Optoelectronică

Curs 4

2017/2018

Disciplina 2017/2018

- 2C/1L Optoelectronică OPTO
- **Minim 7 prezente curs + laborator**
- Curs – sl. Radu Damian
  - an IV μE
  - Vineri 8-11, P5
  - E – 70% din nota
    - **20% test la curs**, saptamana 4-5?
  - probleme + (? 1 subiect teorie) + (2p prez. curs)
  - toate materialele permise
- Laborator – sl. Daniel Matasaru
  - an IV μE, an IV Tc
    - Joi 14-16 par/impar
  - L – 15% din nota
  - C – 15% din nota

Orar 2017/2018

- Curs
  - Vineri 8-11, P5
  - 2C ⇨ 3C
    - $14*2/3 \approx 9.33$
    - $9 \div 10$ C

Examen partial 2017/2018

- Vineri 16.03.2018, 10, 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

Recapitulare

Reprezentare logaritmică!!!

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

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

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]

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

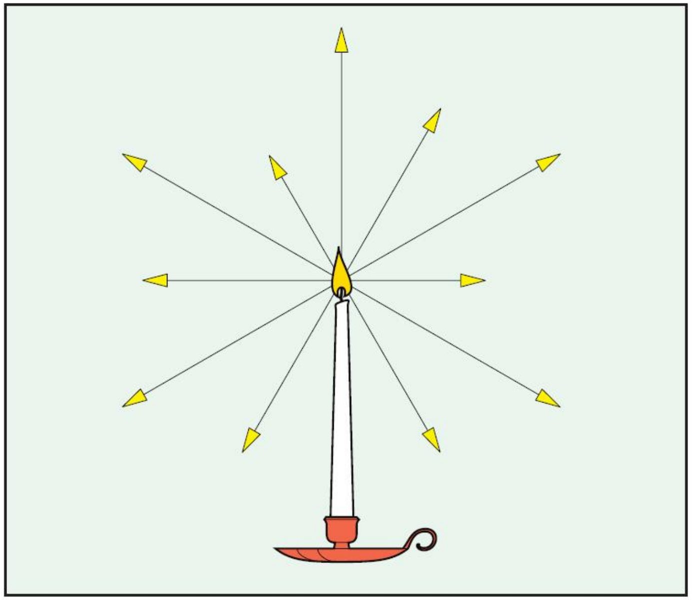
"a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz"

Optică geometrică

Capitolul 2

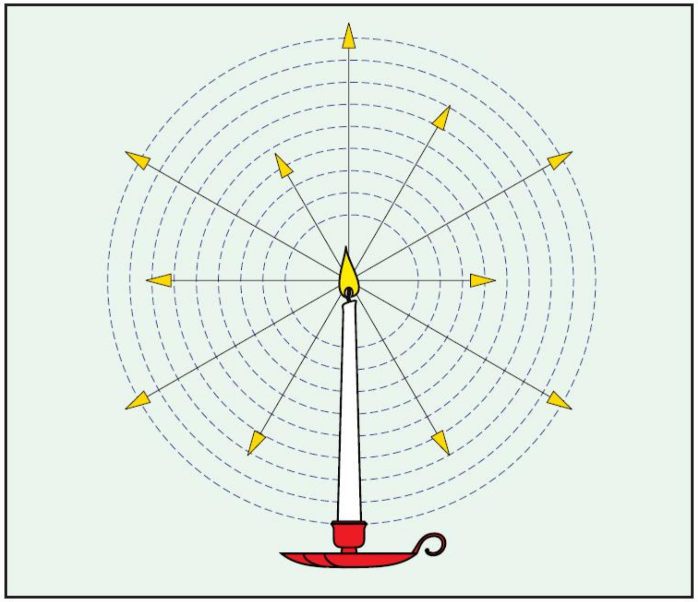
Raze de lumina

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



- Densitatea de energie luminoasa descrește invers proporțional cu pătratul distantei fata de sursa (energia se împarte uniform pe suprafața întregii sfere)

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



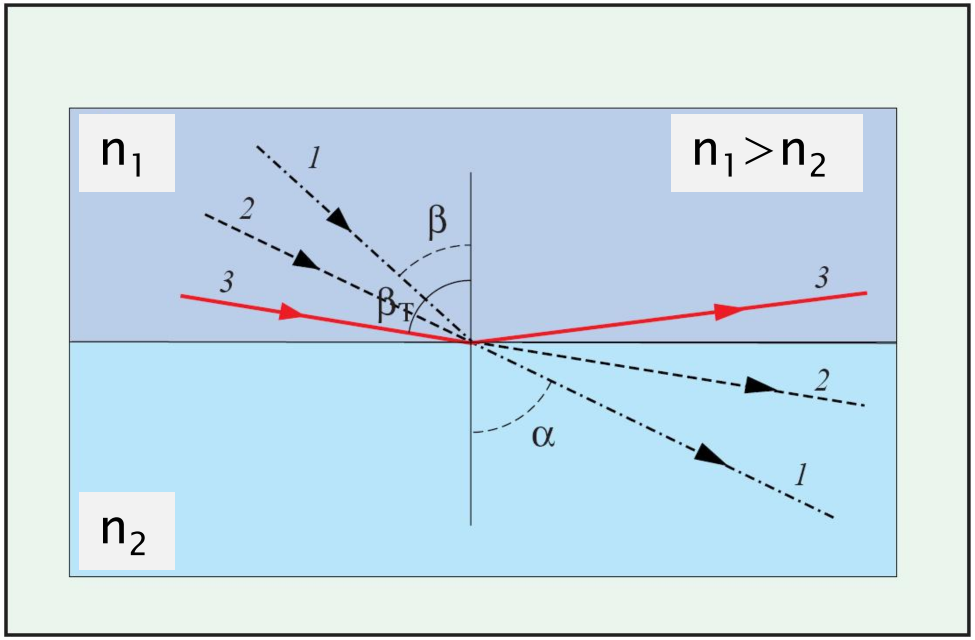
Reflexia totala

- 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

$$n_1 > n_2; \quad \phi_R = 90°$$

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

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



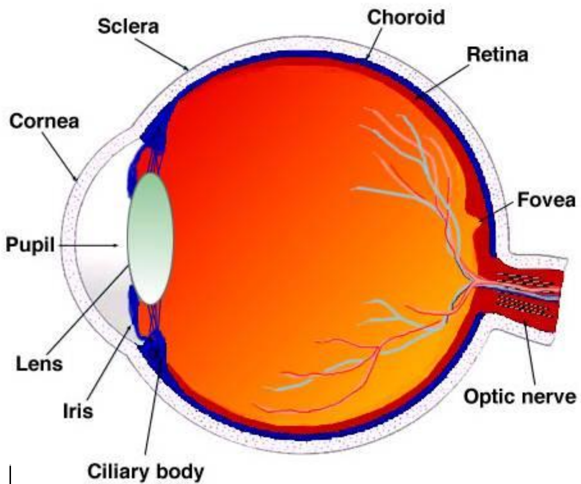
Fotometrie şi radiometrie

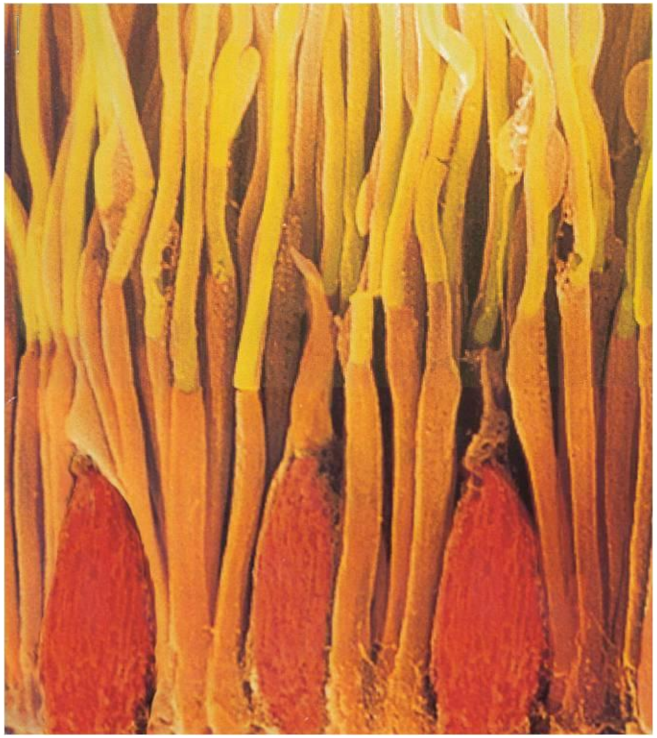
Capitolul 3

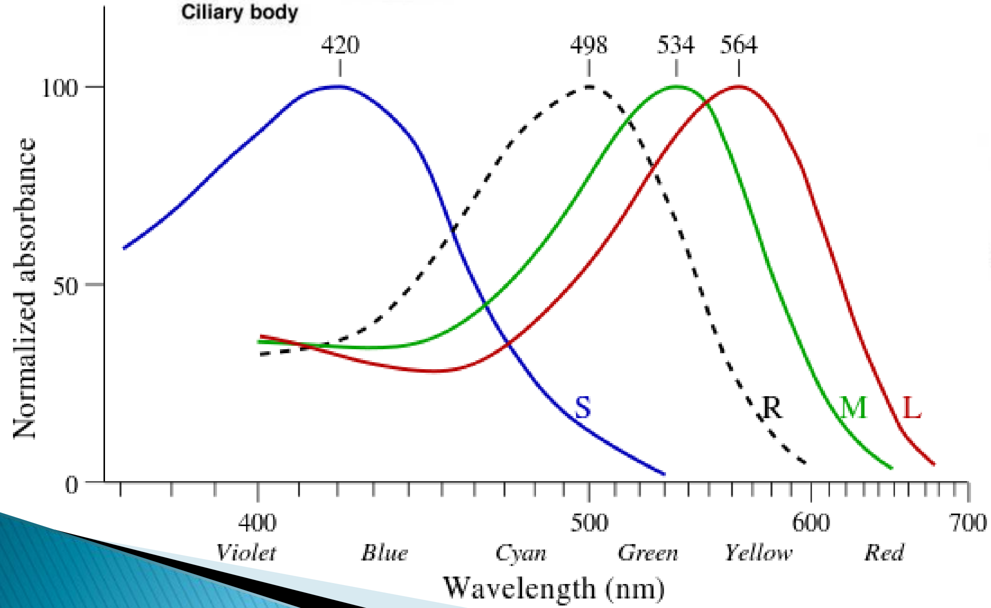
O alta dualitate

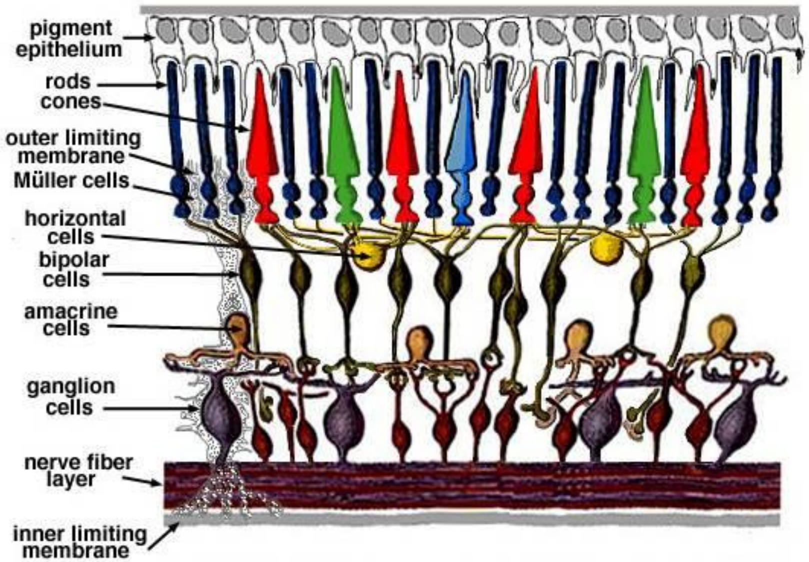
- In optoelectronica, lumina poate fi privita din doua puncte de vedere
  - energetic (efect asupra dispozitivului)
  - uman (efect asupra ochiului uman)
- Dualitatea mărimilor implicate
  - energetice
  - luminoase
- Candela (cd) **<u>este</u>** una din cele 7 mărimi fundamentale ale SI
  - Cd = intensitatea 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



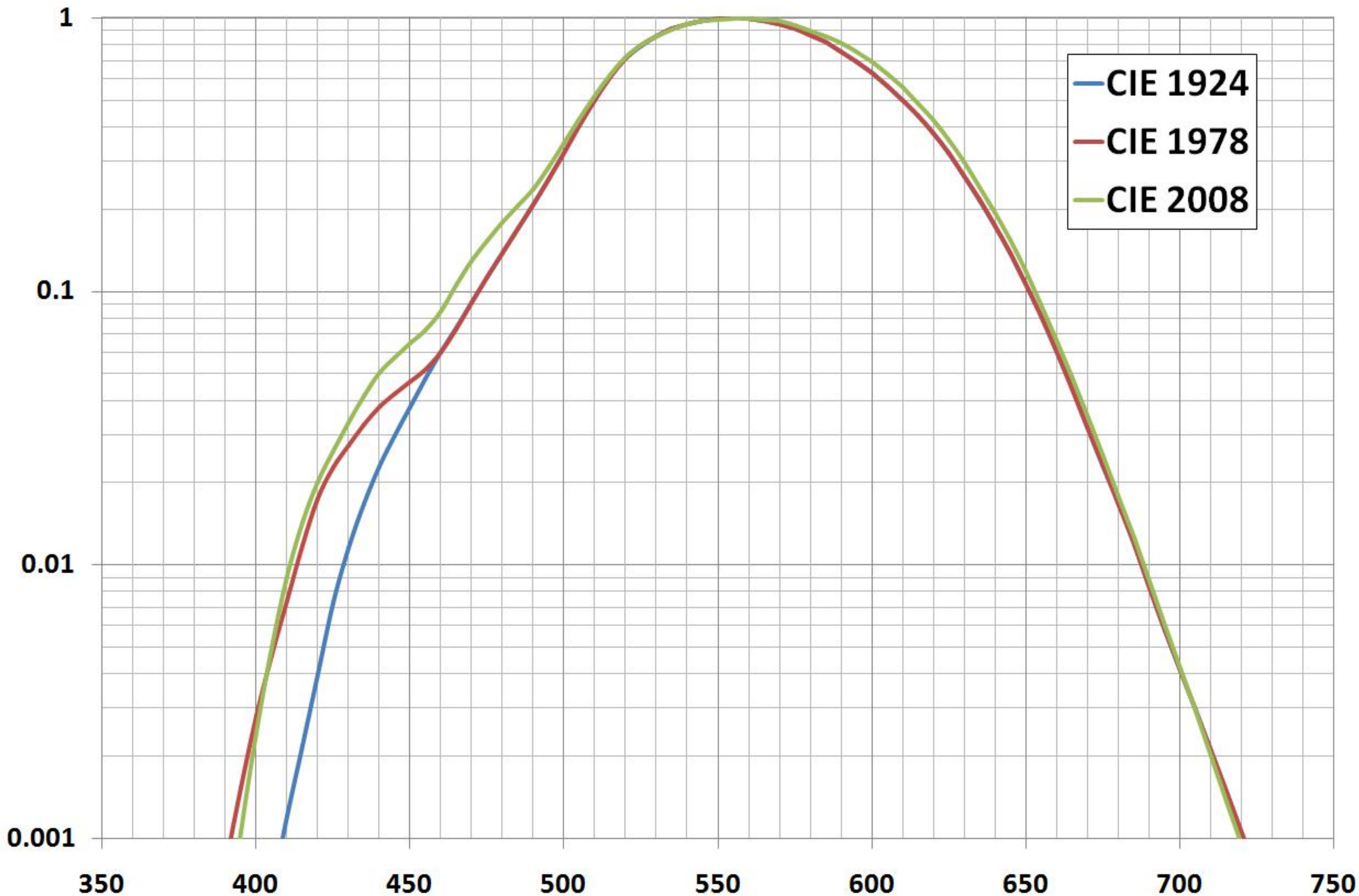

420
498
534
564
100
50
0
Normalized absorbance
S
R
M
L
400
500
600
700
Violet
Blue
Cyan
Green
Yellow
Red
Wavelength (nm)


