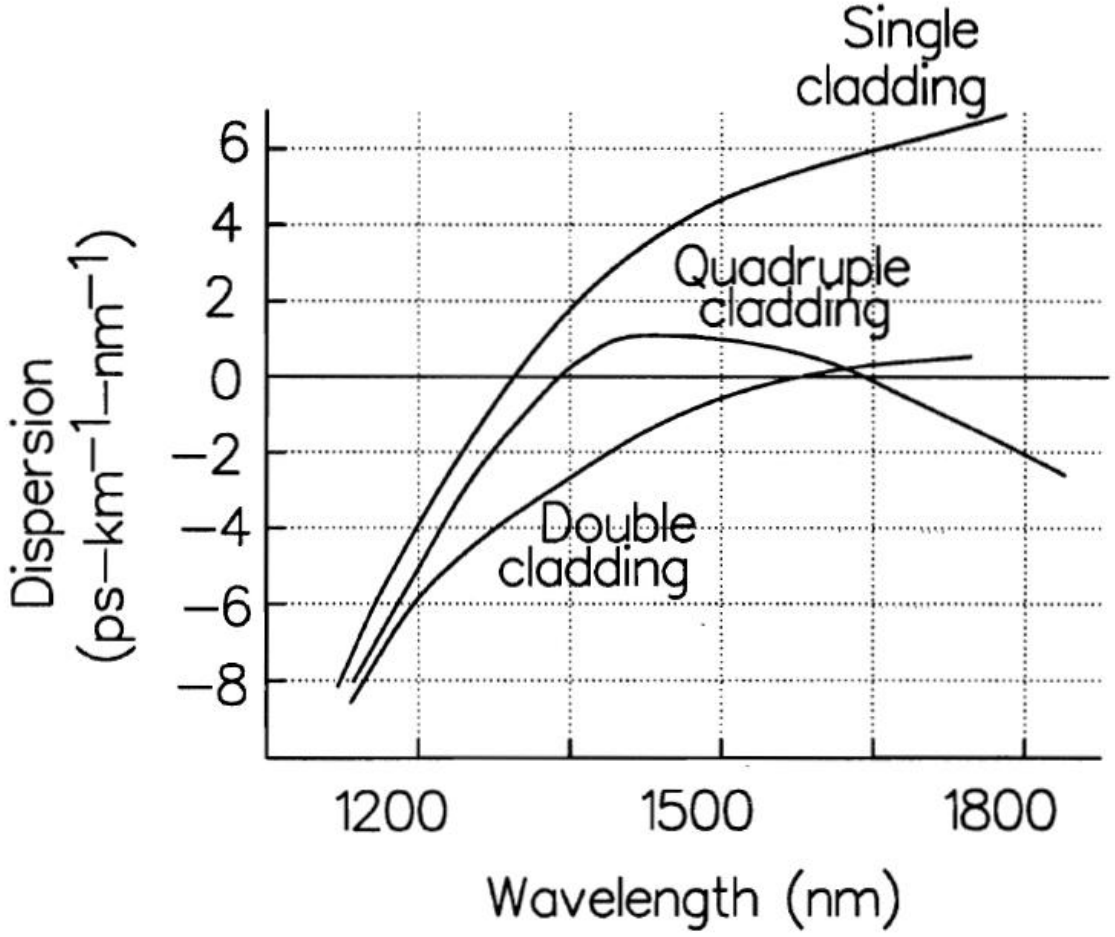
Zero Dispersion Wavelength (λ_0)	1317 nm
Zero Dispersion Slope (S_0)	0.088 ps/(nm²•km)
Effective Group Index	1310 nm: 1.4670

