Optoelectronică, structuri şi tehnologii

Curs 4

2016/2017

Disciplina 2016/2017

- 2C/1L Optoelectronică, structuri, tehnologii, circuite, OSTC
- **Minim** 7 prezente curs + laborator
- Curs – sl. Radu Damian
  - Joi 15-18, P5
  - E – 70% din nota
    - **20% test la curs**, saptamana 4-5?
  - probleme + (?1 subiect teorie) + (2p prez. Curs)
    - 2prez=0.5p
  - toate materialele permise
- Laborator – sl. Daniel Matasaru
  - Joi 8-14 par
  - L – 15% din nota
  - C – 15% din nota

Examen partial 2016/2017

- Joi 16.03.2017, 15, P5
  - toate materialele permise
- 20% nota
  - Singura proba la care minim 5 nu e necesar
  - Absenta = 0p
- Primele 3 capitole
  - Introducere
  - Lumina ca undă electromagnetică
  - Fotometrie şi radiometrie

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:

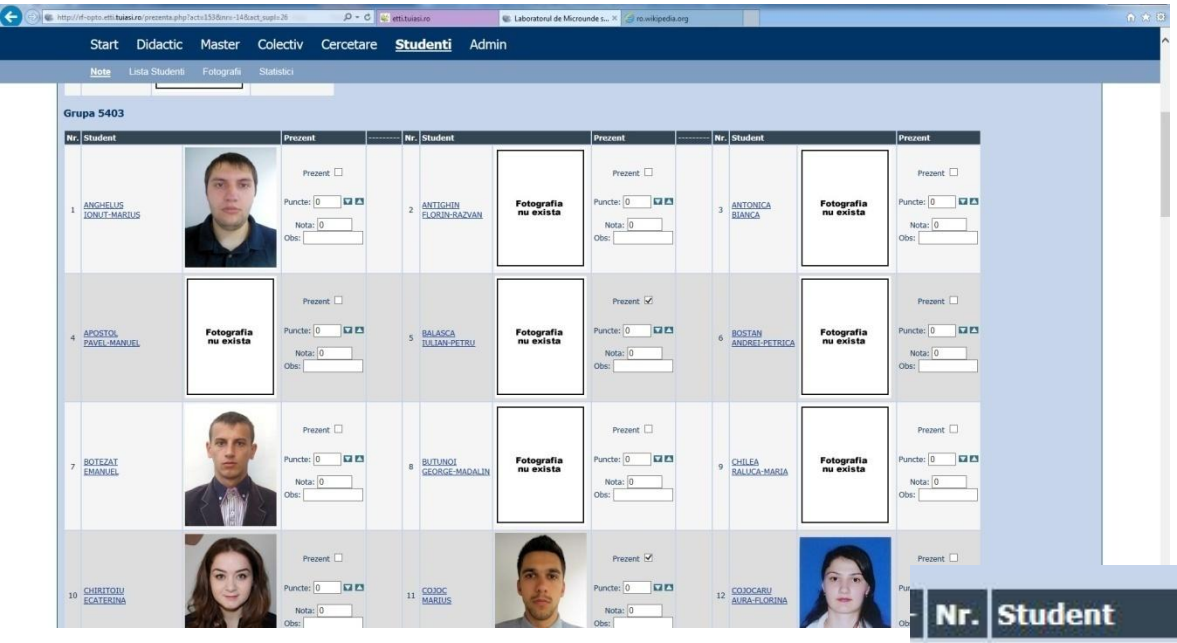
Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Acceseaza ca acest student

Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TW	**Tehnologii 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	-	

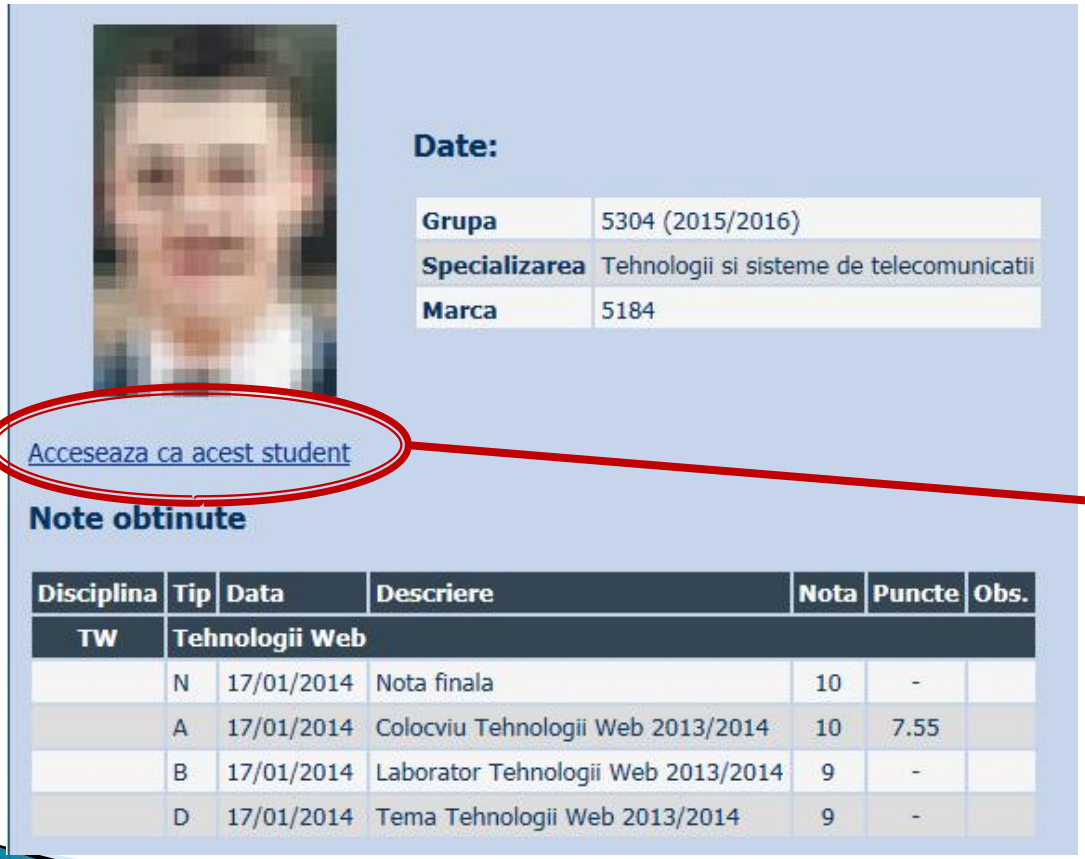
Fotografii


Start Didactic Master Colectiv Cercetare Studenti Admin
Note Lista Studenti Fotografii Statistici
Grupa 5403
Nr. Student Prezent
1 ANGHELUS IONUT-MARIUS
2 ANTIGHIN FLORIN-RAZVAN
3 ANTONICA BIANCA
4 APOSTOL PAVEL-MANUEL
5 BALASCA IULIAN-PETRU
6 BOSTAN ANDREI-PETRICA
7 BOTEZAT EMANUEL
8 BUTUNOI GEORGE-MADALIN
9 CHILEA RALUCA-MARIA
10 CHIRITOIU ECATERINA
11 COJOC MARIUS
12 COJOCARU AURA-FLORINA
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:


Nr.
Student
Prezent
2
ANTIGHIN FLORIN-RAZVAN
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:

Acces

- ~~Personalizat~~



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	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

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]

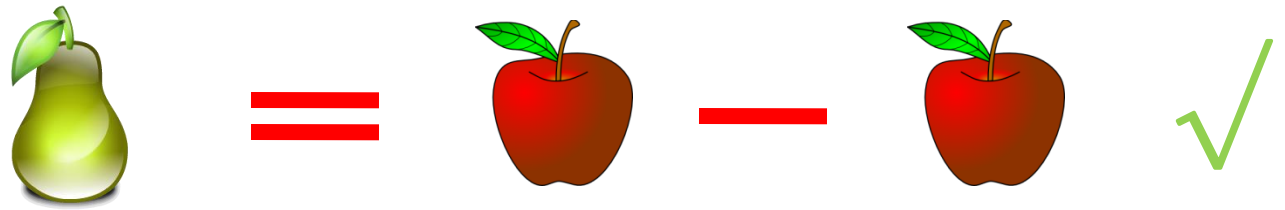
[x] + [dB] = [x]

Calculul atenuarii

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

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

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



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

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/2(3)prez
- 3 teste
- foto

Recapitulare

Curs 3

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%)
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0 dBm	= 1 mW
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20 dBm	= 100 mW
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−10 dBm	= 100 μW
−30 dBm	= 1 μW
−60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

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

[x] + [dB] = [x]

Lumina ca undă electromagnetică

Capitolul 2

Parametri, dependenta de mediu

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\Omega \qquad c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8 \ m/s$$

$n = 1$

$$T = \frac{2\pi}{\omega} = \frac{1}{f} \qquad \lambda_0 = \frac{2\pi}{\beta} = \frac{c_0}{f}$$

$$\eta = \frac{\eta_0}{n} \qquad c = \frac{c_0}{n}$$

$n = \sqrt{\varepsilon_r}$

$$T = \frac{2\pi}{\omega} = \frac{1}{f} \qquad \lambda = \frac{c_0}{n \cdot f} = \frac{\lambda_0}{n}$$

$$\lambda = \lambda(n)$$

$$f = \text{indep.}$$

ITU G.692

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

SI

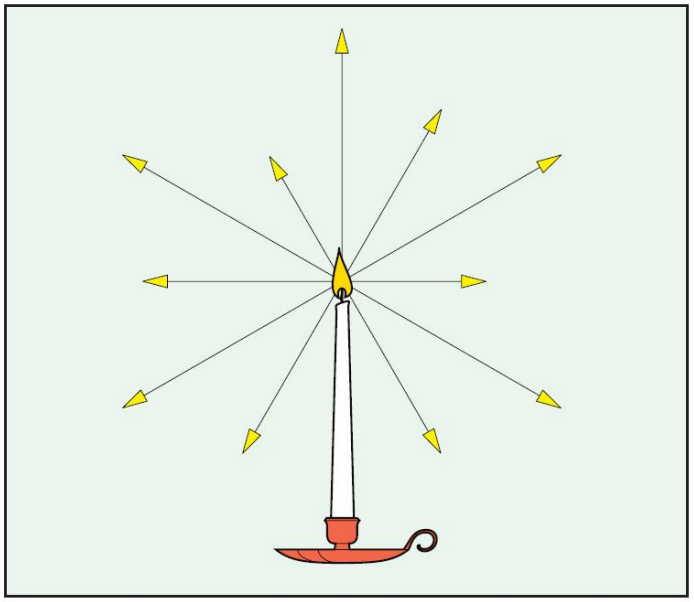
"a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz"

Optică geometrică

Capitolul 2

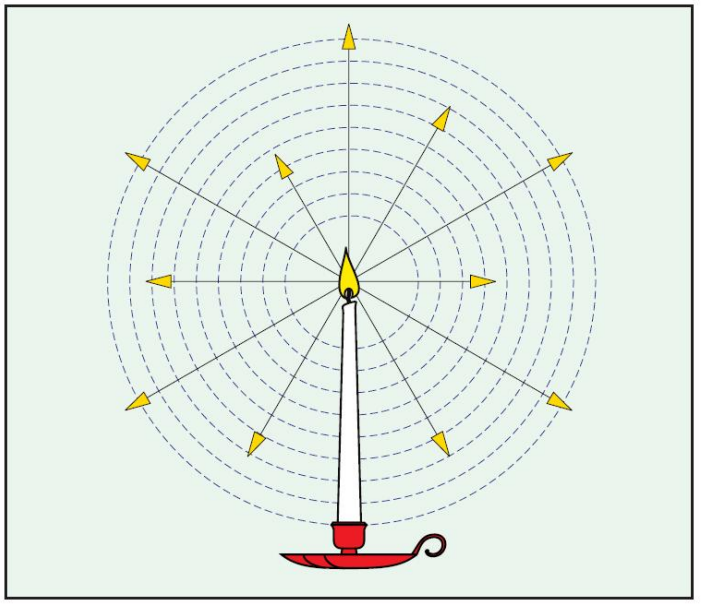
Raze de lumina

- Lumina este constituita din raze care se propaga in linie dreapta in medii omogene
- Sursa omnidirectionala: emite similar in toate directiile



- Energia luminoasa descreste invers proportional cu patratul distantei fata de sursa (energia se imparte uniform pe suprafata intregii sfere)

$$P = \frac{P_0}{r^2}$$



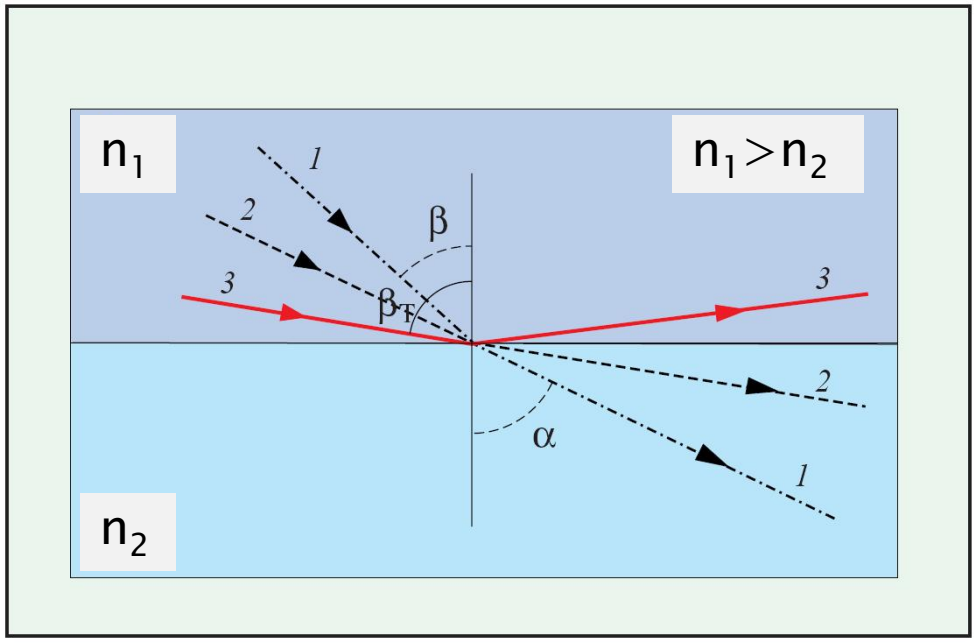
Reflexia totala

- Apare **numai când** lumina se propaga dintr-un mediu mai dens optic intr-un mediu mai puțin dens
- La intersecția luminii cu suprafața de separație a doua medii se întâlnesc in general raze reflectate **si** raze refractate
- Pentru un unghi de incidenta numit **unghi critic**, raza refractata se obține in lungul suprafeței de separație
- Pentru orice unghi mai mare decât unghiul critic exista numai raza reflectata