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

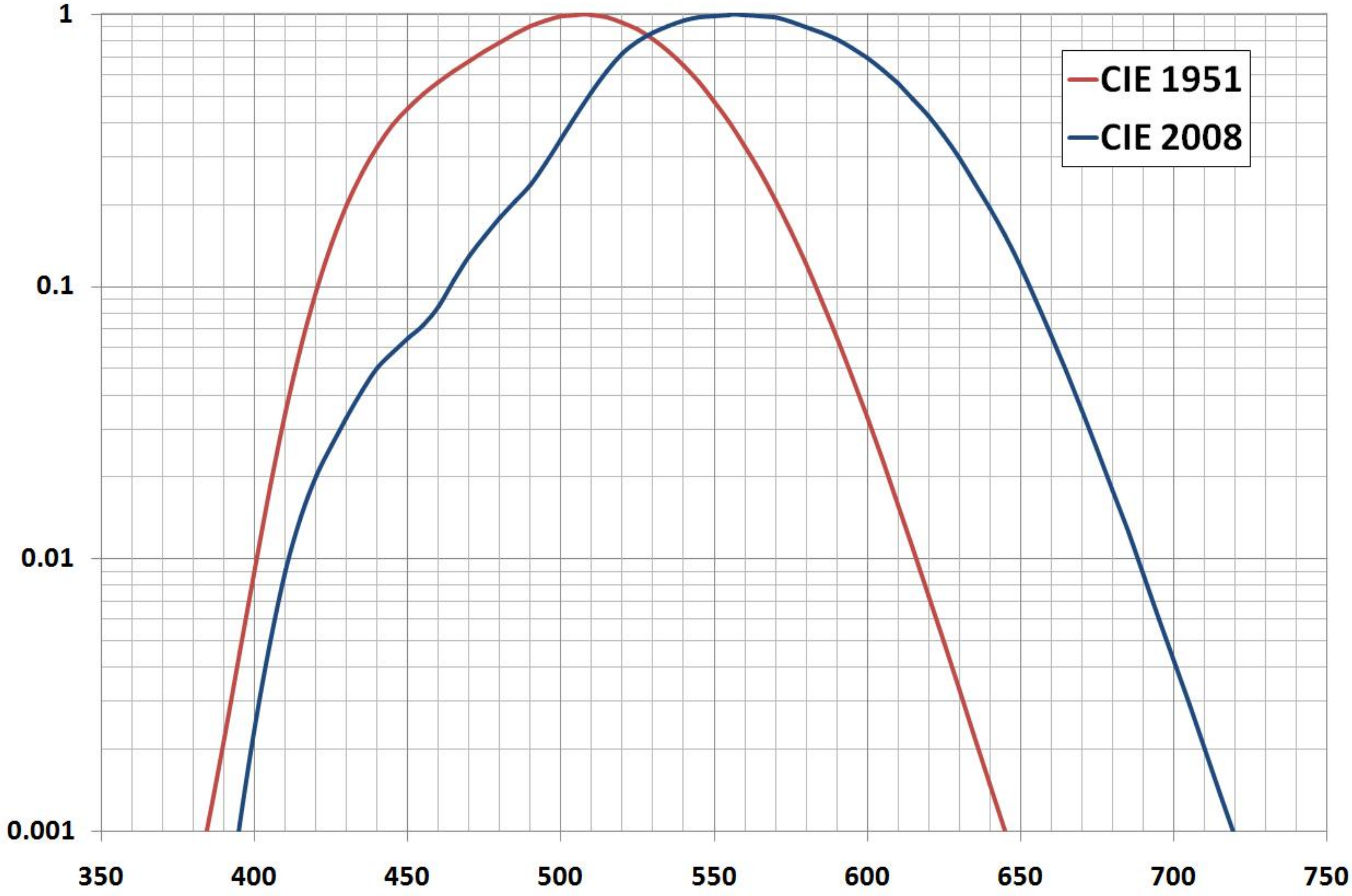
Standarde

- 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**), λ=555 nm, η_v = 683 lm/W
  - vedere nocturna (**scotopic**), λ=507 nm , η_v = 1700 lm/W

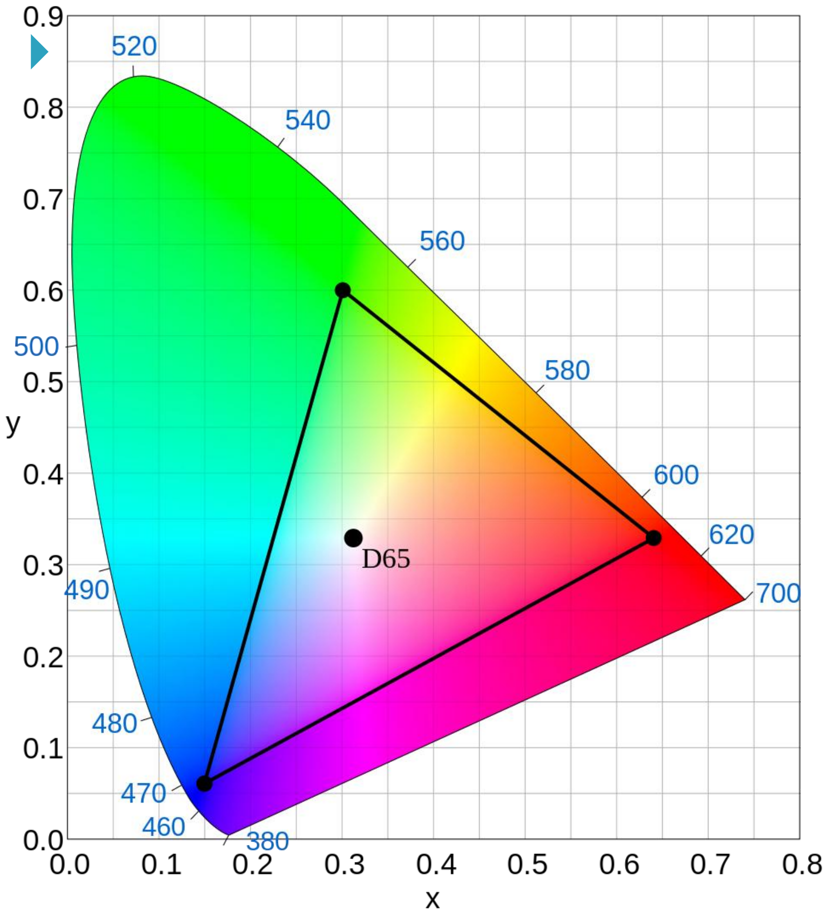
CIE V(λ) fotopic

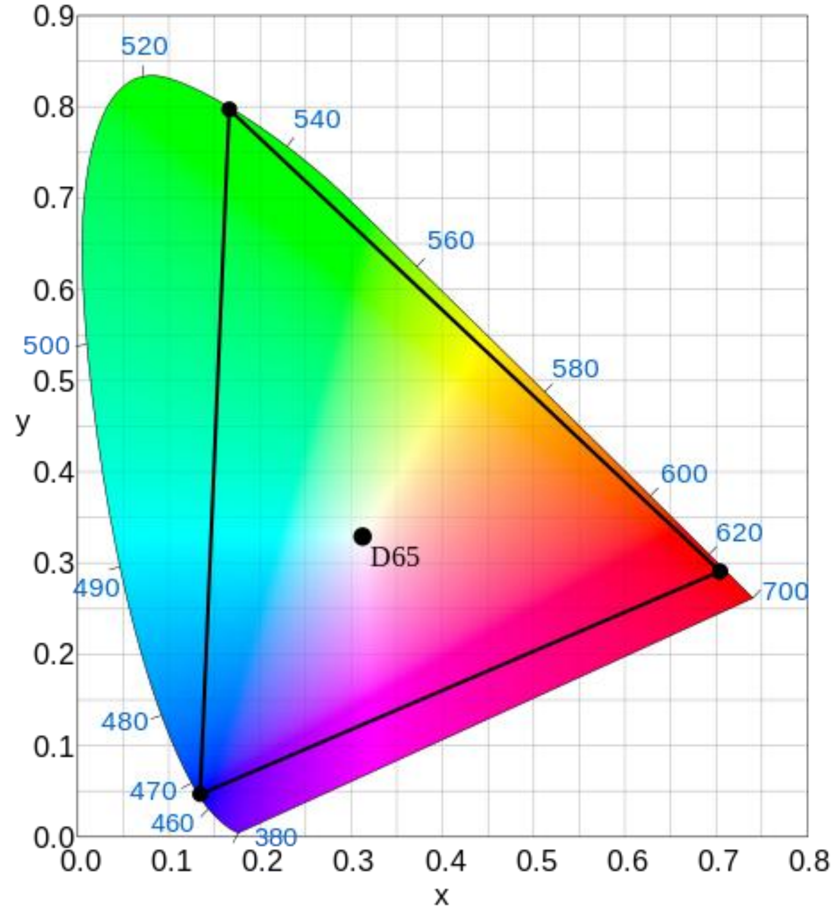


CIE V(λ) fotopic / scotopic



ITU-R BT.709/.2020





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

Marimi luminoase

- Standardele pentru surse luminoase (de ex. semne de circulatie), iluminarea spatiilor de lucru/odihna
  - sunt concepute cu marimi luminoase
  - lm, cd, lx, cd/m^2 etc.
- de multe ori se adapteaza relatiile pentru surse mai simple:

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

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

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°

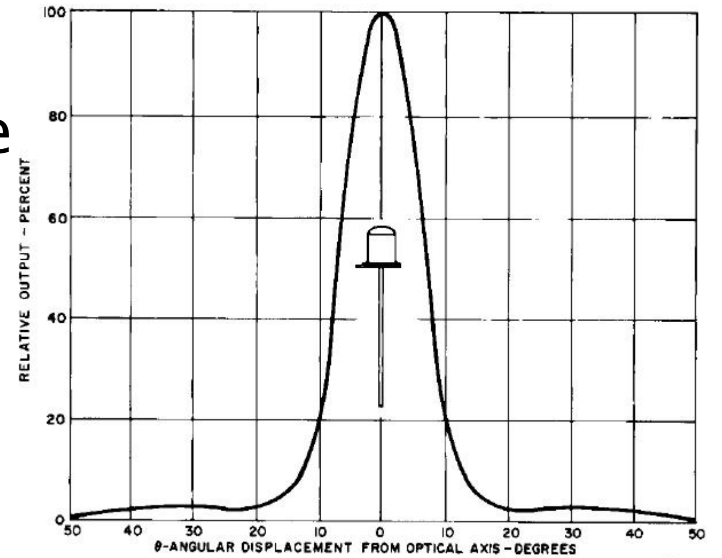
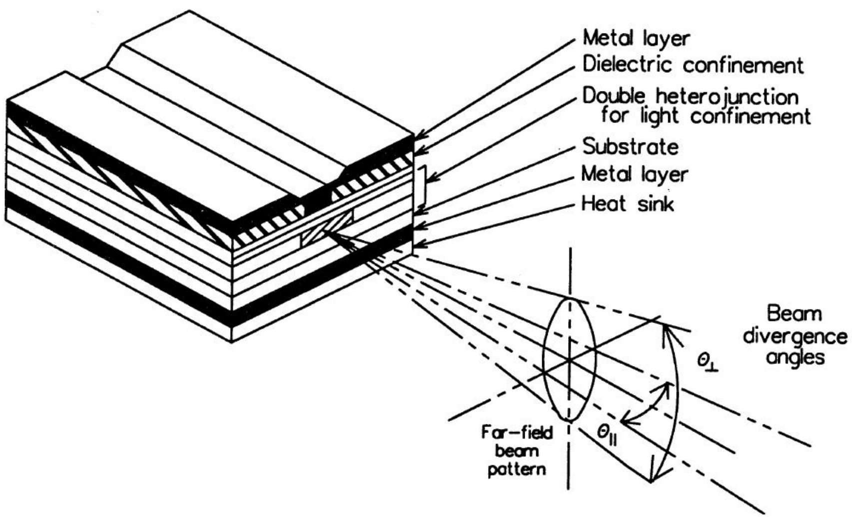


Fig. 5. Typical Radiation Pattern ST1054



Probleme

- Panoul unui dispozitiv conţine două LED-uri de semnalizare, unul de culoare verde şi unul roşu standard. Doriţi ca ambele să ofere aceeaşi luminozitate relativă şi cât mai mare posibilă. Dacă ambele LED-uri acceptă un curent maxim de 50 mA, calculaţi curentul prin cele două LED-uri.
- Rezolvari: http://rf-opto.etti.tuiasi.ro

Probleme

- Trebuie să proiectaţi un semafor cu LED-uri. LED-urile care intră în componenţa sa sunt caracterizate de eficienţă cuantică egală (aceeaşi tehnologie), iar parametrii de catalog pentru LED-ul roşu sunt …
- Proiectaţi semaforul, pentru a obţine o iluminare la 5m, pe direcţie normală, de 50 lx pe timp de zi şi 2 lx pe timp de noapte.
- Cerinţe: luminozitate egală pentru cele 3 culori, alegerea numărului de LED-uri (considerente electronice/practice), necesităţile de curent ale fiecărui LED, parametrii pentru sursa de alimentare, parametrii unui sistem de control a intensităţii luminoase pentru reglare zi/noapte.
- Rezolvari: http://rf-opto.etti.tuiasi.ro

Probleme

- O instalaţie de iluminare de urgenţă este realizată cu LED-uri care emit lungimea de undă dominantă $\lambda_0 = 520$nm sub un con cu unghi la vârf de 8.9° (**emisie presupusă uniformă în acest con**). LED-urile sunt montate în tavanul unei încăperi înaltă de 2.8m şi cu o suprafaţă de 36.5m^2 şi trebuie să asigure o iluminare de 0.95lx la nivelul podelei.
- Rezolvari: **http://rf-opto.etti.tuiasi.ro**

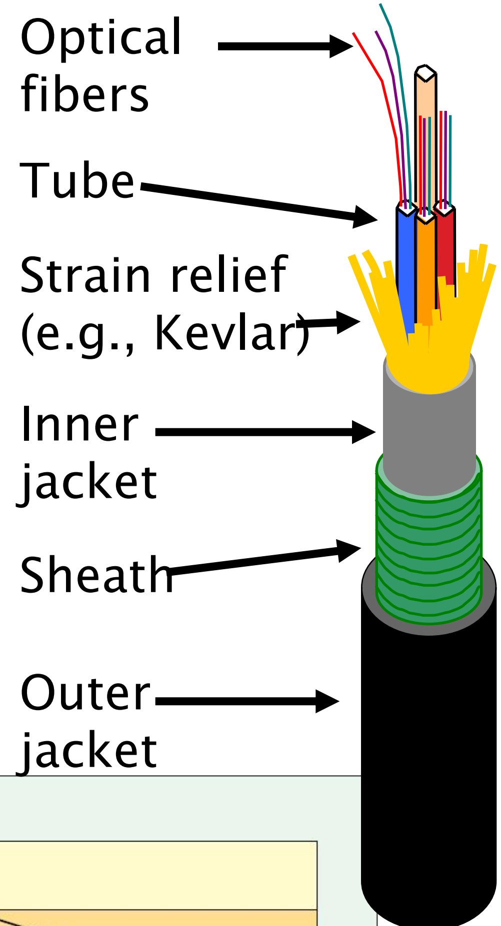
Continuare

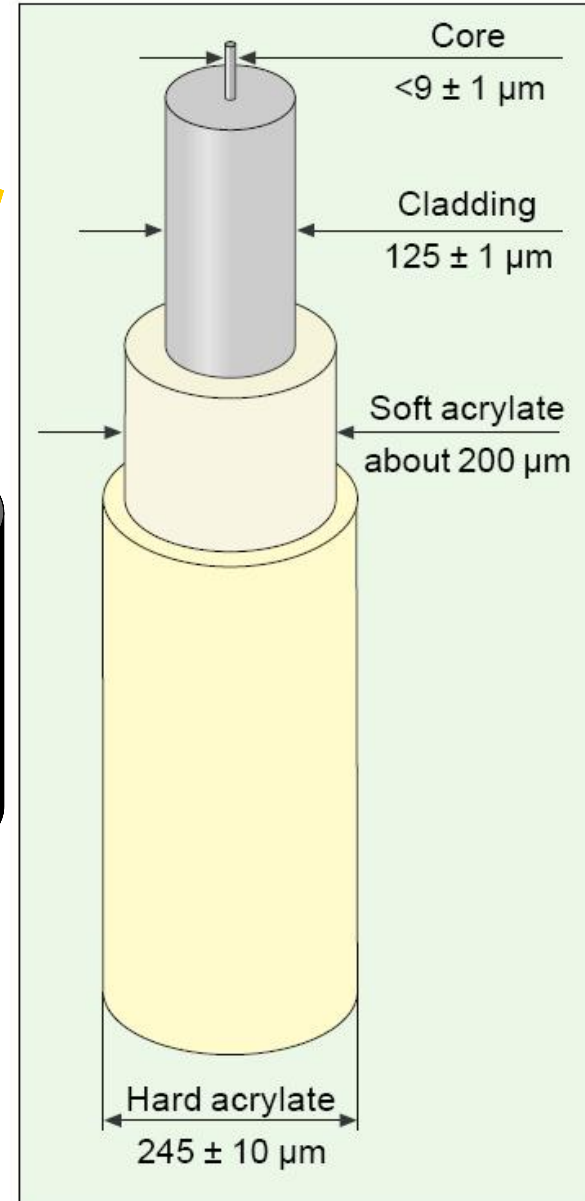
Fibra optică

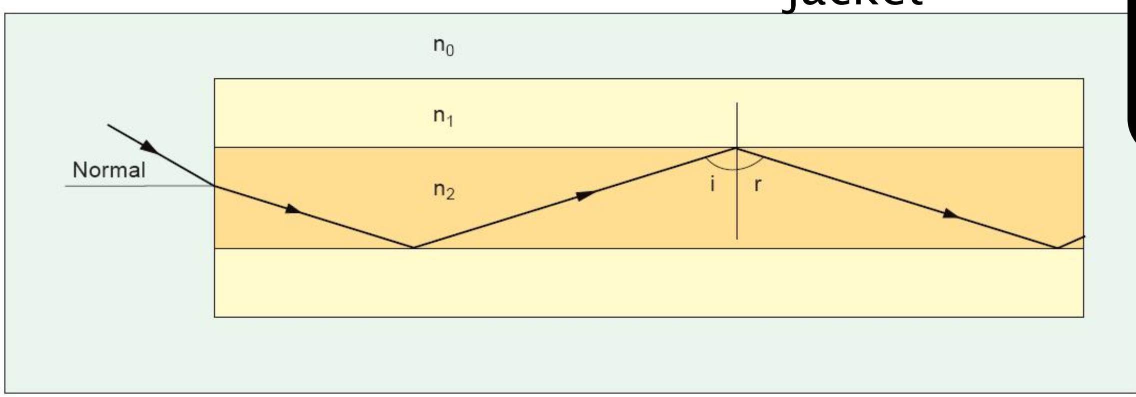
Capitolul 4

Fibra optica

- un ghid de unda dielectric
  - miez
  - teaca







Unghi de acceptanta, apertura numerica

- Unghi de acceptanta

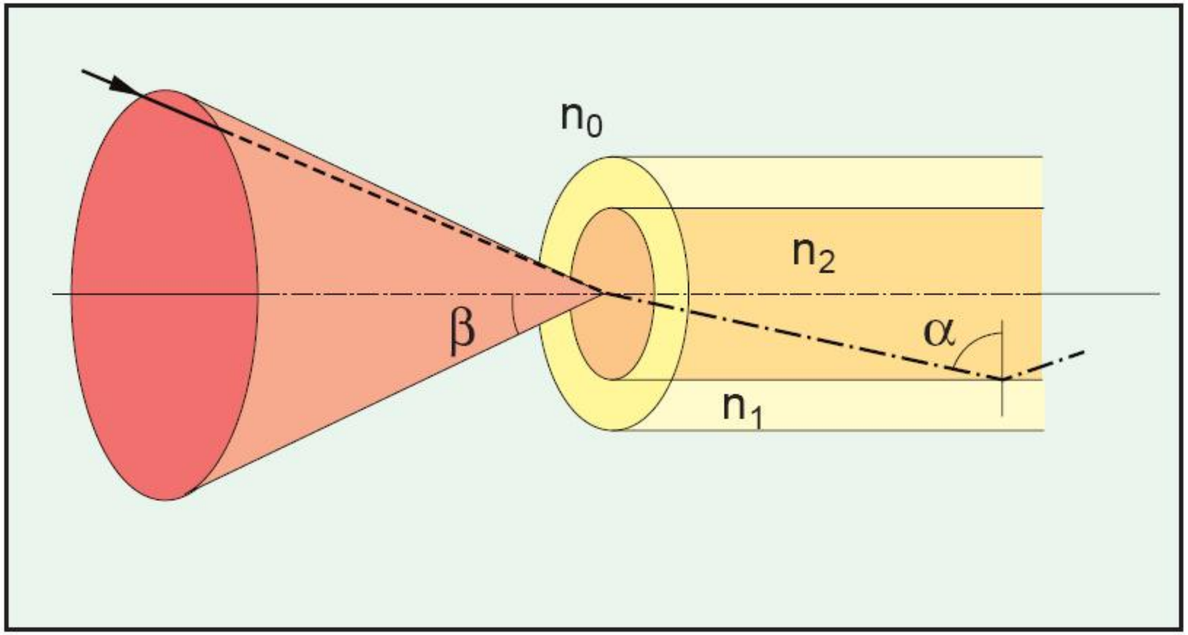
$$n_0 \cdot \sin\theta_{ACC} = n_2 \cdot \sin\phi_c$$