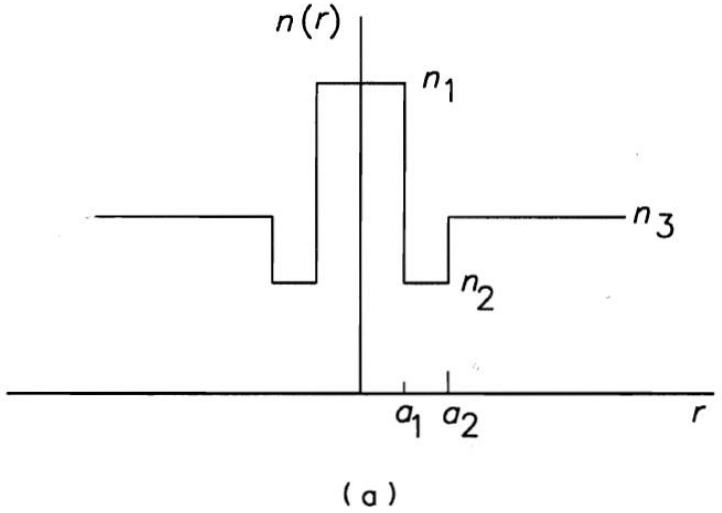
Non-zero Dispersion shifted fibers



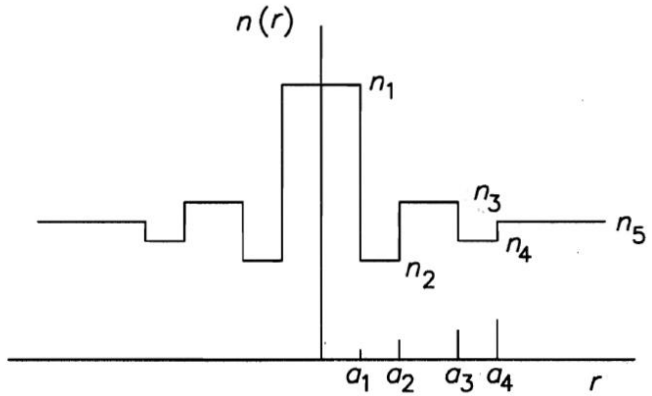


Dispersion shifted fibers



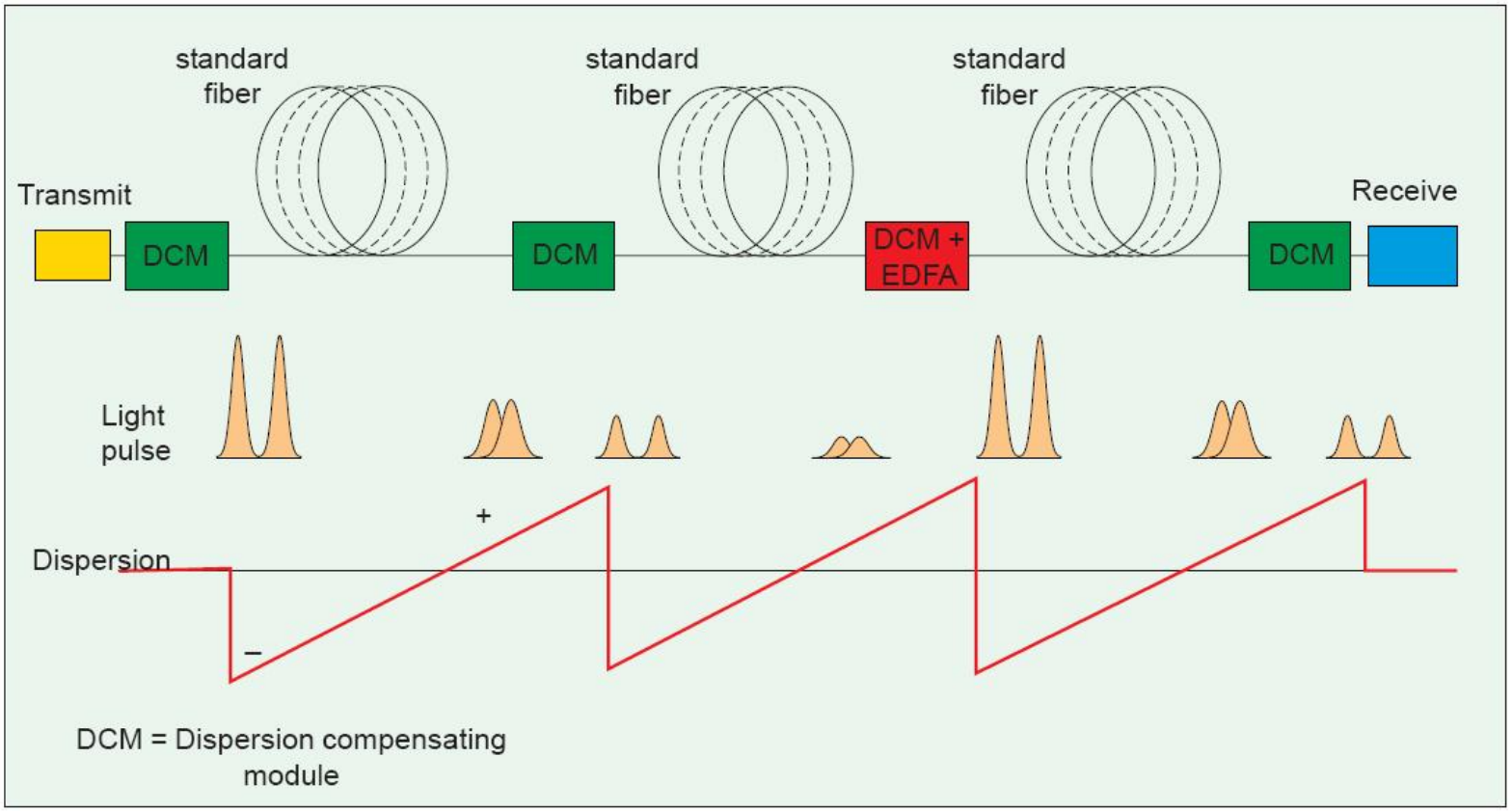


(a)



(b)

