Optoelectronică, structuri şi tehnologii

Curs 1

2011/2012

Cuprins

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

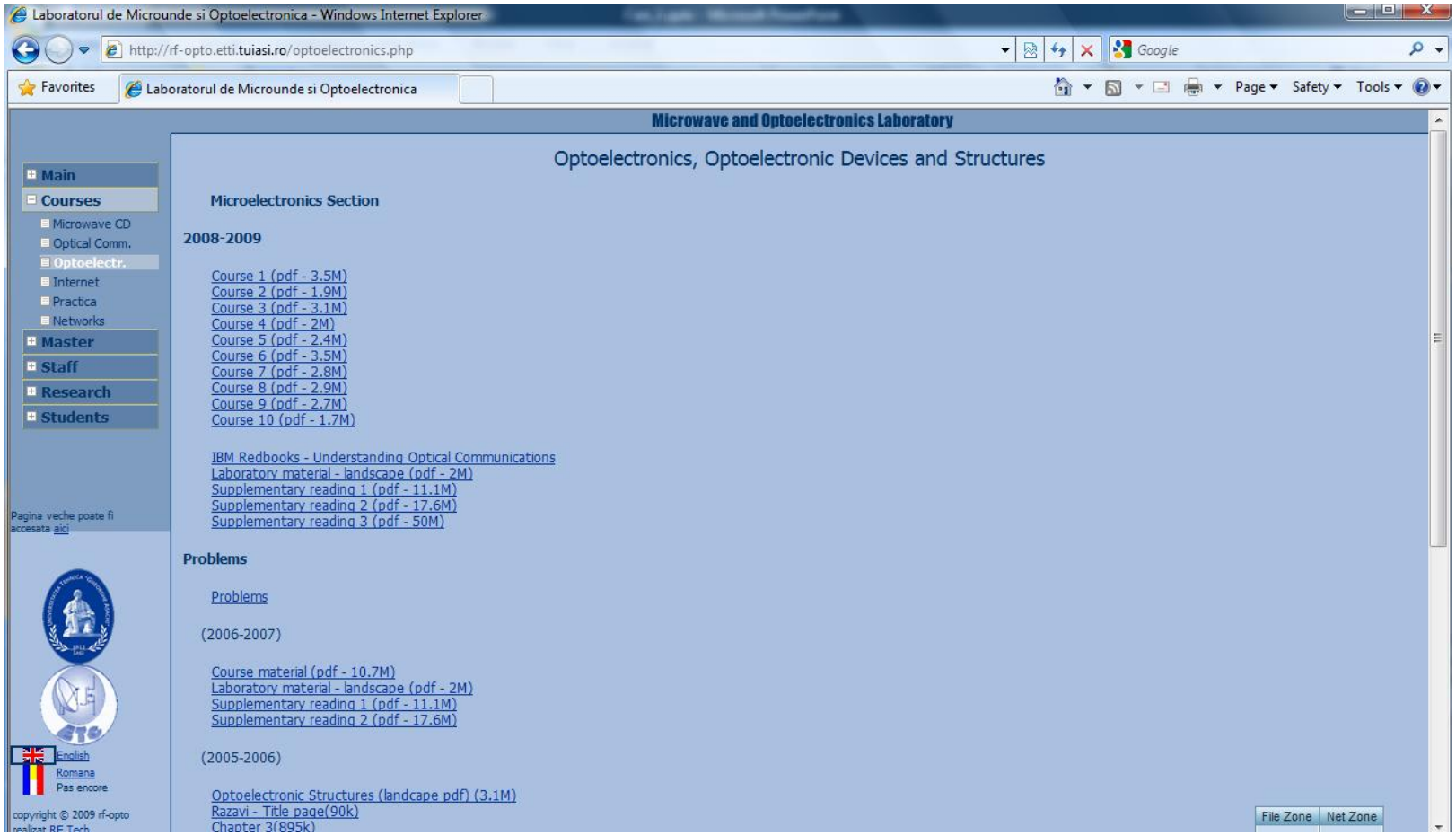
Bibliografie

- http://rf-opto.etc.tuiasi.ro
- Irinel Casian-Botez, "Structuri Optoelectronice", Ed. "CANOVA", Iasi 2001, ISBN 973-96099-2-9
- Behzad Razavi – Design of Integrated Circuits for Optical Communications, Mc Graw Hill
- IBM – Understanding Optical Communications: on-line http://www.redbooks.ibm.com
- Radu Damian, I Casian, D Matăsaru – „Comunicatii Optice” , Indrumar de laborator, 2005

Disciplina

- Curs
  - an IV μE
  - Luni 11-13
  - E – 66% din nota
  - probleme + 1 subiect teorie
  - toate materialele permise
- Laborator
  - an IV μE, an IV Tc
    - Luni 08-10
    - Marti 16-18
  - L – 33% din nota
  - ~~L = C – 0.45(0.9)·Abs~~

Documentatie



Documentatie

- RF-OPTO
  - http://rf-opto.etti.tuiasi.ro
- Fotografie
  - de trimis prin email: rdamian@etti.tuiasi.ro
  - necesara la laborator/curs

Fotografii

Studentii care au trimis fotografiile

Grupa: 5402

Nr.	Nume
1	APETRII MARIA

Grupa: 5403

Nr.	Nume
1	ALEXANDRESCU SEBASTIAN

Grupa: 5404

Nr.	Nume
1	APERGHIS MIHAI-ALIN

Grupa: 5405

Nr.	Nume
1	ANGHELUS MARIL

Studentii care inca nu au trimis fotografiile

Grupa: 5304

Nr.	Nume

Grupa: 5402

Nr.	Nume

Grupa: 5403

Nr.	Nume

Grupa: 5404

Nr.	Nume

Fotografii


FLORESCU DAN-CONSTAN
Date:
Grupa 5405 (2008)
Specializarea Tehnologii si sisteme
Marca 3275
Note obtinute
Disciplina Tip Data Descriere Nota Ob
DCMR Dispozitive si circuite de microunde pentru radiocomuni
Nota 19/06/2009 Nota finala 10
Exam 19/06/2009 Examen DCMR 9
Tema 05/06/2009 Proiect DCMR 10


FLORESCU DAN-CONSTA
Date:
Grupa 5405 (2008)
Specializarea Tehnologii si siste
Marca 3275
Detalii
Finantare Buget
Bursa Bursa de Studii
Domiciliu Iasi, judet Iasi
Promovare Promovare Integrala
Credite 60
Media 8.86

MOTTO

- “Universitatea nu e pentru mase locul de unde emana cunoasterea, ci un obstacol intre individ si diploma pe care i-a harazit-o destinul”

- “Universitatea fiind ceva care se interpune in mod imoral intre individ si dreptul lui natural de a fi diplomat, individul are obligatia morala sa triumfe asupra universitatii prin orice mijloace”

  - Sursa citat: Internet, user: ”un student batran si plesuv”

Examen

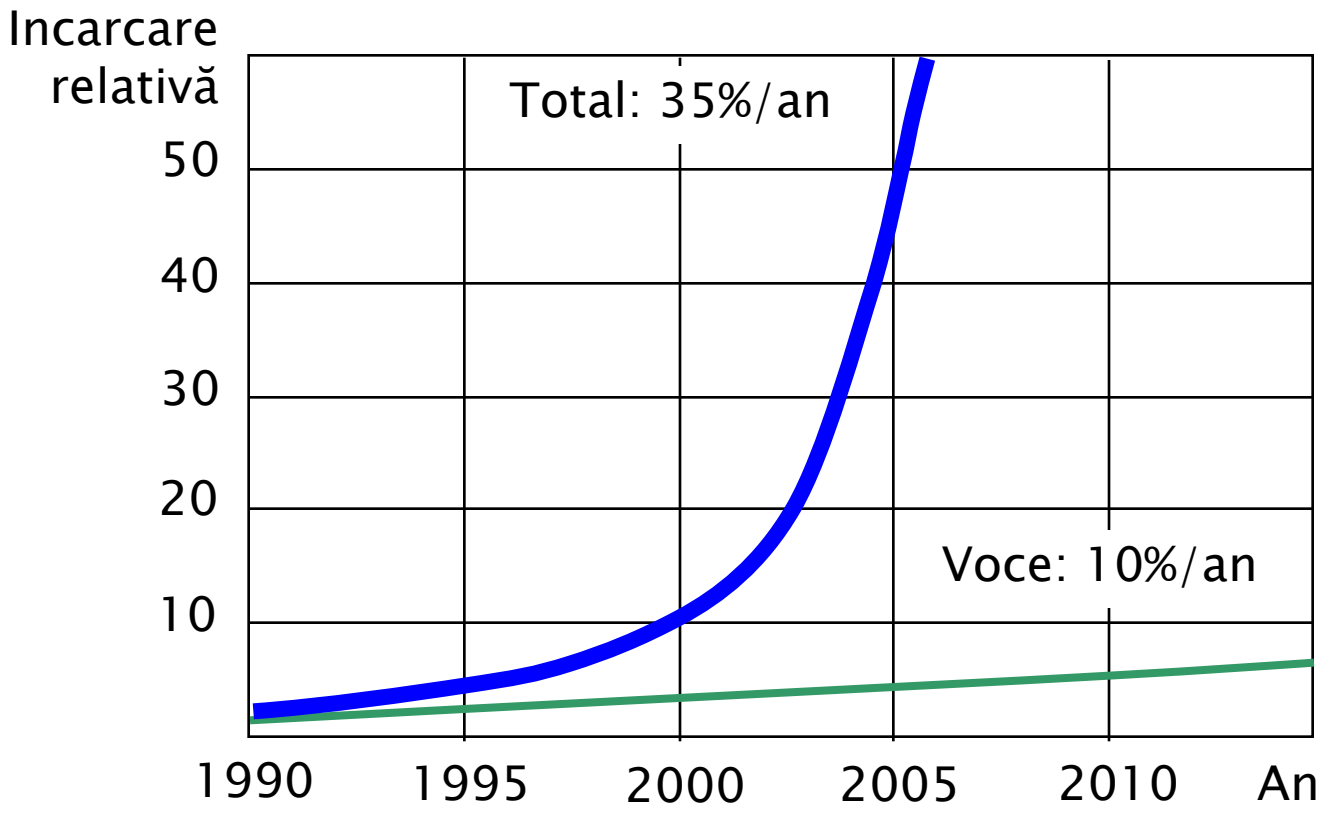
- subiecte individuale
- Note
  - 2007: 9.67±0.66/8.81±1.22
  - 2008: 6.24±1.36/ 4.82±2.10
  - 2009: 5.10±1.46
  - 2010: 3.89±1.32
- La prima aplicare (neanuntata)
  - 50% din studenti au parasit examenul in primele 10 minute
  - 50% din cei ramasi nu au promovat
  - promovabilitate totala 25%, rata contestatiilor: 0%
- Urmatoarele examinari (anuntate)
  - rata contestatiilor: 0%

