

Optoelectronică, structuri și tehnologii

Curs 1
2013/2014

Cuprins

- ▶ **Lumina ca undă electromagnetică** (ecuațiile lui Maxwell, ecuația undelor, parametri de propagare)
- ▶ **Elemente de fotometrie și radiometrie** (mărimi energetice/luminoase)
- ▶ **Fibra optică** (realizare, principiu de funcționare, atenuare, dispersie, banda de frecvență)
- ▶ **Cabluri optice** (tehnologie, conectori, lipire – splice)
- ▶ **Proiectare sistemică a legăturii pe fibra optică** (bandă de frecvență, balanța puterilor)
- ▶ **Emitătoare optice** (LED și dioda laser – realizare fizică și funcționare)
- ▶ **Receptoare optice** (dioda PIN, dioda cu avalanșă – realizare fizică și funcționare)
- ▶ **Amplificatoare transimpedanță** (parametri, scheme tipice, TIA în buclă deschisă, cu reacție, diferențiale, control automat al câștigului)
- ▶ **Realizarea circuitelor pentru controlul emițătoarelor optice** (parametri, scheme tipice, controlul puterii, multiplexoare)
- ▶ **Dispozitive optice pasive** (birefrigența, 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
<http://rf-opto.etc.tuiasi.ro/docs/opto/>
- ▶ IBM – Understanding Optical Communications: on-line <http://www.redbooks.ibm.com>
- ▶ Radu Damian, I Casian, D Matăsaru – „Comunicatii Optice” , Indrumar de laborator, 2005

Disciplina

▶ 2C/2L

▶ Curs

- an IV μE
- Marti 17–20, P4
- E – 66% din nota
- probleme + (? 1 subiect teorie)
- toate materialele permise

▶ Laborator

- an IV μE , an IV Tc
 - Miercuri 11-16
- L – 33% din nota
- ~~◦ $L = C - 0.45(0.9) \cdot Abs$~~

Orar

▶ Curs

- marti, 17–20, P4
- $2C \Rightarrow 3C$
 - $14 * 2/3 \approx 9.33$
 - $9 \div 10 C$

Documentatie

Laboratorul de Microunde si Optoelectronica - Windows Internet Explorer

http://rf-opto.eti.tuiasi.ro/optoelectronics.php

Google

Favorites Laboratorul de Microunde si Optoelectronica

Page Safety Tools

Microwave and Optoelectronics Laboratory

Optoelectronics, Optoelectronic Devices and Structures

Microelectronics Section

2008-2009

- [Course 1 \(pdf - 3.5M\)](#)
- [Course 2 \(pdf - 1.9M\)](#)
- [Course 3 \(pdf - 3.1M\)](#)
- [Course 4 \(pdf - 2M\)](#)
- [Course 5 \(pdf - 2.4M\)](#)
- [Course 6 \(pdf - 3.5M\)](#)
- [Course 7 \(pdf - 2.8M\)](#)
- [Course 8 \(pdf - 2.9M\)](#)
- [Course 9 \(pdf - 2.7M\)](#)
- [Course 10 \(pdf - 1.7M\)](#)

[IBM Redbooks - Understanding Optical Communications](#)

[Laboratory material - landscape \(pdf - 2M\)](#)

[Supplementary reading 1 \(pdf - 11.1M\)](#)

[Supplementary reading 2 \(pdf - 17.6M\)](#)

[Supplementary reading 3 \(pdf - 50M\)](#)

Problems

[Problems](#)

(2006-2007)

[Course material \(pdf - 10.7M\)](#)

[Laboratory material - landscape \(pdf - 2M\)](#)

[Supplementary reading 1 \(pdf - 11.1M\)](#)

[Supplementary reading 2 \(pdf - 17.6M\)](#)

(2005-2006)

[Optoelectronic Structures \(landscape pdf\) \(3.1M\)](#)

[Razavi - Title page\(90k\)](#)

[Chapter 3\(895k\)](#)

Pagina veche poate fi accesata [aici](#)




English
Romana
Pas encore

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File Zone Net Zone

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	<u>APETRII MARIA</u>

Grupa: 5403

Nr.	Nume
1	<u>ALEXANDRESCU SEBASTIAN</u>

Grupa: 5404

Nr.	Nume
1	<u>APERGHIS MIHAI-ALIN</u>

Grupa: 5405

Nr.	Nume
1	<u>ANGHELUS MARIU</u>

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 radiocomunic				
	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 sisteme
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: $9.67 \pm 0.66 / 8.81 \pm 1.22$
 - 2008: $6.24 \pm 1.36 / 4.82 \pm 2.10$
 - 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%