Fibra pentru compensarea dispersiei

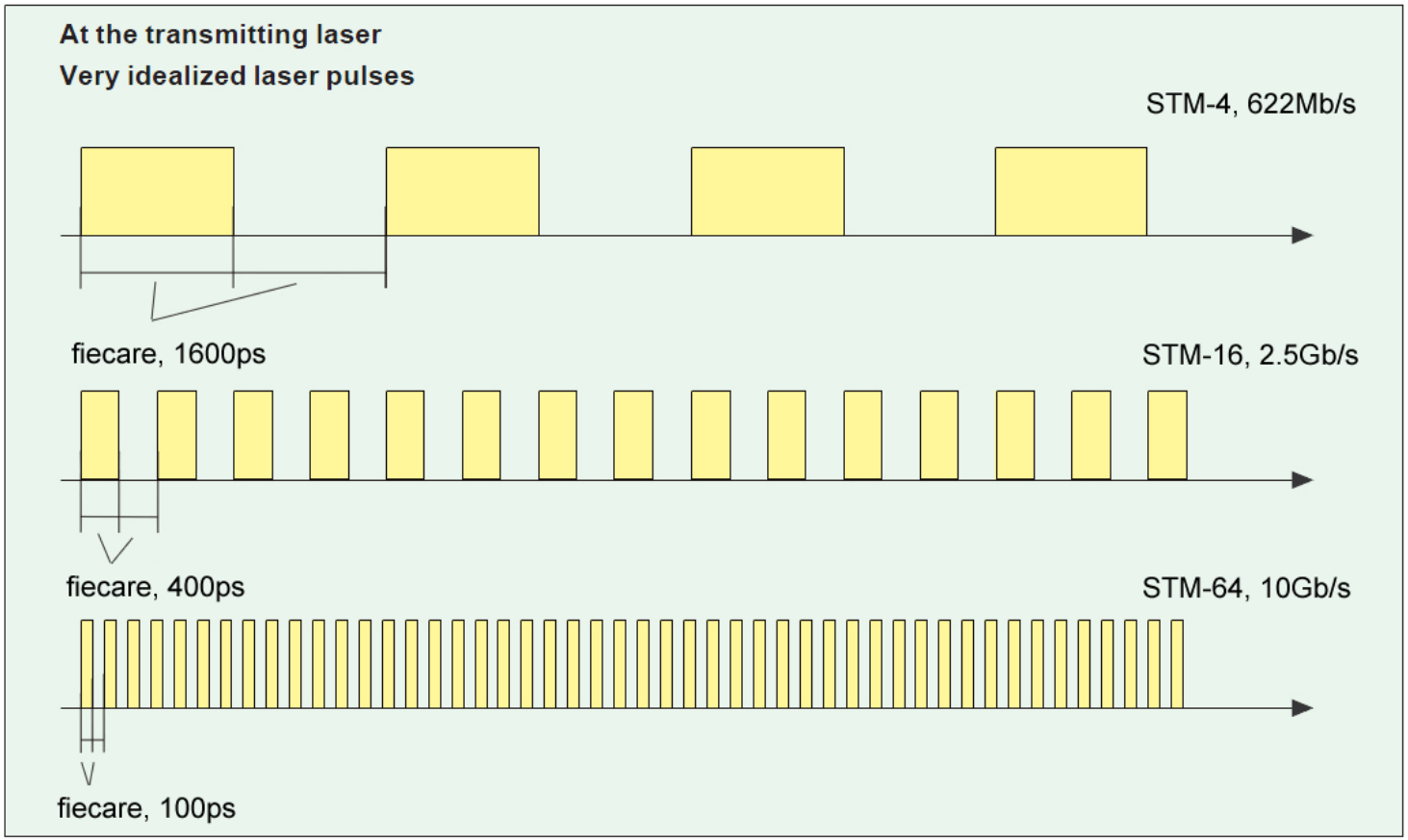


- Dispersie -100 ps/nm/km
- Atenuare 0.5 dB/km

Dispersie exemplu – 1

- transmisii cu viteze diferite

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

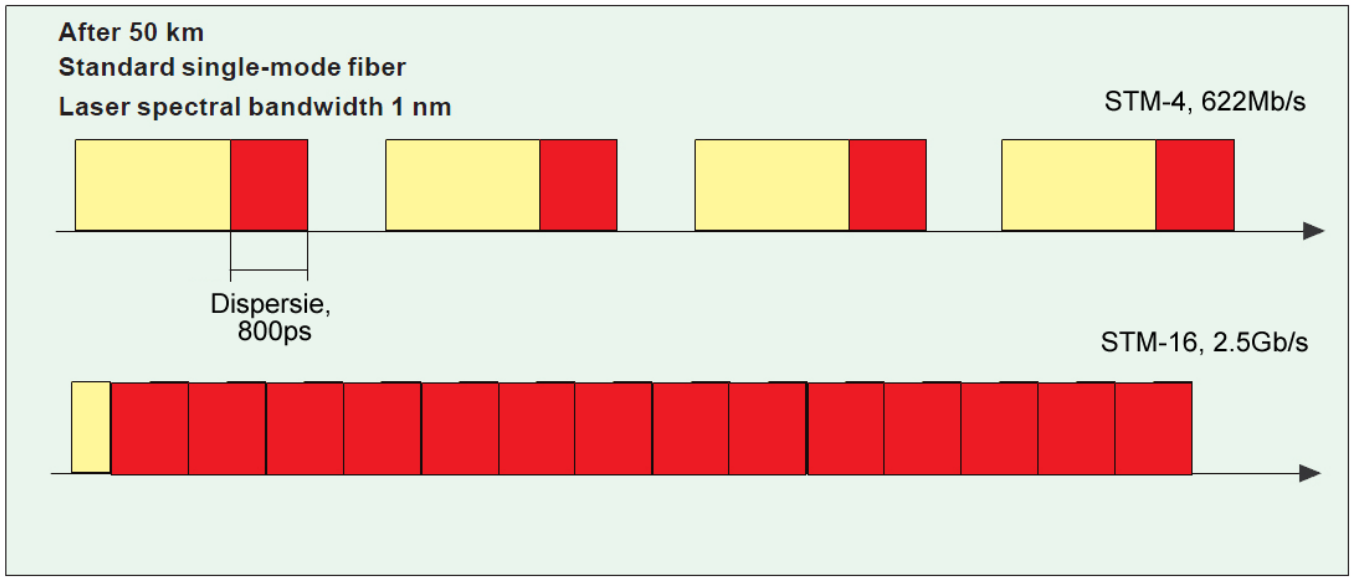