$$n_1 > n_2; \quad \phi_R = 90°$$

$$n_1 \cdot \sin\phi_C = n_2$$

$$\phi_C = \arcsin\left(\frac{n_2}{n_1}\right)$$



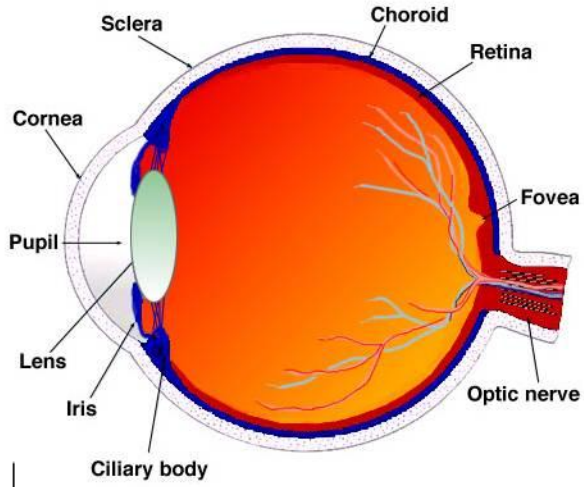
Fotometrie şi radiometrie

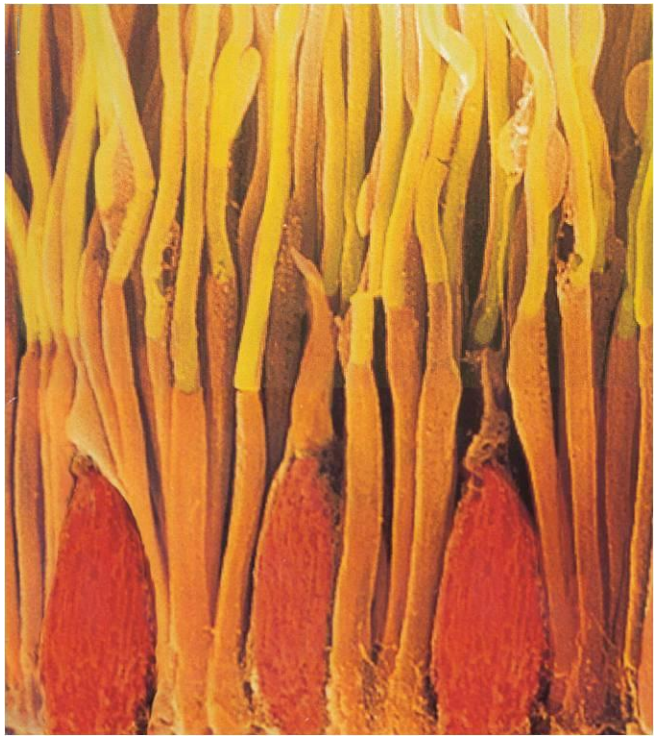
Capitolul 3

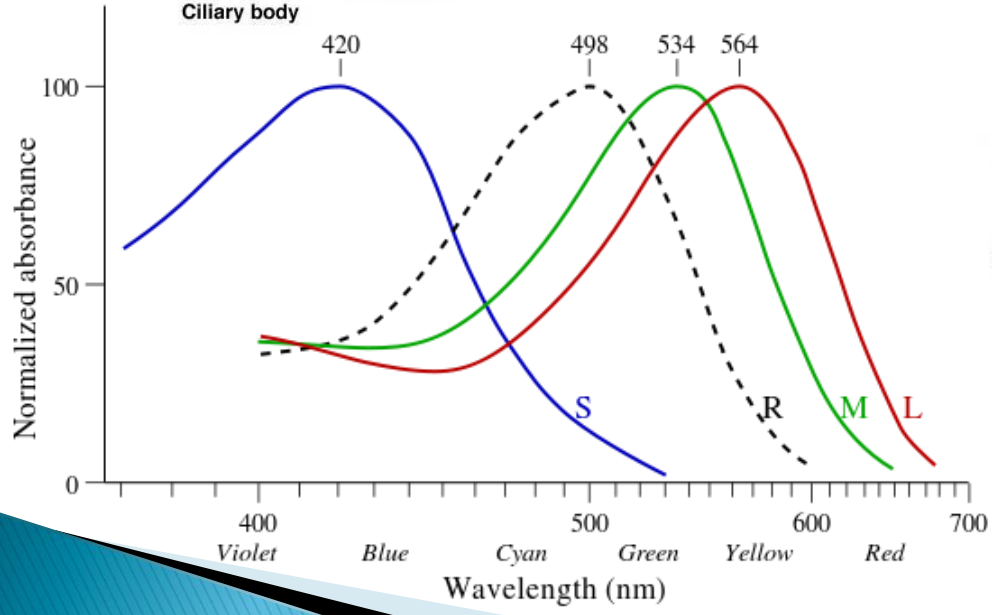
O alta dualitate

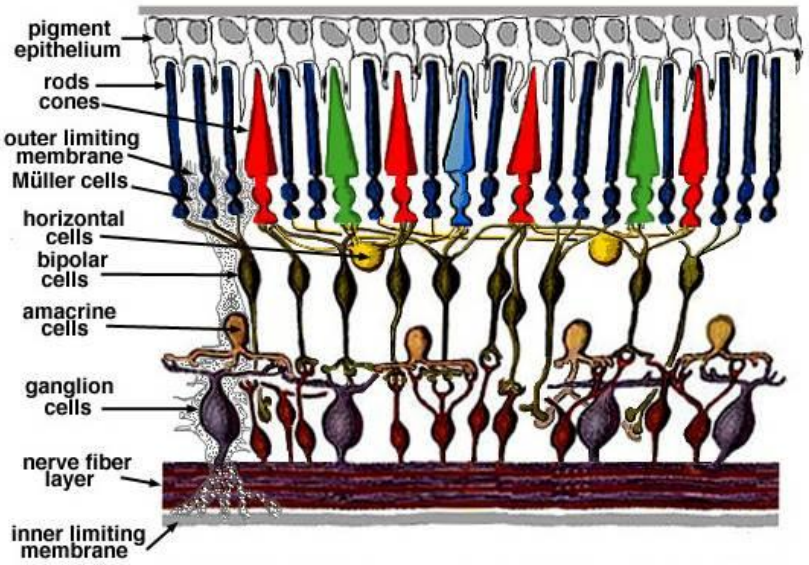
- In optoelectronica, lumina poate fi privita din doua puncte de vedere
  - energetic (efect asupra dispozitivului)
  - uman (efect asupra ochiului uman)
- Dualitatea mărimilor implicate
  - energetice
  - luminoase
- Candela (cd) **este** una din cele 7 mărimi fundamentale ale SI
  - Cd = intensitatea luminoasa a unei surse ce emite o radiație monocromatica cu frecventa $540 \cdot 10^{12}$ Hz (λ = 555nm in vid) si are o intensitate radianta de 1/683 W/sr

Ochiul uman


Sclera
Choroid
Retina
Cornea
Fovea
Pupil
Lens
Iris
Optic nerve
Ciliary body



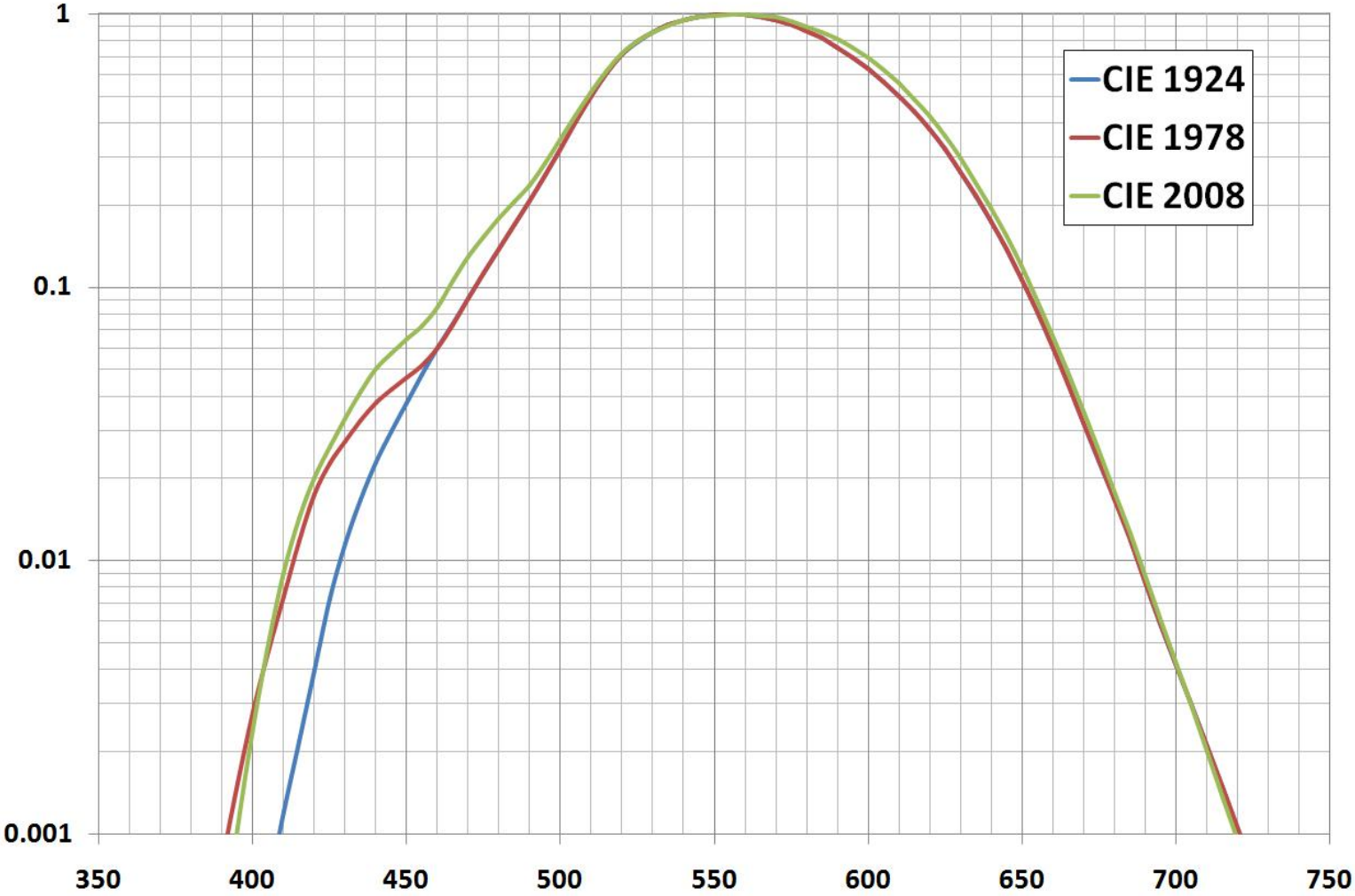

420
498
534
564
100
50
0
Normalized absorbance
S
R
M
L
400
500
600
700
Violet
Blue
Cyan
Green
Yellow
Red
Wavelength (nm)


pigment epithelium
rods
cones
outer limiting membrane
Müller cells
horizontal cells
bipolar cells
amacrine cells
ganglion cells
nerve fiber layer
inner limiting membrane

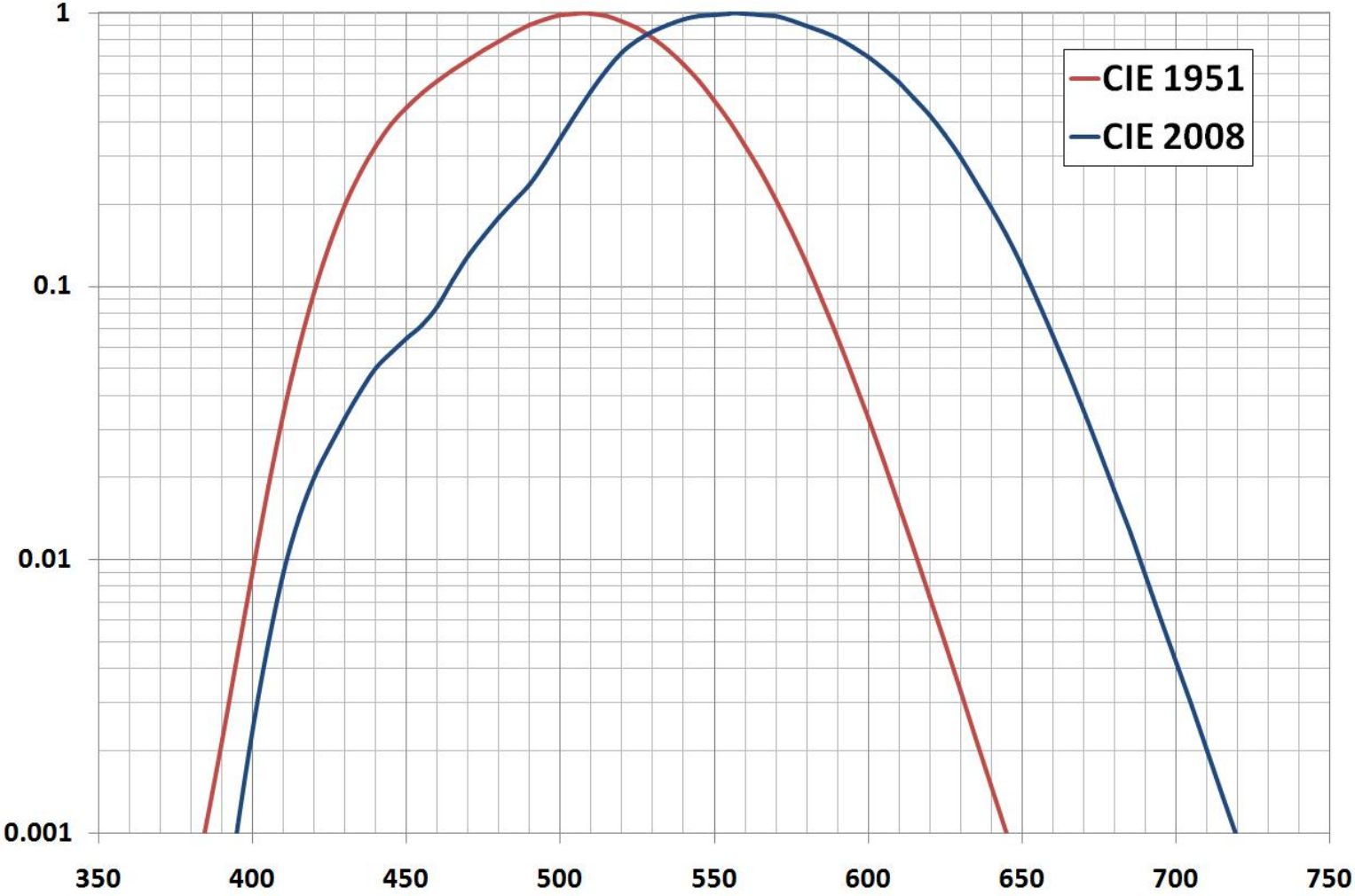
Standarde

- Se incearca definirea omului “standard”
- CIE – Commission Internationale de l'Éclairage
  - 1931 – luminozitatea relativa standard V(λ) – **fotopic**
  - 1951 – luminozitatea relativa standard V(λ) – **scotopic**
  - 1978 – Vos
  - 2005 – Sharpe, Stockman, Jagla, Jägle
  - 2008 – CIE V(λ) – fotopic (~Sharpe)
- Sensibilitatea maxima a ochiului uman
  - vedere diurna (**fotopic**), $\lambda=555$ nm, $\eta_v = 683$ lm/W
  - vedere nocturna (**scotopic**), $\lambda=507$ nm , $\eta_v = 1700$ lm/W

CIE V(λ) fotopic



CIE V(λ) fotopic / scotopic



Marimi luminoase

- Intensitatea
  - raportul dintre fluxul care părăseşte sursa şi se propagă într-un element de unghi solid ce conţine direcţia de propagare şi elementul de unghi solid.
  - o masura a puterii emise de o sursa intr-un element de unghi solid

Intensitatea			
Fotometrie		Radiometrie	
$I_v = \frac{d\Phi_v}{d\Omega}$	SI: cd	$I_e = \frac{d\Phi_e}{d\Omega}$	SI: W/sr

Directivitatea radiatiei exterioare

- SLED
  - radiatia este emisa cu simetrie circulara, in interiorul unui con cu unghi la varf tipic de 60°
  - Viewing Half Angle ~ 10÷15°
- ELED
  - radiatia emisa nesimetric in forma de con eliptic
    - perpendicular pe jonctiune ~60°
    - paralel cu jonctiunea ~30°

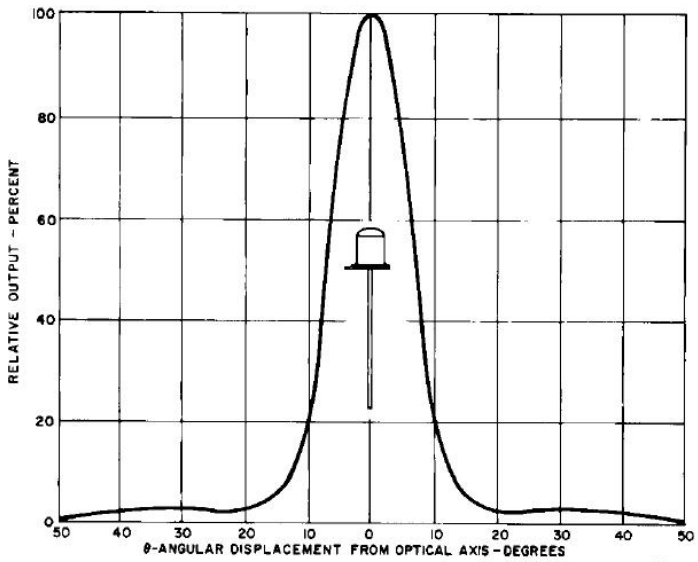
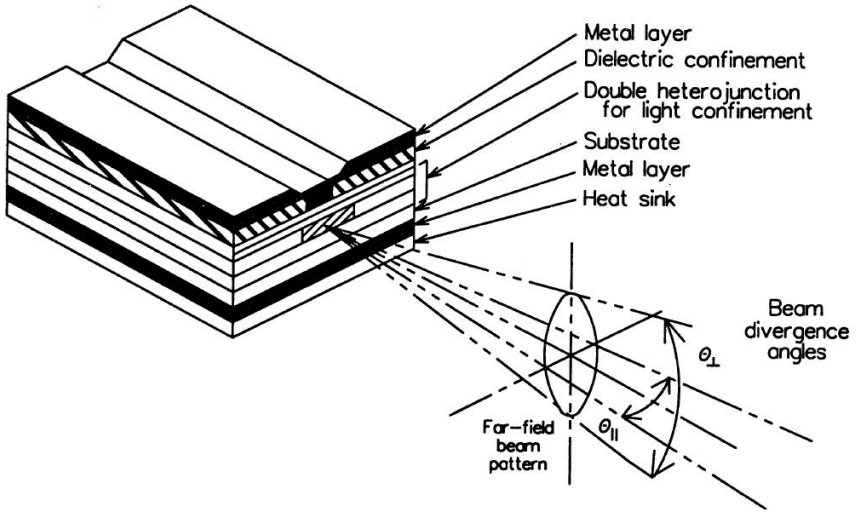


Fig. 5. Typical Radiation Pattern



Directivitatea radiatiei exterioare

- Sursa lambertiana

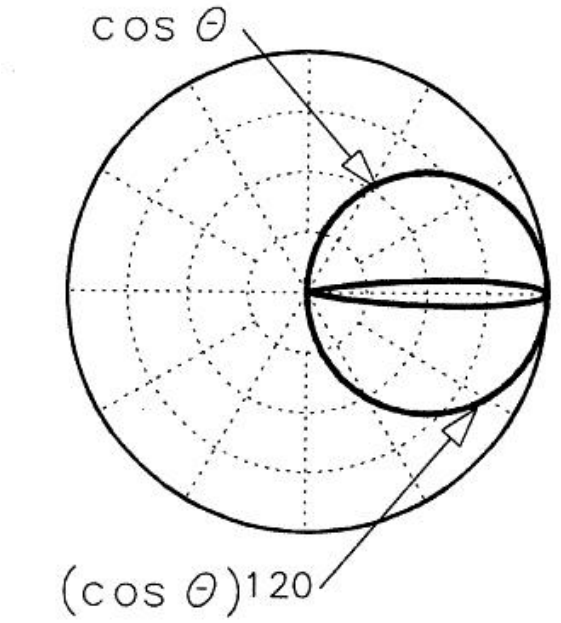
$$P(\theta) = P_0 \cdot \cos\theta$$

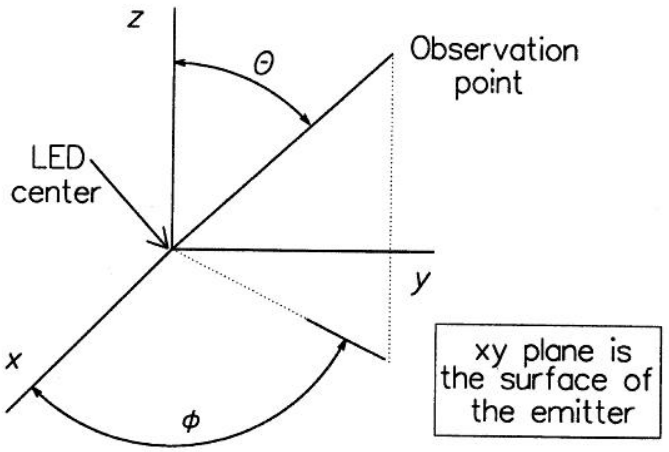
- Aproximatie Lambertiana pentru surse cu directivitate crescuta

$$P(\theta) = P_0 \cdot \cos^n \theta$$

- Surse cu emisie asimetrica

$$P(\theta) = \frac{P_0}{\frac{\sin^2 \phi}{\cos^T \theta} + \frac{\cos^2 \phi}{\cos^L \theta}}$$