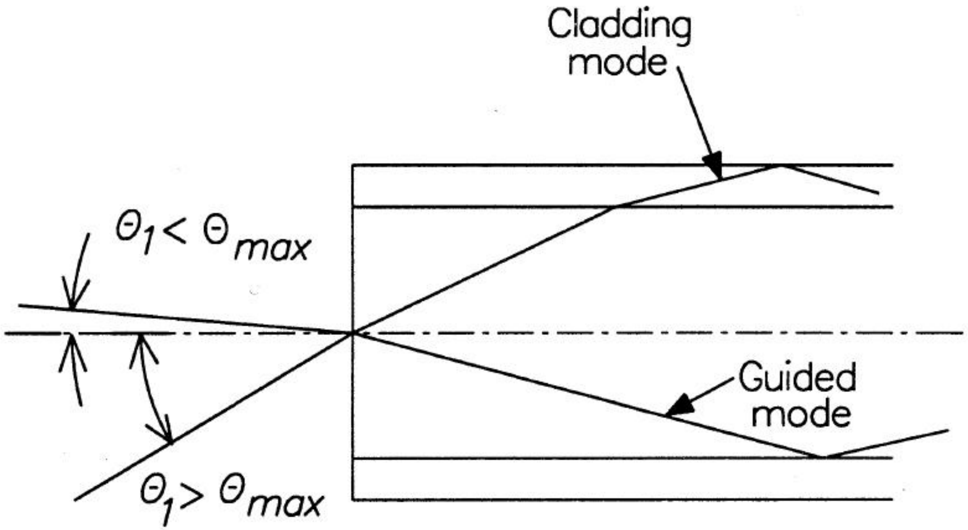
- **Apertura numerica**

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

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

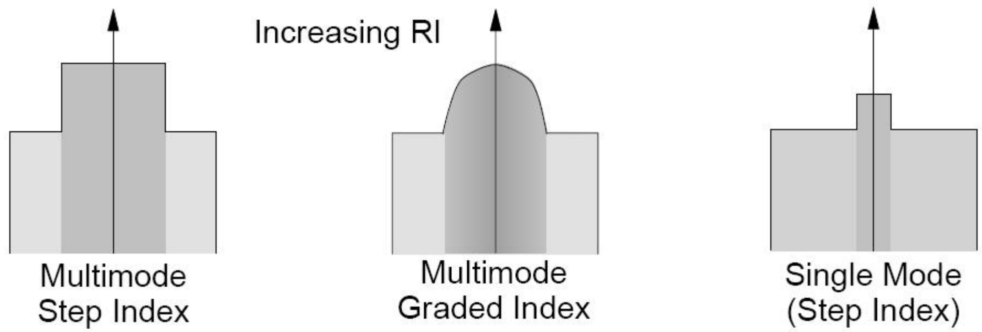
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

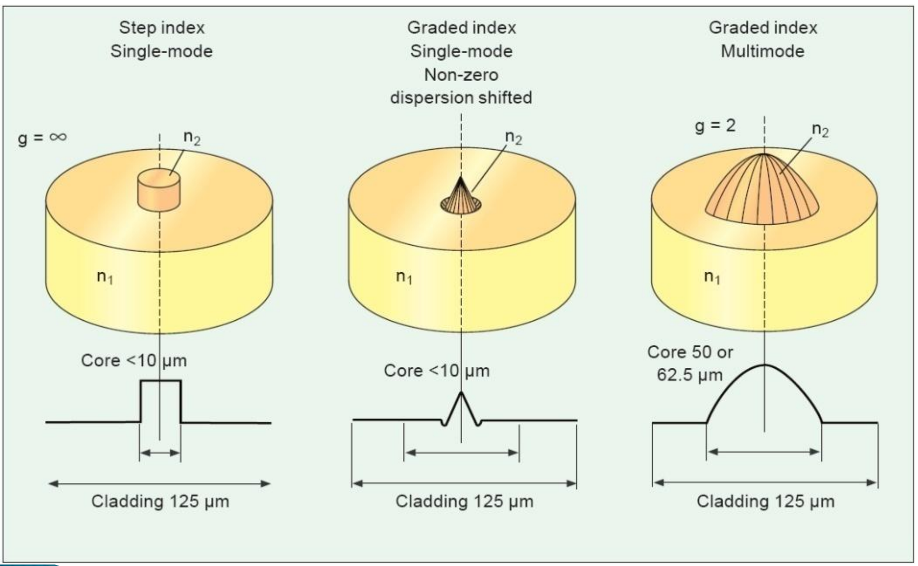


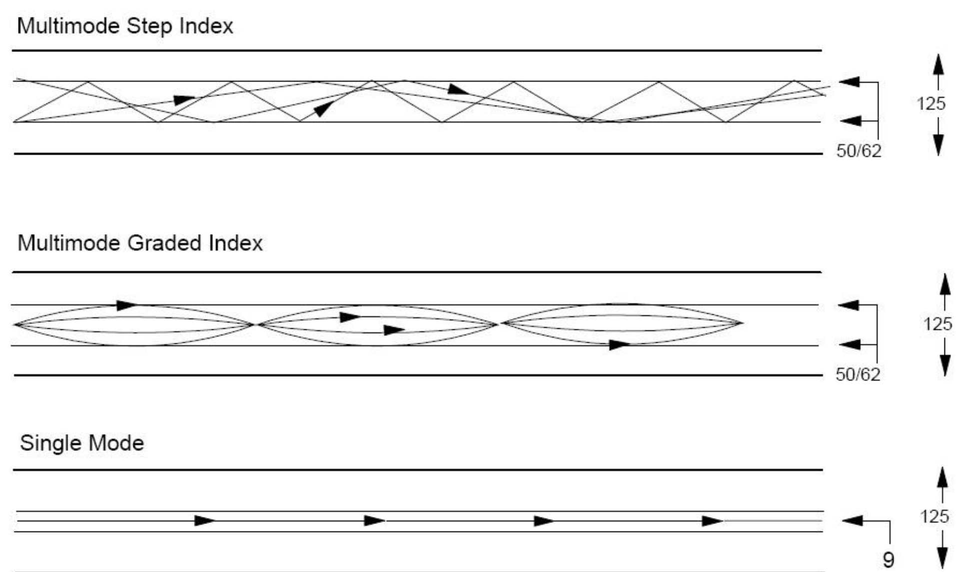


Tipuri de fibra

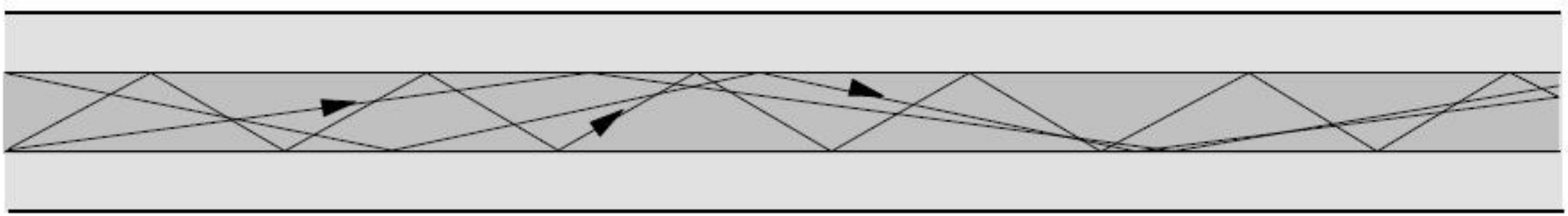
- Monomod
- Multimod
  - cu salt de indice
  - cu indice gradat



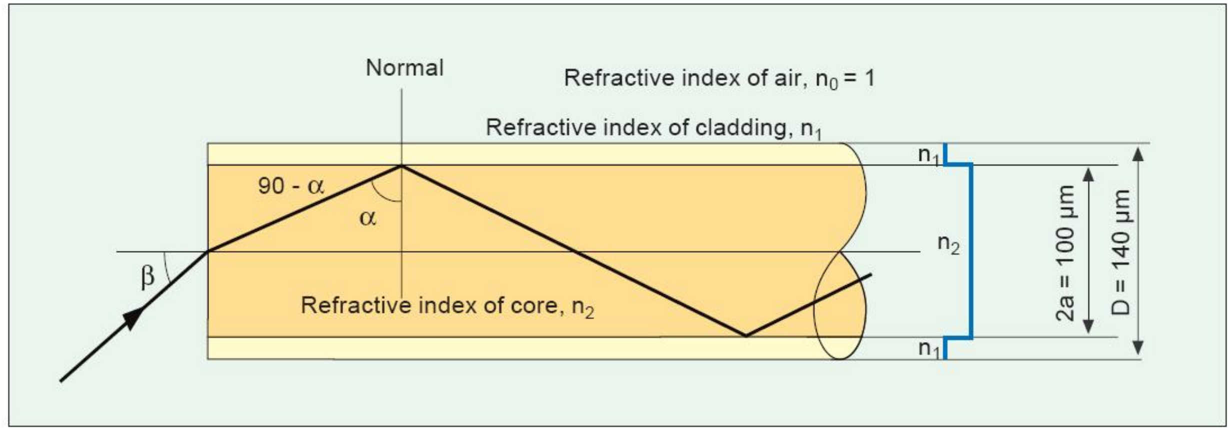


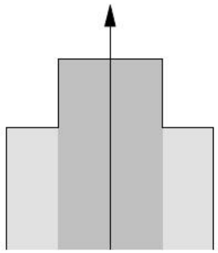


Fibre multimod cu salt de indice



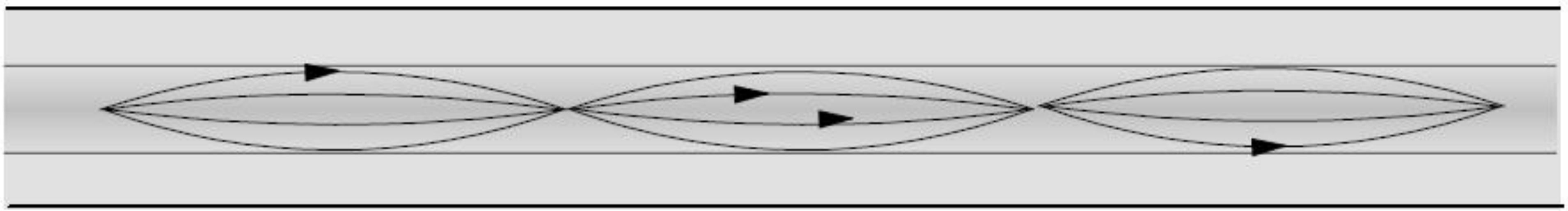
- 50/125 sau 62.5/125 (µm)
- 15-50 MHz · km



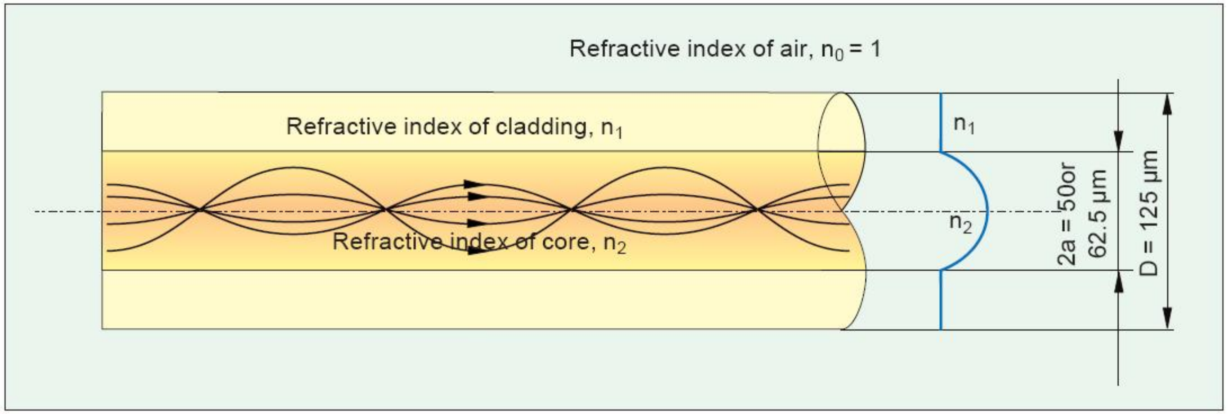


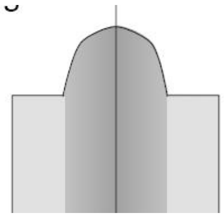
	glass	plastic
core diameter 2a	100 µm	980 µm
cladding diameter D	140 µm	1000 µm
core refractive index n_2	1.48	
cladding refractive index n_1	1.45	

Fibre multimod cu indice gradat



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

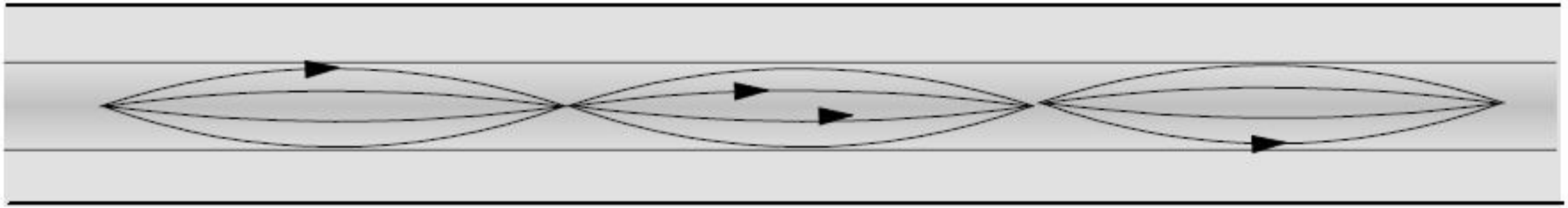




Core diameter 2a	50 or 62.5 µm
Cladding diameter D	125 µm
Maximum refractive index, core	1.46
Relative differential refractive index	0.010

Fata Morgana

Fibre multimod cu indice gradat

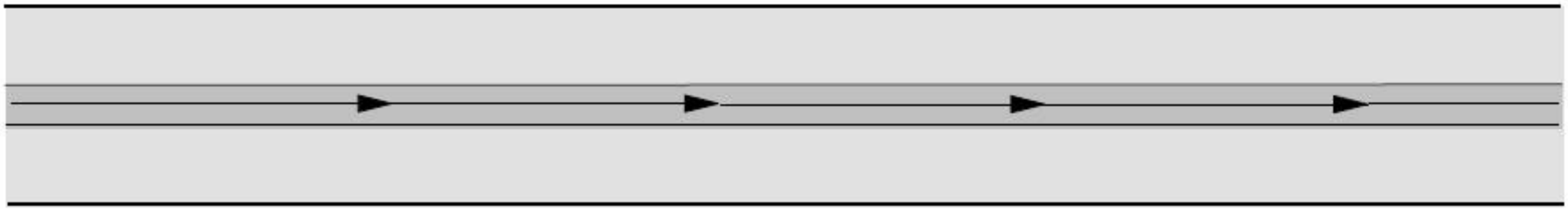


$$n(r) = n_2\left[1 - \Delta\left(\frac{r}{a}\right)^g\right]$$

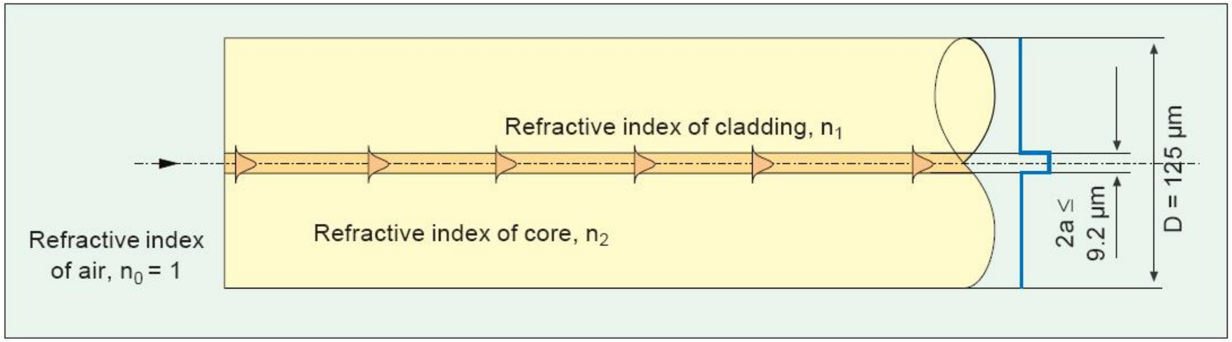
$$\Delta = \frac{NA^2}{2n_2^2} = \frac{n_2^2 - n_1^2}{2n_2^2} \approx \frac{n_2 - n_1}{n_2} \approx \frac{\Delta n}{n} \quad \text{for } \Delta << 1$$