Examen

Introducere

Capitolul 1

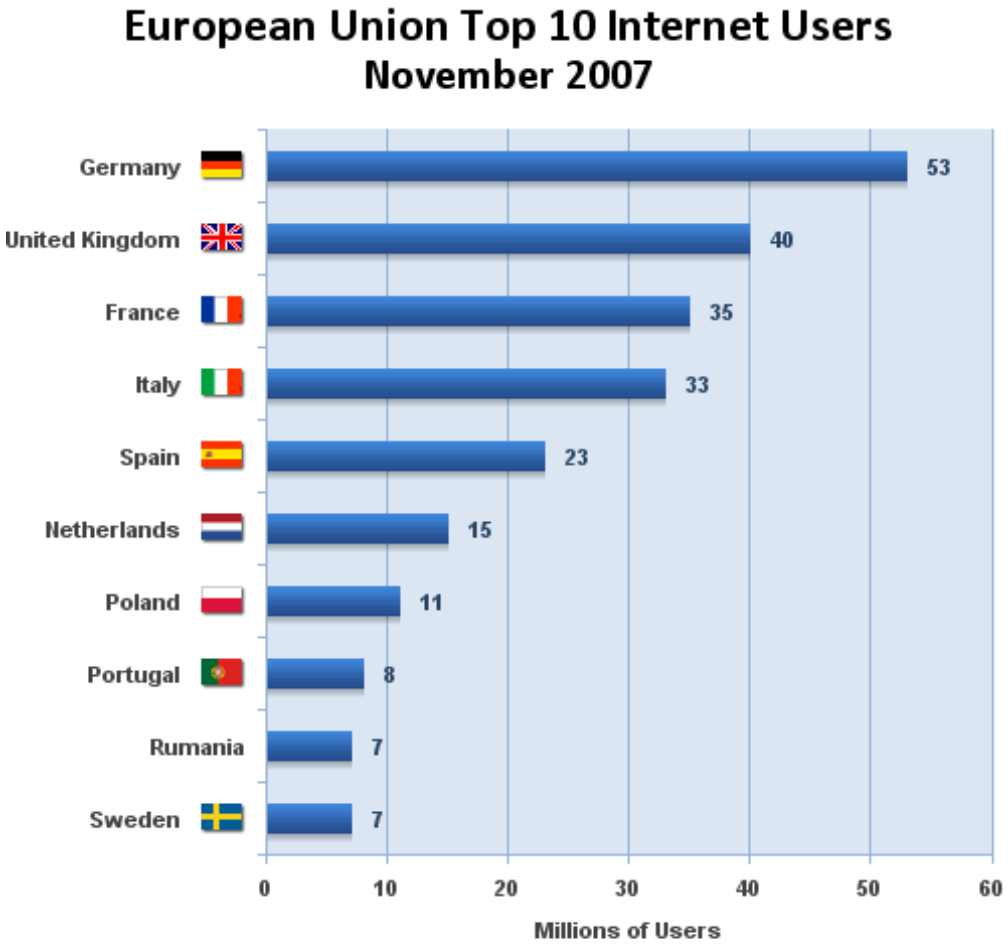
Evoluţia lăţimii de bandă utilizată în reţelele de telecomunicaţii



Sursa:

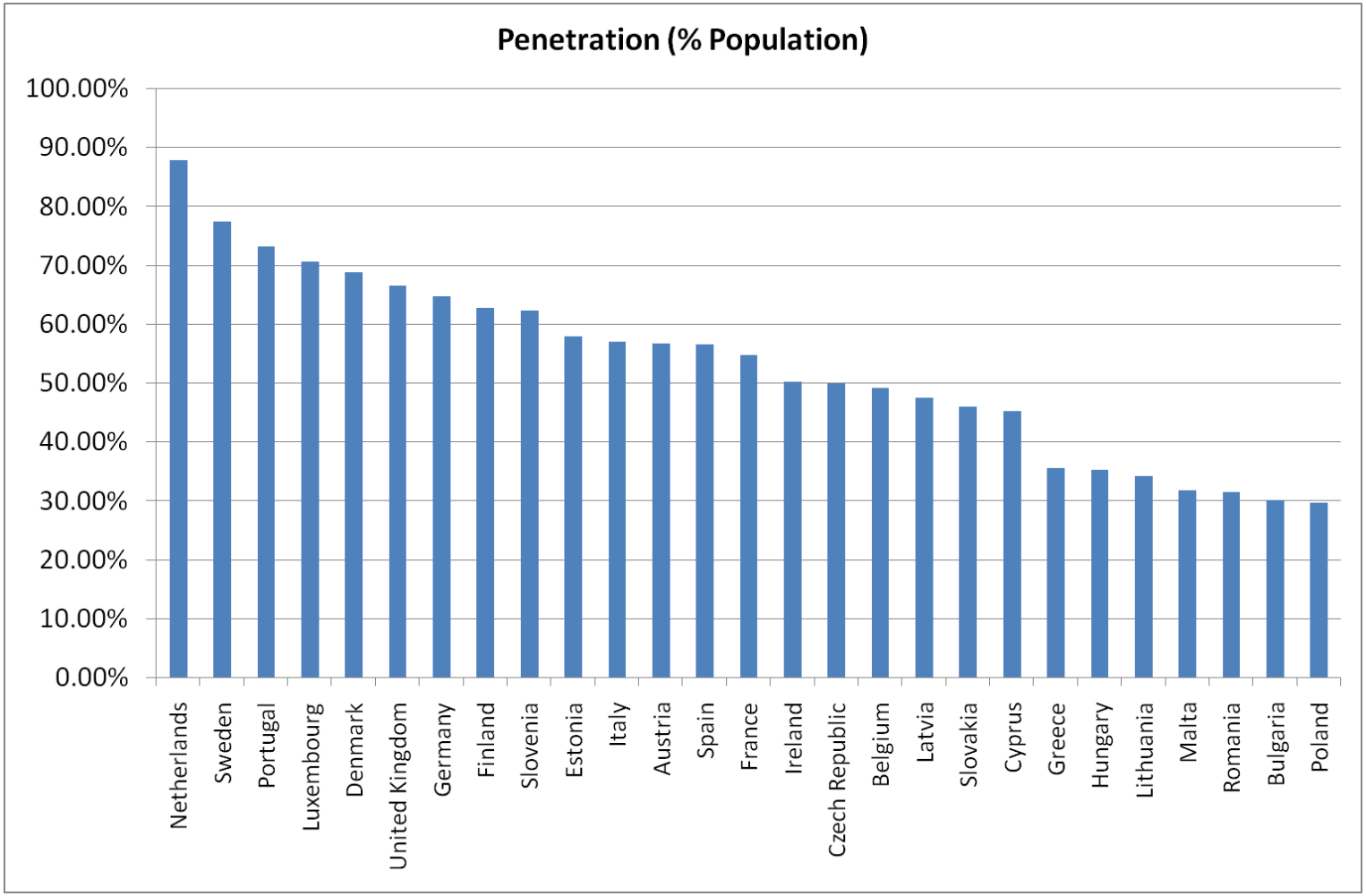
ElectroniCast Corporation

Utilizatori Internet in EU

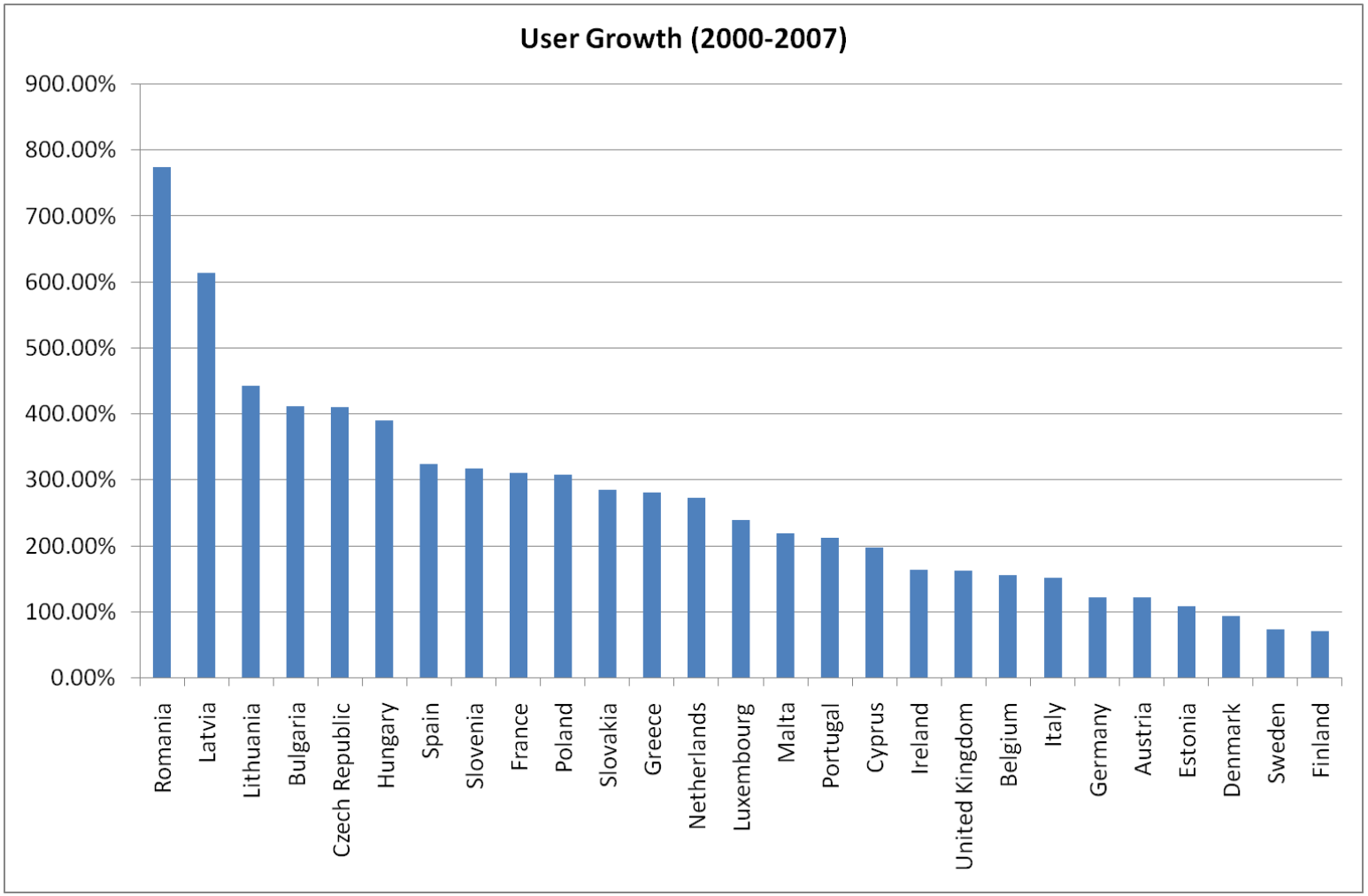


Source: www.internetworldstats.com

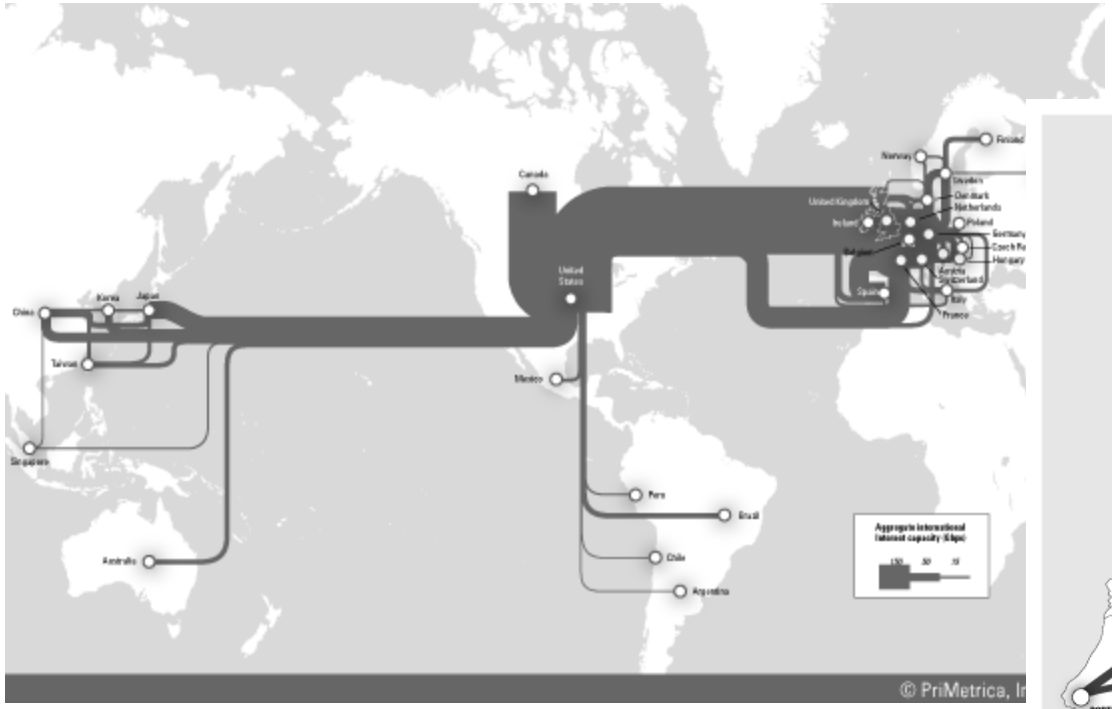
Rata de penetrare in EU

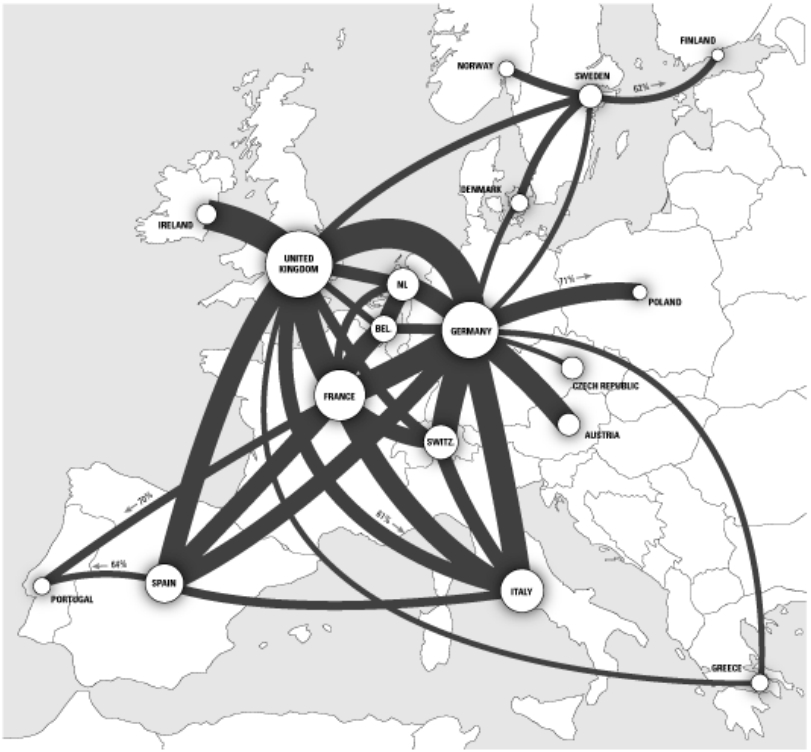


Crestere 2000-2007



Internet Backbone





Internet Backbone

Avantajele comunicaţiilor prin fibra optică – 1

- Greutate şi volum
- Costul materialelor primare
  - SiO_2/Cu
- Capacitate de transmisie a informaţiei
  - 15.5 Tbit/s @ 7000 km, 69.1Tb/s @ 240km
  - Banda (Viteza) x Distanţă [MHz·km] [? MHz/km]
- Lipsa conexiunilor electrice
  - Bucle de masă (1-2V/km)
  - Siguranţă în exploatare
  - Imunitate la fulgere/lipsa scânteilor

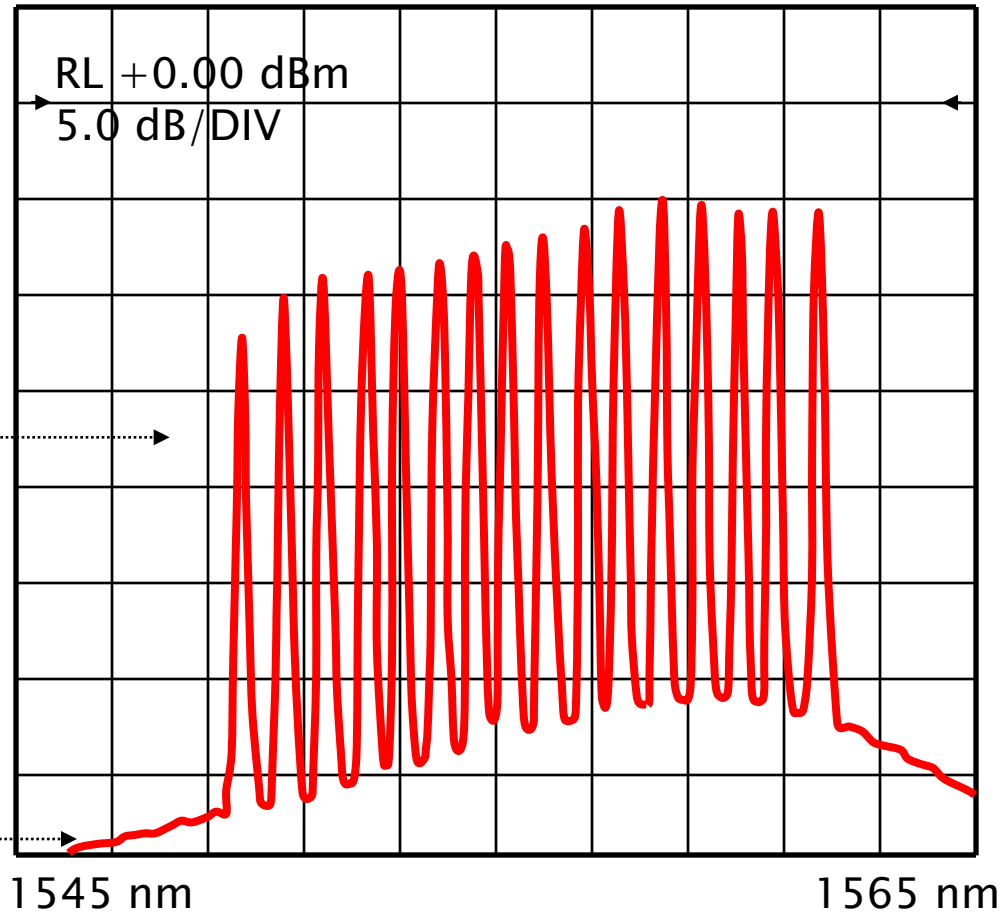
Avantajele comunicaţiilor prin fibra optică – 2

- Imunitate la interferenţă electromagnetică
- Distanta între repetoare
  - 100km/2-5km
- Posibilitate de creştere a capacităţii de transmisie a informaţiei
  - Teoretic extrem de mare (aproape infinită)
  - Reutilizarea cablurilor existente
- Securitate
  - Interceptare dificilă şi detectabilă
  - Inserare de semnal practic imposibilă

Spectrul WDM – Wavelength Division Multiplexing

Canale: 16
Spaţiere: 0.8 nm

Emisie spontană
Amplificată (ASE)



Dezavantajele comunicaţiilor prin fibra optică

- Conexiuni complexe şi esenţiale
  - Costul circuitelor integrate cresut considerabil de cuplarea luminii in fibra
- Curbarea cablurilor optice
- Dezvoltarea greoaie a standardelor
- Optica folosită strict pentru transmisie (aproape)
  - EDFA – Erbidium Dopped Fiber Amplifier
- Sensibilitate la radiaţii gama şi câmpuri electrice intense
- Rozătoare şi termite

Standarde

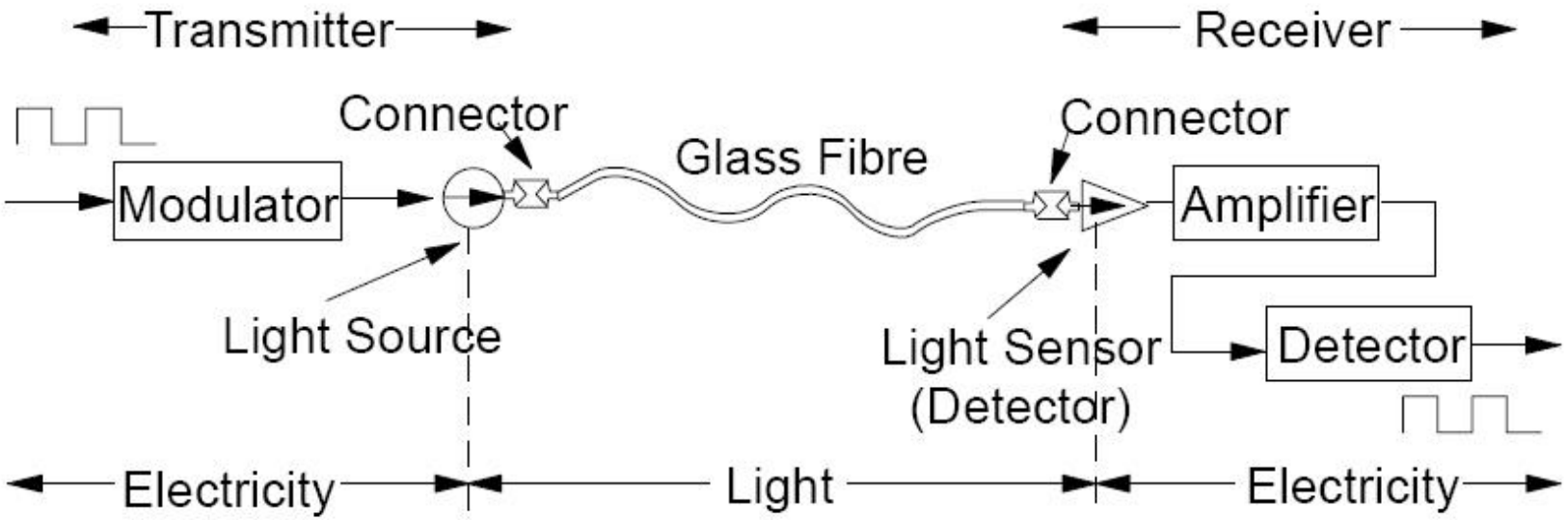
- SUA

STS-1 and OC-1	51.840 Mb/s	
STS-3 and OC-3	155.52 Mb/s	same as STM-1
STS-9 and OC-9	466.56 Mb/s	
STS-12 and OC-12	622.08 Mb/s	same as STM-4
STS-18 and OC-18	933.12 Mb/s	
STS-24 and OC-24	1244.16 Mb/s	same as STM-8
STS-36 and OC-36	1866.24 Mb/s	
STS-48 and OC-48	2488.32 Mb/s	same as STM-16
STS-192 and OC-192	9953.28 Mb/s	same as STM-64
STS-256 and OC-256	13271.04 Mb/s	same as STM-86
STS-768 and OC-768	39813.12 Mb/s	same as STM-256
STS-3072 and OC-3072	159252.48 Mb/s	same as STM-1024
STS-12288 and OC-12288	639009.92 Mb/s	same as STM-4096