Marimi luminoase

- Standardele pentru surse luminoase (de ex. semne de circulatie), iluminarea spatiilor de lucru/odihna sunt concepute cu marimi luminoase
- de multe ori se adapteaza relatiile pentru surse mai simple:

$$I_v = \frac{d\Phi_v}{d\Omega} \rightarrow I_v = \left.\frac{\Phi_v}{\Omega}\right|_{I_v \approx ct.\, in\, \Omega} \qquad E_v = \frac{d\Phi_v}{dS} \rightarrow E_v = \left.\frac{\Phi_v}{S}\right|_{\Phi_v \approx ct.\, pe\, S}$$

$$\Phi_v = 683\frac{lm}{W}\int_{390nm}^{830nm}\frac{d\Phi_e}{d\lambda}\cdot V(\lambda)\,d\lambda \rightarrow \Phi_v = 683\frac{lm}{W}\cdot\sum_i \Phi_e(\lambda_i)\cdot V(\lambda_i)$$

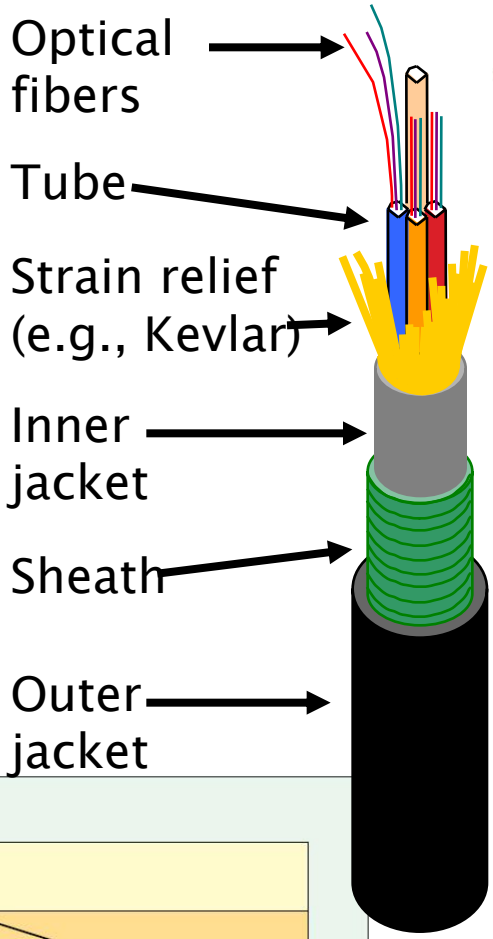
Continuare

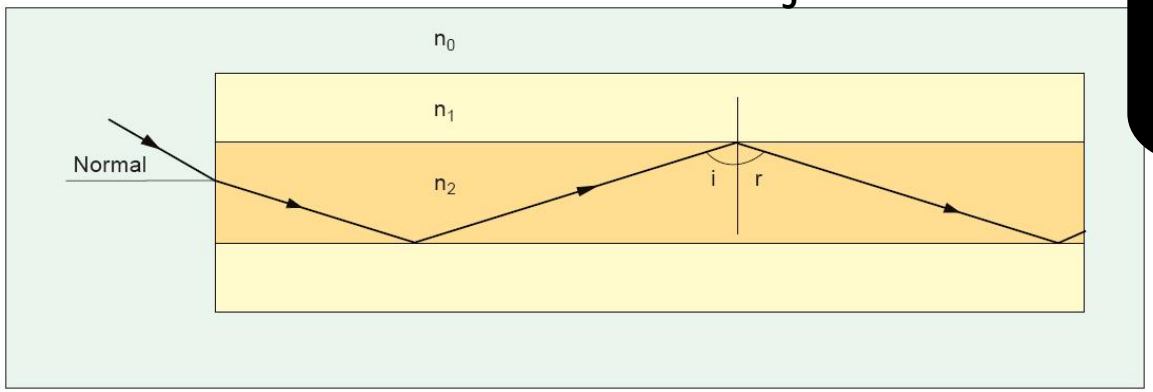
Fibra optică

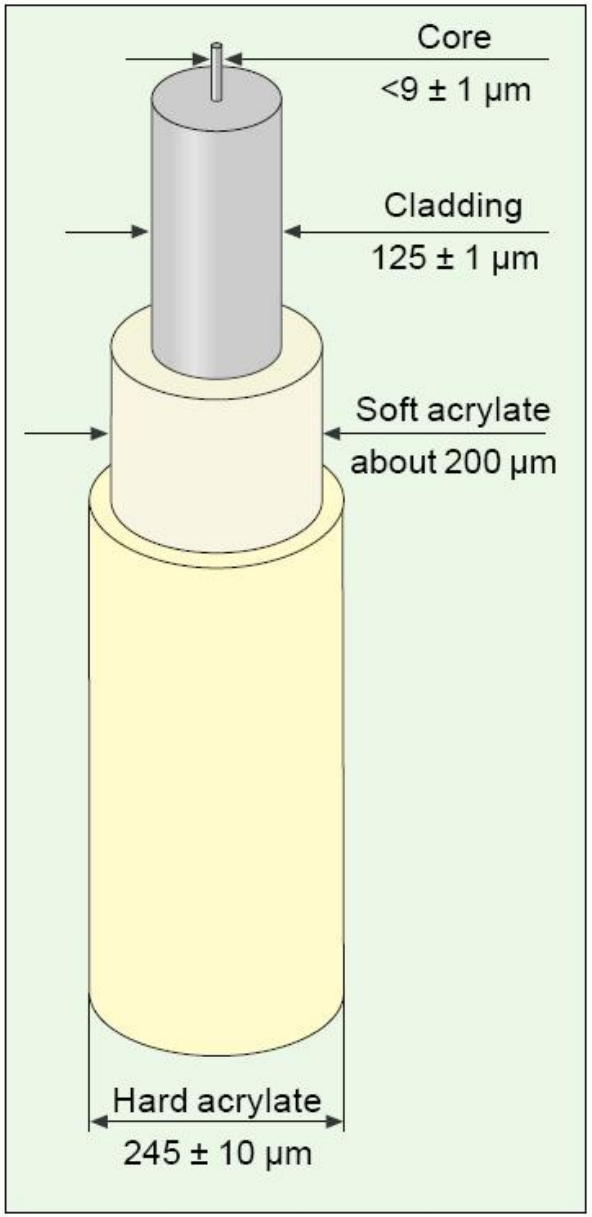
Capitolul 4

Fibra optica

- un ghid de unda dielectric
  - miez
  - teaca

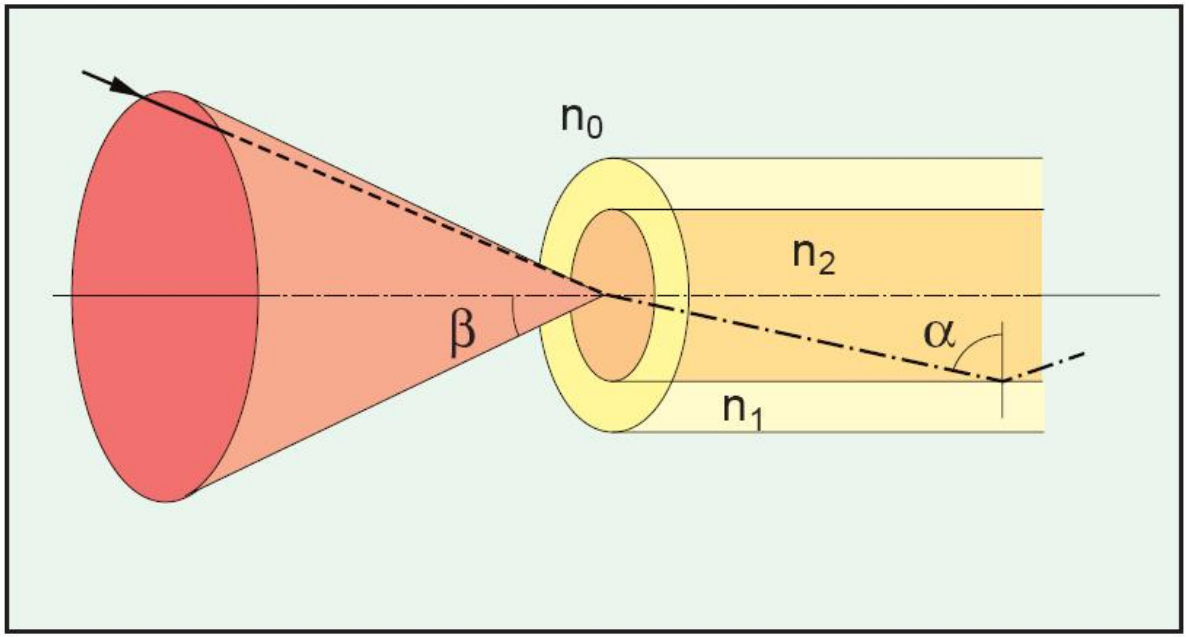






Unghi de acceptanta, apertura numerica

- Unghi de acceptanta



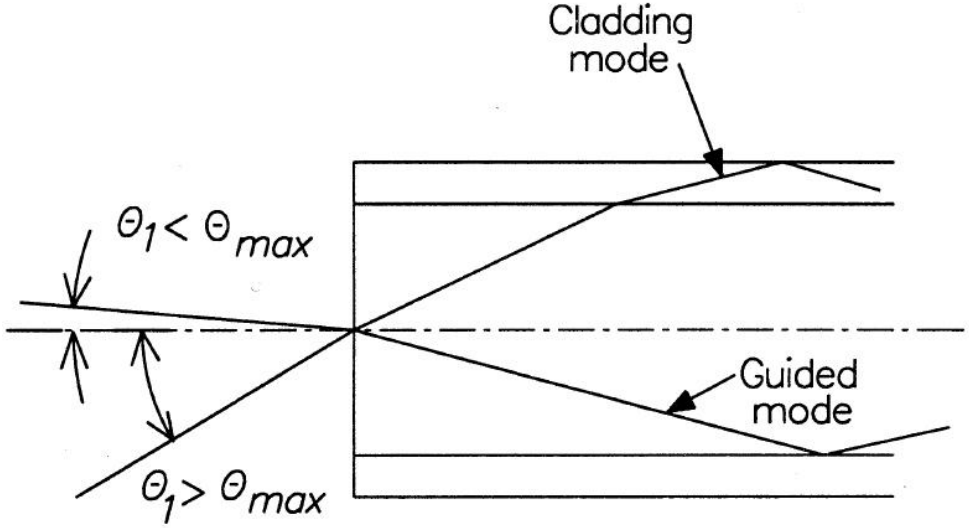
$$n_0 \cdot \sin\theta_{ACC} = n_2 \cdot \sin\phi_c$$

- **Apertura numerica**

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

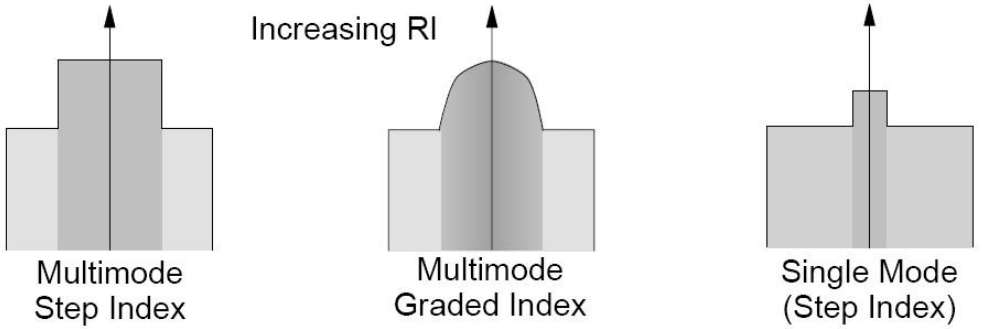
$$NA = n_2\sqrt{\frac{n_2^2 - n_1^2}{n_2^2}} = \sqrt{n_2^2 - n_1^2}$$

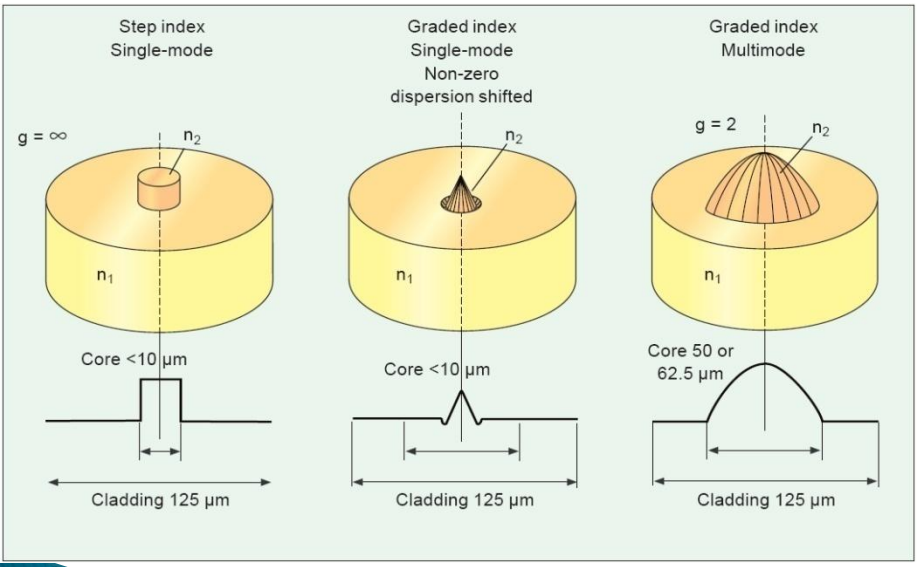
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

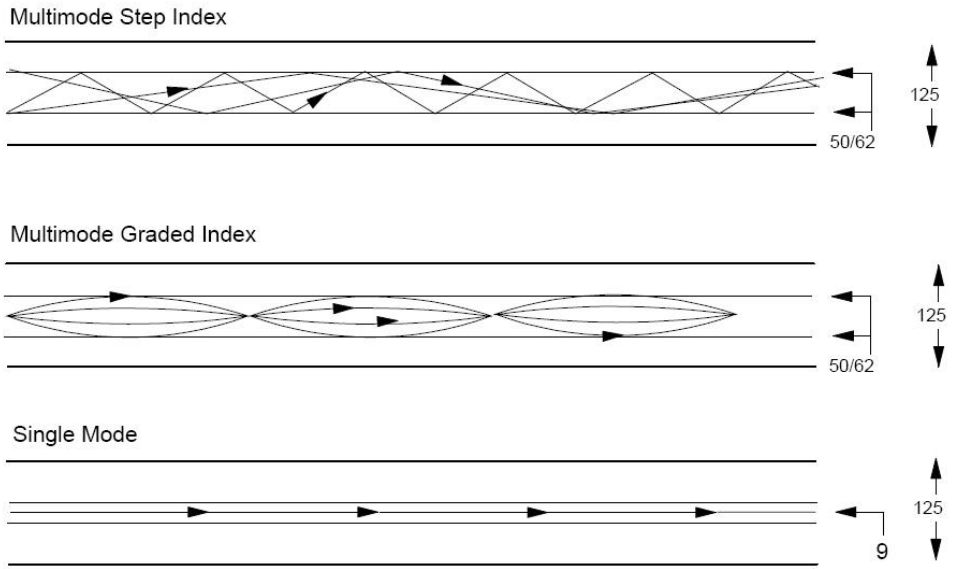


Tipuri de fibra

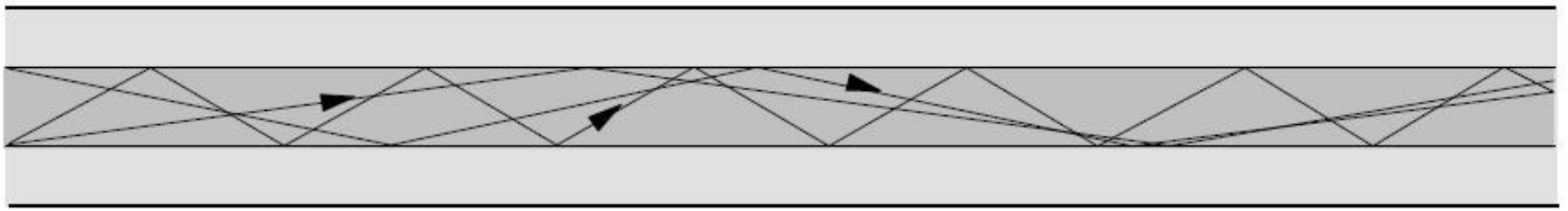
- Monomod
- Multimod
  - cu salt de indice
  - cu indice gradat