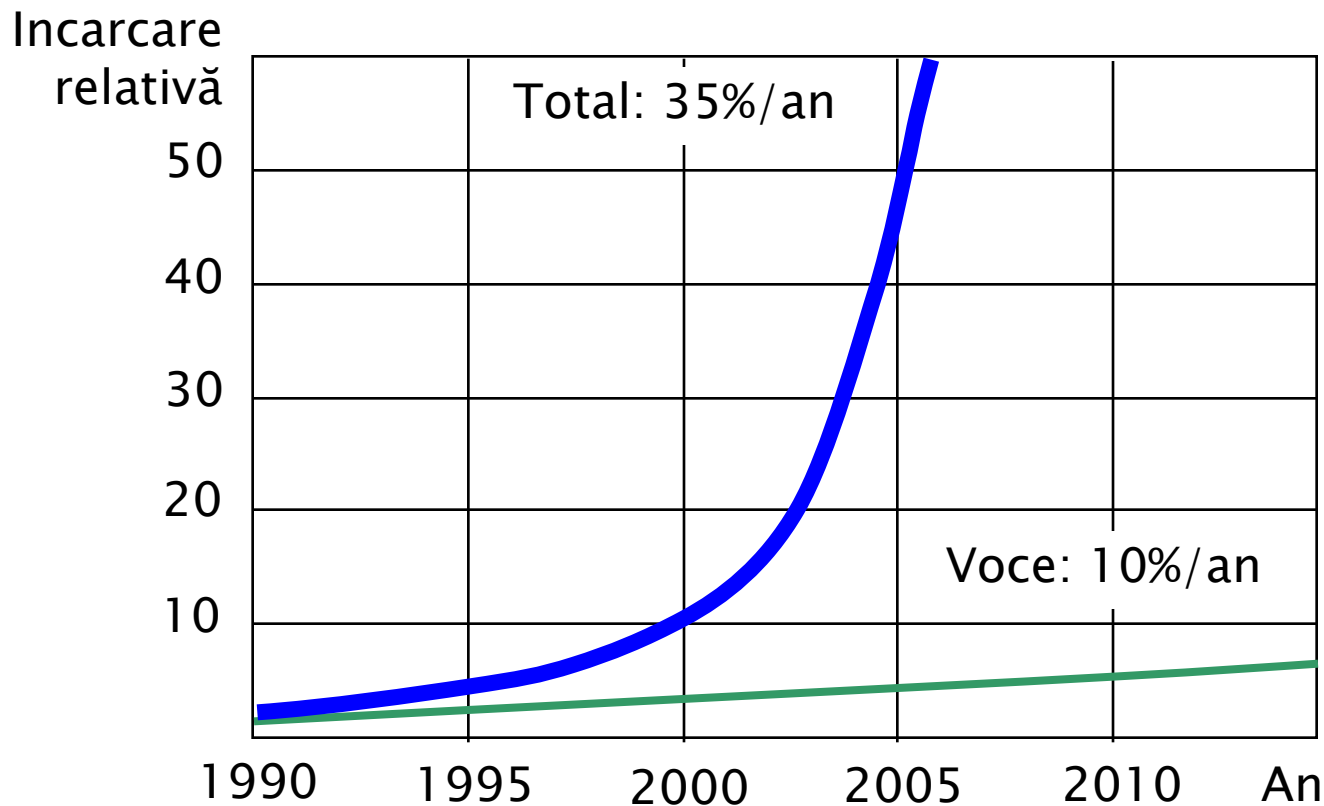
Examen



Introducere

Capitolul 1

Evoluția lățimii de bandă utilizată în rețelele de telecomunicații

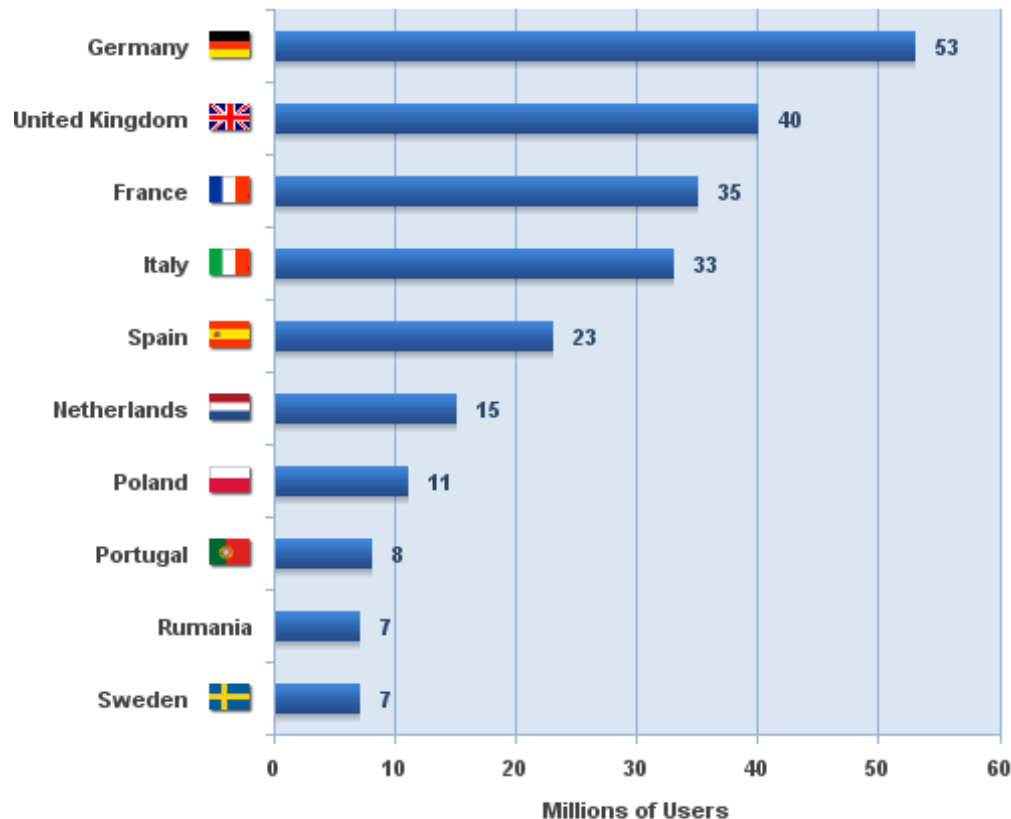


Sursa:

EC ELECTRONiCAST
CORPORATION

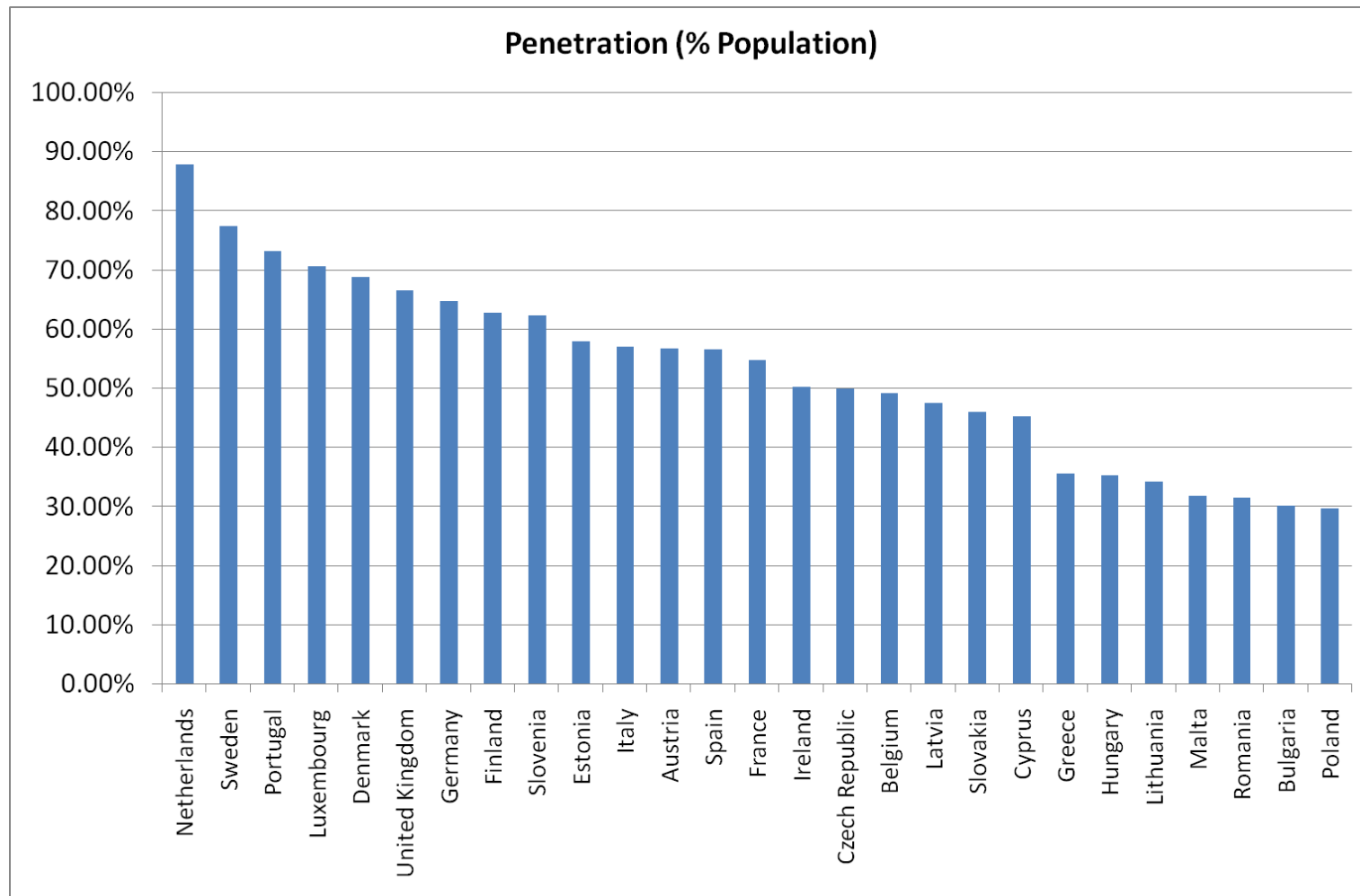
Utilizzatori Internet in EU

European Union Top 10 Internet Users November 2007

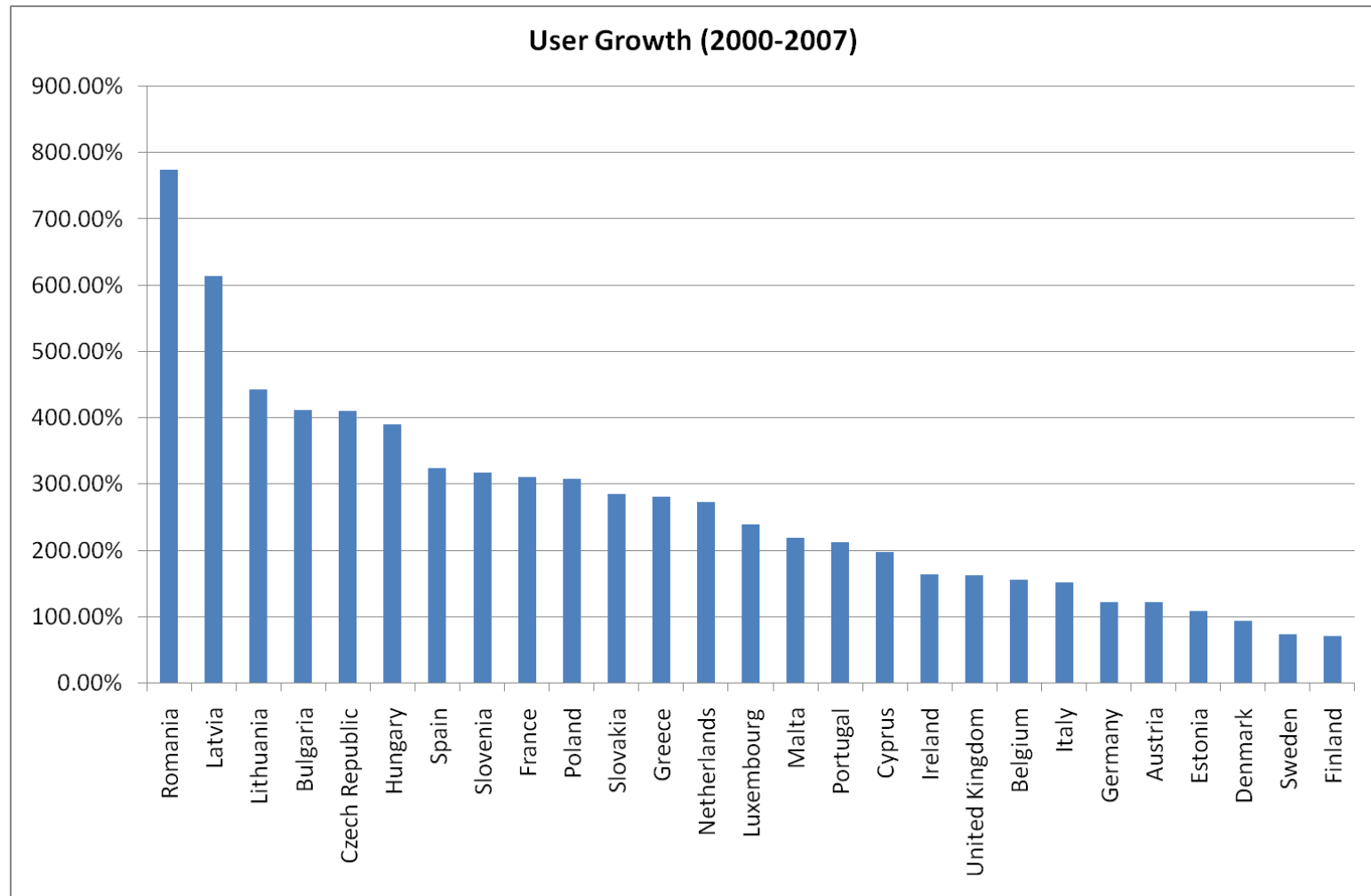