Dispersie exemplu – 2

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

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

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



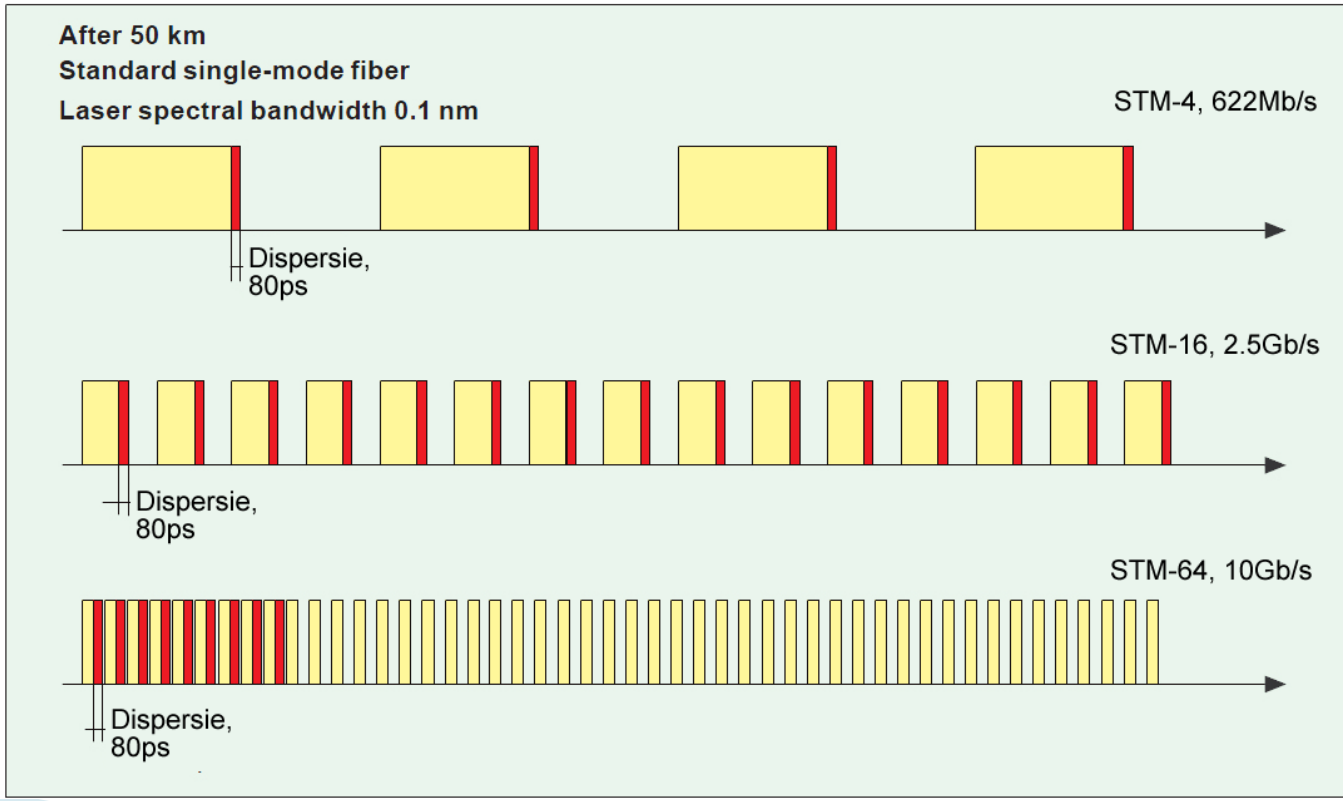
100<400<800<1600

Dispersie exemplu – 3