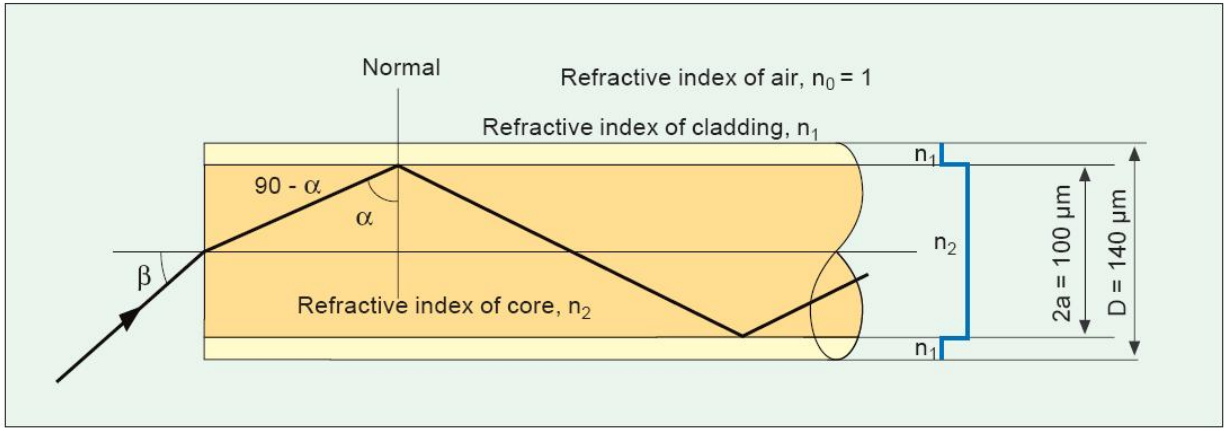


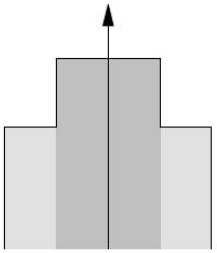


Fibre multimod cu salt de indice



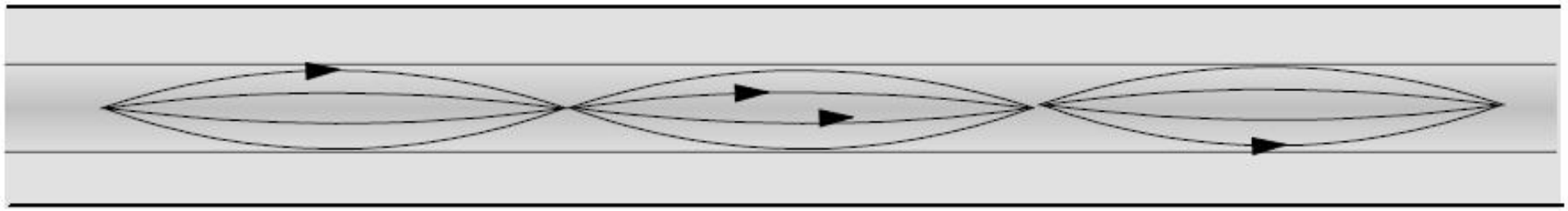
- 50/125 sau 62.5/125 (µm)
- 15–50 MHz · km



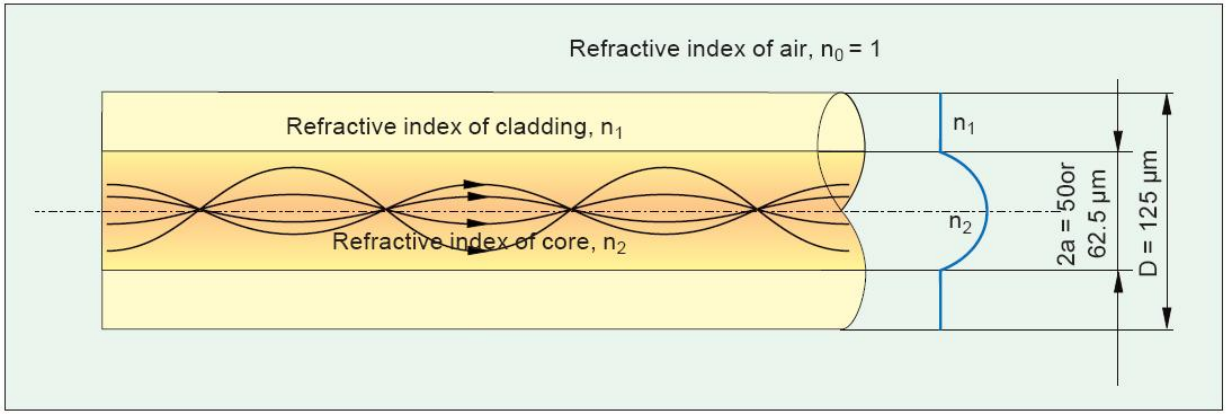


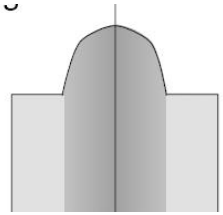
	glass	plastic
core diameter 2a	100 µm	980 µm
cladding diameter D	140 µm	1000 µm
core refractive index n_2	1.48	
cladding refractive index n_1	1.45	

Fibre multimod cu indice gradat



- 50/125 sau 62.5/125 (µm)
- 700–1200 MHz·km

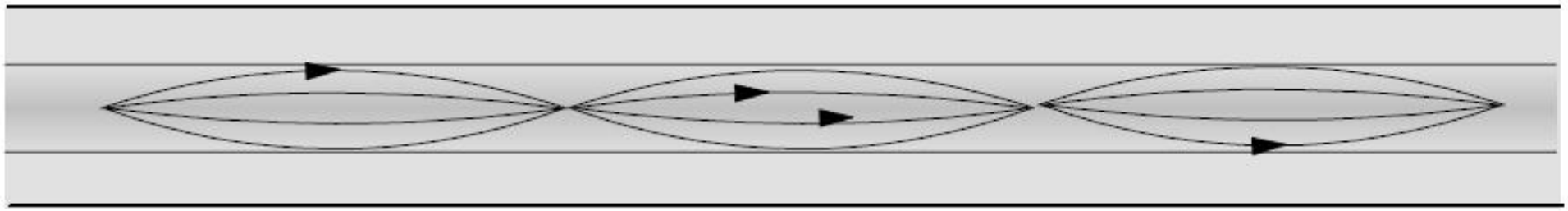




Core diameter 2a	50 or 62.5 µm
Cladding diameter D	125 µm
Maximum refractive index, core	1.46
Relative differential refractive index	0.010

Fata Morgana

Fibre multimod cu indice gradat

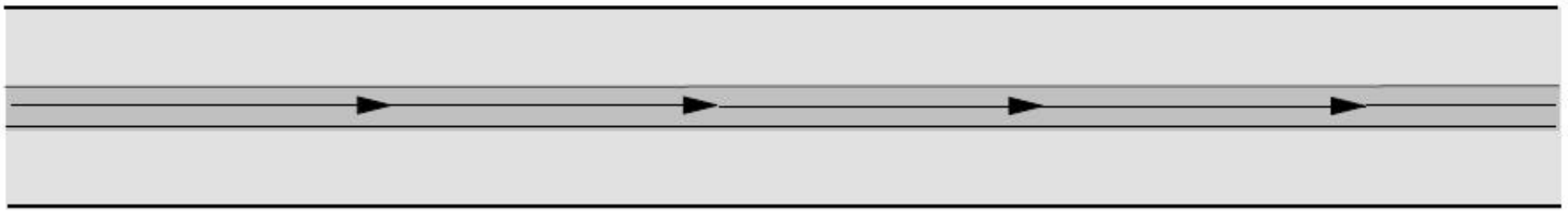


$$n(r) = n_2\left[1 - \Delta\left(\frac{r}{a}\right)^g\right]$$

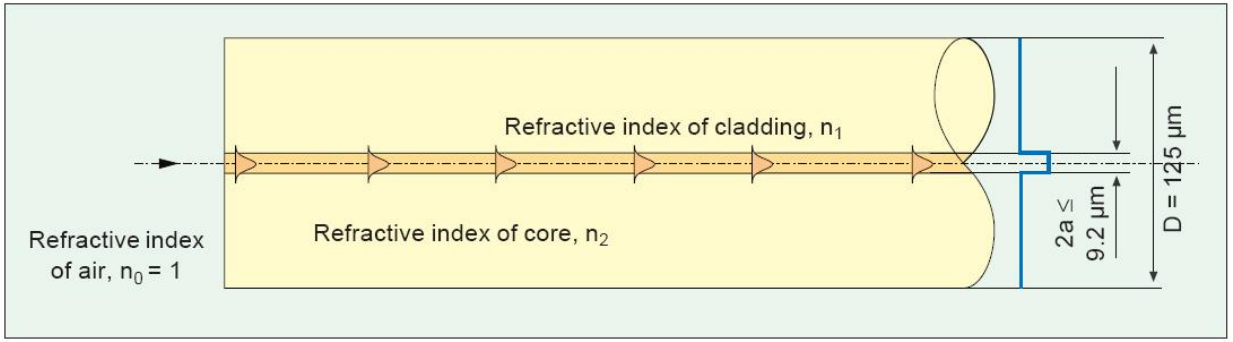
$$\Delta = \frac{NA^2}{2n_2^2} = \frac{n_2^2 - n_1^2}{2n_2^2} \approx \frac{n_2 - n_1}{n_2} \approx \frac{\Delta n}{n} \quad \text{for } \Delta << 1$$

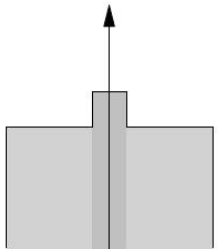
- g = 1 – indice gradat triunghiular
- g = 2 – indice gradat parabolic
- g = ∞ – salt de indice

Fibre monomod



- 6-8/125 (µm)
- MHz·km nerelevant
- MFD – Mode Field Diameter





Cladding diameter D	125 µm
Core refractive index n_2	1.4485
Cladding refractive index n_1	1.4440
Refractive index differential	0.003 = 0.3%

Ghid cilindric dielectric

- Ecuatiile lui Maxwell in coordonate cilindrice

$$\frac{\partial^2 U}{\partial r^2} + \frac{1}{r}\frac{\partial U}{\partial r} + \frac{1}{r^2}\frac{\partial^2 U}{\partial \phi^2} + \frac{\partial^2 U}{\partial z^2} + n^2 k_o^2 U = 0$$

a – raza miezului
U – E(r) sau H(r)

$$U(r,\phi,z) = u(r)e^{-jl\phi}e^{-j\beta z}, \qquad l = 0, \pm 1, \pm 2, \ldots$$

$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \left(n^2(r)k_o^2 - \beta^2 - \frac{l^2}{r^2}\right)u = 0$$

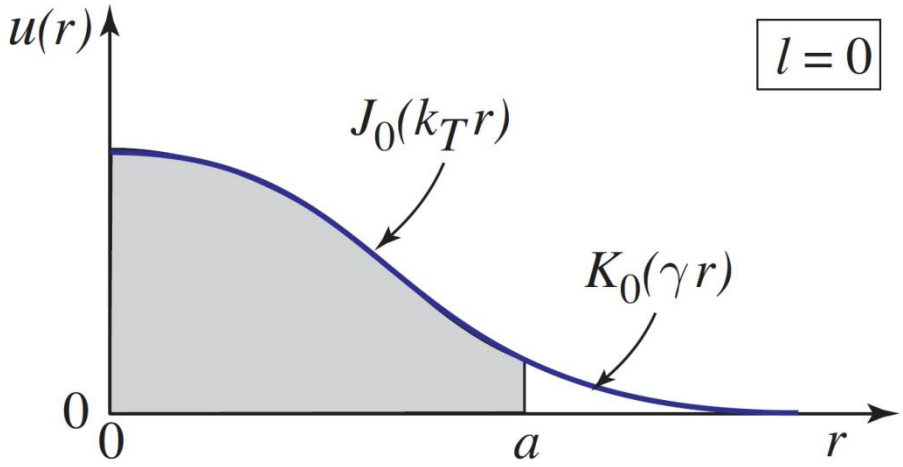
$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \left(k_T^2 - \frac{l^2}{r^2}\right)u = 0, \qquad r < a$$

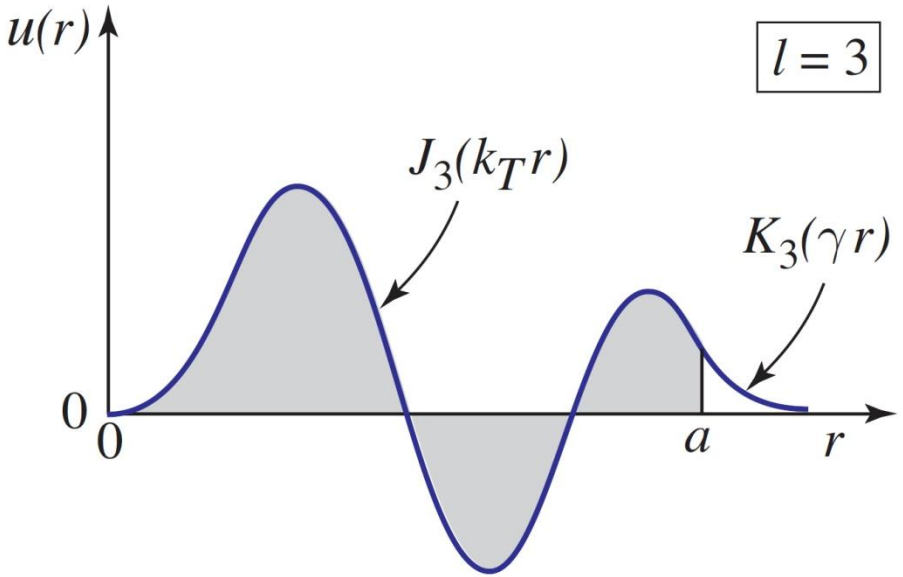
$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} - \left(\gamma^2 + \frac{l^2}{r^2}\right)u = 0, \qquad r > a$$

Ghid cilindric dielectric

- solutii proportionale cu functii Bessel

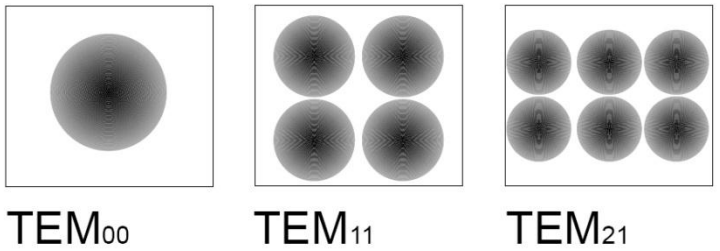
$$u(r) \propto \begin{cases} J_l(k_T r), & r < a \quad \text{(core)} \\ K_l(\gamma r), & r > a \quad \text{(cladding)} \end{cases}$$