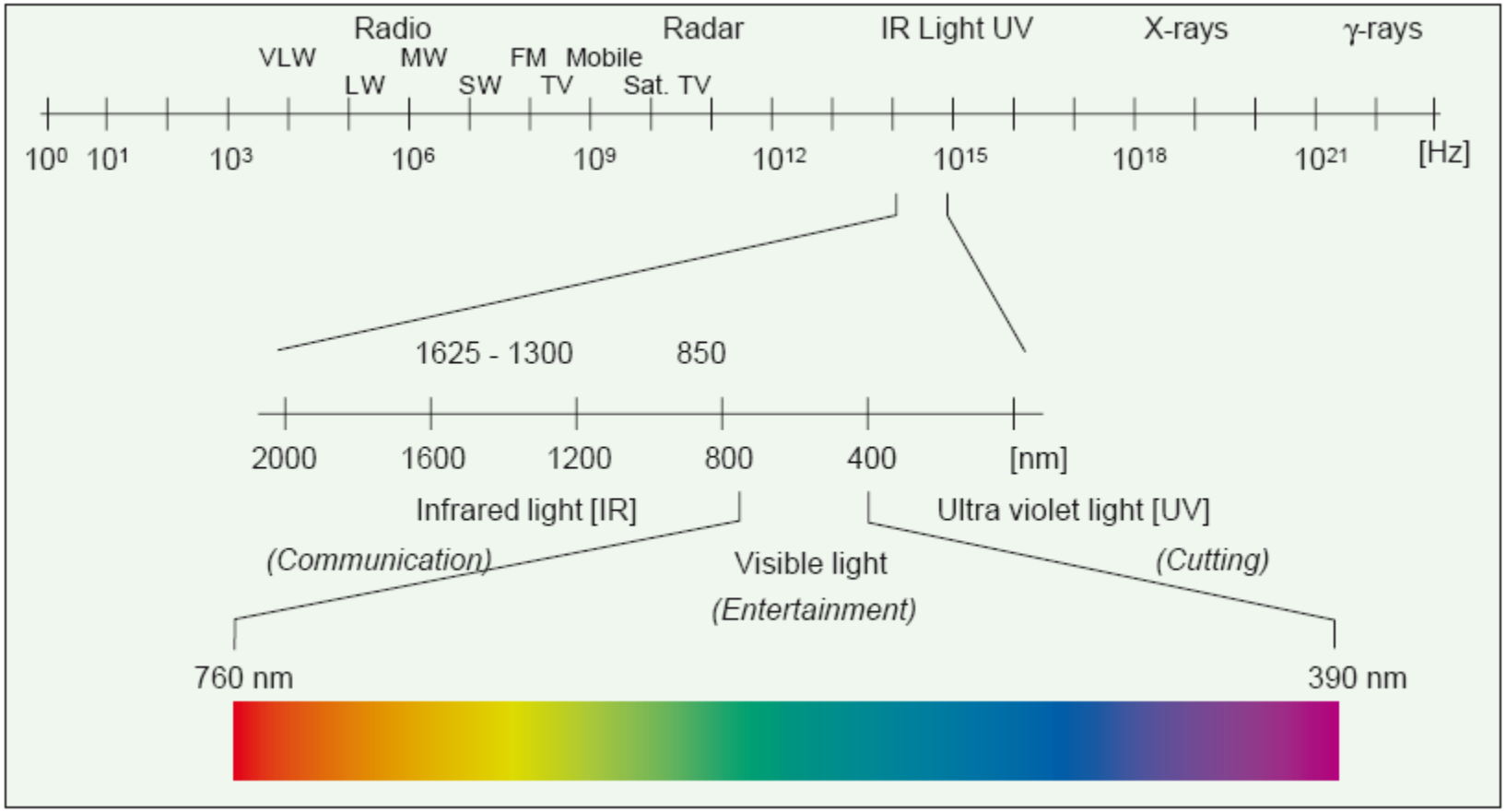
- Europa

E0	64 Kb/s	
E1	2.048 Mb/s	
E2	8.448 Mb/s	4 E1s
E3	34.364 Mb/s	16 E1s
E4	139.264 Mb/s	64 E1s