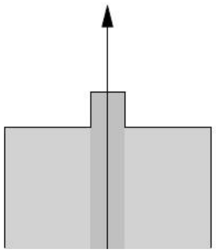
- g = 1 – indice gradat triunghiular
- g = 2 – indice gradat parabolic
- g = ∞ – salt de indice

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)

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

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

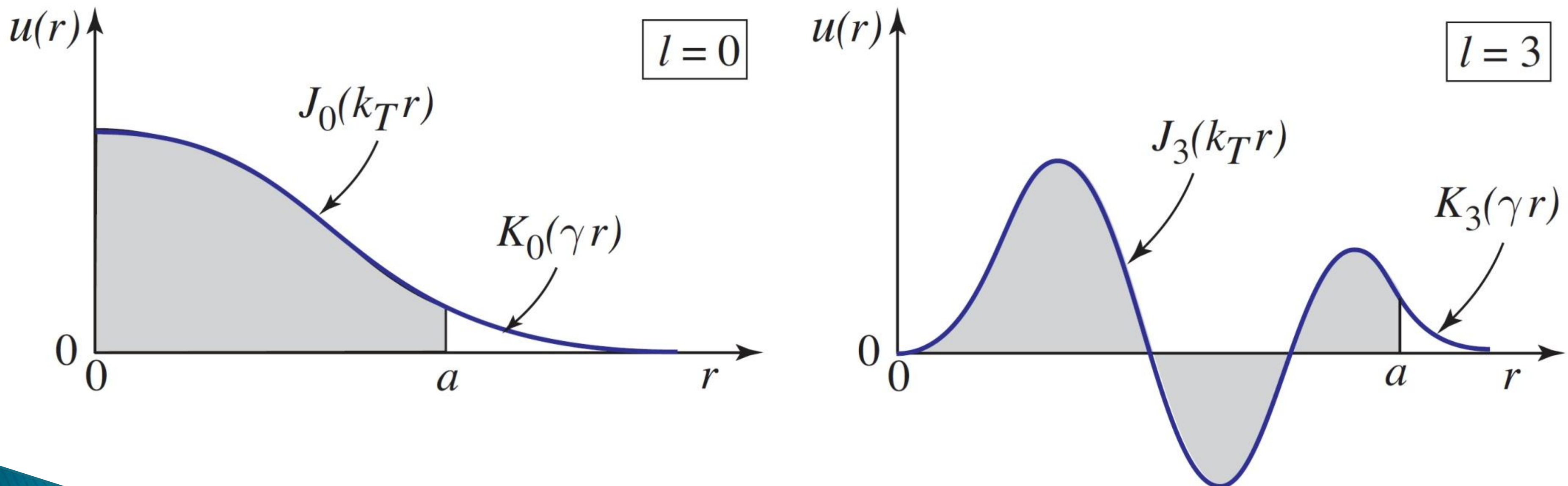
$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \left(k_T^2 - \frac{l^2}{r^2}\right)u = 0, \qquad r < a$$

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

Ghid cilindric dielectric

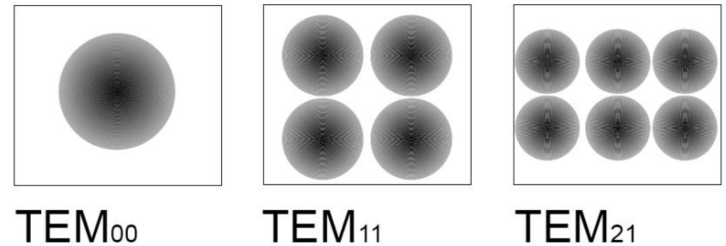
- solutii proportionale cu functii Bessel

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

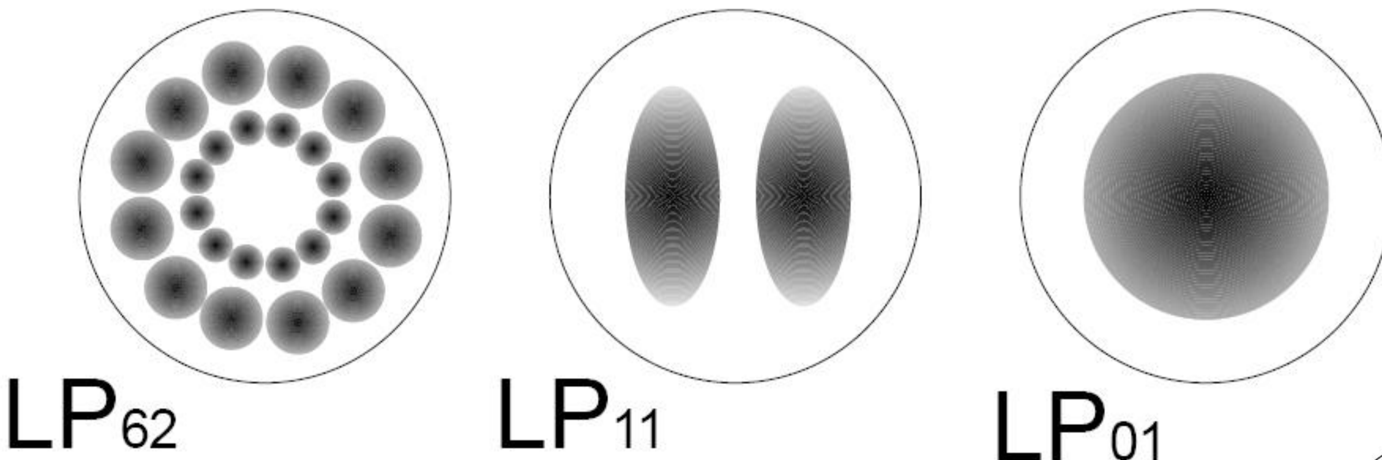


Moduri in fibra

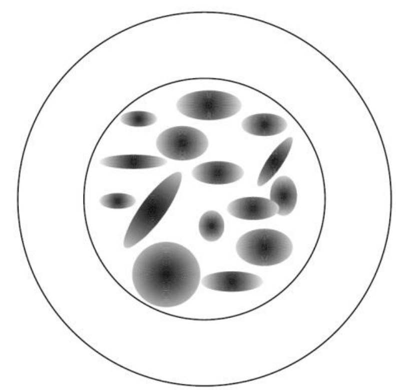
- Moduri in ghid rectangular



- Moduri linear polarizate in fibra



"Sparkle" pattern



Frecventa normalizata

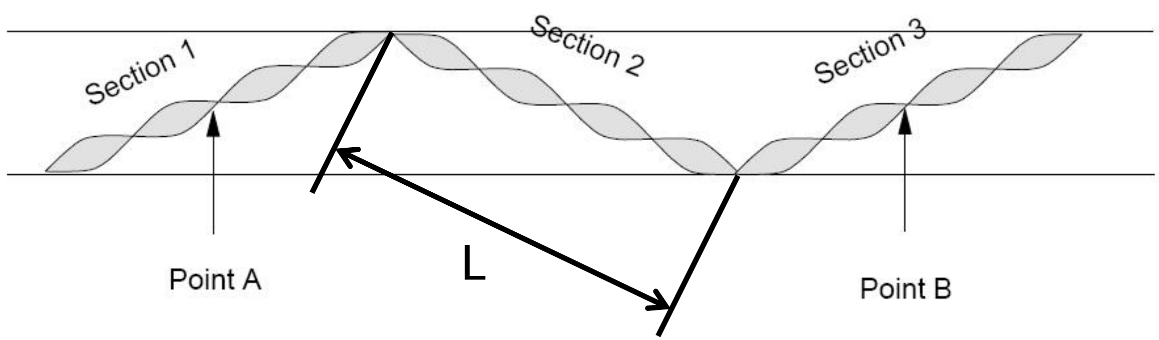
- Frecventa normalizata

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

a – raza miezului

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

- Numar de moduri

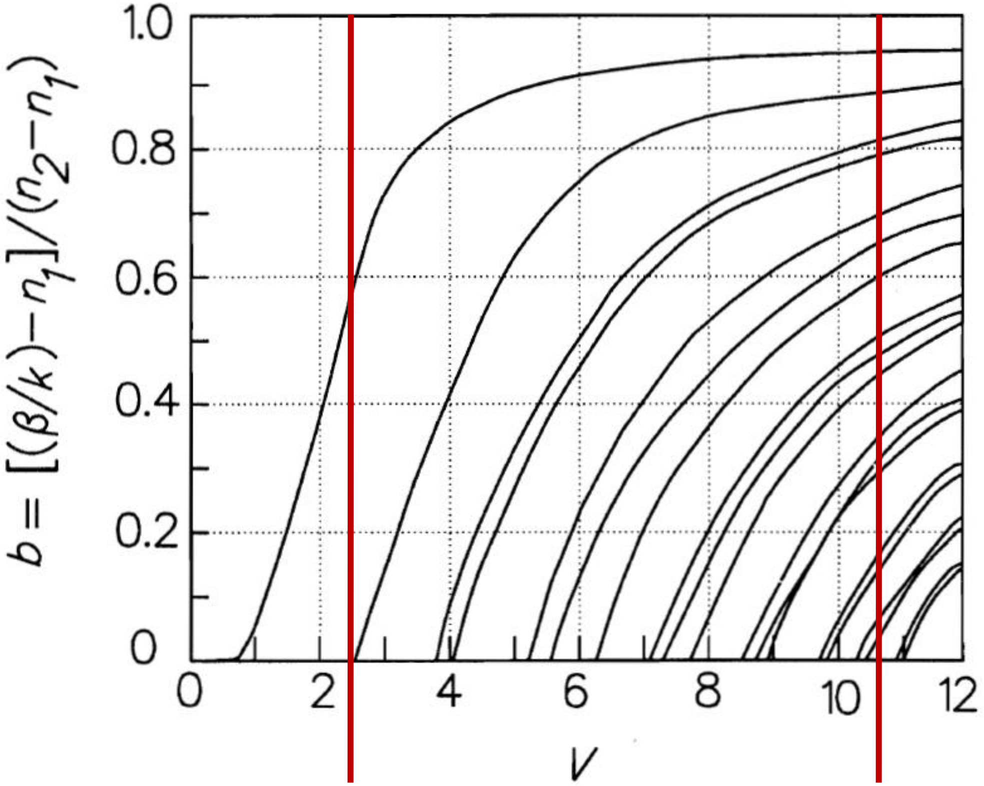


$$L = m \cdot \lambda$$

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

Frecventa normalizata – monomod

- Fibre monomod



b – coeficient de propagare modal relativ

$$V \leq V_C = 2.405$$

exista un **singur** mod (solutii fc. Bessel)

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

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

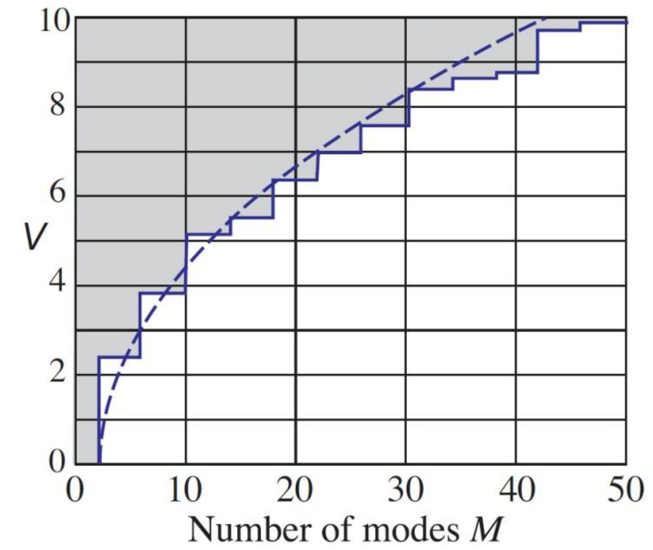
$$g = \infty \quad \Rightarrow \quad N \approx \frac{V^2}{2}$$

  - Multimod cu indice gradat

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

  - Monomod

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



$V \leq V_C = 2.405$ exista un singur mod (solutii fc. Bessel)

Exemplu

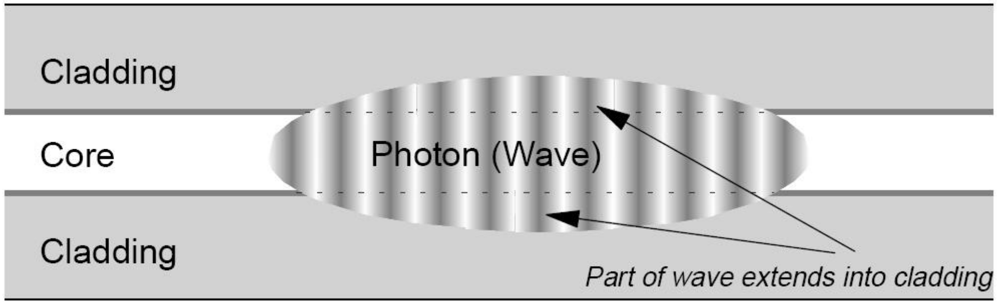
- fibra tipica multimod
  - g=2
  - 2a = 50µm -> a = 25µm
  - NA = 0.2 la λ = 1µm

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

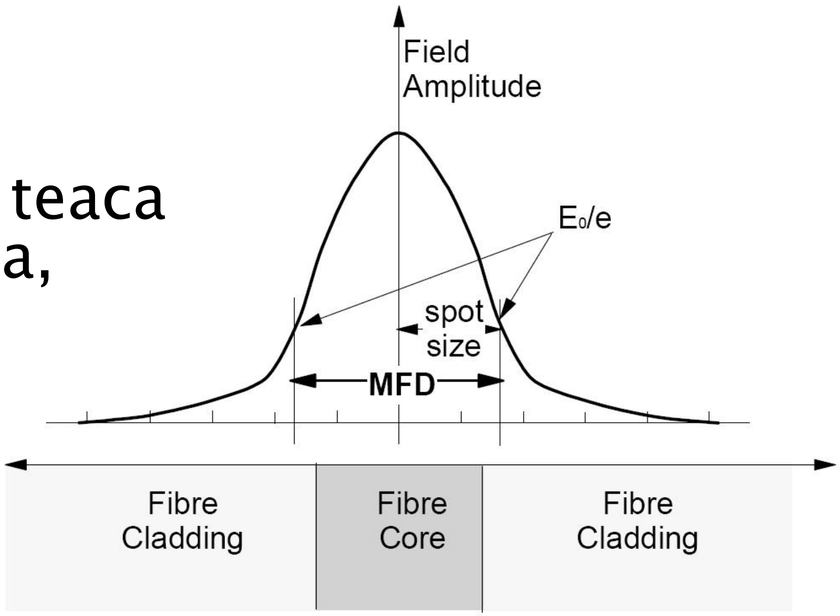
$$g = 2 \quad \Rightarrow \quad N = \frac{V^2}{4} = \frac{31.4^2}{4} = 247$$

Propagarea in fibra monomod

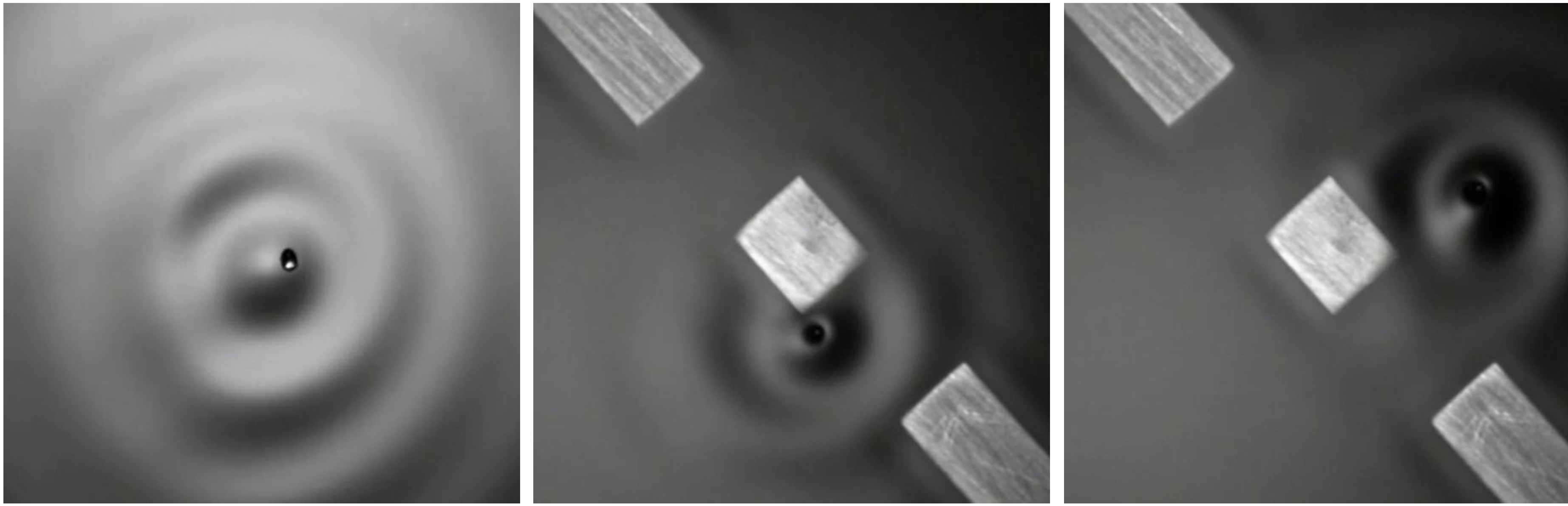
- Propagarea luminii poate fi explicata doar prin teoria electromagnetica