Source: www.internetworldstats.com
Copyright © 2008, Miniwatts Marketing Group

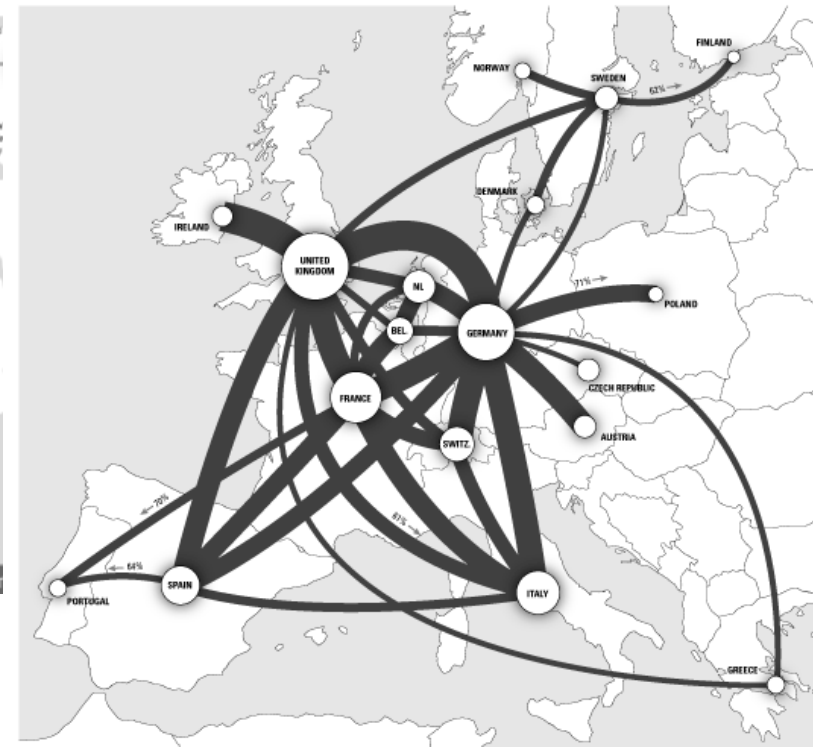
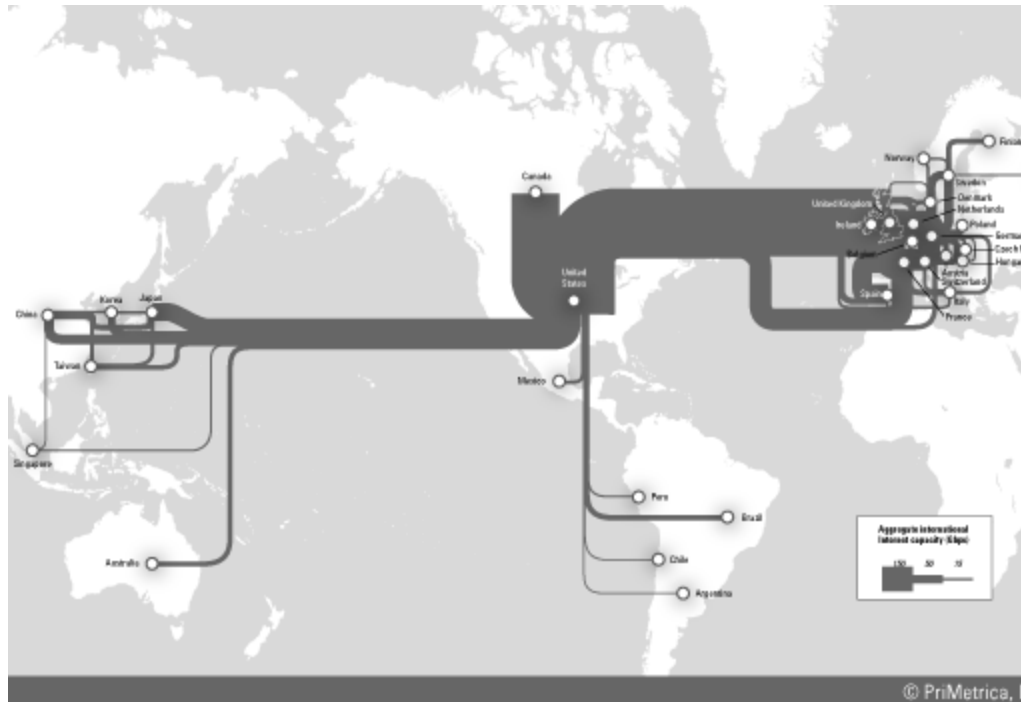
Rata de penetrare in EU