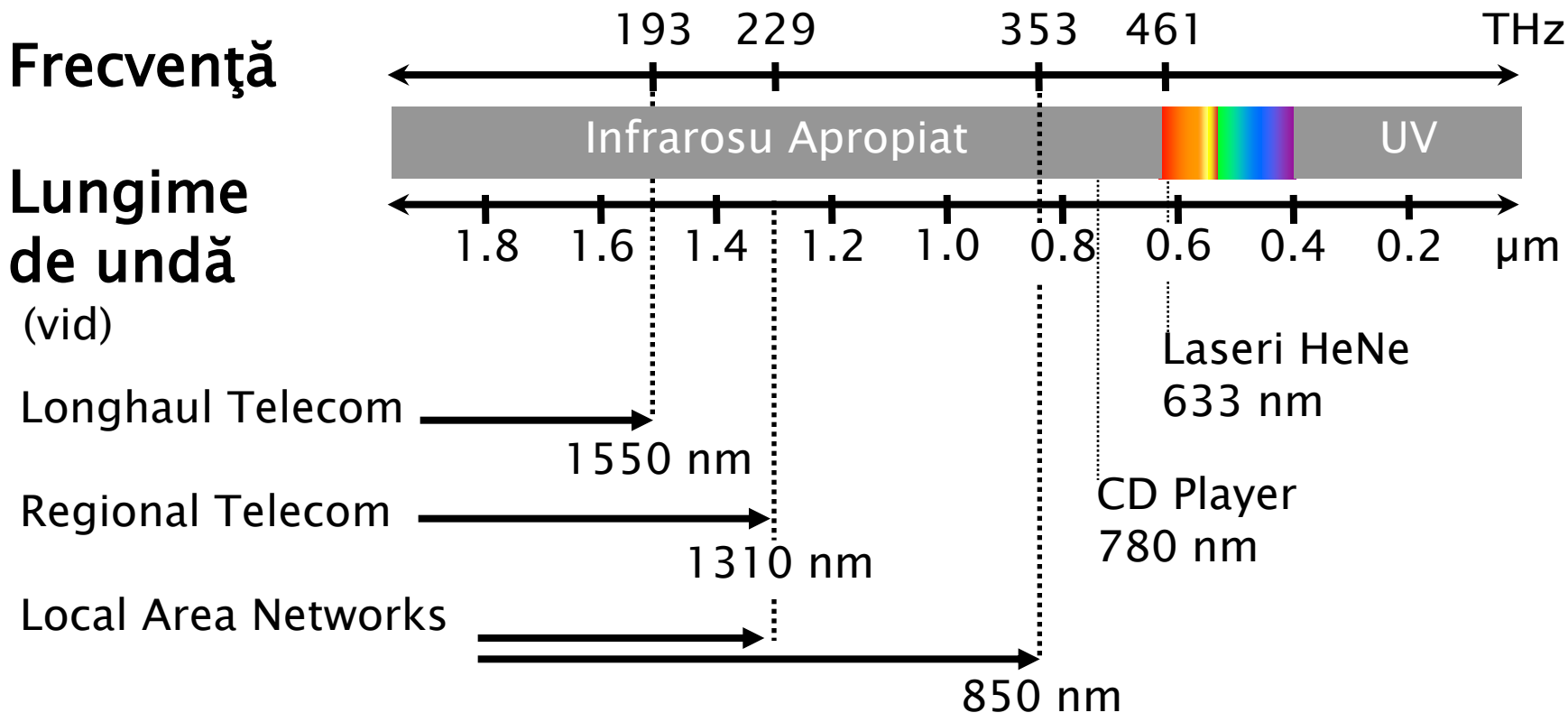
Transmisia optica



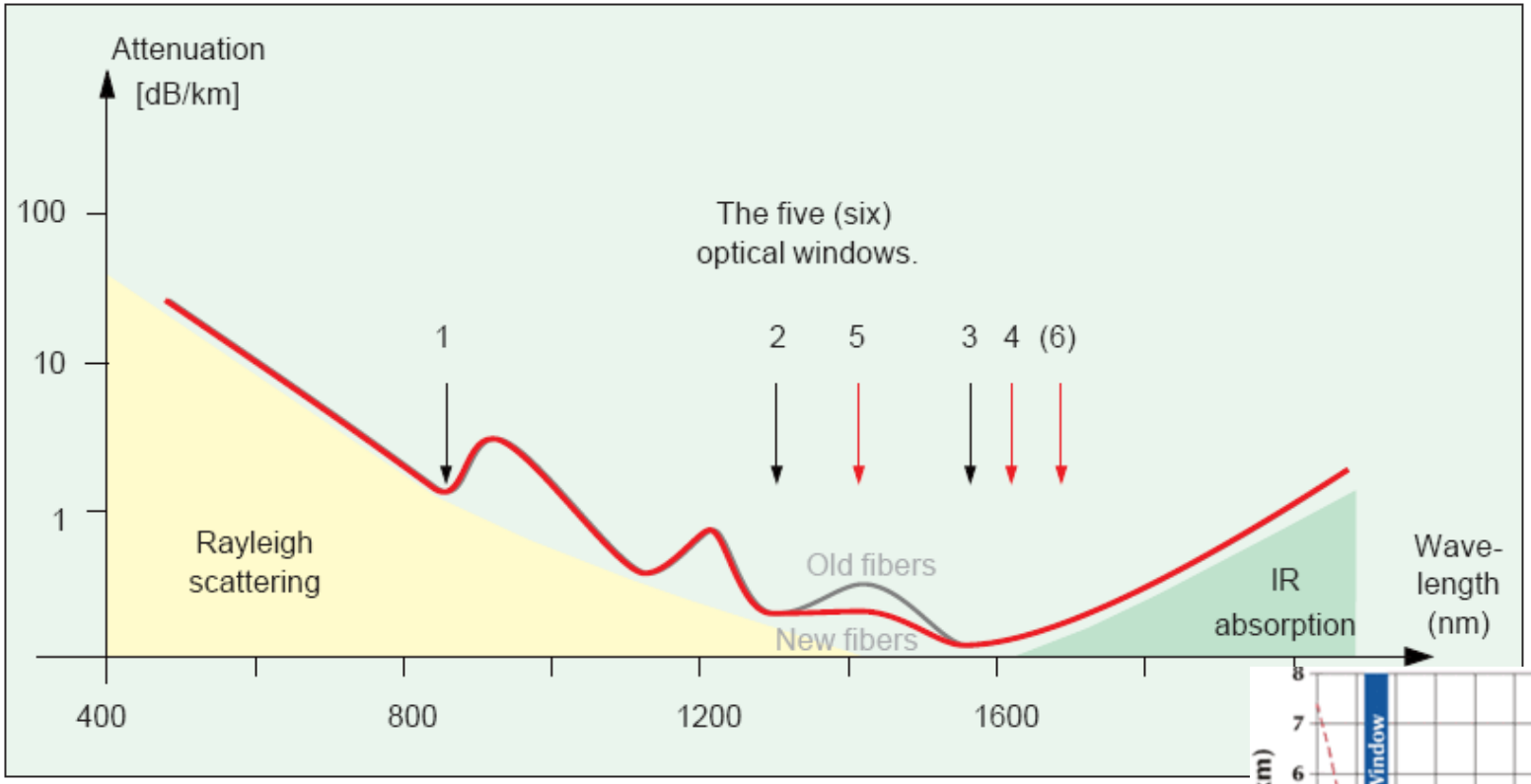
Spectrul electromagnetic



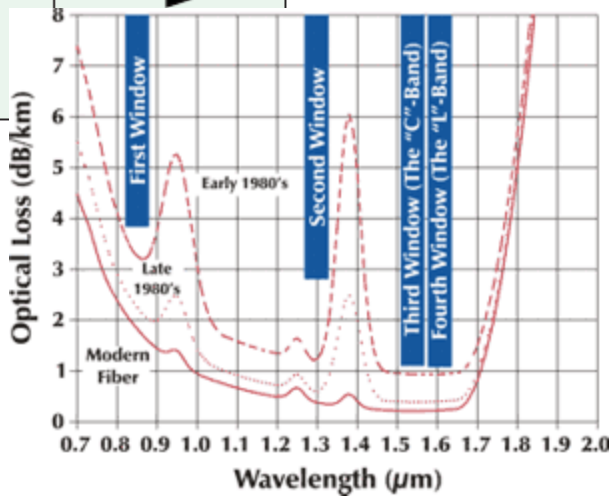
Benzi de lucru in comunicaţiile optice



Atenuarea în fibra optică (SiO_2)

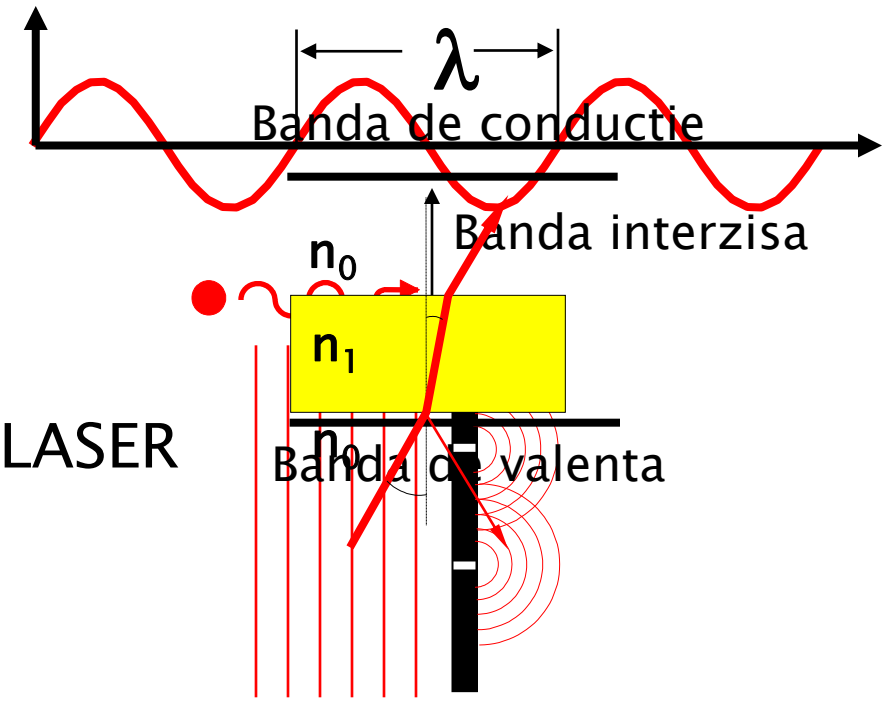


850nm, 1310nm, 1550nm



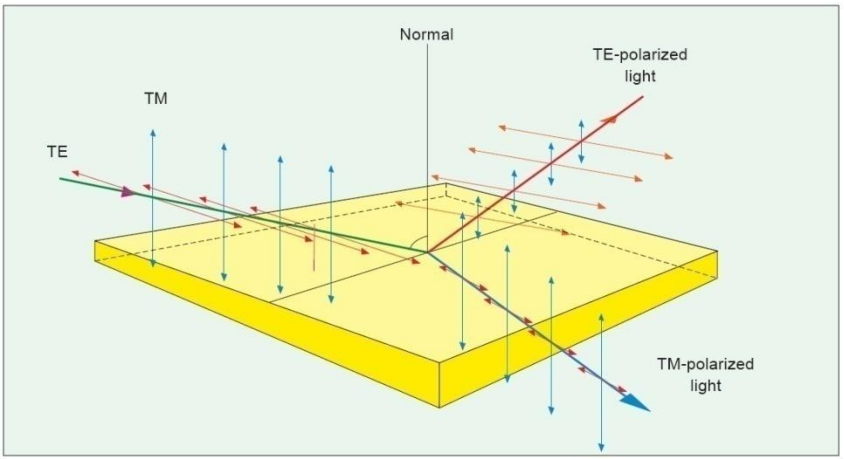
Modelarea luminii

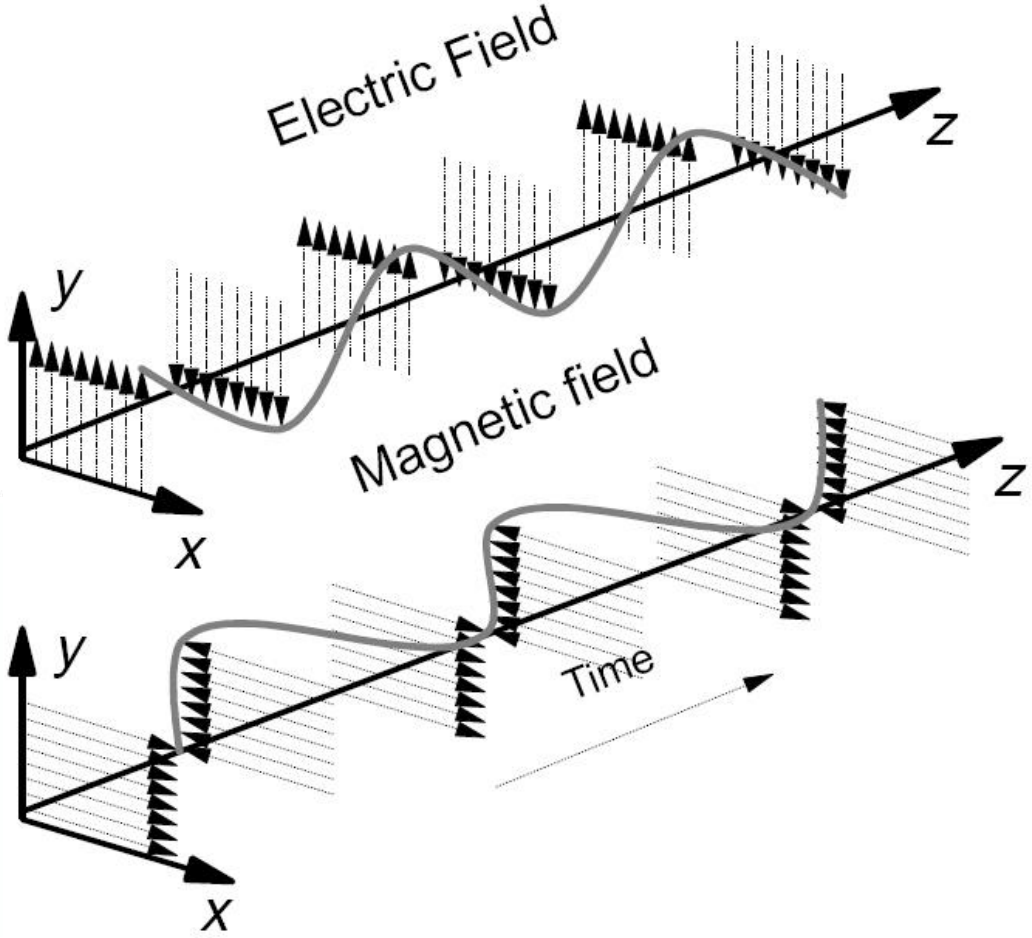
- Undă electromagnetică
  - Ecuaţiile lui Maxwell
  - λ, ε, ω, f
- Teoria cuantică
  - Benzi energetice $E = h \nu$
  - fotoni, emisie stimulată, LASER
- Optică geometrică
  - n, θ
  - raze de lumină
  - intuitivă