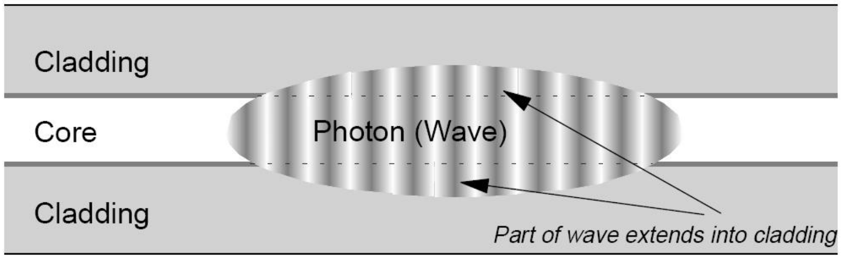
- Energia campului se extinde in teaca (diametrul efectiv al spotului luminos – MFD, Mode Field Diameter)
- MFD > 2a
- Adancimea de patrundere in teaca depinde de lungimea de unda, generand dispersia de ghid



Modelare



Through the Wormhole
S02E07 How Does the Universe Work



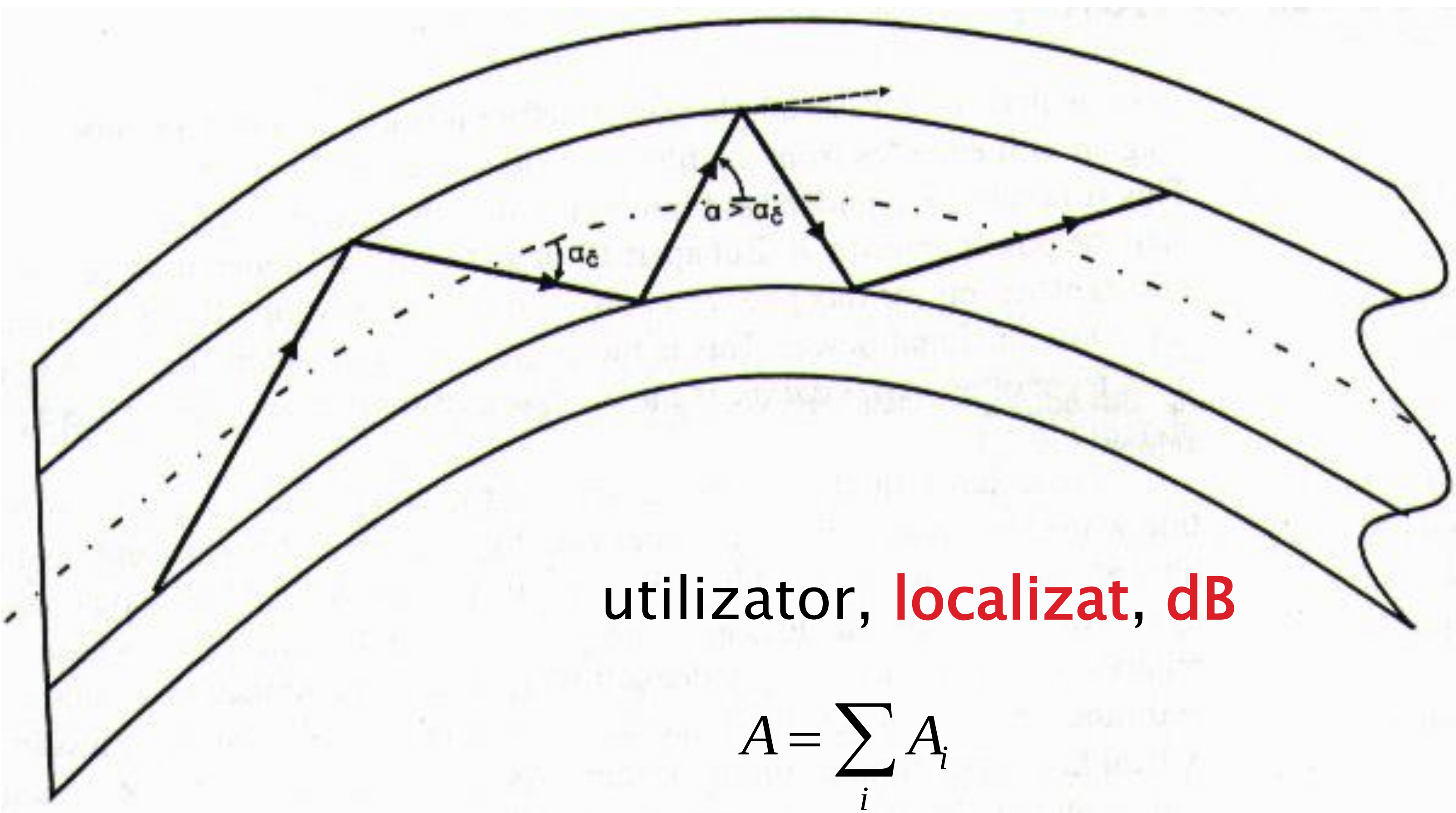
Fenomene de interes

- 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



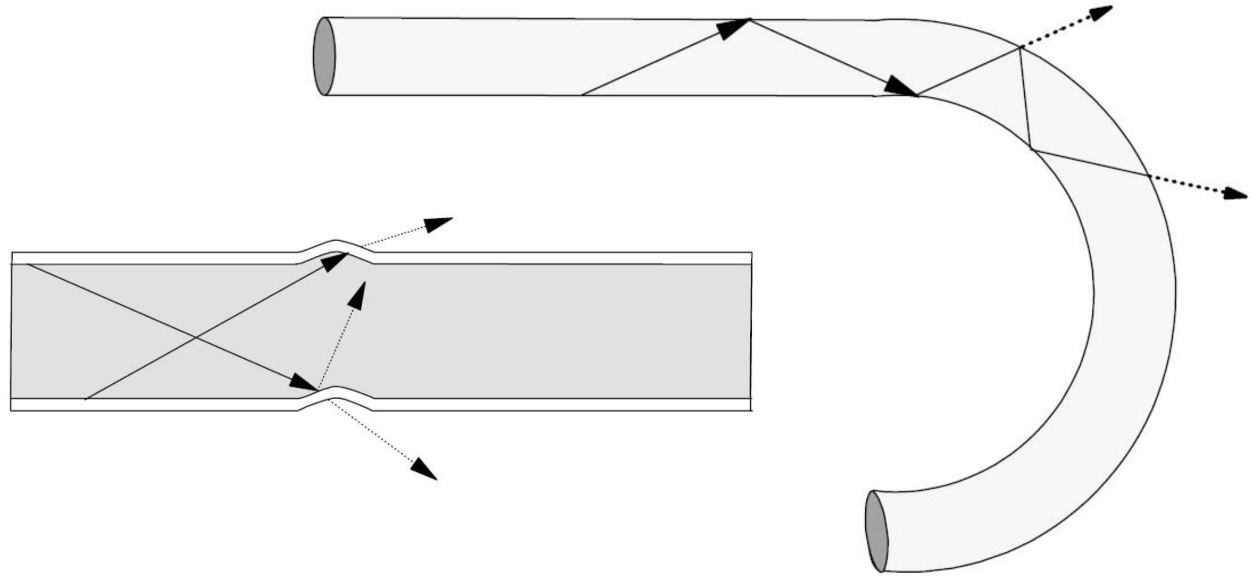
utilizator, **localizat**, **dB**

$$A = \sum_i A_i$$

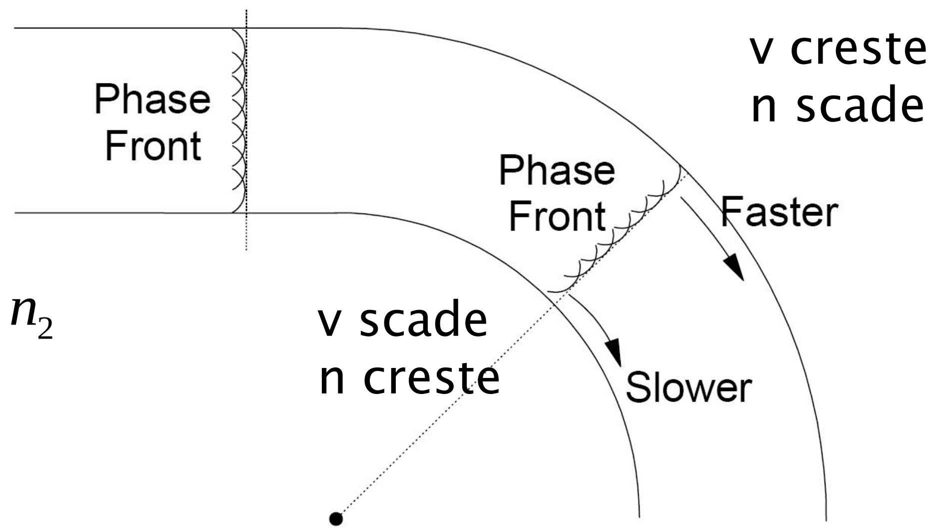
$$A = N \cdot A_i$$

Efectul curburilor

- Multimod



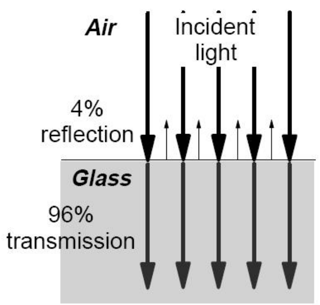
- Monomod

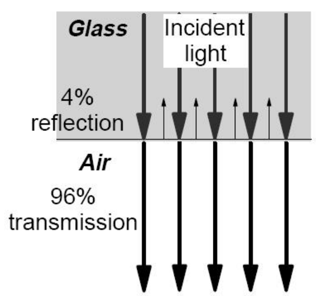


$$R > R_C \quad \Rightarrow \quad n_{1,ext} > n_2$$

Discontinuitate in fibra

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



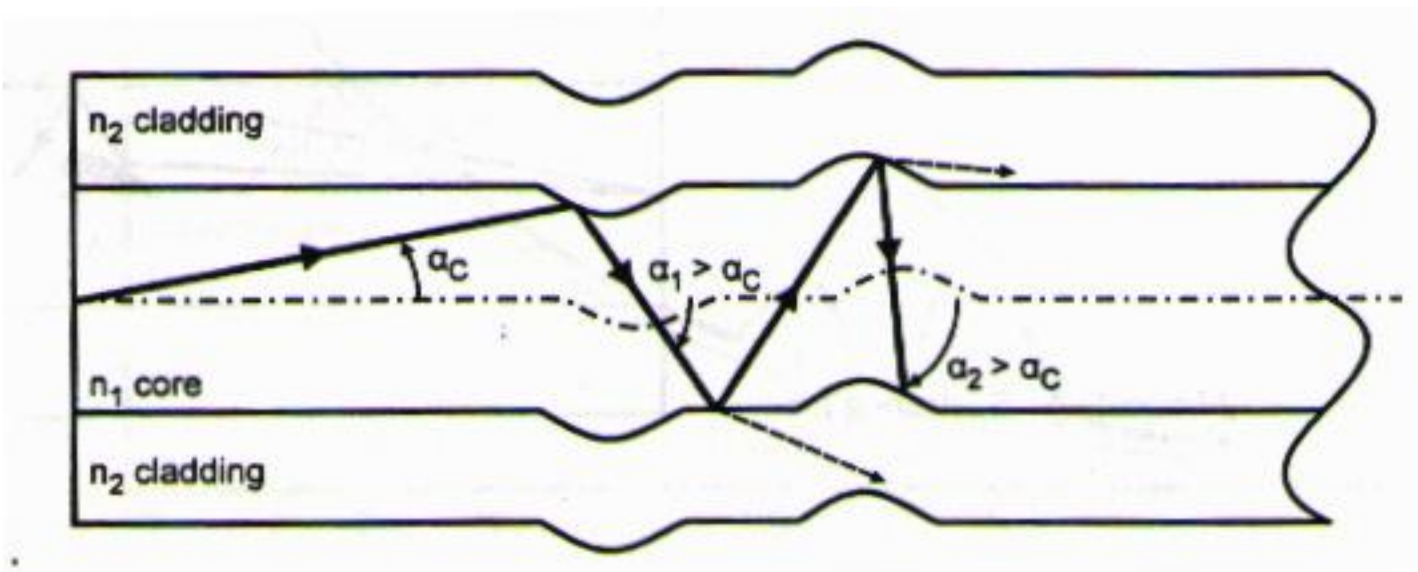


utilizator, localizat, dB

$$A = \sum_i A_i$$

$$A = N \cdot A_i$$

Microcurburi

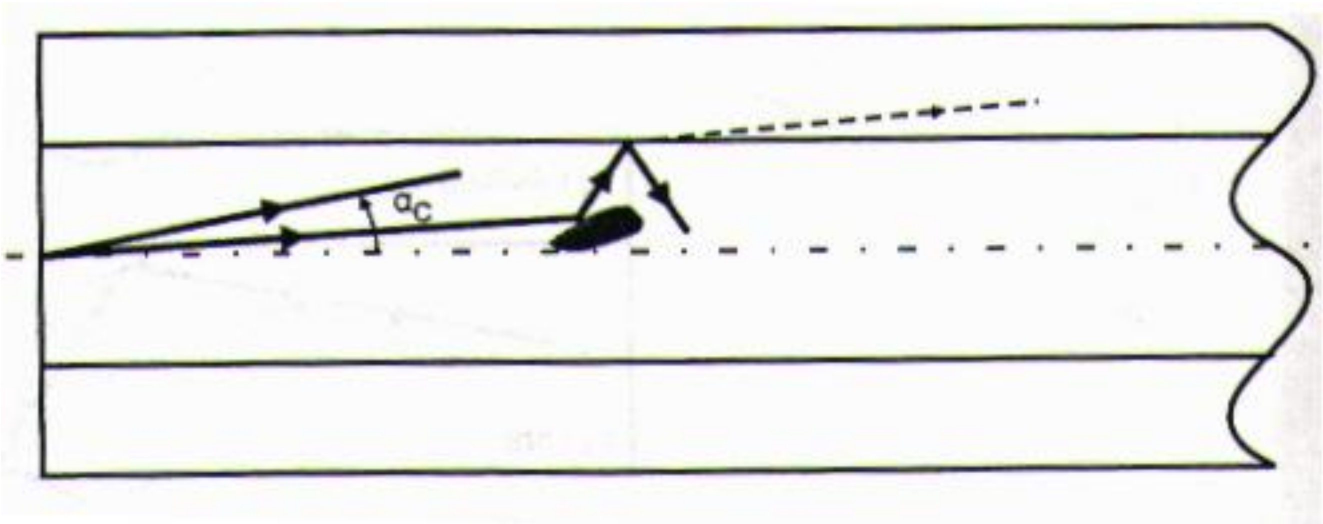


distribuit, tehnologie, dB/km

$$A = A_i \cdot L$$

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

Imprastiere

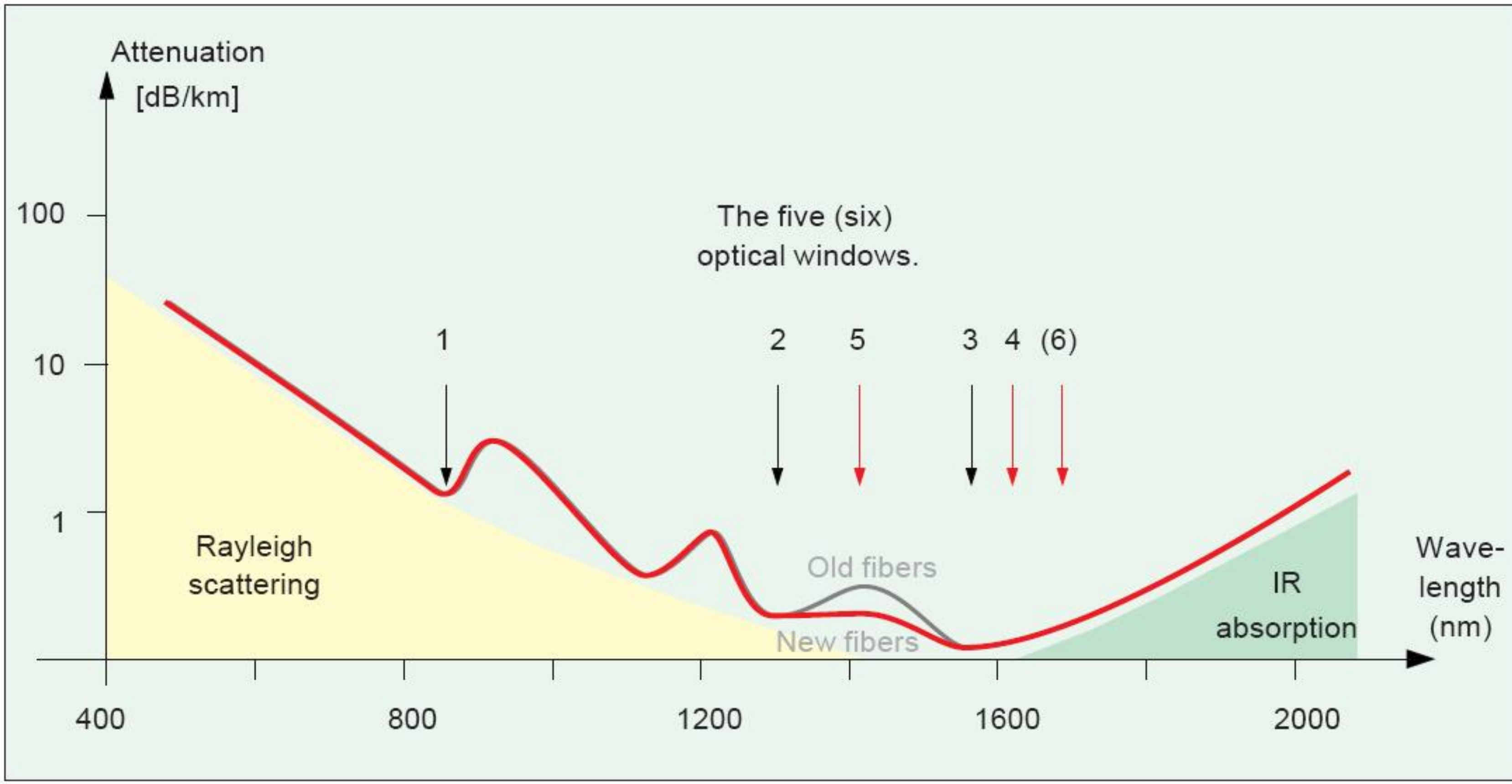


distribuit, tehnologie, dB/km

$$A = A_i \cdot L$$

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

Absorbtie

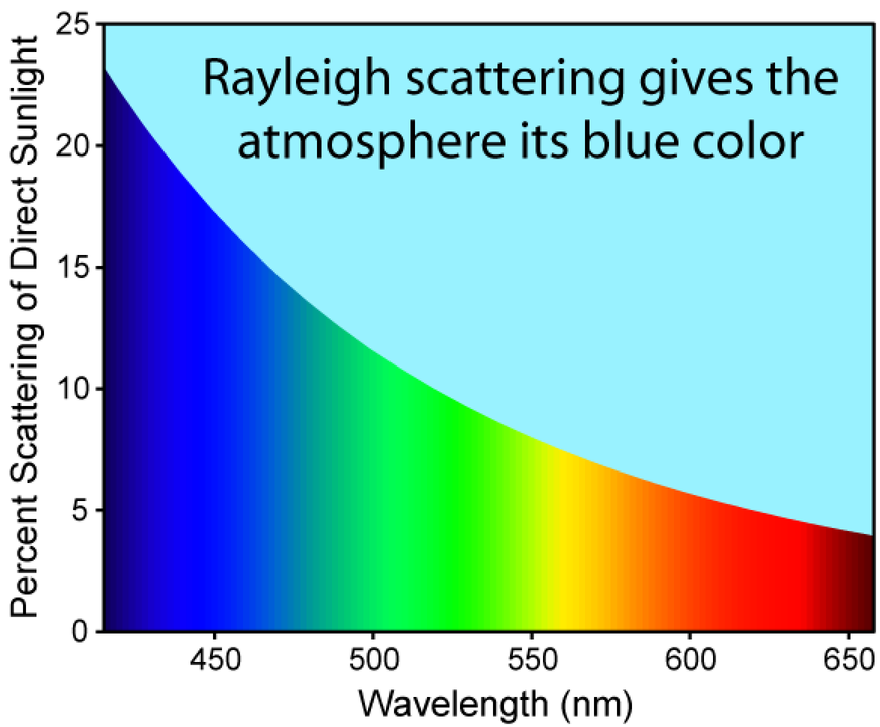


distribuit, material, **dB/km**

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

Difractie Rayleygh

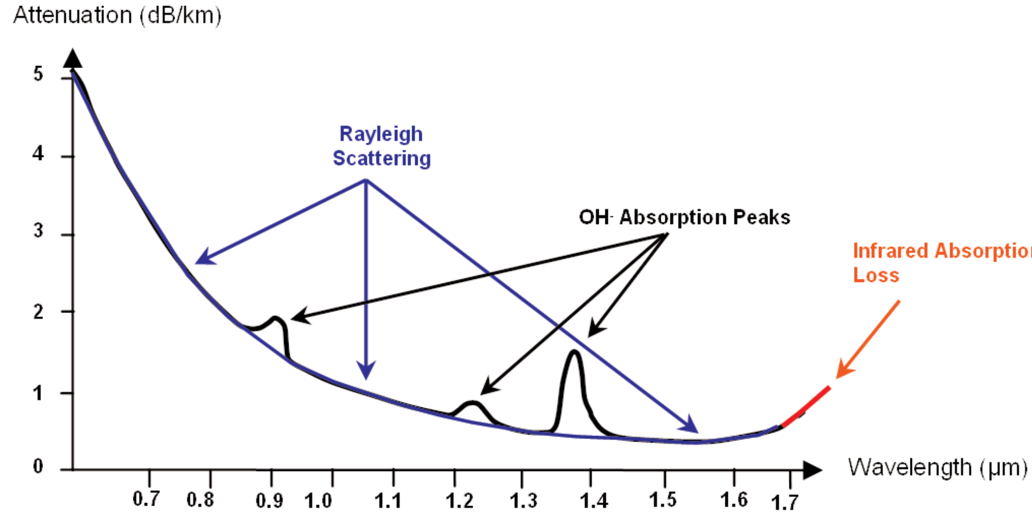
- imprastierea luminii (si a altor radiatii electromagnetice) de particule (molecule) mult mai mici decat lungimea de unda