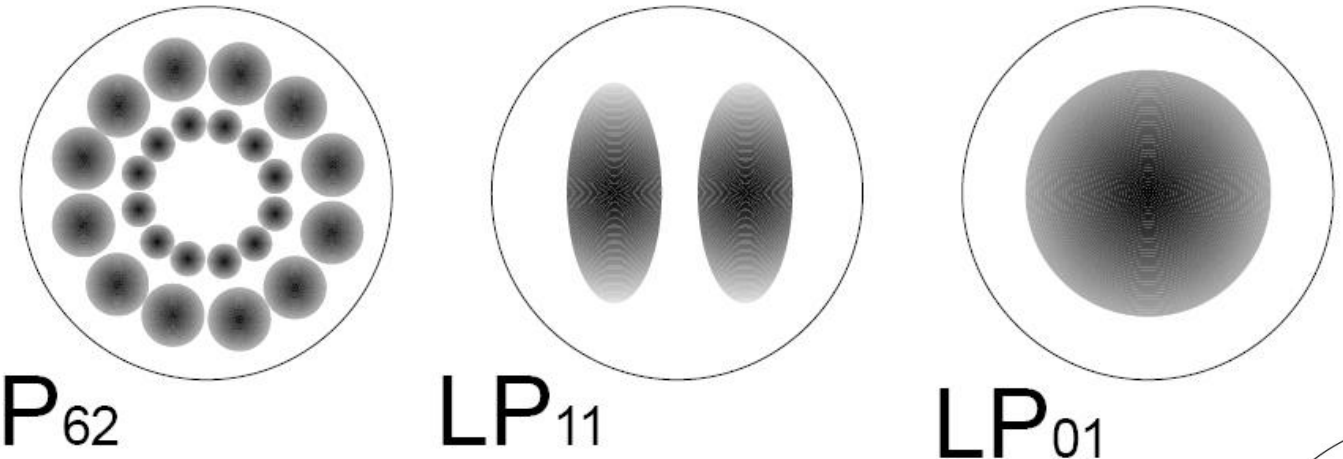


Moduri in fibra

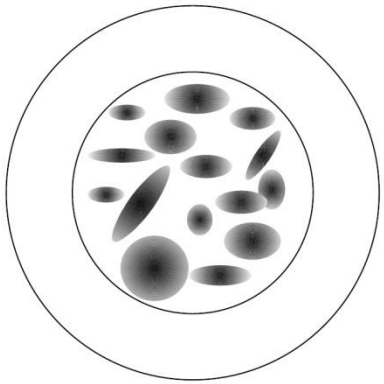
- Moduri in ghid rectangular



- Moduri linear polarizate in fibra



"Sparkle" pattern



Frecventa normalizata

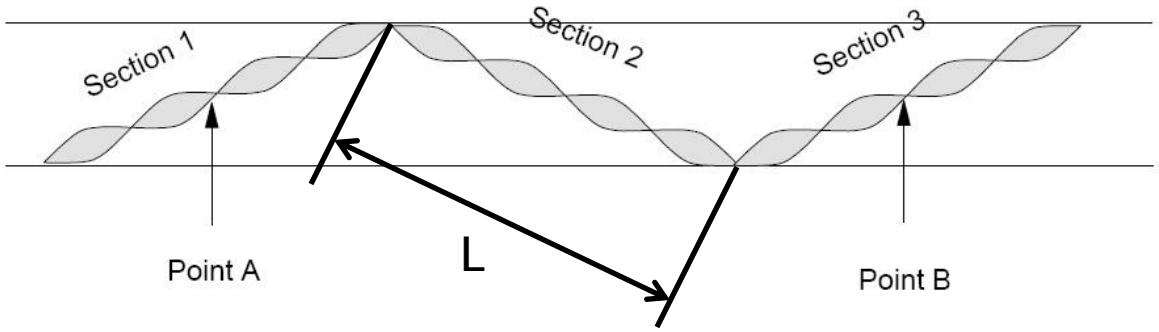
- Frecventa normalizata

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

a – raza miezului

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

- Numar de moduri

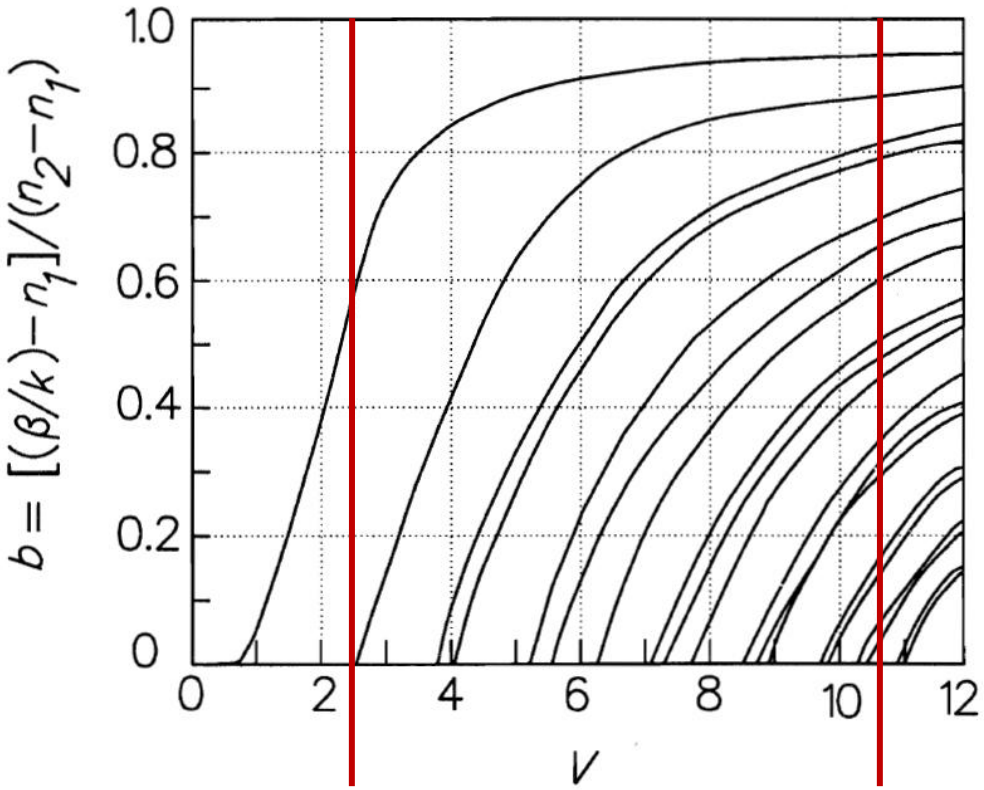


$$L = m \cdot \lambda$$

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

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 = 8.5μm

NA = 0.11

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

Frecventa normalizata

- Numar de moduri
  - Multimod cu salt de indice

$$g = \infty \quad \Rightarrow \quad N \approx \frac{V^2}{2}$$

  - Multimod cu indice gradat

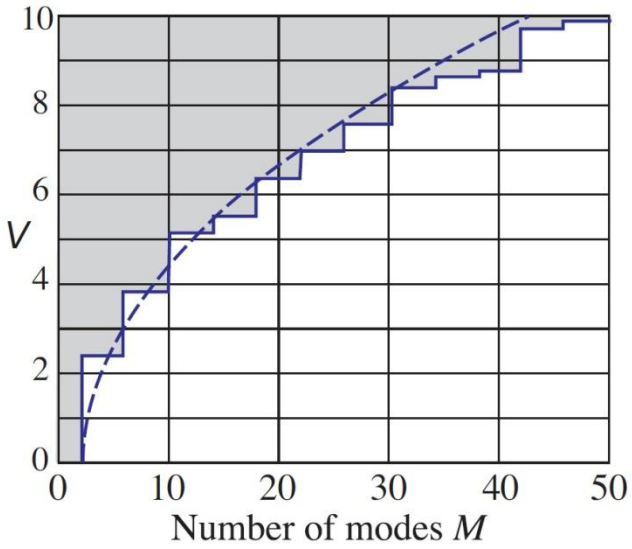
$$g = 2 \quad \Rightarrow \quad N \approx \frac{V^2}{4}$$

  - Monomod

$$V \le V_C = 2.405$$

exista un singur mod (solutii fc. Bessel)

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



Exemplu

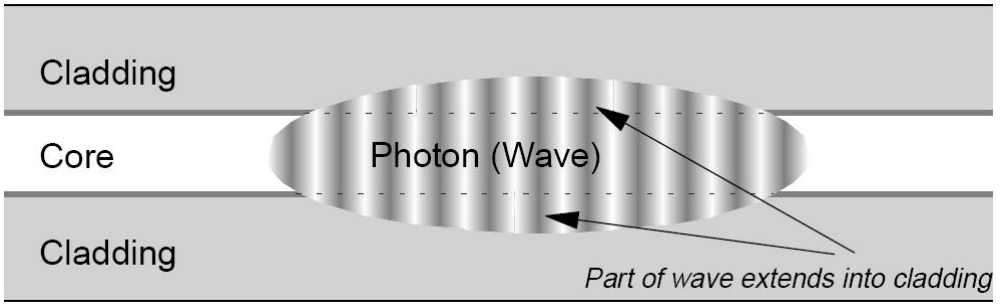
- fibra tipica multimod
  - g=2
  - 2a = 50µm -> a = 25µm
  - NA = 0.2 la λ = 1µm

$$V = 2\pi \frac{a}{\lambda} NA = 2\pi \frac{25}{1} 0.2 = 2 \cdot \pi \cdot 5 \approx 31.4$$

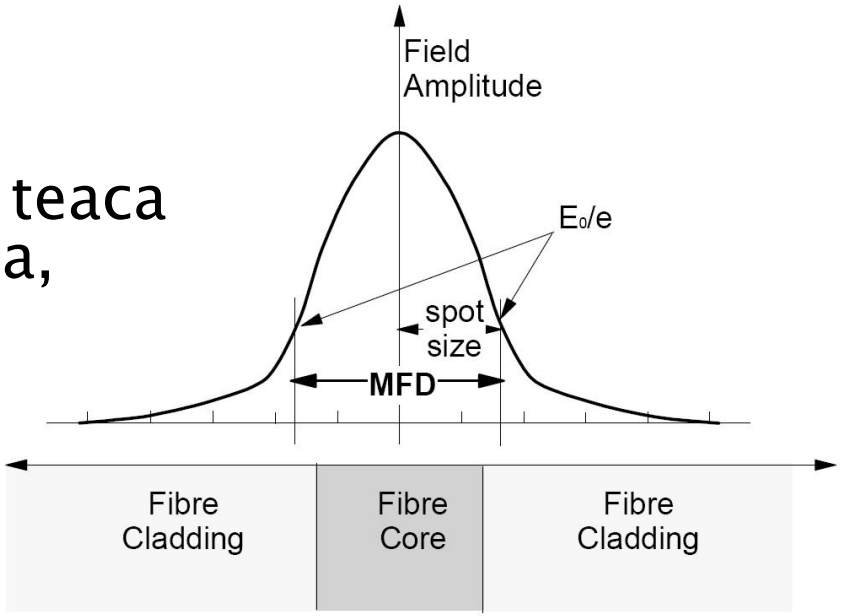
$$g = 2 \quad \Rightarrow \quad N = \frac{V^2}{4} = \frac{31.4^2}{4} = 247$$

Propagarea in fibra monomod

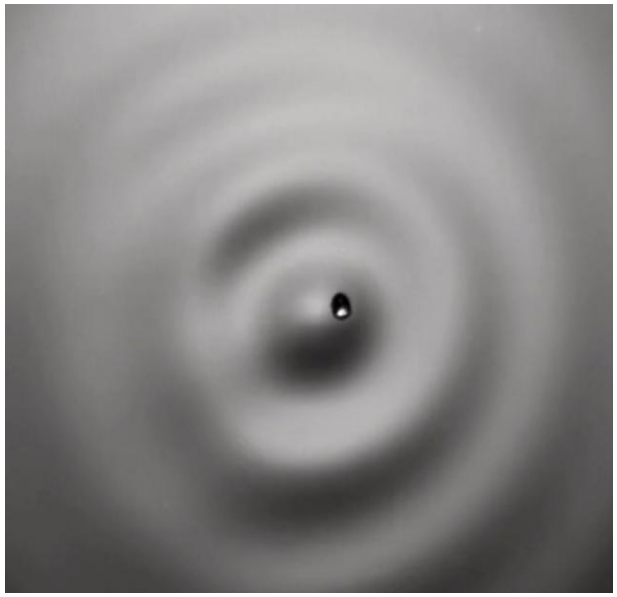
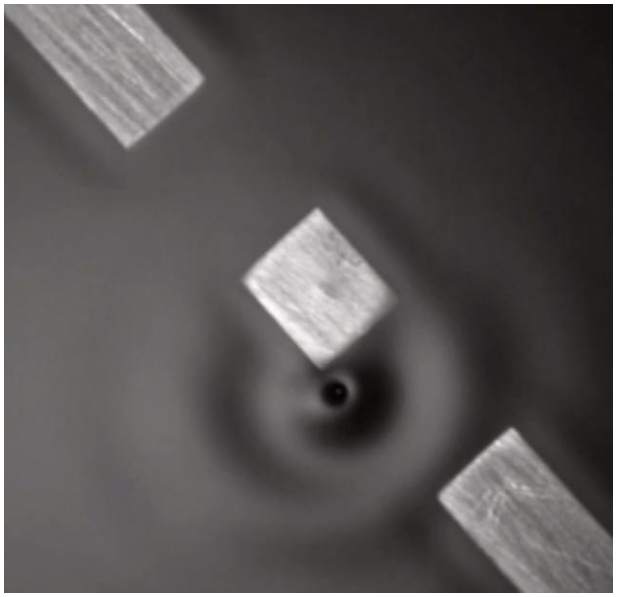
- Propagarea luminii poate fi explicata doar prin teoria electromagnetica



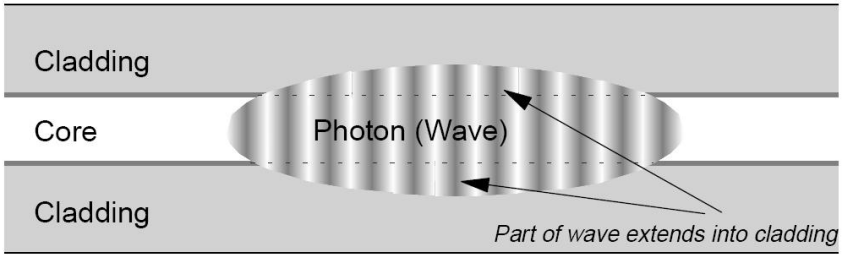
- Energia campului se extinde in teaca (diametrul efectiv al spotului luminos – MFD, Mode Field Diameter)
- MFD > 2a
- Adancimea de patrundere in teaca depinde de lungimea de unda, generand dispersia de ghid



Modelare


Through the Wormhole
S02E07 How Does the Universe Work



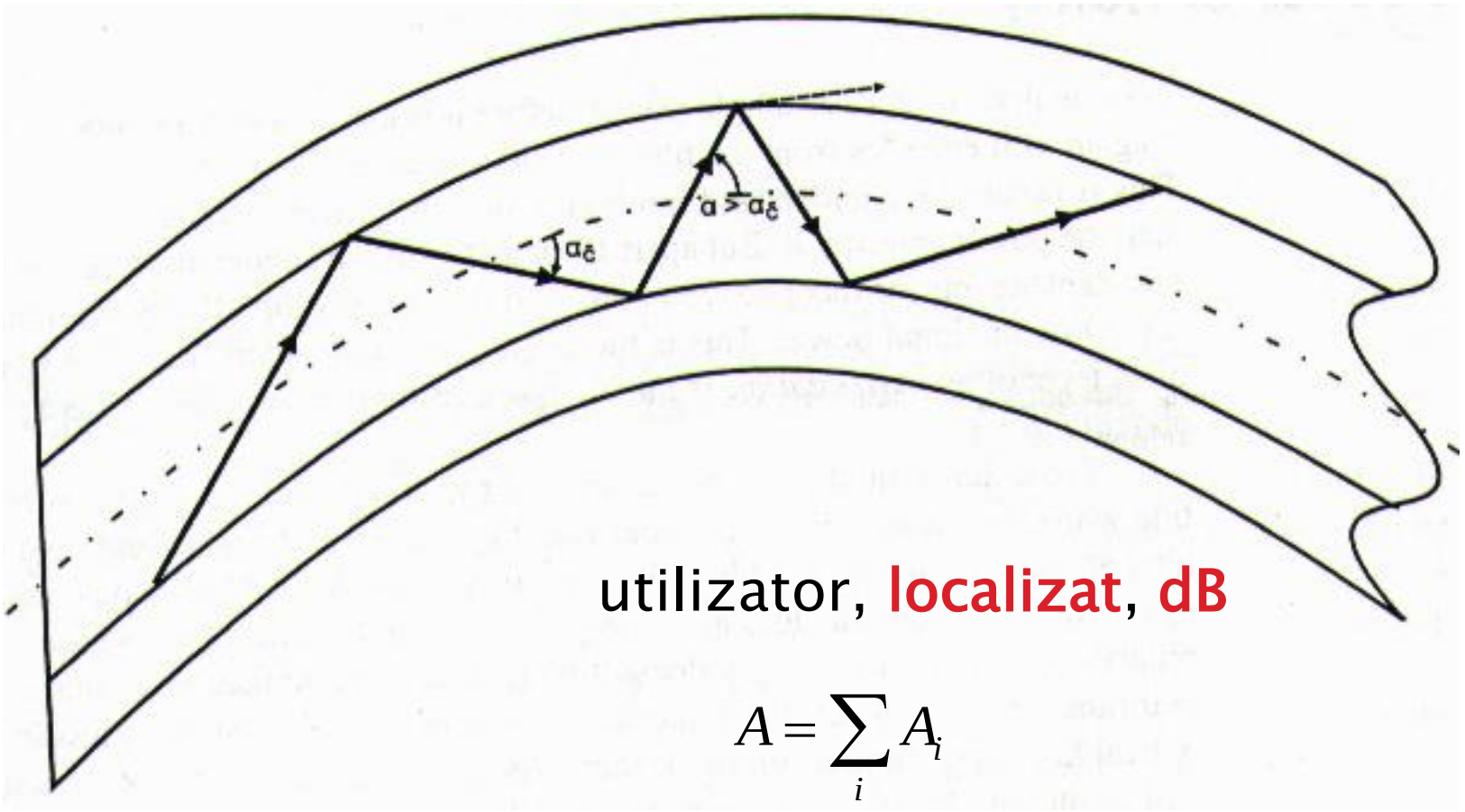
Fenomene de interes

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

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

Macrocurburi



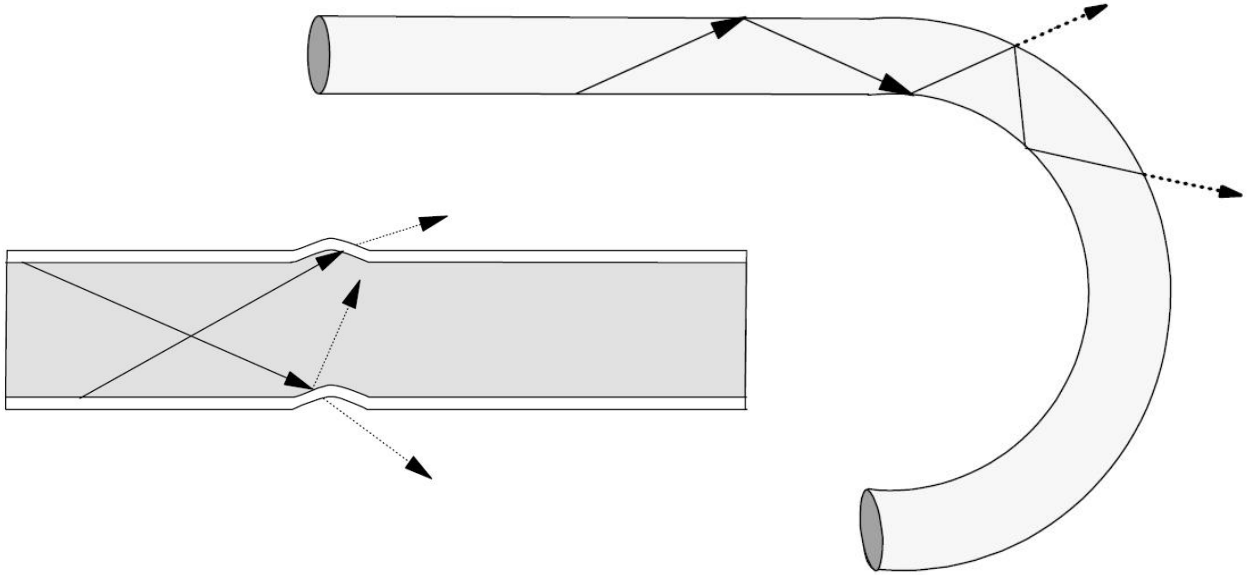
utilizator, localizat, dB

$$A = \sum_i A_i$$

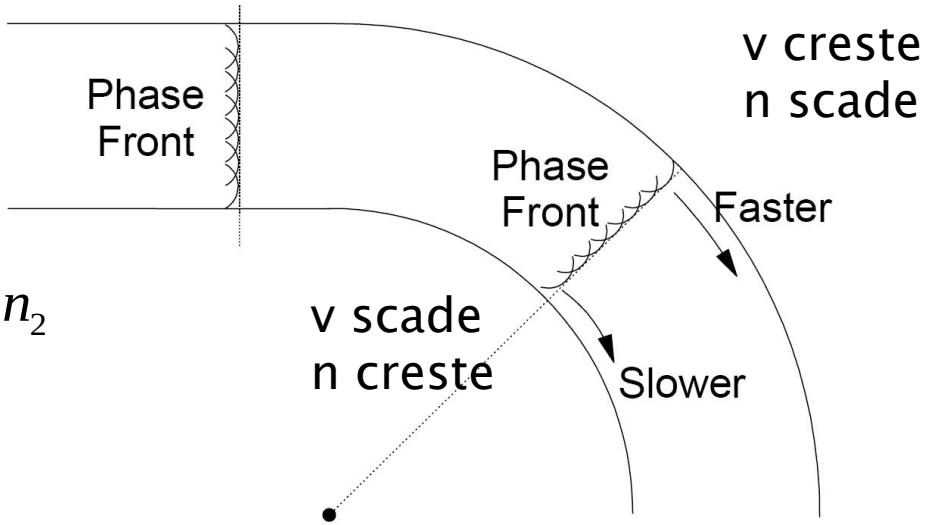
$$A = N \cdot A_i$$

Efectul curburilor

- Multimod



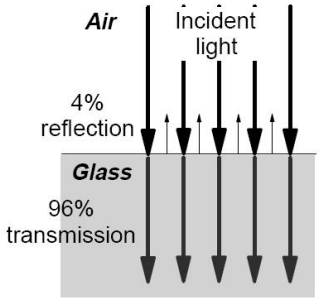
- Monomod

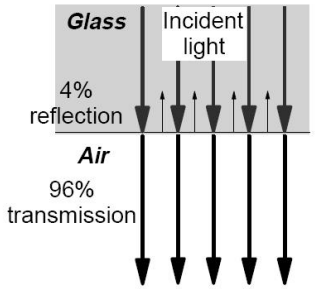


$$R > R_C \quad \Rightarrow \quad n_{1,ext} > n_2$$

Discontinuitate in fibra

- Apare cand nu putem considera fibra un singur ghid dielectric
  - defectiuni
  - conectori