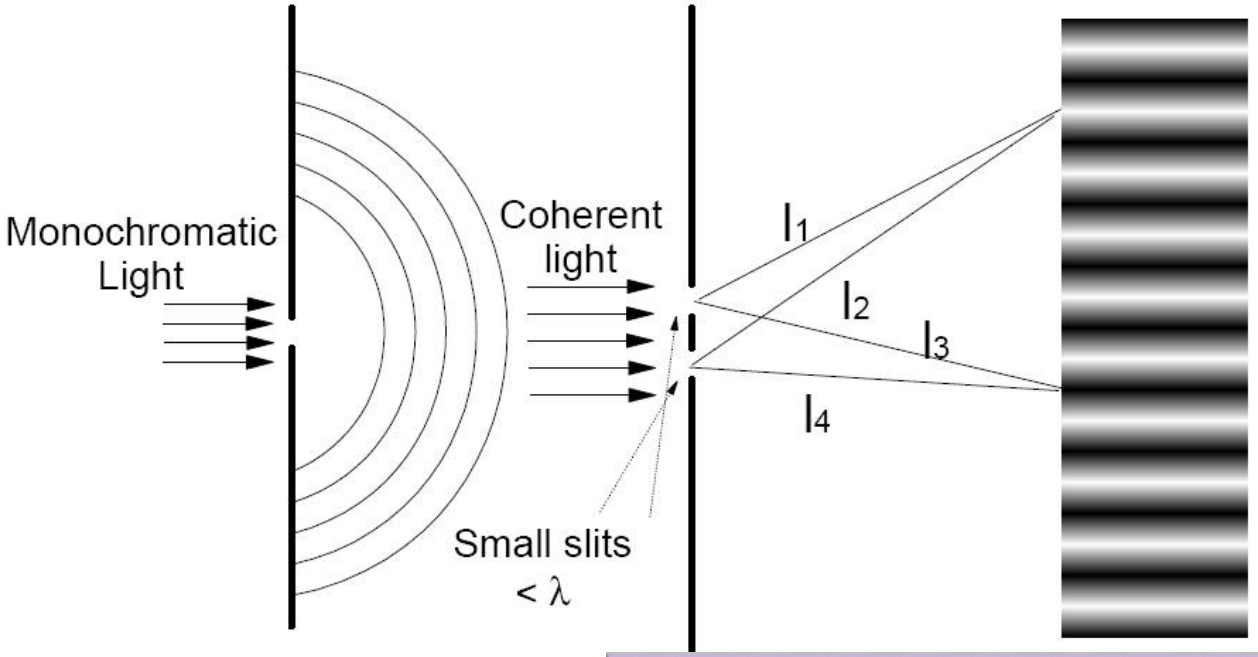
Unda electromagnetica

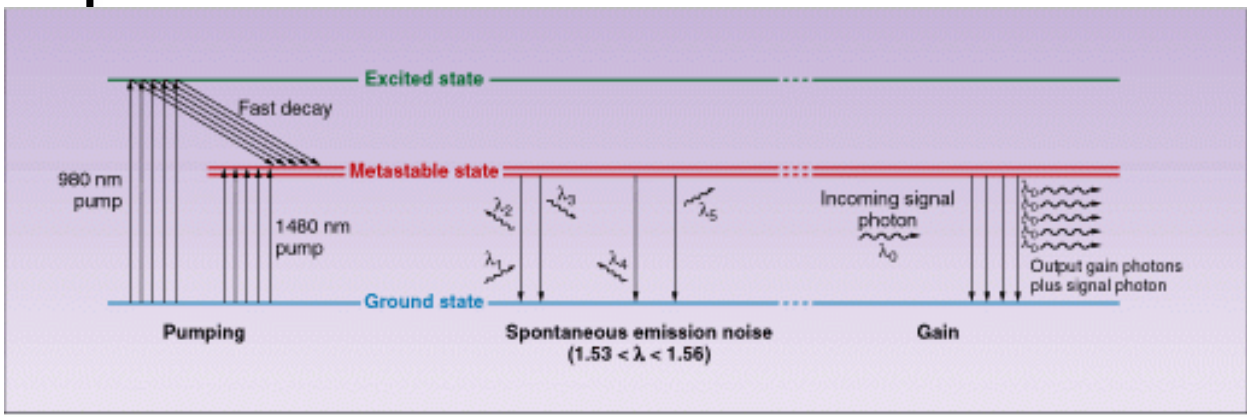
- Dispersie
- Fibre monomod
- Interferenta
- Polarizare





Fotoni/Unda





8-FEA-4 97 Fig. 2

Lăţimea benzii interzise/lungime de undă pentru materialele uzuale

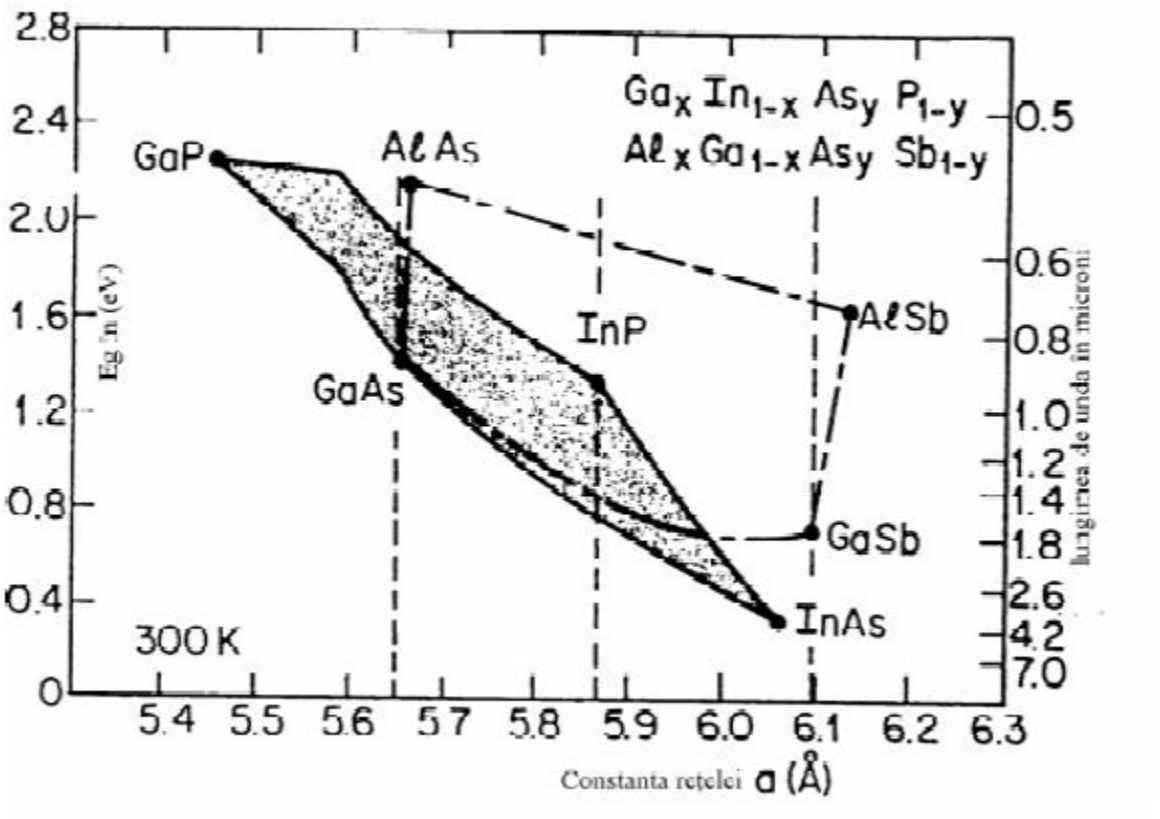
$$\lambda = \frac{hc}{E_g}$$

h - este constanta lui Planck, $6.62 \cdot 10^{-34}$ Ws^2;

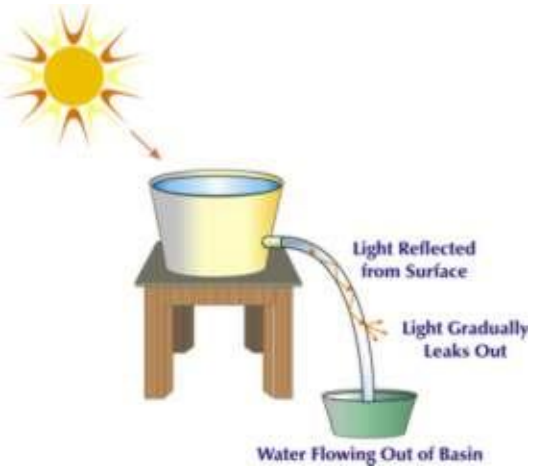
c - viteza luminii, $2.998 \cdot 10^8$ m/s;

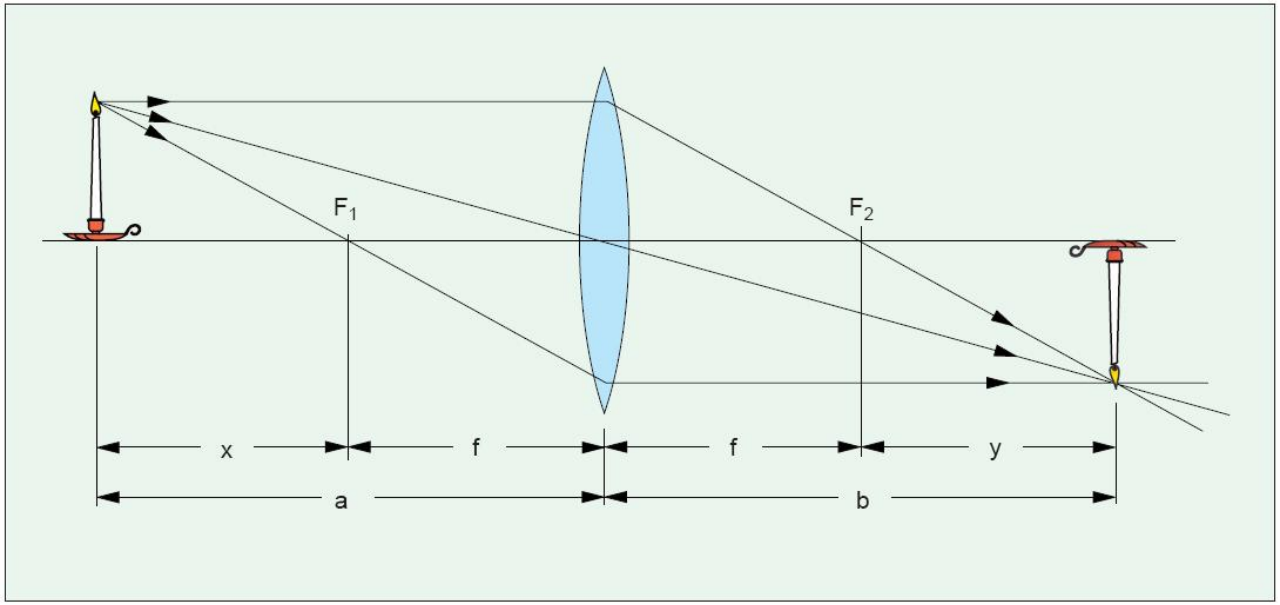
Material	Formula	Wavelength Range λ (μm)	Bandgap Energy W_g (eV)
Indium Phosphide	InP	0.92	1.35
Indium Arsenide	InAs	3.6	0.34
Gallium Phosphide	GaP	0.55	2.24
Gallium Arsenide	GaAs	0.87	1.42
Aluminium Arsenide	AlAs	0.59	2.09
Gallium Indium Phosphide	GaInP	0.64-0.68	1.82-1.94
Aluminium Gallium Arsenide	AlGaAs	0.8-0.9	1.4-1.55
Indium Gallium Arsenide	InGaAs	1.0-1.3	0.95-1.24
Indium Gallium Arsenide Phosphide	InGaAsP	0.9-1.7	0.73-1.35

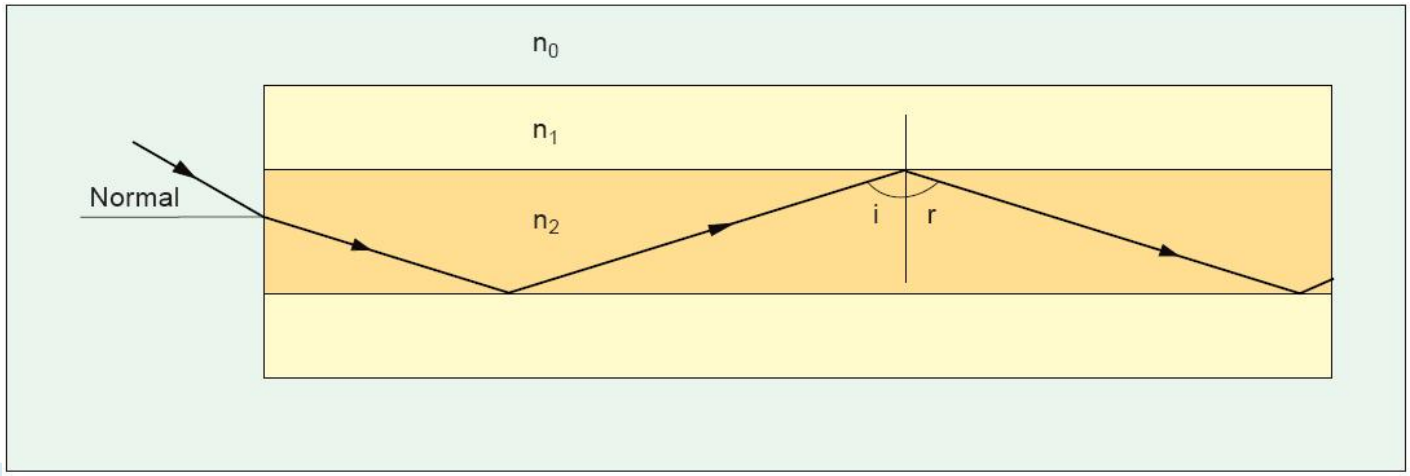
Dependenţa benzii interzise de constanta reţelei