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

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

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



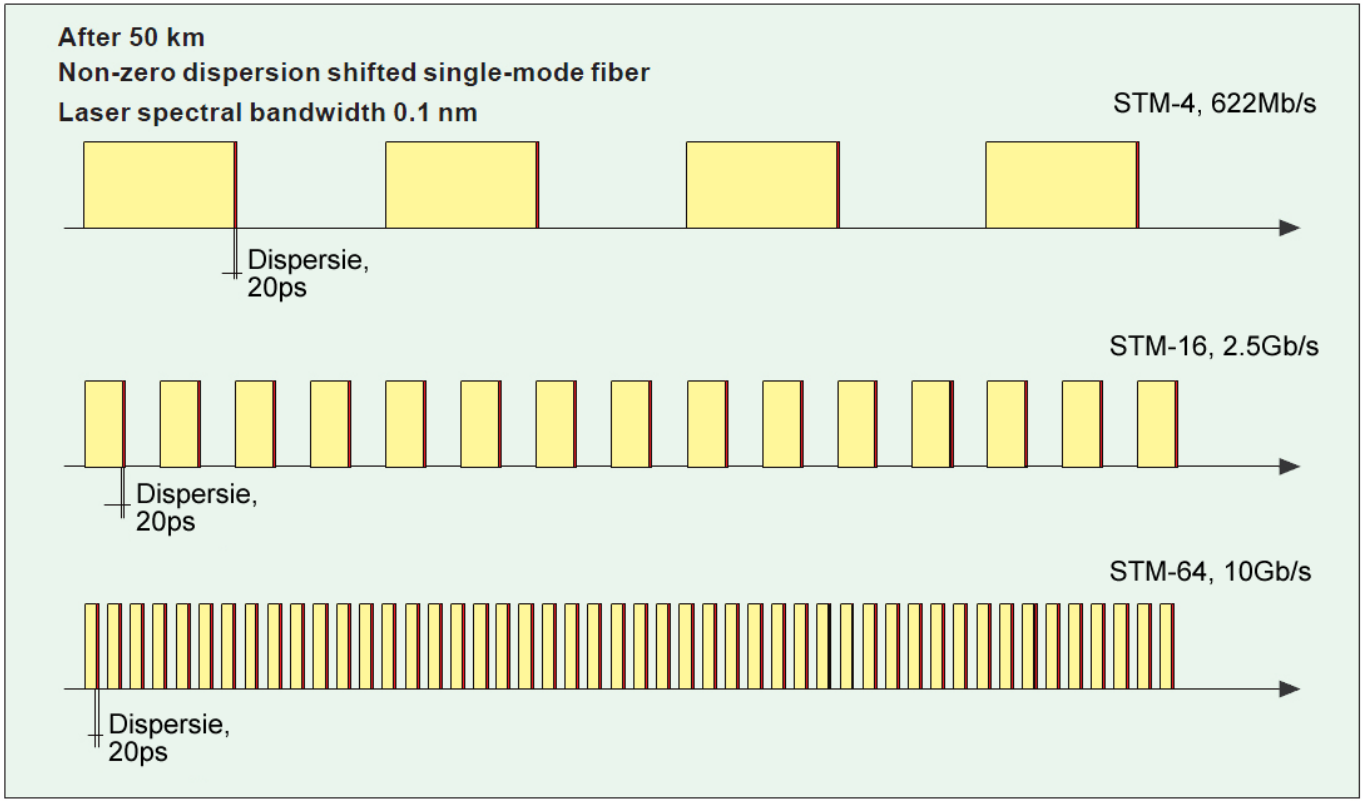
$100 \approx 80 < 400 < 1600$

Dispersie exemplu – 4

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