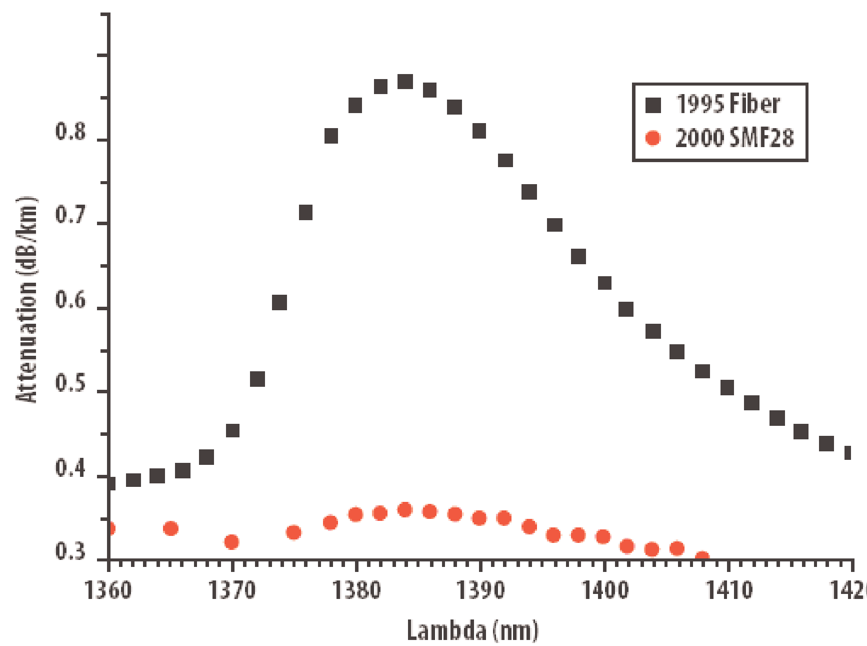


$$A \sim \frac{1}{\lambda^4}$$

Absorbtie OH

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





Fiber Attenuation Comparison

Atenuare

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

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

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

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

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

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

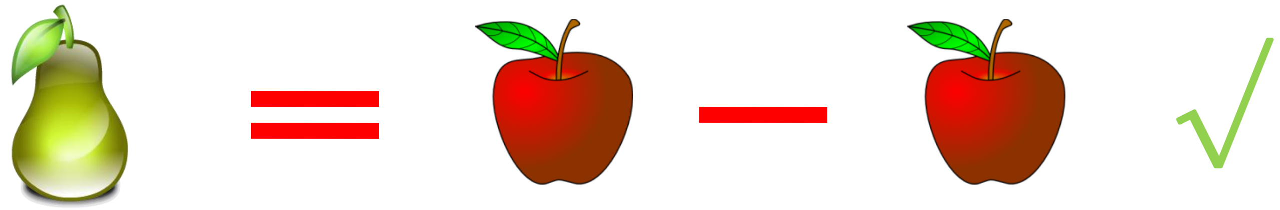
- Atenuarea se exprima de obicei in **dB/km**
  - de obicei valori pozitive
  - semnul = **implicit**

Calculul atenuarii

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

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

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

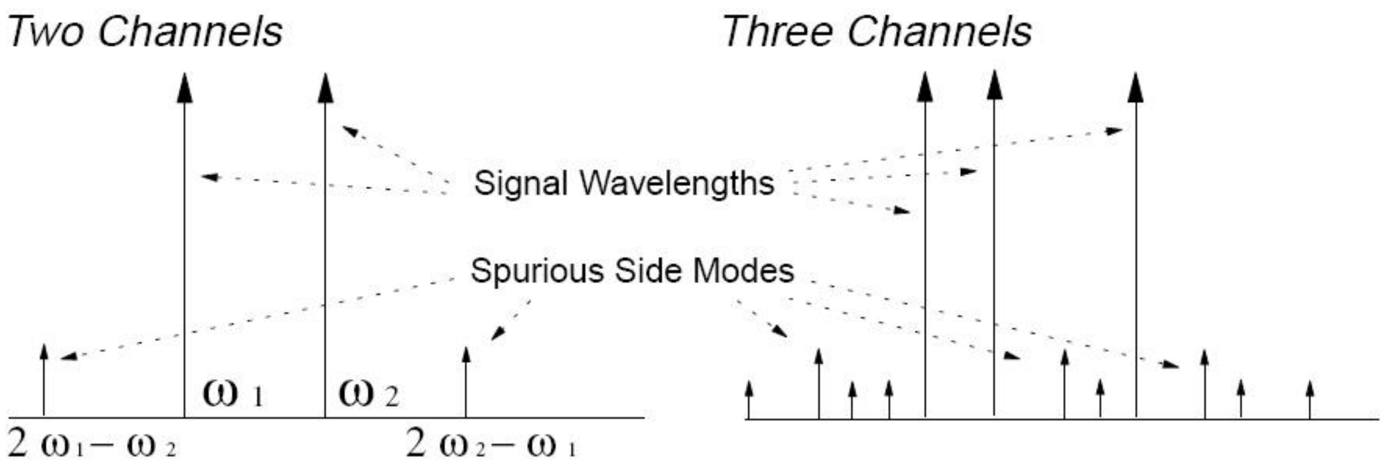


$$\text{Atenuare}[\text{dB/km}] = \frac{\text{Pierderi}[\text{dB}]}{\text{lungime}[\text{km}]}$$

Efecte neliniare in fibra

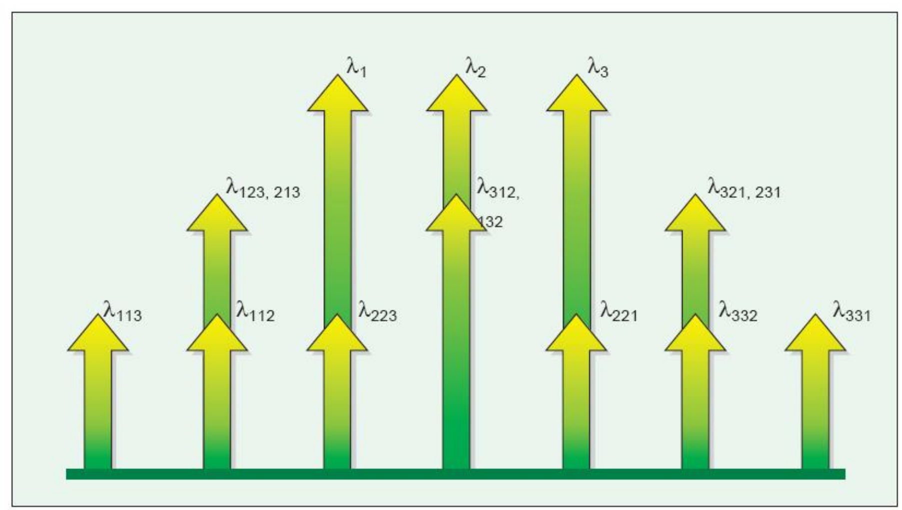
- Stimulated Brillouin Scattering, SBC
  - difractia luminii inspre emitator datorita undelor mecano-acustice generate in fibra
  - 6-10 dBm
- Stimulated Raman Scattering, SRS
  - interactiunea luminii cu vibratiile moleculare
  - 27 dBm (~1W)
- Self Phase Modulation, SPM
  - Frontiera impulsului implica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

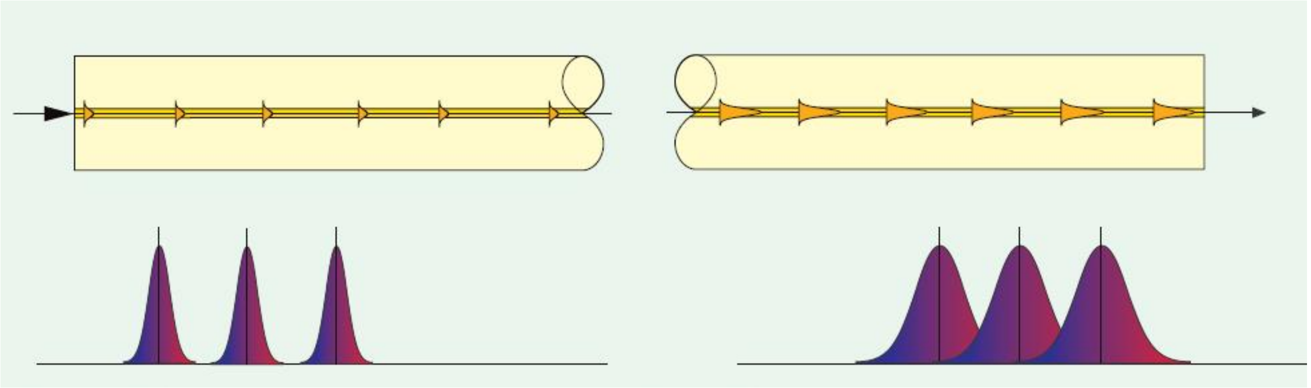


Fenomene de interes

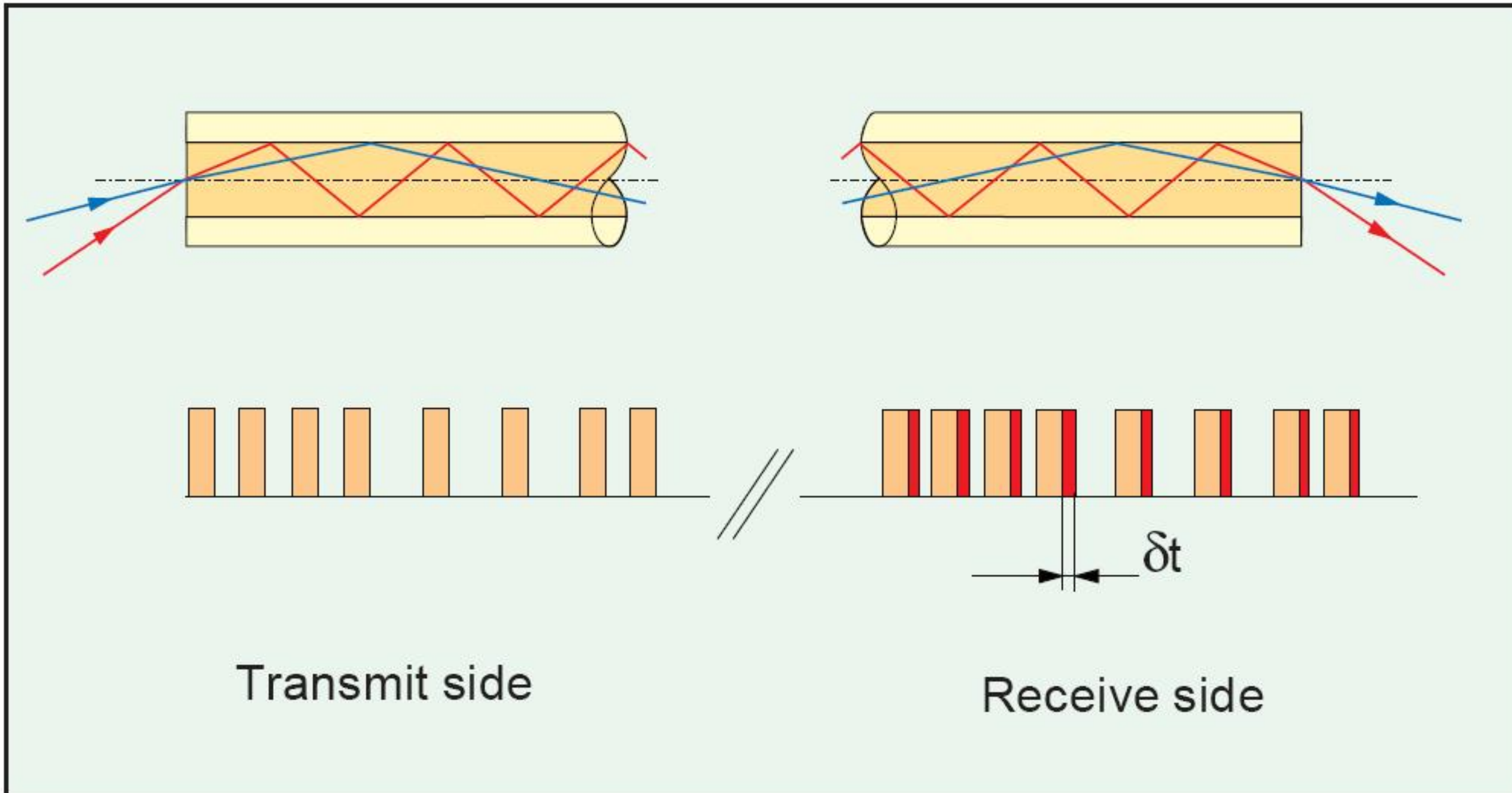
- Cat de departe pot transmite semnalul luminos pe fibra
  - atenuare
- Cat de rapid pot transmite informația
  - **dispersie**