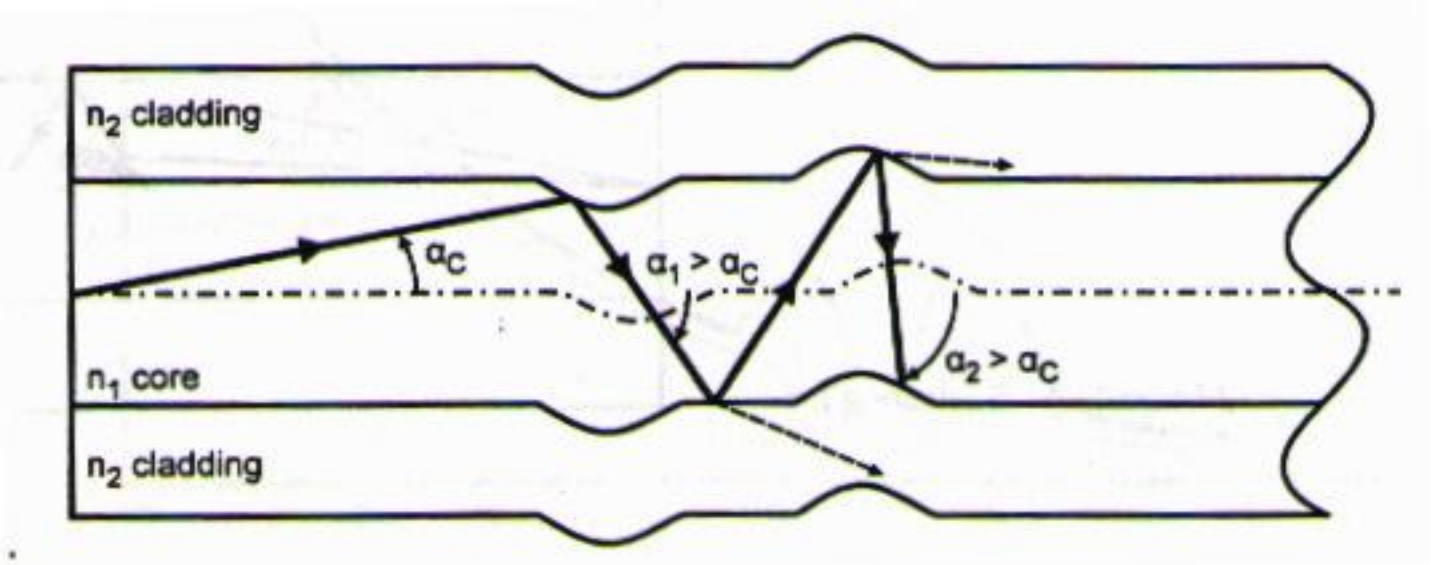


utilizator, localizat, dB

$$A = \sum_i A_i$$

$$A = N \cdot A_i$$

Microcurburi

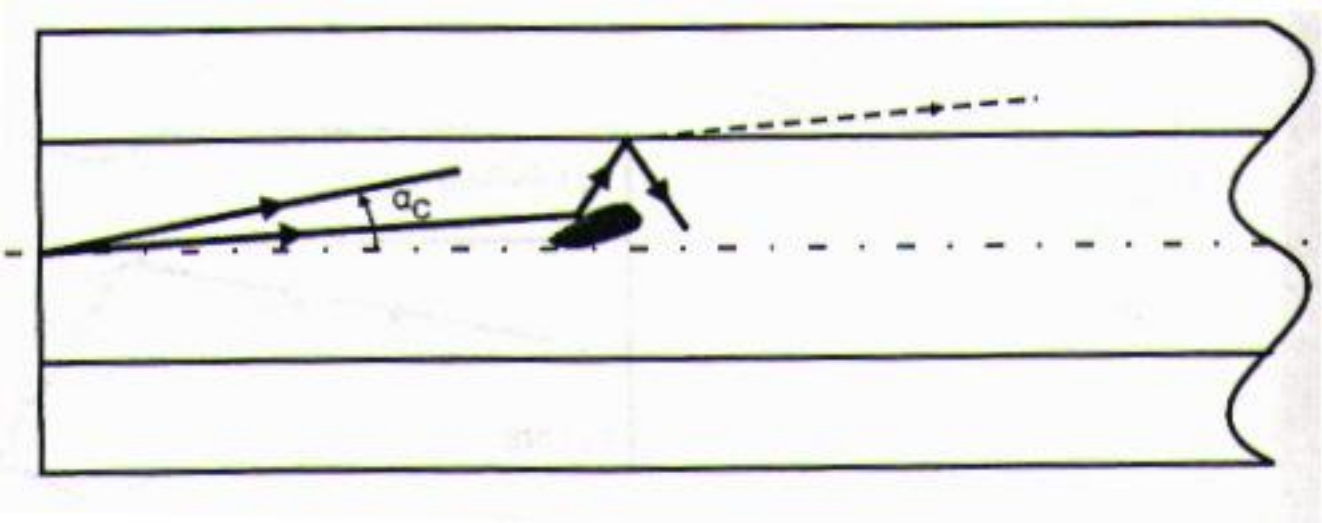


distribuit, tehnologie, **dB/km**

$$A = A_i \cdot L$$

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

Imprastiere

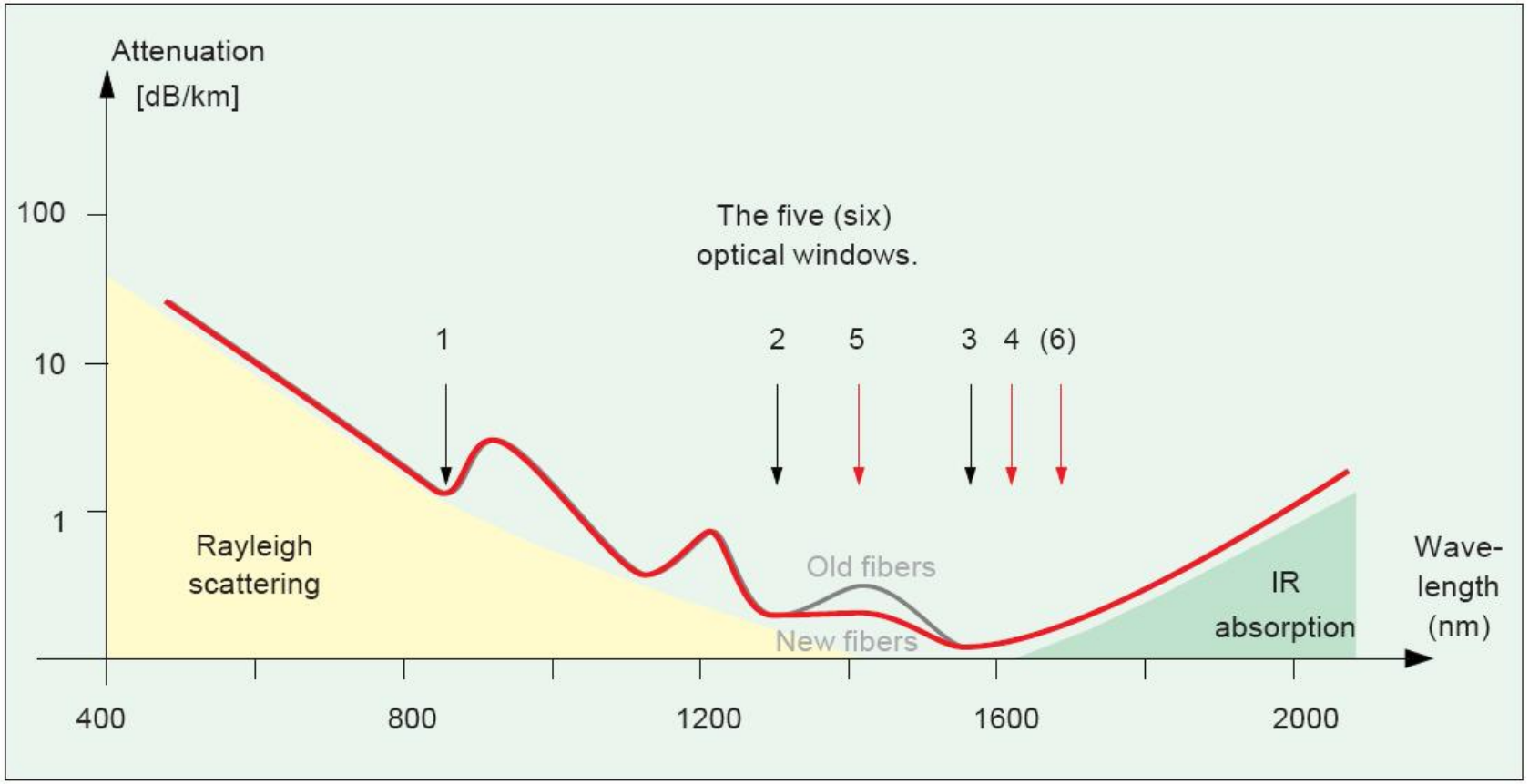


distribuit, tehnologie, **dB/km**

$$A = A_i \cdot L$$

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

Absorbtie

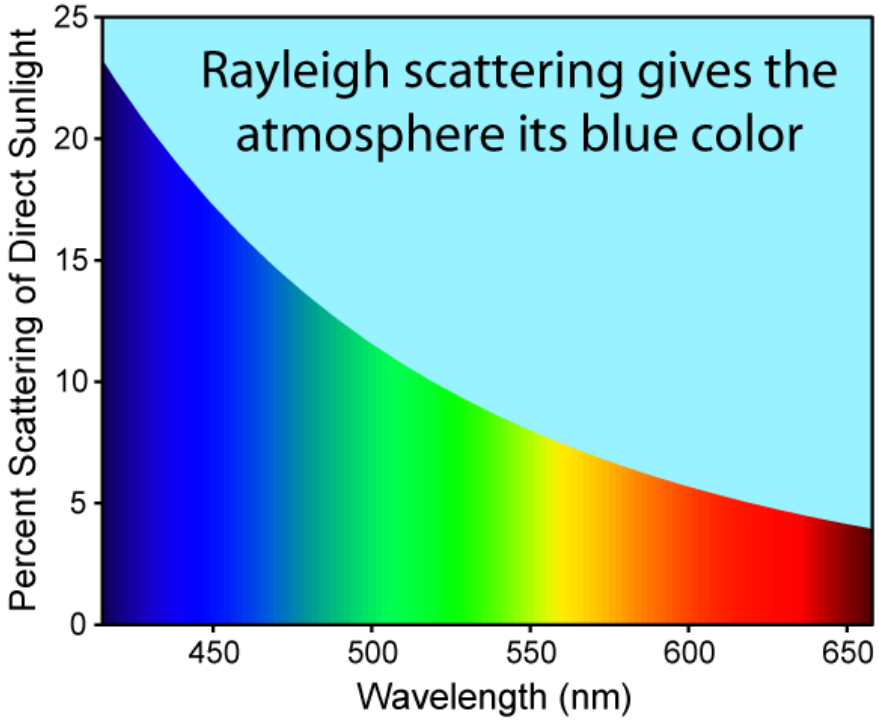


distribuit, material, **dB/km**

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

Difractie Rayleygh

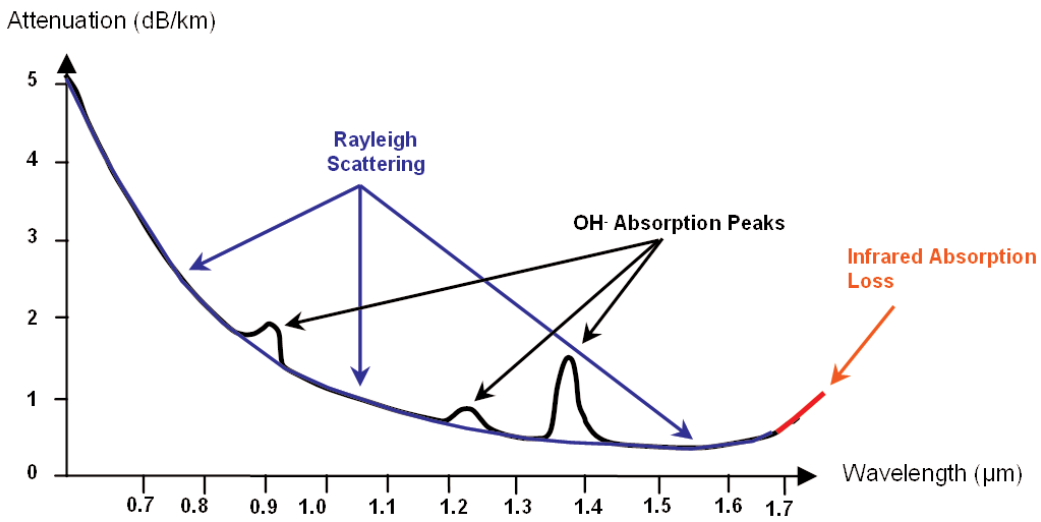
- imprastierea luminii (si a altor radiatii electromagnetice) de particule (molecule) mult mai mici decat lungimea de unda

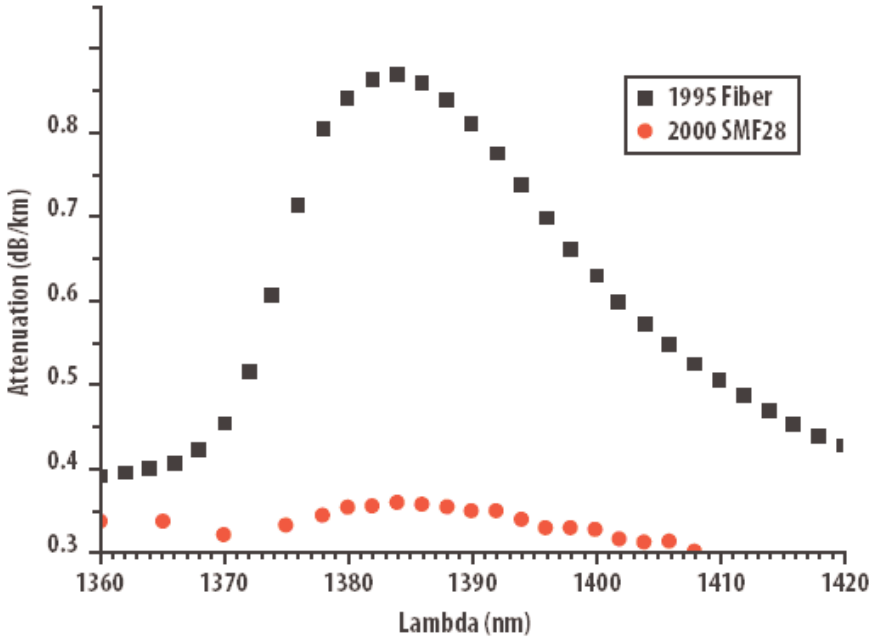


$$A \sim \frac{1}{\lambda^4}$$

Absorbtie OH

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





Fiber Attenuation Comparison

Atenuare

$$E_y(z_1) = Ct \cdot e^{-\alpha \cdot z_1} \cdot e^{j(\omega \cdot t - \beta \cdot z_1)} \qquad E_y(z_2) = Ct \cdot e^{-\alpha \cdot z_2} \cdot e^{j(\omega \cdot t - \beta \cdot z_2)}$$

$$W, P \sim \int E^2$$

$$A = \frac{P_2}{P_1} = \frac{Ct^2 \cdot e^{-2\alpha \cdot z_2}}{Ct^2 \cdot e^{-2\alpha \cdot z_1}} = e^{-2\alpha \cdot (z_2 - z_1)}$$

$$A[dB] = 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \left[e^{-2\alpha \cdot (z_2 - z_1)} \right]$$

$$A[dB] = -20 \cdot \alpha \cdot (z_2 - z_1) \log_{10} e = -8.686 \cdot \alpha \cdot (z_2 - z_1)$$

$$A / L[dB / km] = -8.686 \cdot \alpha < 0$$

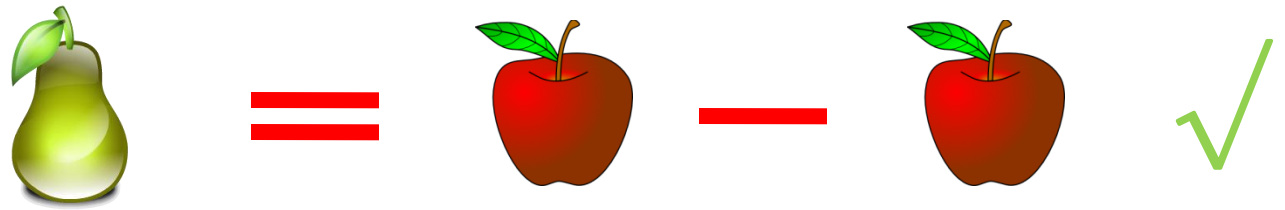
- Atenuarea se exprima de obicei in **dB/km**
  - de obicei valori pozitive
  - semnul = **implicit**