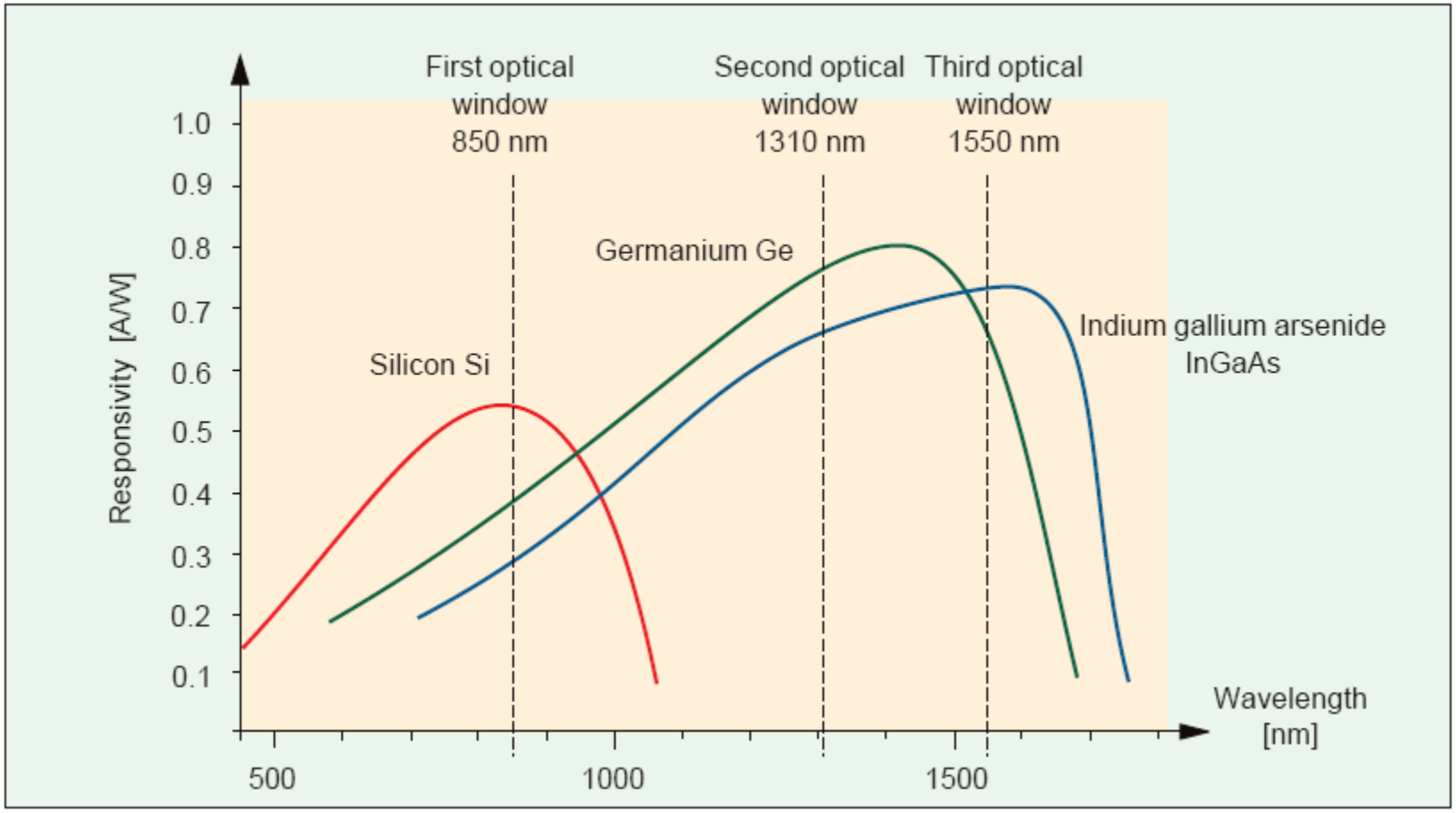
Optica geometrica







Materiale semiconductoare utilizate in optoelectronică



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

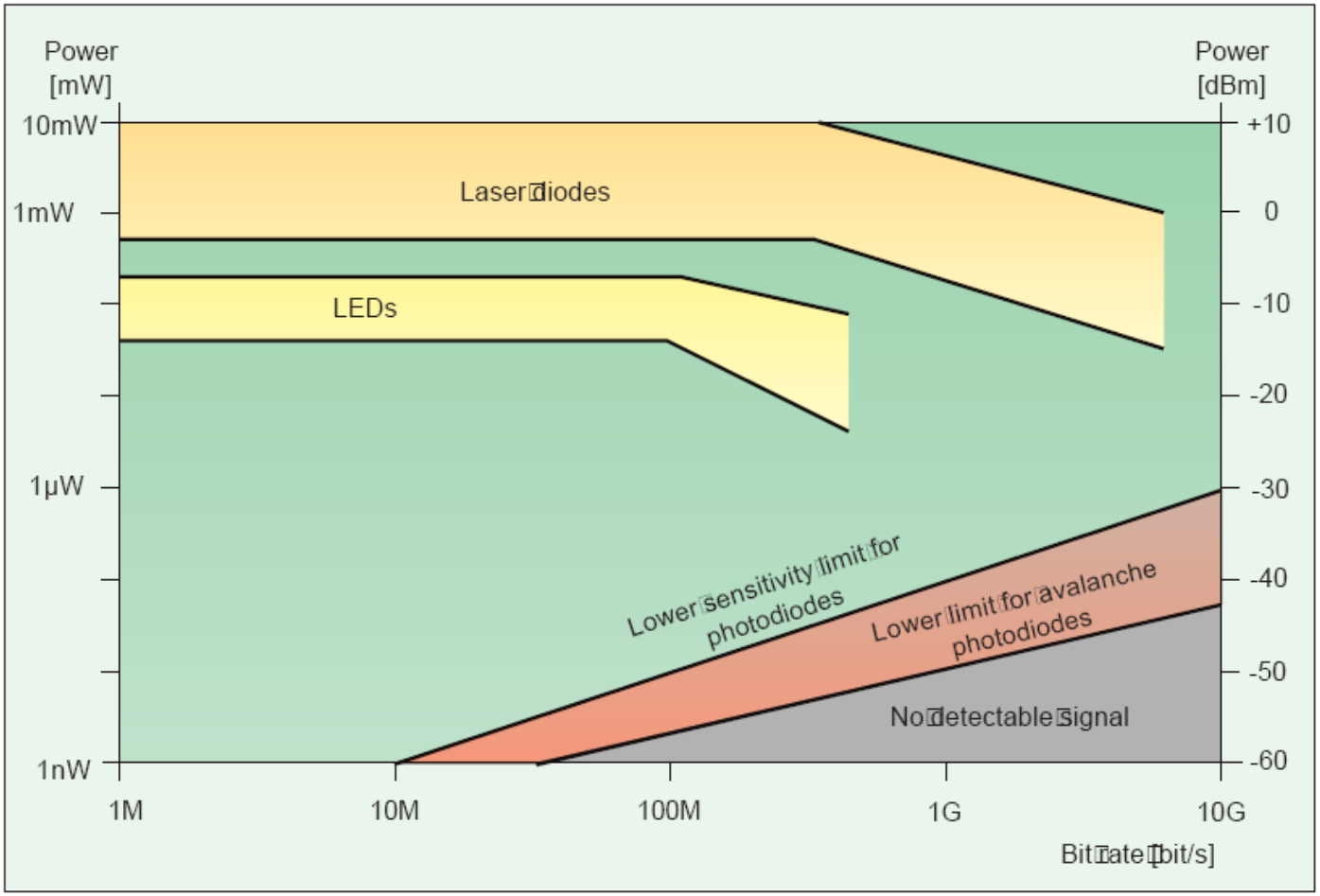
0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
−3 dBm	= 0.5 mW
−10 dBm	= 100 μW
−30 dBm	= 1 μW
−60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

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

[x] + [dB] = [x]

Limite putere/bandă a dispozitivelor optoelectronice



Lumina ca undă electromagnetică

Capitolul 2

Ecuatiile lui Maxwell

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = \frac{\partial D}{\partial t} + J$$

$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \cdot J = -\frac{\partial \rho}{\partial t}$$

- Ecuatii constitutive

$$D = \varepsilon \cdot E$$

$$B = \mu \cdot H$$

$$J = \sigma \cdot E$$

- In vid

$$\mu_0 = 4\pi \times 10^{-7}\ H/m$$

$$\varepsilon_0 = 8{,}854 \times 10^{-12}\ F/m$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790\ m/s$$

Câmpuri electromagnetic cu variaţie armonică în timp

$$X = X_0 e^{j\cdot\omega\cdot t} \quad \frac{\partial X}{\partial t} = j\cdot\omega\cdot X \quad g(\omega)=\int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}dt \quad f(t)=\int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$$

- Simplificarea ecuatiilor lui Maxwell

$$\nabla^2 E + \omega^2 \varepsilon\mu E = j\omega\mu J + \frac{1}{\varepsilon}\nabla\rho$$

$$\nabla^2 H + \omega^2 \varepsilon\mu H = -\nabla\times J$$

$$\nabla\cdot E = \frac{\rho}{\varepsilon}$$

$$\nabla\cdot H = 0$$

- Ecuaţiile Helmoltz sau ecuaţiile de propagare

Mediu lipsit de sarcini electrice

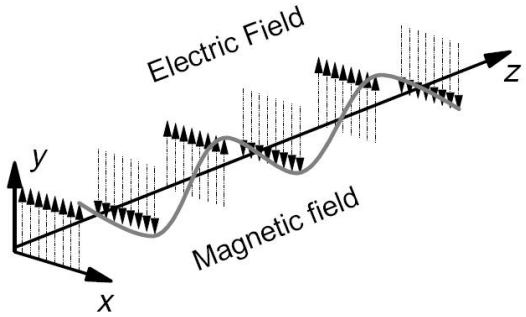
$$\nabla^2 E - \gamma^2 E = 0$$

$$\nabla^2 H - \gamma^2 H = 0$$

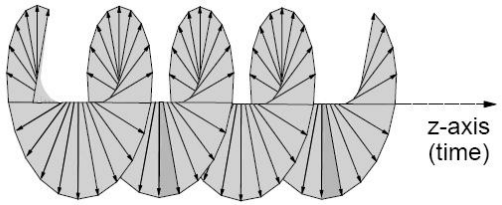
$$\gamma^2 = -\omega^2\varepsilon\mu + j\omega\mu\sigma$$

γ – Constanta de propagare

Solutia ecuatiilor de propagare



Propagare



Polarizare circulara

Camp electric dupa directia Oy, propagare dupa directia Oz

$$E_y = E_+ e^{-\gamma \cdot z} + E_- e^{\gamma \cdot z}$$

$$\gamma = \sqrt{-\omega^2 \varepsilon \mu + j\omega\mu\sigma} = \alpha + j \cdot \beta$$