Crestere 2000-2007



Internet Backbone

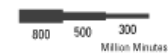


Key

All figures are given in millions of minutes of telecommunications traffic for the public telephone network.

The map shows all intra-European routes with a combined 2004 volume of more than 300 million minutes.

Traffic Flows



Each band is proportional to the total annual traffic on the public telephone network in both directions between each pair of countries.

Total Outgoing Traffic



The area of each circle is proportional to the volume of the total annual outgoing traffic from each country.

Balance of Traffic

On routes where traffic in one direction accounts for more than 60 percent of the total, an arrow shows the direction most of the traffic flows.

Internet Backbone



Avantajele comunicațiilor prin fibra optică – 1

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

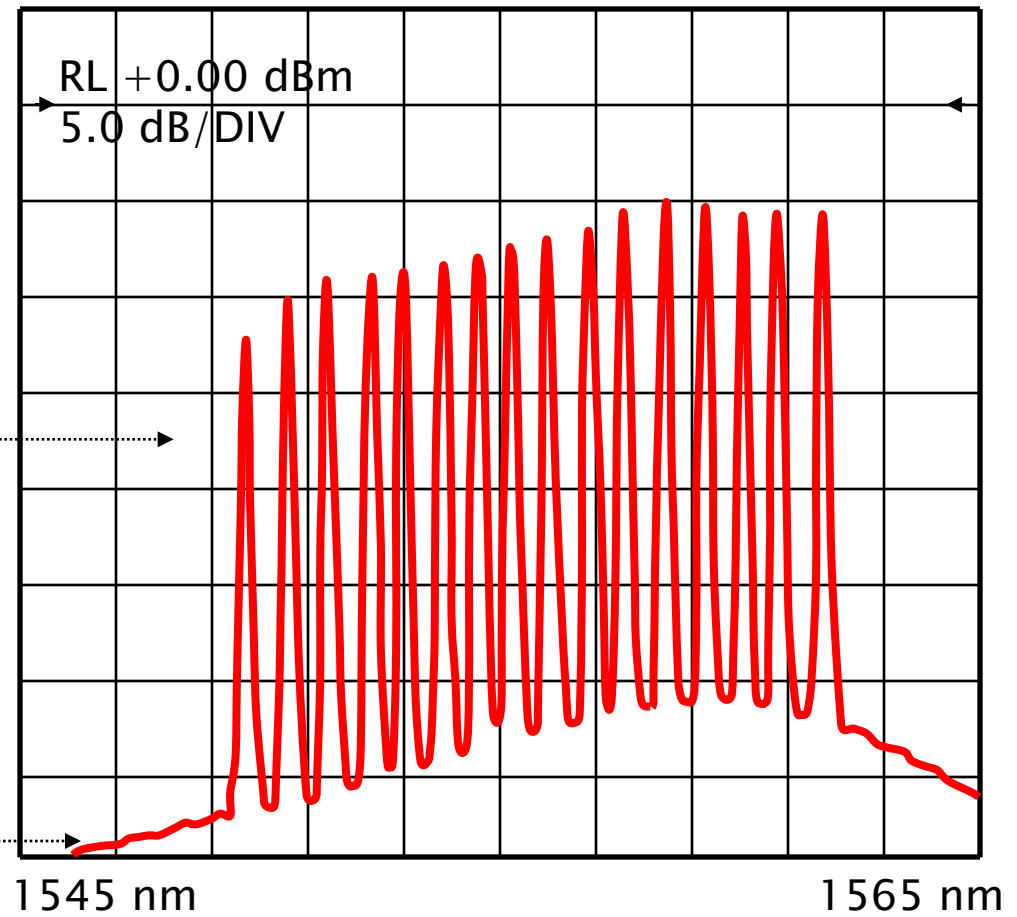
Avantajele comunicațiilor prin fibra optică – 2

- ▶ Imunitate la interferență electromagnetică
- ▶ Distanța între repetoare
 - 100km/2–5km
- ▶ Posibilitate de creștere a capacității de transmisie a informației
 - Teoretic extrem de mare (aproape infinită)
 - Reutilizarea cablurilor existente
- ▶ Securitate
 - Interceptare dificilă și detectabilă
 - Inserare de semnal practic imposibilă