Calculul atenuarii

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

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

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

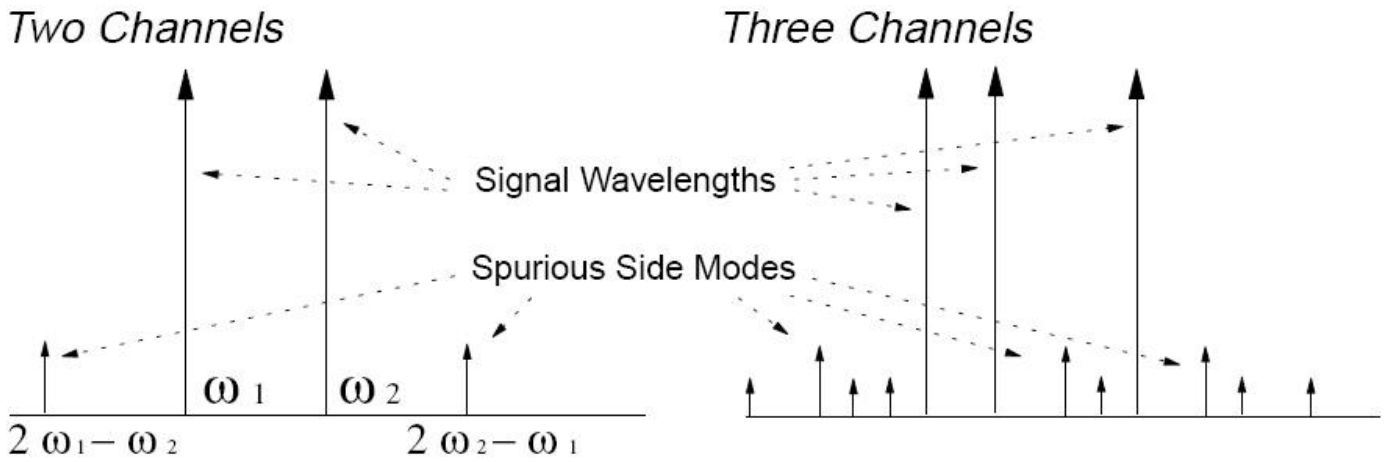


$$\text{Atenuare}[\text{dB/km}] = \frac{\text{Pierderi}[\text{dB}]}{\text{lungime}[\text{km}]}$$

Efecte neliniare in fibra

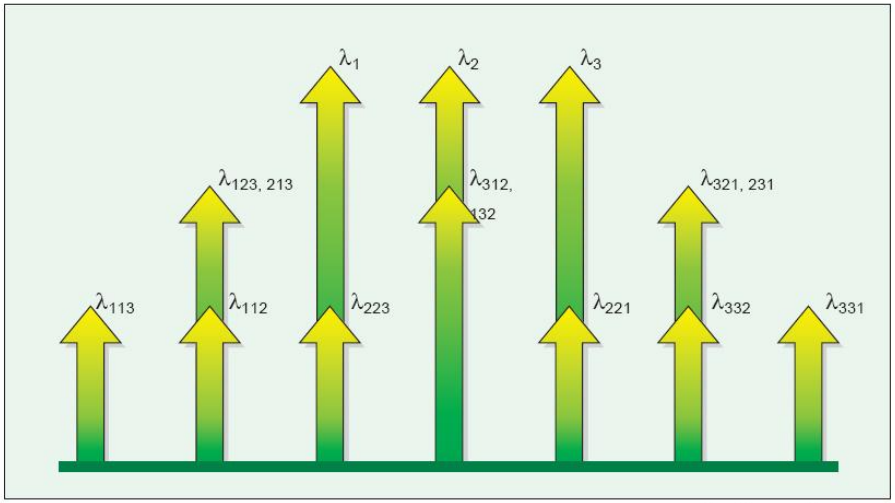
- Stimulated Brillouin Scattering, SBC
  - difractia luminii inspre emitator datorita undelor mecano-acustice generate in fibra
  - 6-10 dBm
- Stimulated Raman Scattering, SRS
  - interactiunea luminii cu vibratiile moleculare
  - 27 dBm (~1W)
- Self Phase Modulation, SPM
  - Frontiera impulsului implica 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

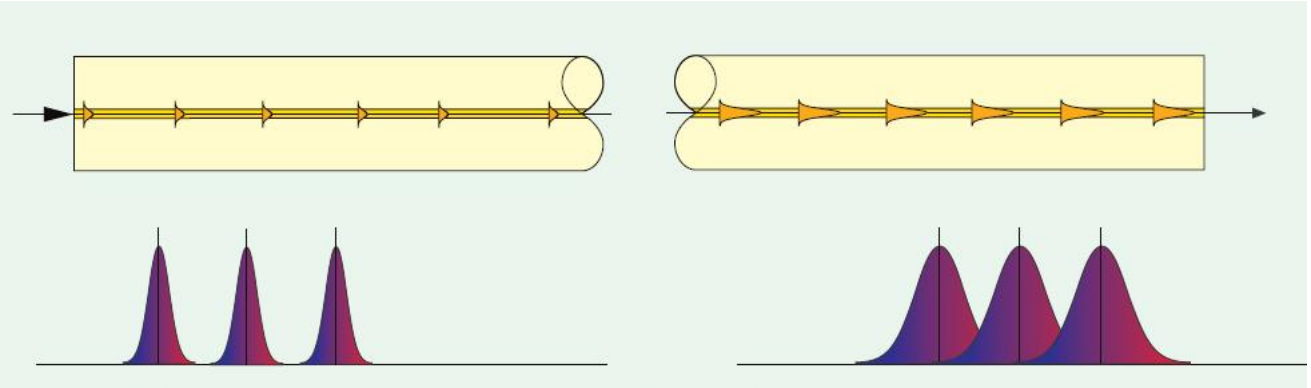


Fenomene de interes

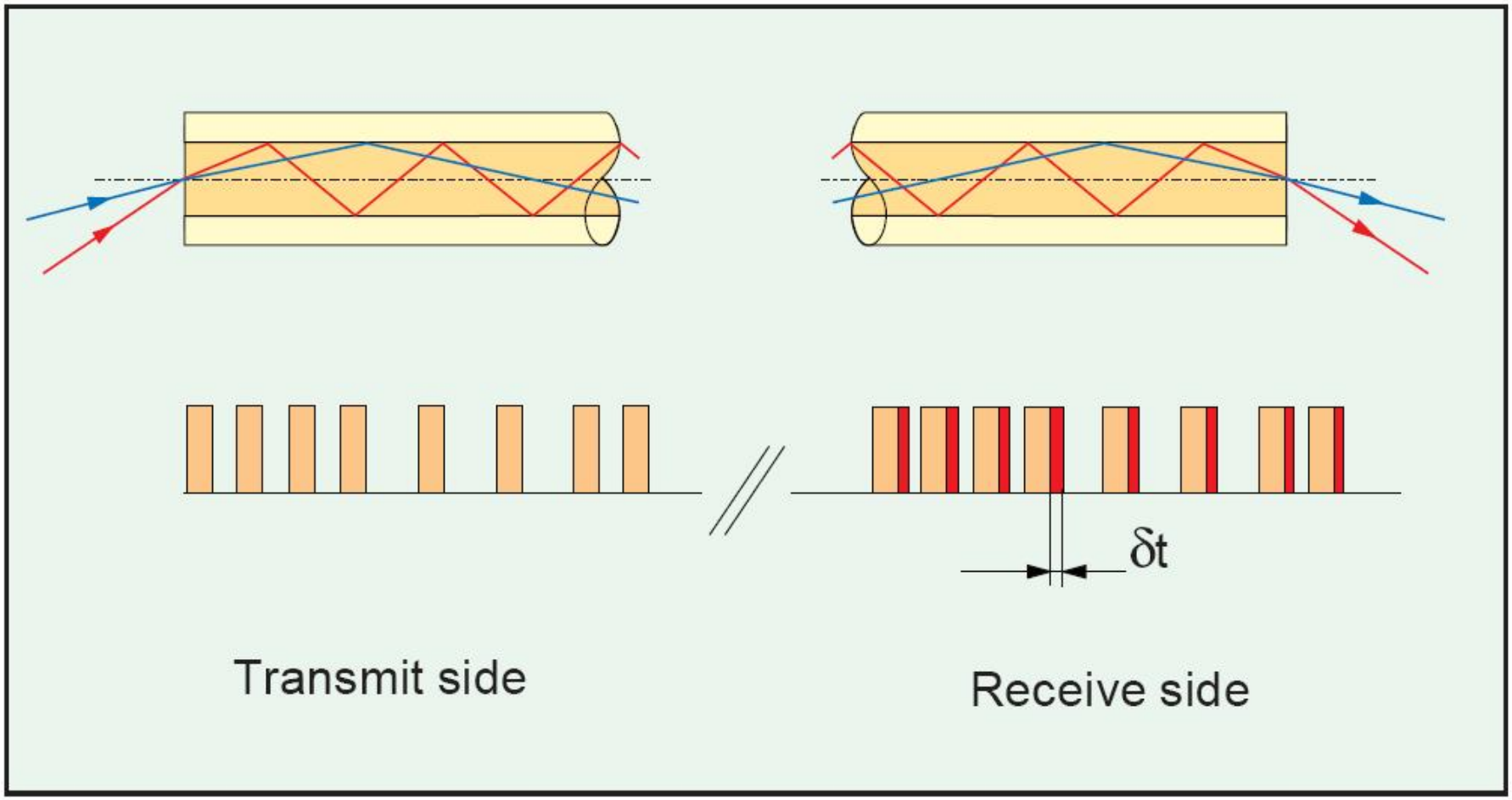
- Cat de departe pot transmite semnalul luminos pe fibra
  - atenuare
- Cat de rapid pot transmite informația
  - **dispersie**

Dispersia

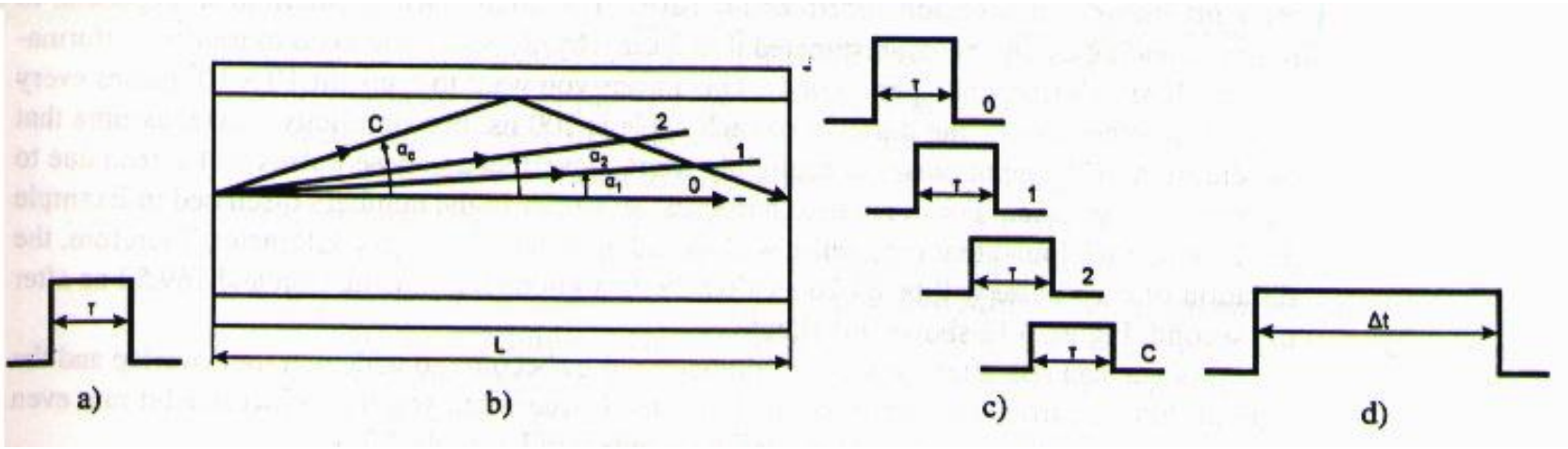
- Propagarea cu viteze diferite a radiatiilor cu lungimi de unda diferite
  - intermodala (modala – depinde de prezenta modurilor)
  - intramodala (cromatica – depinde de lungimea de unda)
    - de material
    - de ghid



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

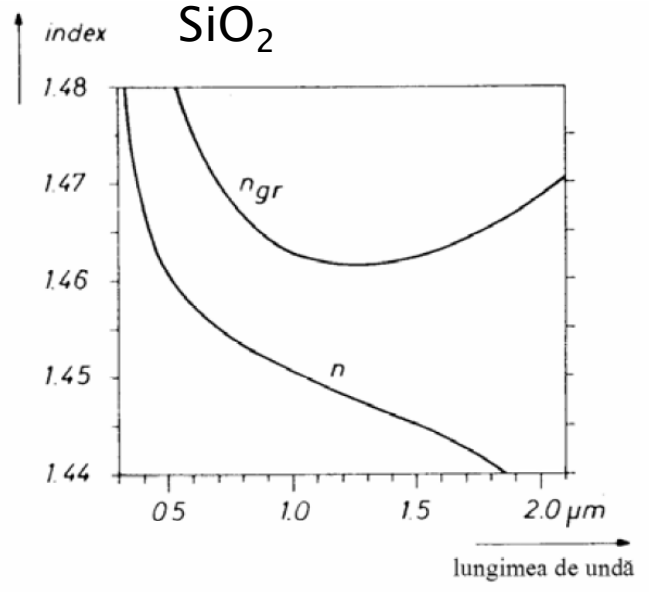
$$dt = \frac{L \cdot n_2 \cdot \Delta^2}{2c} \approx \frac{L \cdot NA^4}{8 \cdot c \cdot n_2^3}$$

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

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

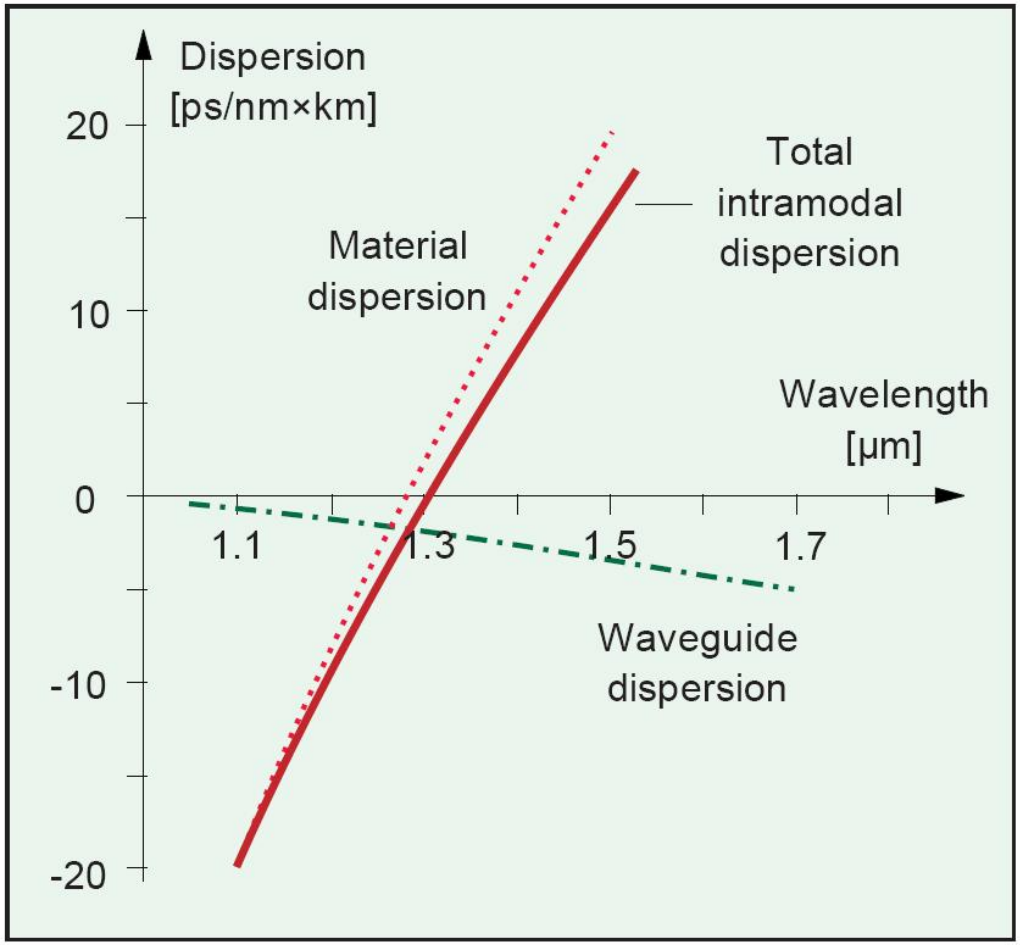
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