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

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



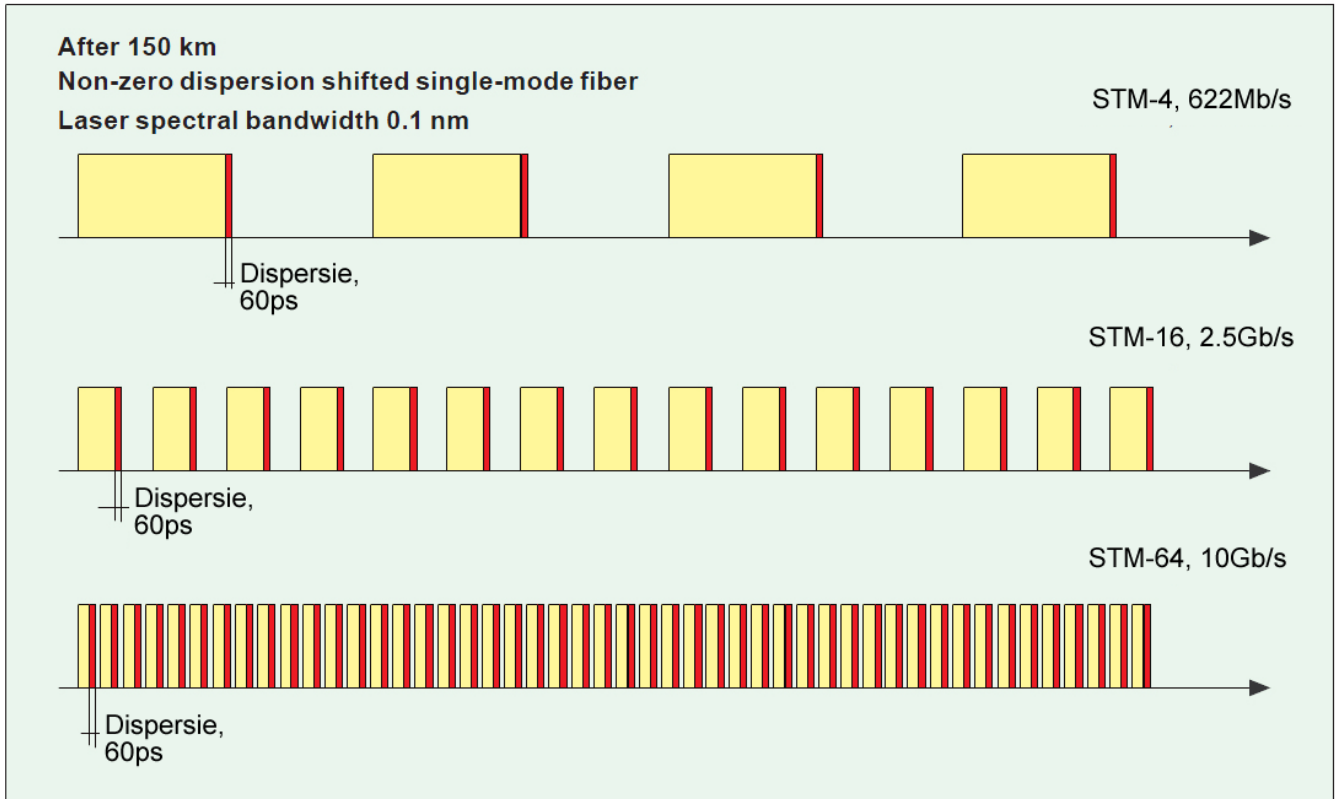
20<100<400<1600

Dispersie exemplu – 5

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