Exista numai unda progresiva $E_+ \Rightarrow$ A

$$E_y = A e^{-(\alpha + j \cdot \beta) \cdot z}$$

Camp armonic

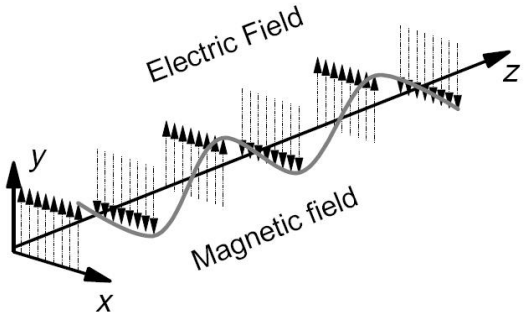
$$E_y = A \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)}$$

Amplitudine

Atenuare

Propagare
(variatie in timp si spatiu)

Parametri de propagare



$$\nabla \times E = -j\omega\mu \cdot H$$

$$H_x = \frac{j\gamma \cdot E_y}{\omega\mu}$$

Mediu fara pierderi, $\sigma = 0$ $\qquad \gamma = j\omega \cdot \sqrt{\varepsilon\mu}$

$$\eta = \frac{E_y}{H_x} = \sqrt{\frac{\mu}{\varepsilon}}$$ Impedanta intrinseca a mediului

$E_y = A \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)}$ punctele de faza constanta: $(\omega \cdot t - \beta \cdot z) = \text{const}$

Viteza de faza $\quad v = \frac{dz}{dt} = \frac{\omega}{\beta} = \frac{1}{\sqrt{\varepsilon\mu}}$

Viteza de grup $\quad v_g = \frac{dz}{dt} = \frac{d\omega}{d\beta}$ in medii dispersive unde $\beta = \beta(\omega)$

Parametri de propagare

- In vid

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

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

Periodicitate in spatiu Periodicitate in timp

- In mediu nedispersiv ε_r

$$c = \frac{1}{\sqrt{\varepsilon \cdot \mu_0}} = \frac{1}{\sqrt{\varepsilon_0 \varepsilon_r \cdot \mu_0}} = \frac{c_0}{\sqrt{\varepsilon_r}}$$

$n = \sqrt{\varepsilon_r}$ Indice de refractie al mediului $c = \frac{c_0}{n}$

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

Dispersia

- In medii dispersive $\beta = \beta(\omega)$, $n = n(\omega)$

$$\frac{d\beta}{d\omega} = \frac{d}{d\omega}\left(\frac{\omega \cdot n}{c}\right) = \frac{1}{c}\left(n + \omega\frac{dn}{d\omega}\right)$$

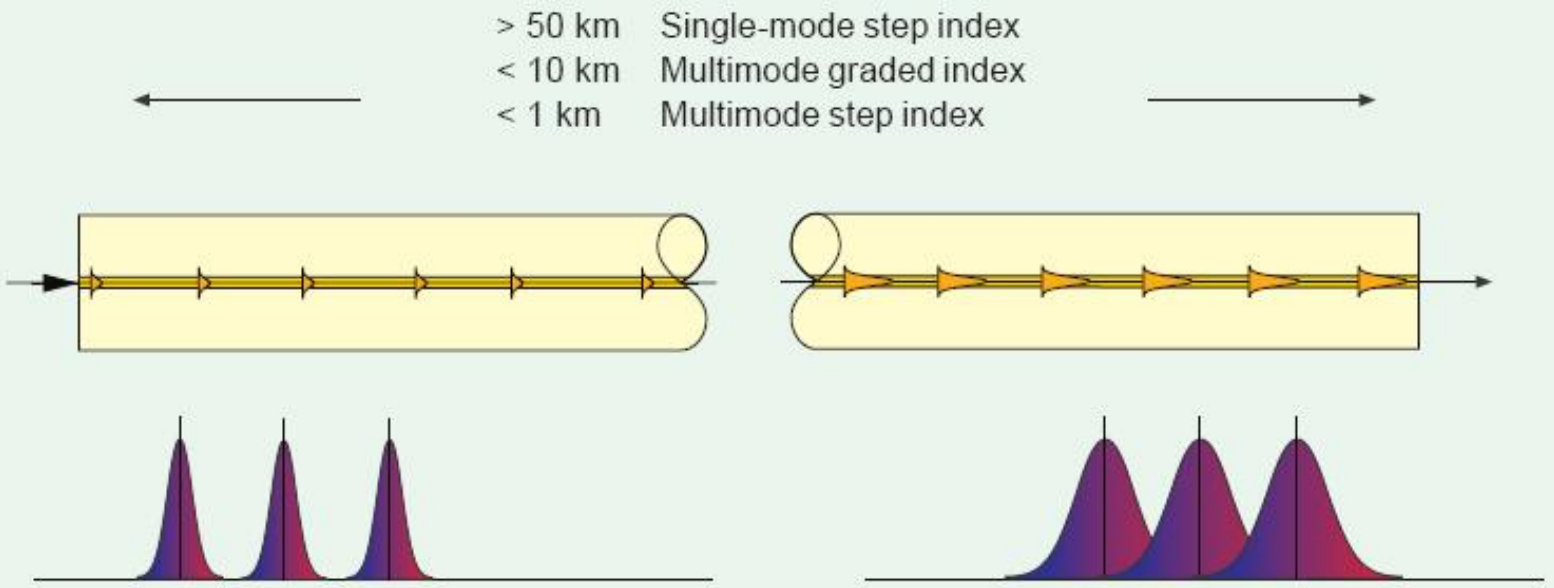
$$\frac{d\beta}{d\omega} = -\frac{\lambda}{\omega}\cdot\frac{d\beta}{d\lambda} = \frac{1}{c}\left(n - \lambda\frac{dn}{d\lambda}\right) = \tau \quad (s/m)$$

$$D = \frac{d\tau}{d\lambda} = \frac{1}{c}\left(\frac{dn}{d\lambda} - \lambda\frac{d^2n}{d\lambda^2} - \frac{dn}{d\lambda}\right) = -\frac{\lambda}{c}\frac{d^2n}{d\lambda^2} \quad (s/m^2)$$

- Dispersia se exprima de obicei in ps/nm/km si permite aflarea intarzierilor aparute intre moduri (latirea impulsurilor) pentru o anumita latime spectrala si o anumita distanta parcursa

$$\Delta\tau = D \cdot \Delta\lambda \cdot L$$

Dispersie

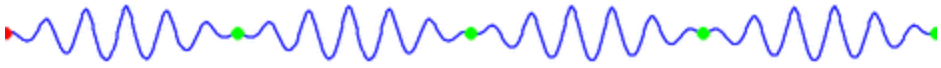


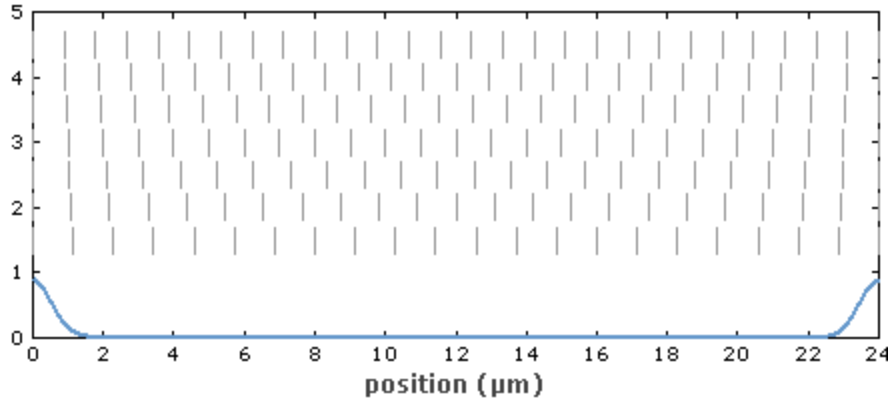
Transmission:
Well-defined pulses but not absolutely monochromatic.
Typical spectal width < 0.8 nm

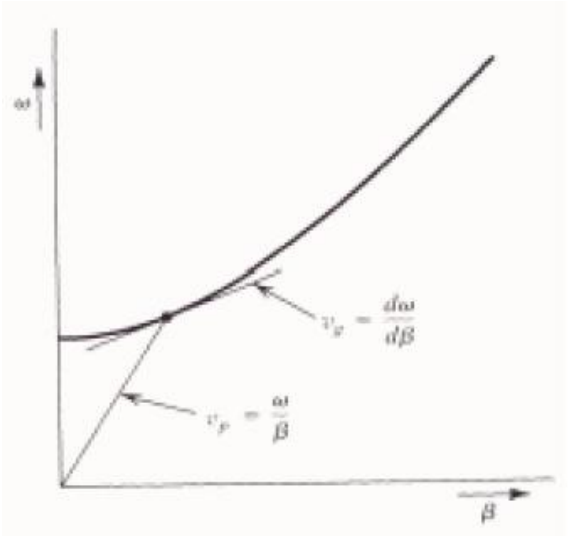
Reception:
Pulse broadening caused by the laser's spectral width and the difference between the refractive indices of the red and blue ends of the light pulse.

Viteze de grup si faza

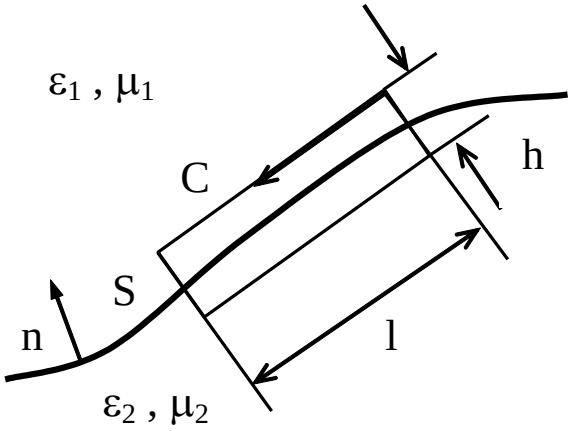
- Viteza de faza – viteza cu care circula energia
- Viteza de grup – viteza cu care circcula informatia



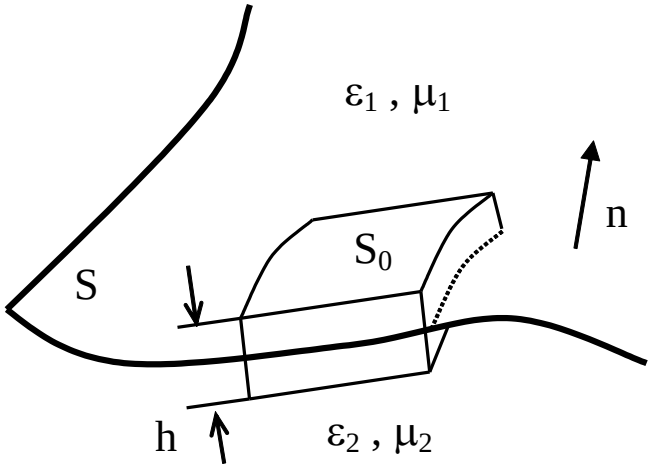




Condiţii la limita de separaţie între două medii



a)



b)

$$n \times \left(E_1 - E_2\right) = 0$$

$$n \times \left(H_1 - H_2\right) = J_S$$

$$n \cdot \left(D_1 - D_2\right) = \rho_S$$

$$n \cdot \left(B_1 - B_2\right) = 0$$

Contact

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