Dispersia

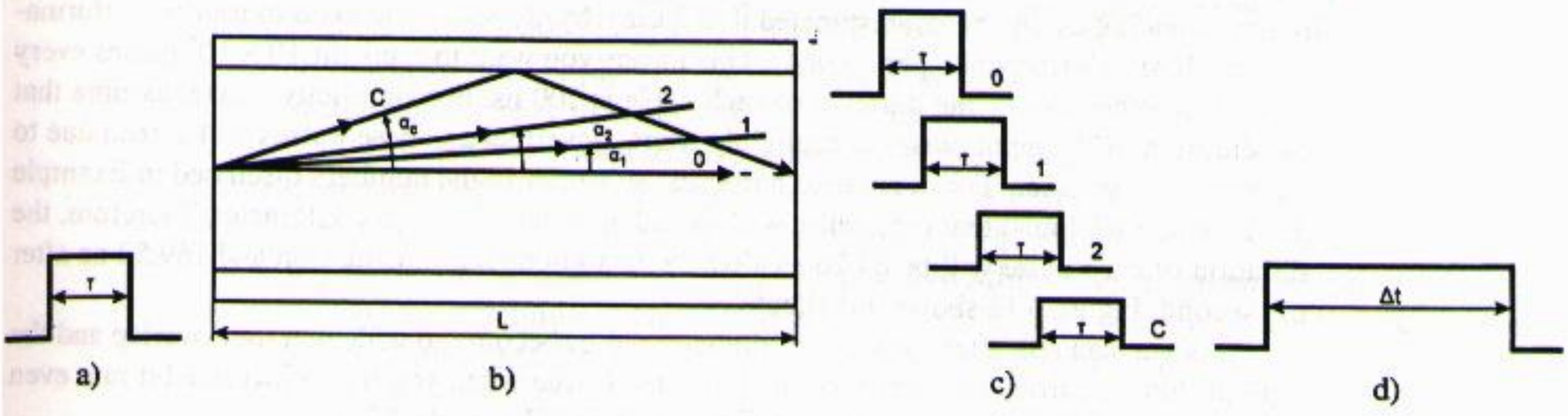
- Propagarea cu viteze diferite a radiatiilor cu lungimi de unda diferite
  - intermodala (modala – depinde de prezenta modurilor)
  - intramodala (cromatica – depinde de lungimea de unda)
    - de material
    - de ghid



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 $\Delta = \frac{n_2 - n_1}{n_1} << 1$

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

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

- indice gradat

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

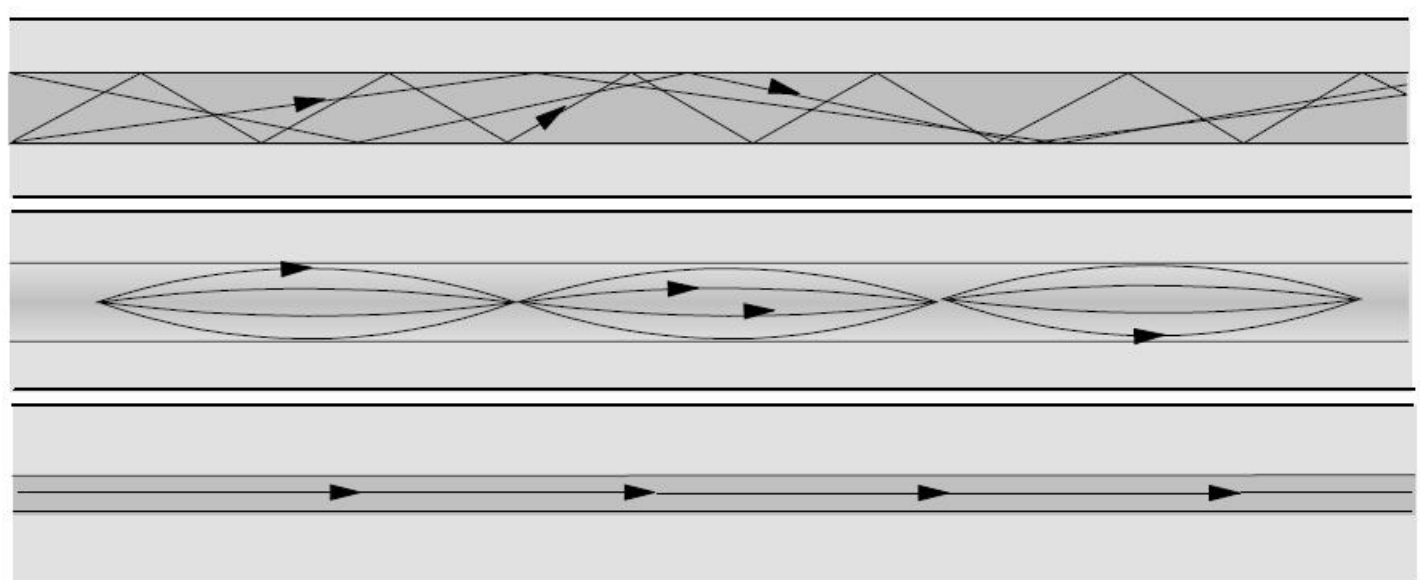
$$\Delta\tau_{mod} \cong \frac{L \cdot n_2 \cdot \Delta^2}{4\sqrt{3} \cdot c}$$

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

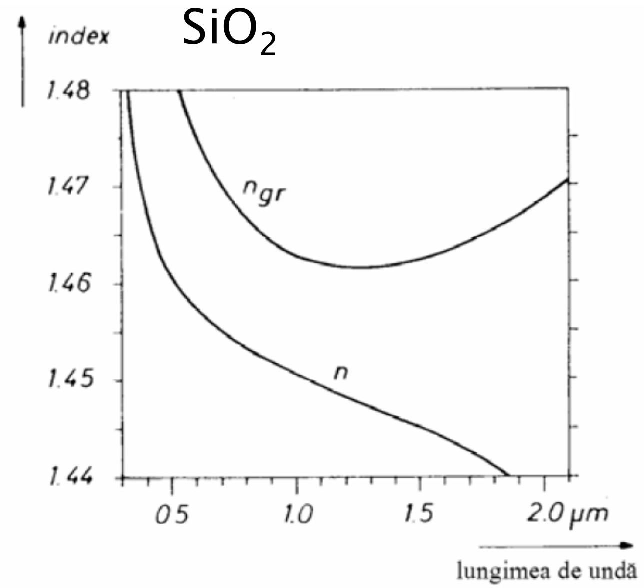
n_2 – miez
n_1 – teaca
$n_2 > n_1$!!

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

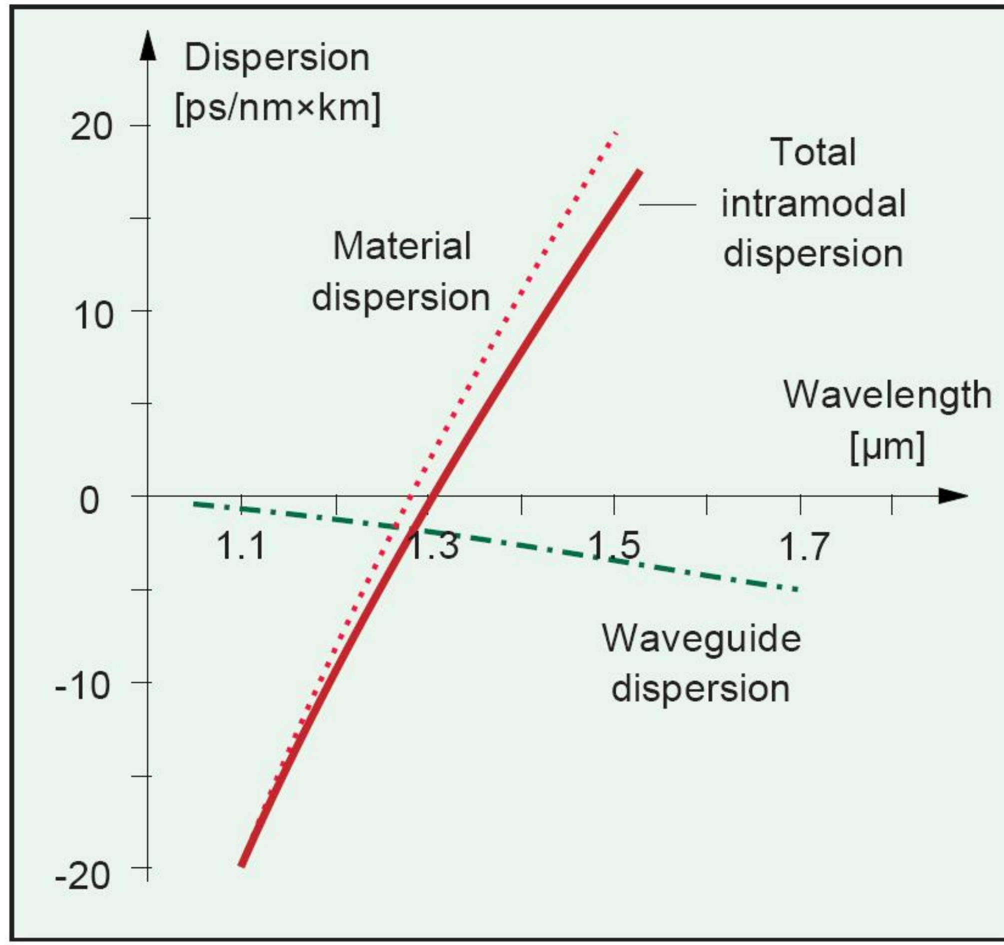


Dispersia de material



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

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

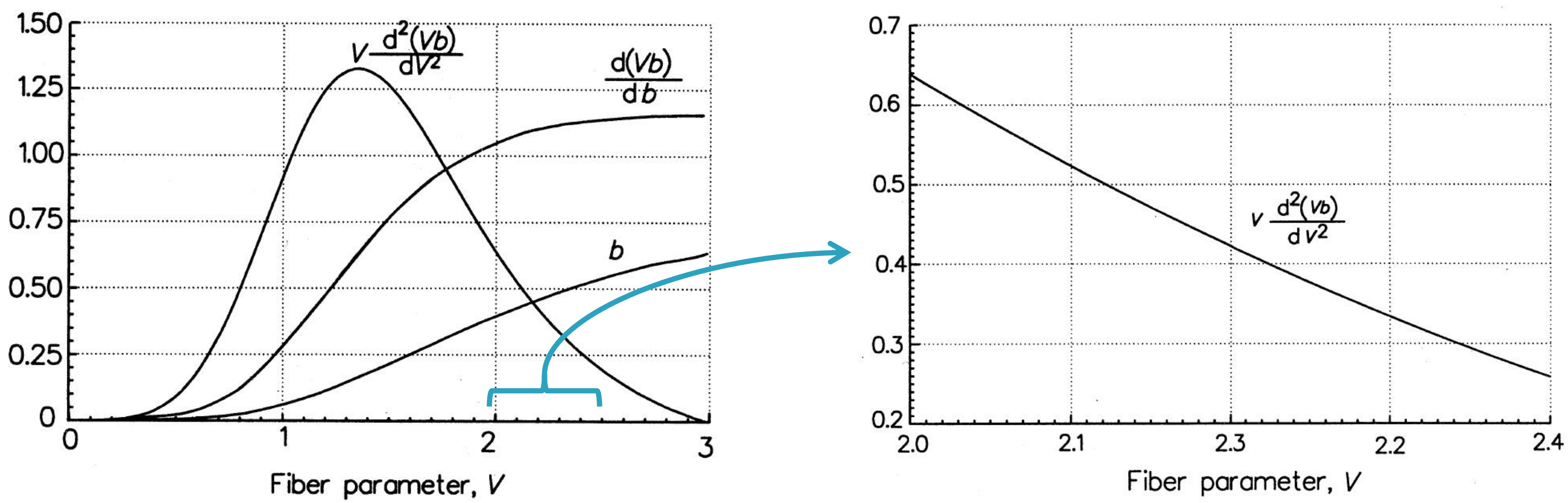


Dispersia de ghid

- Neglijabila in fibrele multimod fata de dispersia modala

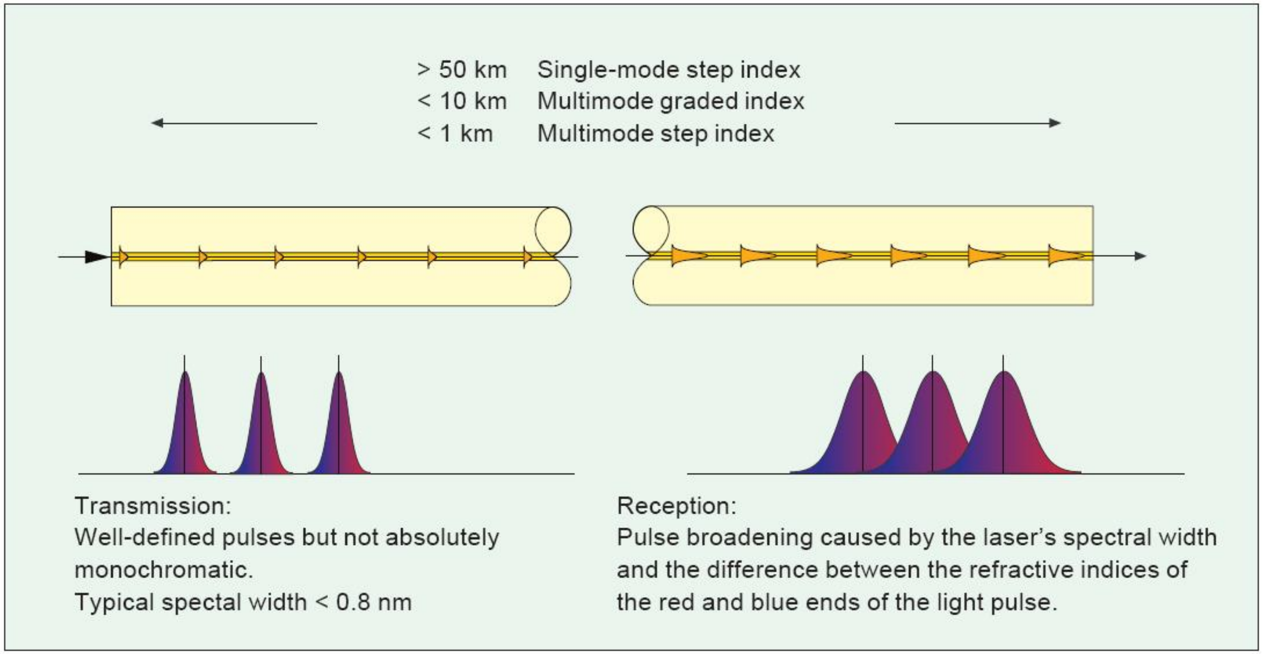
$$\Delta\tau_{gh} = \frac{n \cdot L \cdot \Delta}{c} \cdot \frac{\Delta\lambda}{\lambda} \cdot \left(V \frac{d^2(Vb)}{dV^2} \right)$$

b – constanta de propagare normalizata



$$V \le V_C = 2.405$$

Dispersia cromatica (gh+mat)



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

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

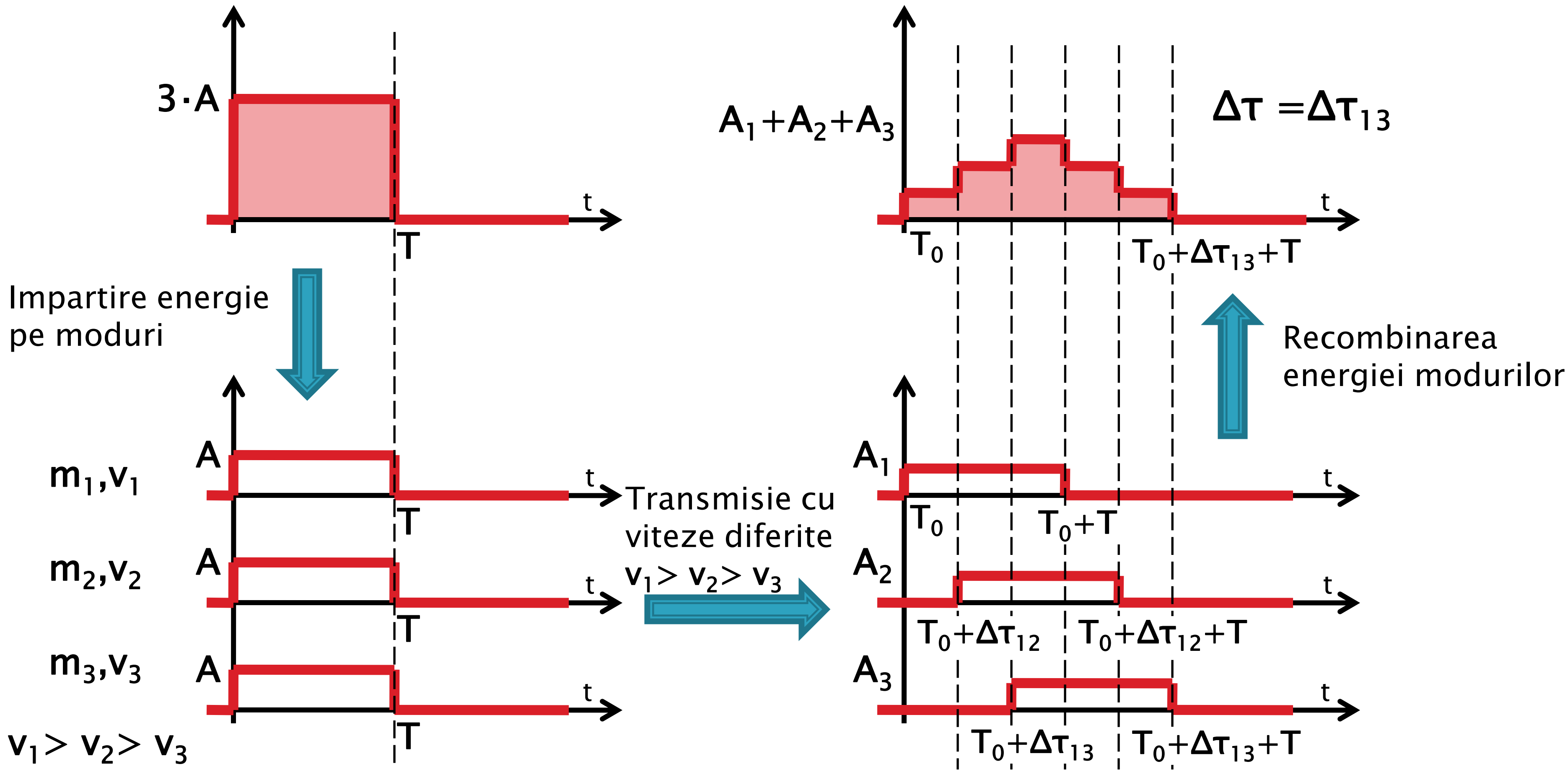
S_0 panta dispersiei – $ps/nm^2/km$

$$D(\lambda_0) = 0$$

- D(λ) ≈ 100 + 0.4 (850 – λ) [ps/nm/km] pentru 800 < λ < 900 nm
- D(λ) ≤ 3,5 ps/nm/km pentru 1285 < λ < 1330 nm
- D(λ) ≤ 17 ps/nm/km pentru 1525 < λ < 1575 nm