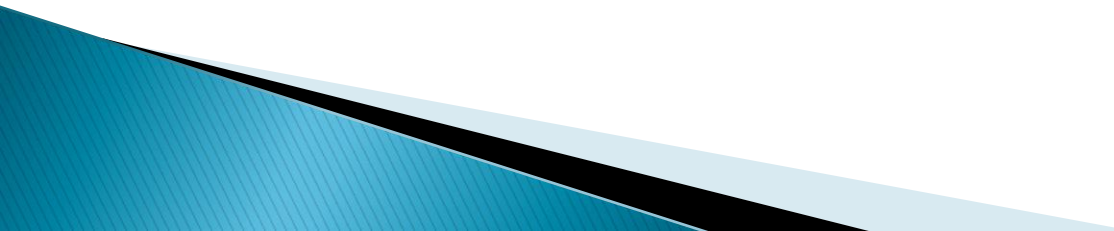
Spectrul WDM – Wavelength Division Multiplexing

Canale: 16
Spațiere: 0.8 nm

Emisie spontană
Amplificată (ASE)



Dezavantajele comunicațiilor prin fibra optică

- ▶ Conexiuni complexe și esențiale
 - Costul circuitelor integrate crescut considerabil de cuplarea luminii în fibra
 - ▶ Curbarea cablurilor optice
 - ▶ Dezvoltarea greoaie a standardelor
 - ▶ Optica folosită strict pentru transmisie (aproape)
 - EDFA – Erbium Doped Fiber Amplifier
 - ▶ Sensibilitate la radiații gama și câmpuri electrice intense
 - ▶ Rozătoare și 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

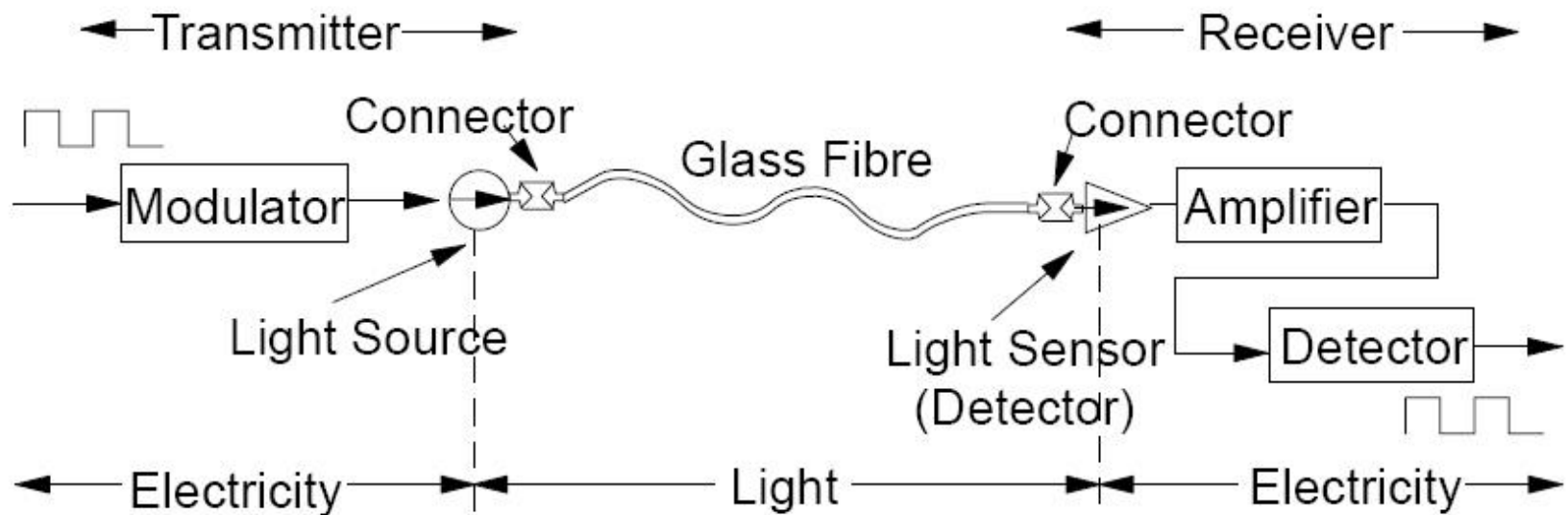
E0	64 Kb/s	
E1	2.048 Mb/s	
E2	8.448 Mb/s	4 E1s
E3	34.364 Mb/s	16 E1s
E4	139.264 Mb/s	64 E1s