Dispersia de material



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

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

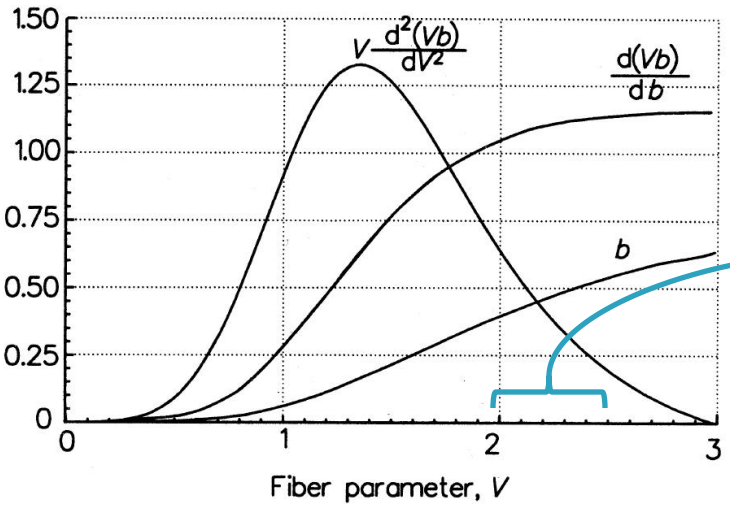


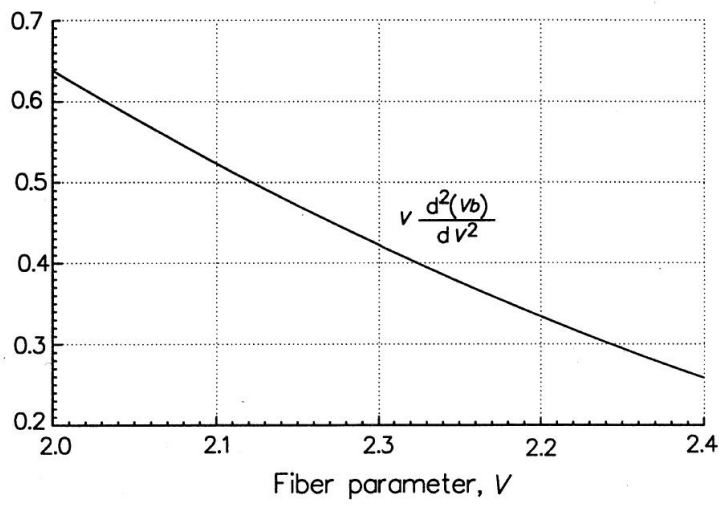
Dispersia de ghid

- Neglijabila in fibrele multimod fata de dispersia modala

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

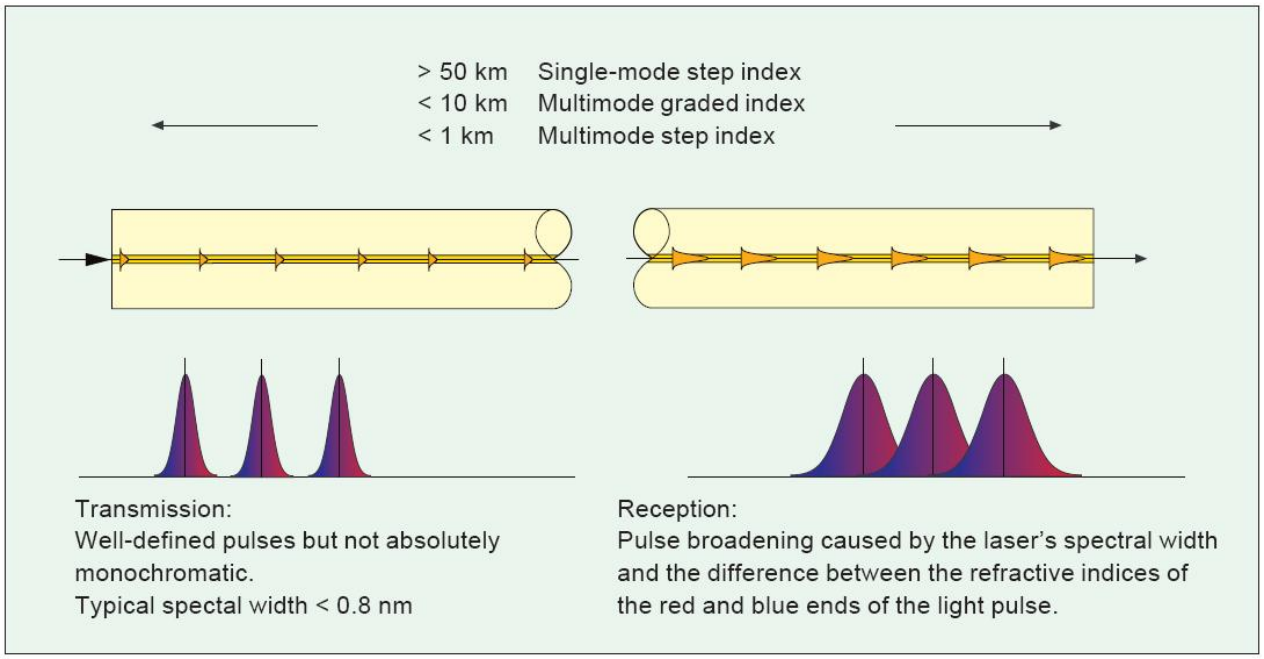
b – constanta de propagare normalizata





$$V \le V_C = 2.405$$

Dispersia cromatica (gh+mat)



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

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

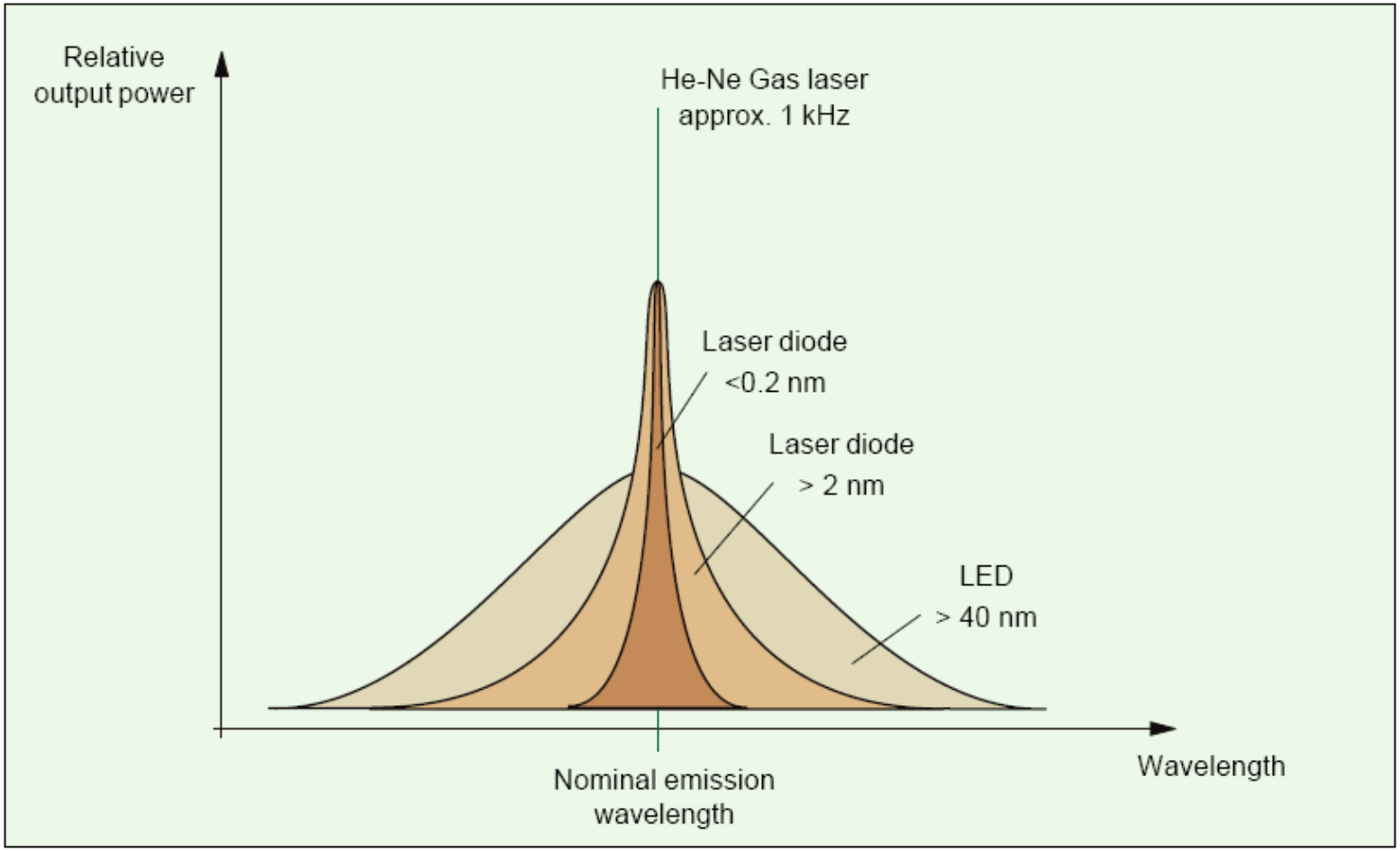
S_0 panta dispersiei – $ps/nm^2/km$

$$D(\lambda_0) = 0$$

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

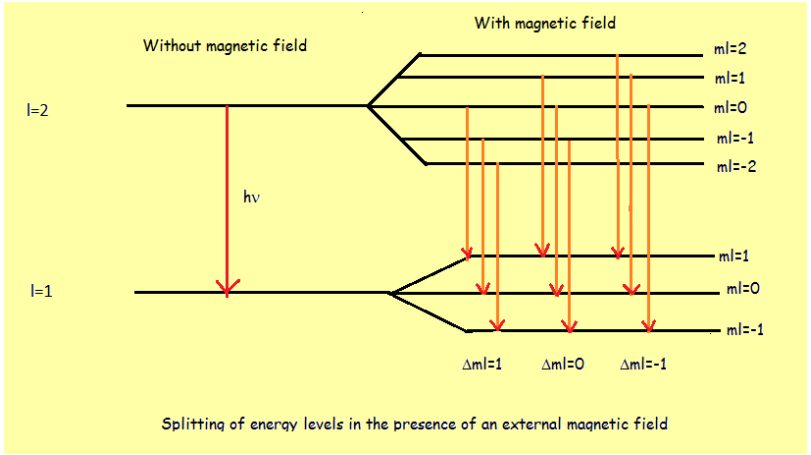
$$D(\lambda) = \frac{S_0}{4}\cdot\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

Calitatea spectrală a emiţătorilor optici

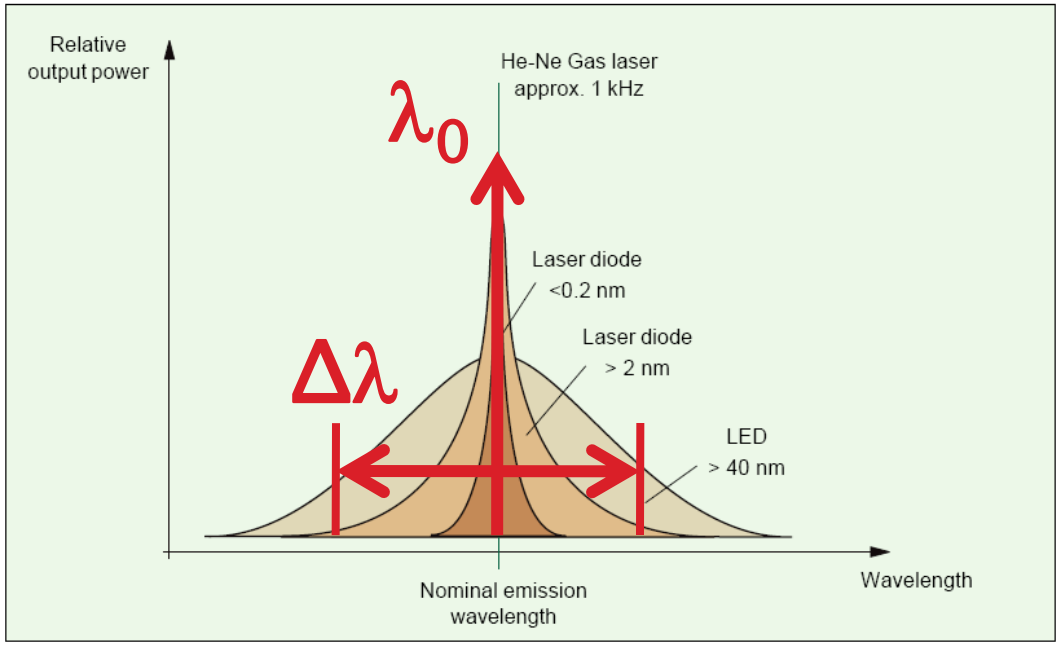


Calitatea spectrală a emiţătorilor optici

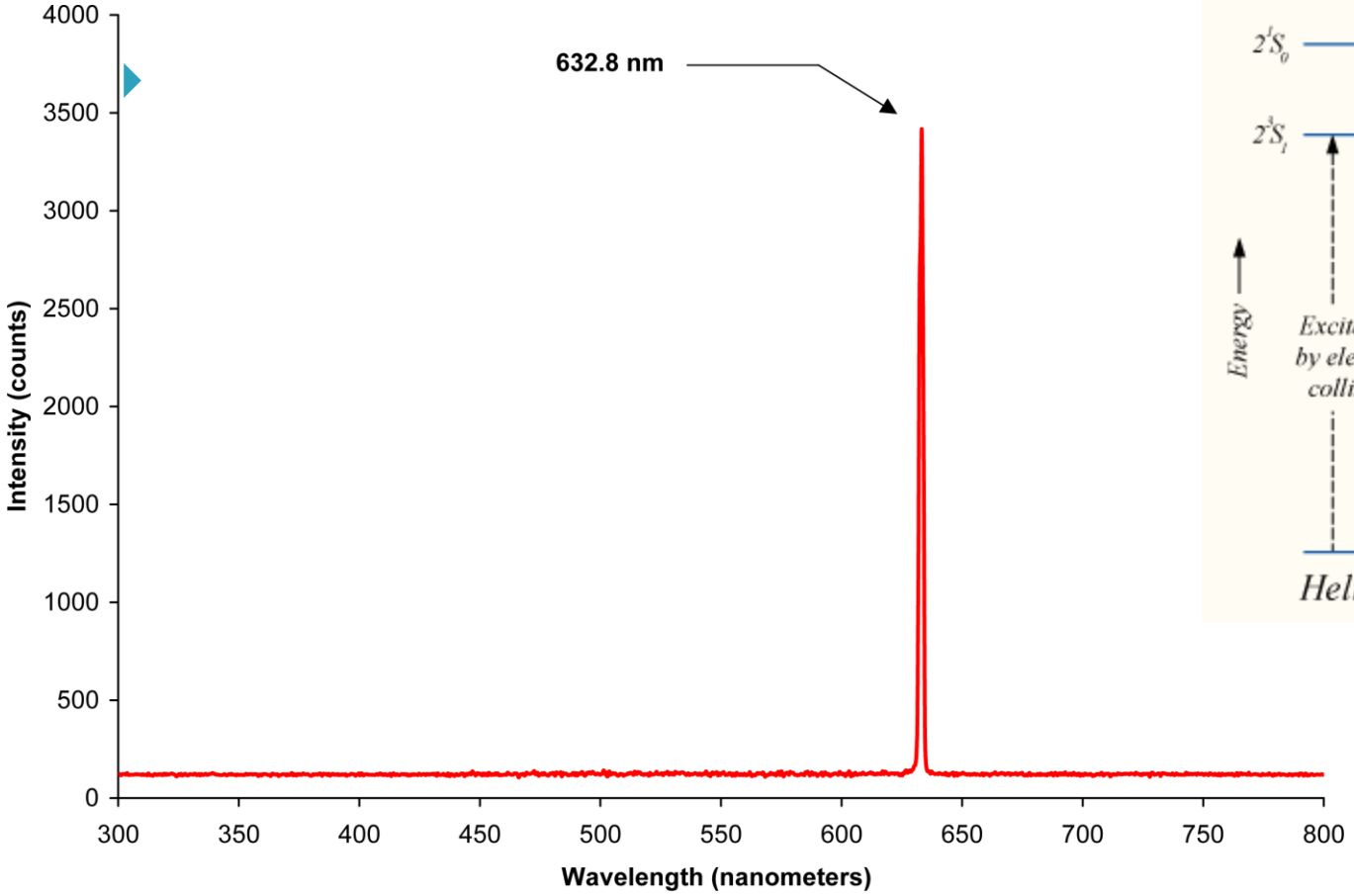
- degenerarea nivelelor energetice duce la aparitia benzilor energetice
- Multitudinea de tranzitii posibile intre cate doua nivele situate in benzi energetice diferite duce la largirea caracteristicii spectrale a surselor

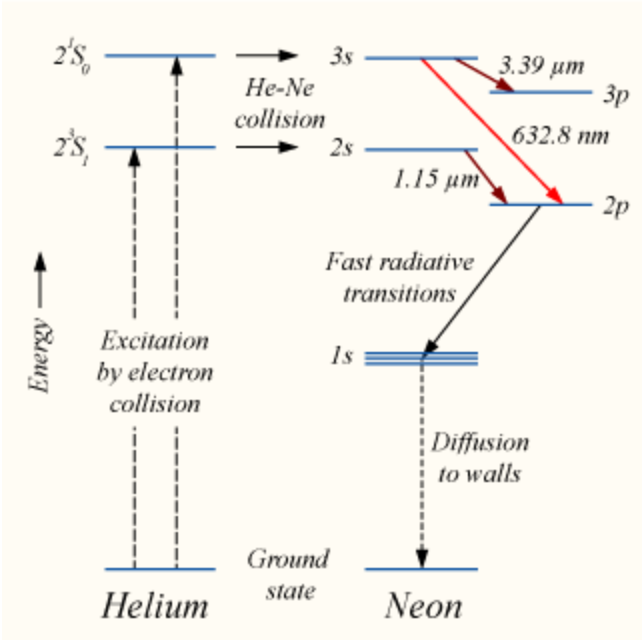


$$\lambda_0 \rightarrow \left[\lambda_0 - \frac{\Delta\lambda}{2}, \lambda_0 + \frac{\Delta\lambda}{2}\right]$$



He-Ne Laser





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

Contact

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