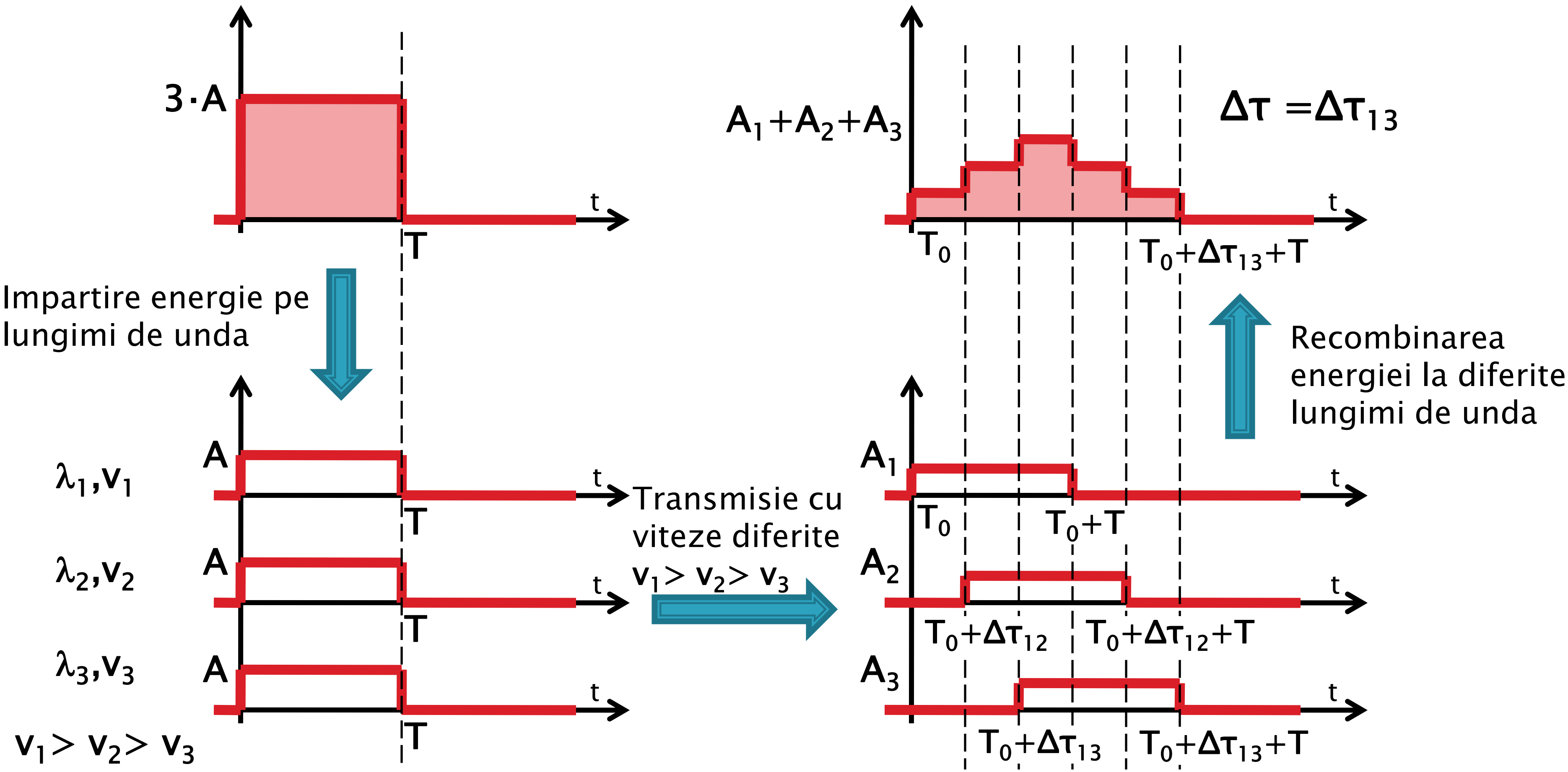
$$D(\lambda) = \frac{S_0}{4}\cdot\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right)$$

Dispersia modala



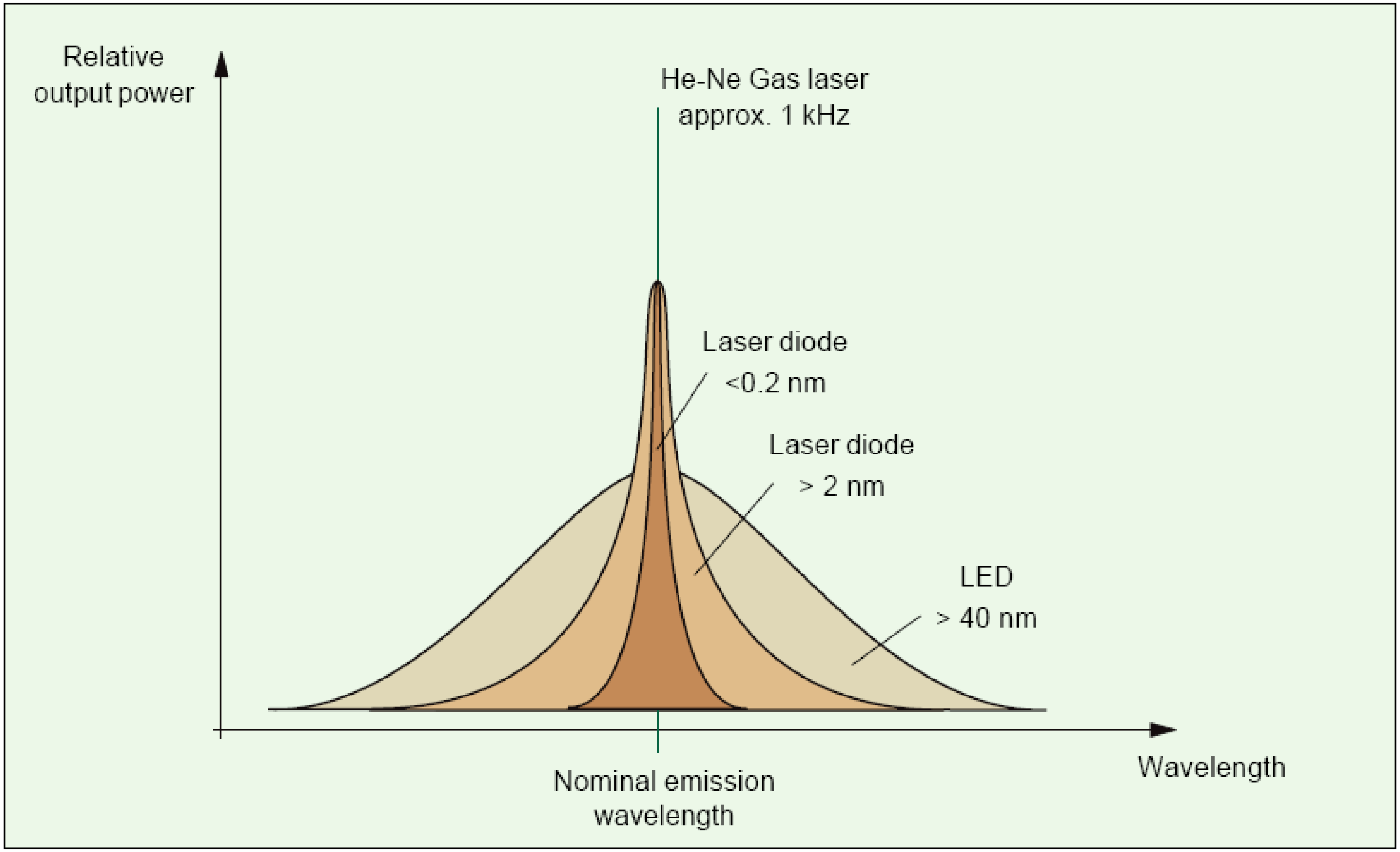
Conceptual→ $f(t) = \int_{-\infty}^{\infty} g(\omega) \cdot e^{j\omega t} d\omega$

Dispersia cromatica (gh+mat)



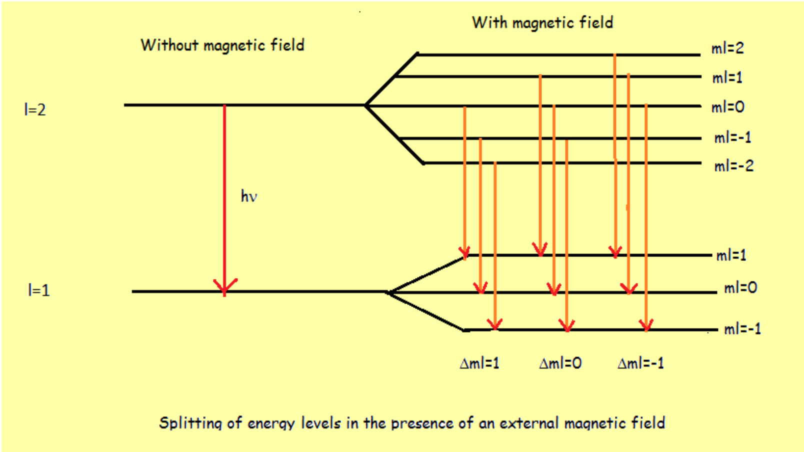
Efectiv→ $f(t)=\int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$

Calitatea spectrală a emiţătorilor optici



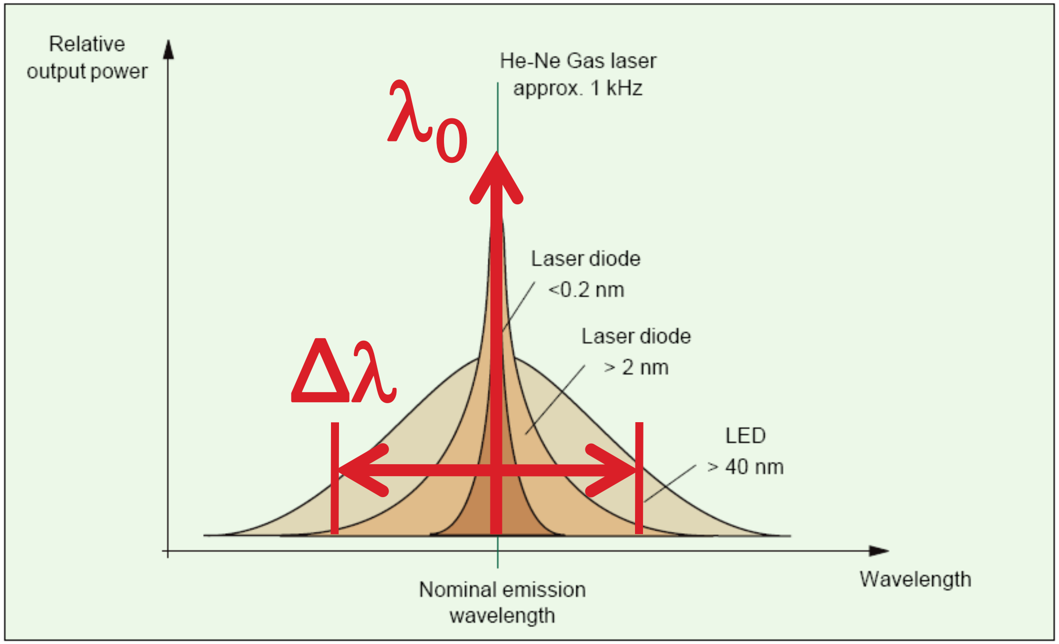
Calitatea spectrală a emiţătorilor optici

- degenerarea nivelelor energetice duce la aparitia benzilor energetice

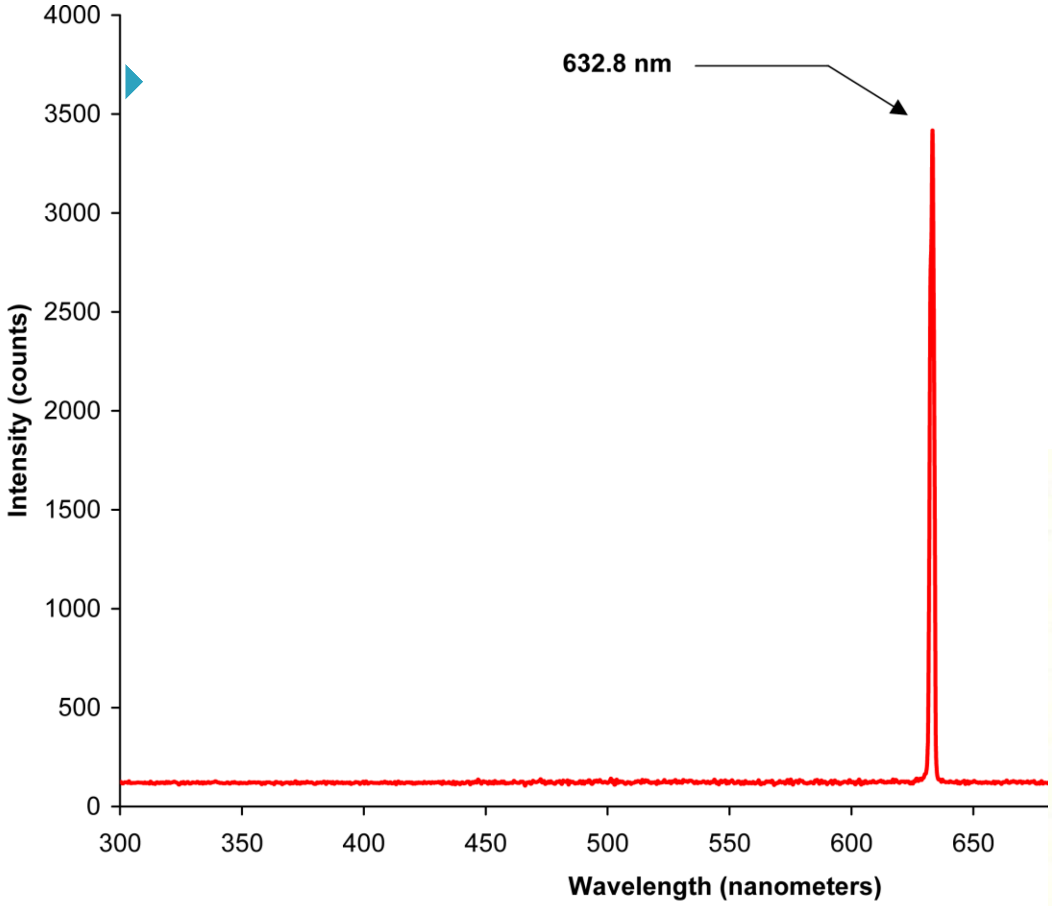


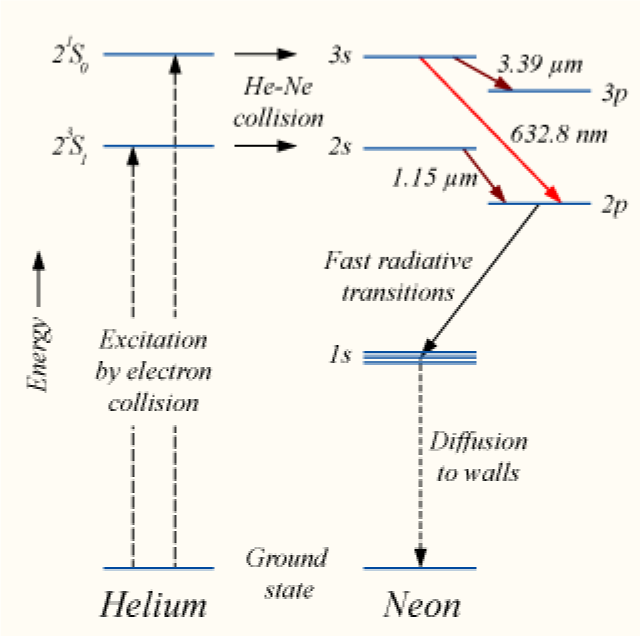
- Multitudinea de tranzitii posibile intre cate doua nivele situate in benzi energetice diferite duce la largirea caracteristicii spectrale a surselor

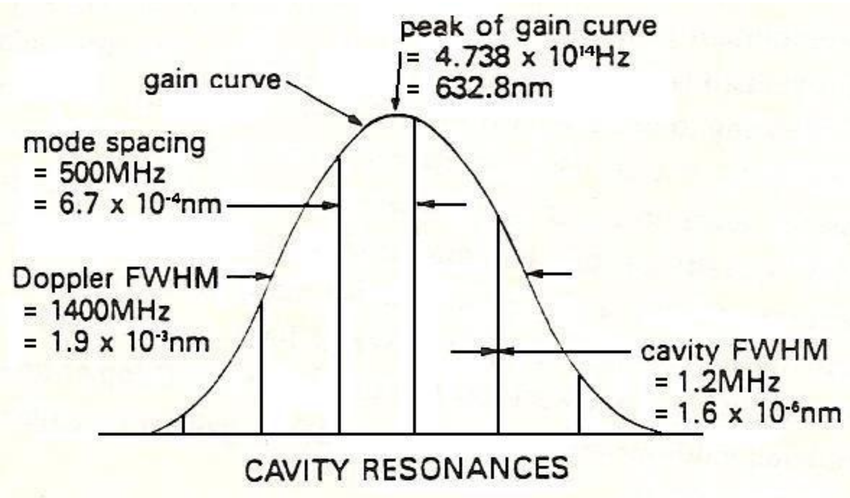
$$\lambda_0 \rightarrow \left[\lambda_0 - \frac{\Delta\lambda}{2}, \lambda_0 + \frac{\Delta\lambda}{2}\right]$$



He-Ne Laser







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

Contact

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