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

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



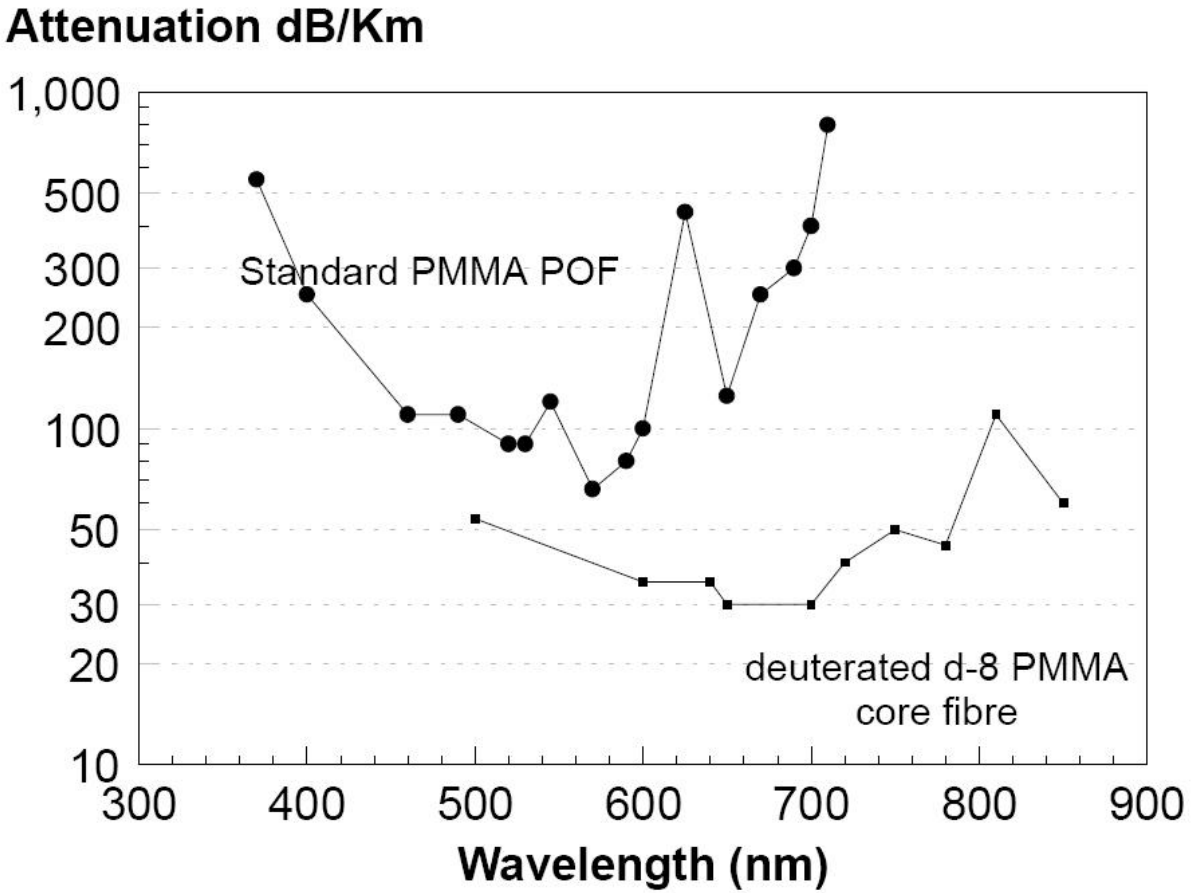
60<100<400<1600

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)

Contact

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