1 mile=1760 yards

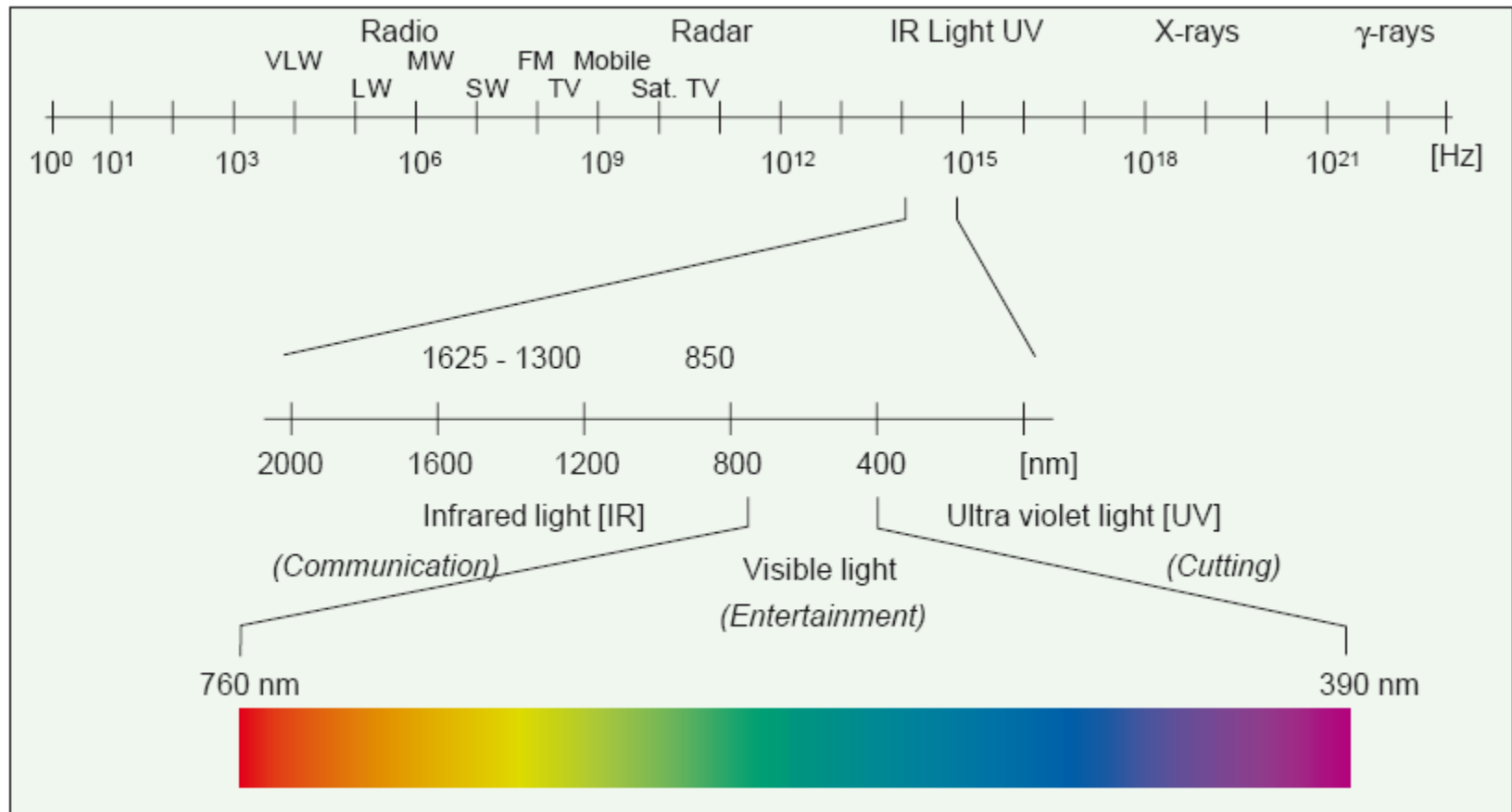
1 yards=3 feet

1 mile≈1609.34 m

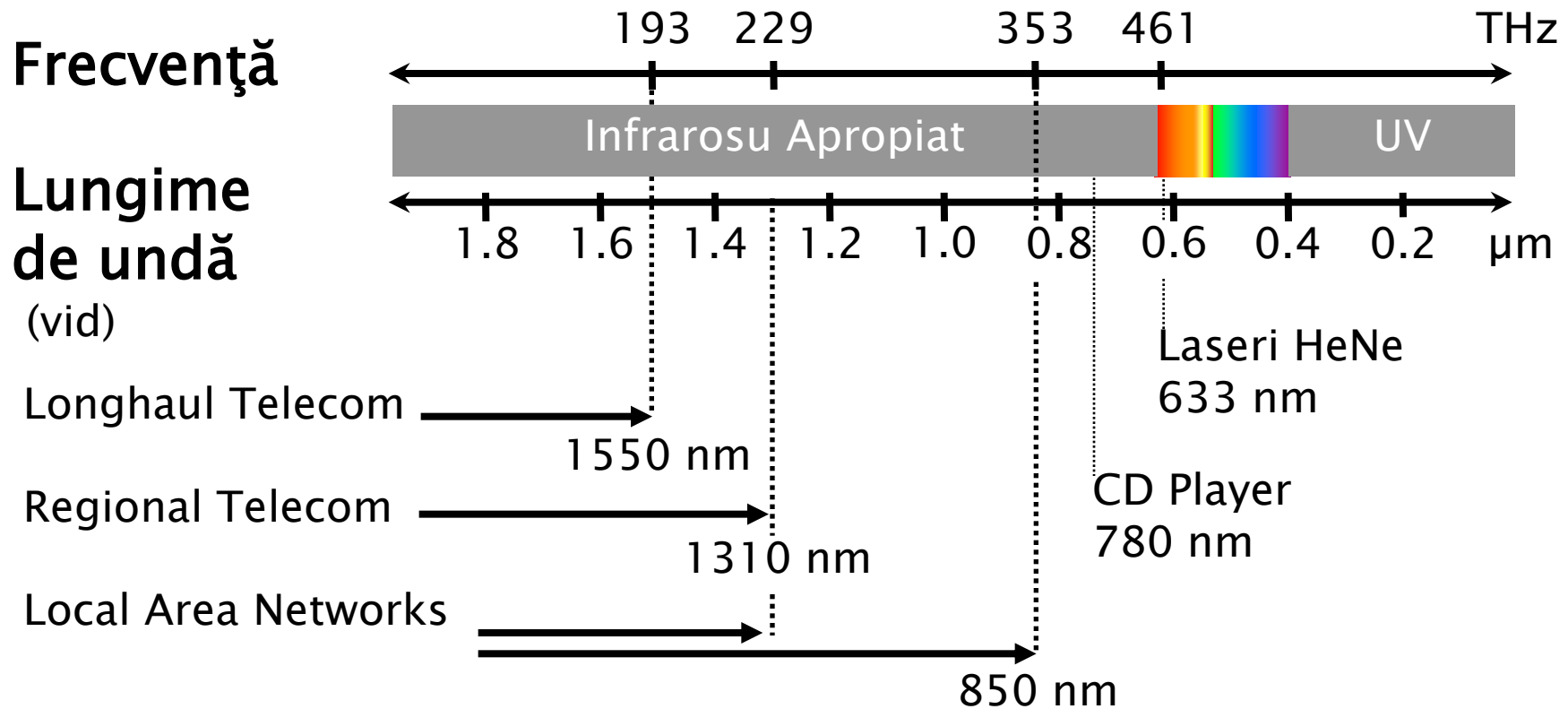
Transmisia optica



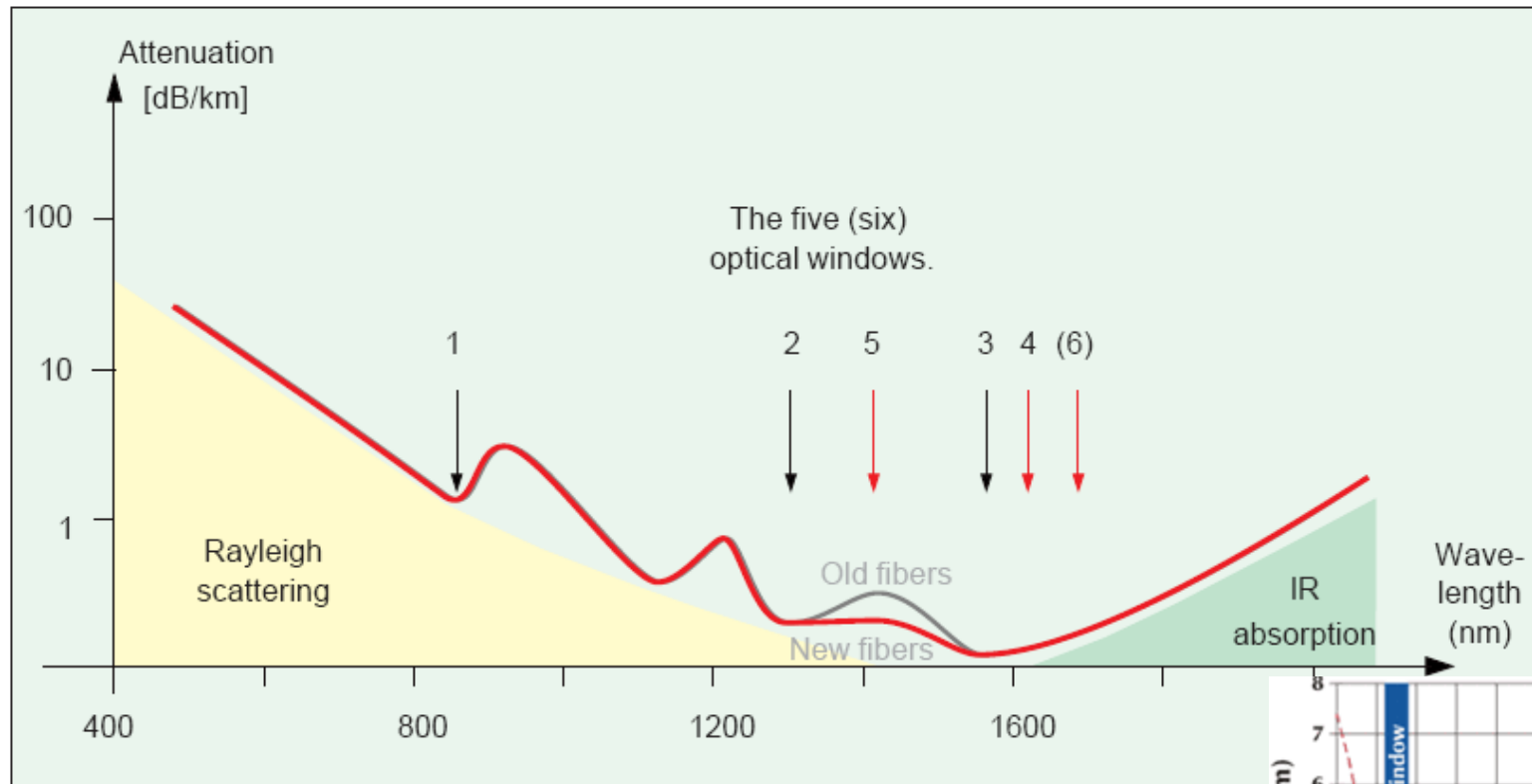
Spectrul electromagnetic



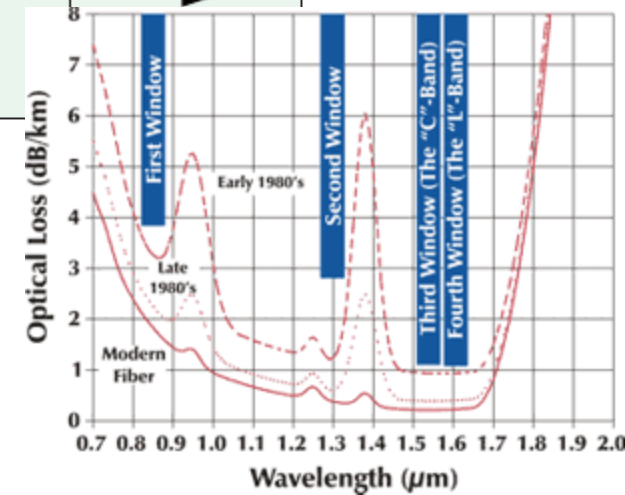
Benzi de lucru in comunicațiile optice



Atenuarea în fibra optică (SiO_2)



850nm, 1310nm, 1550nm



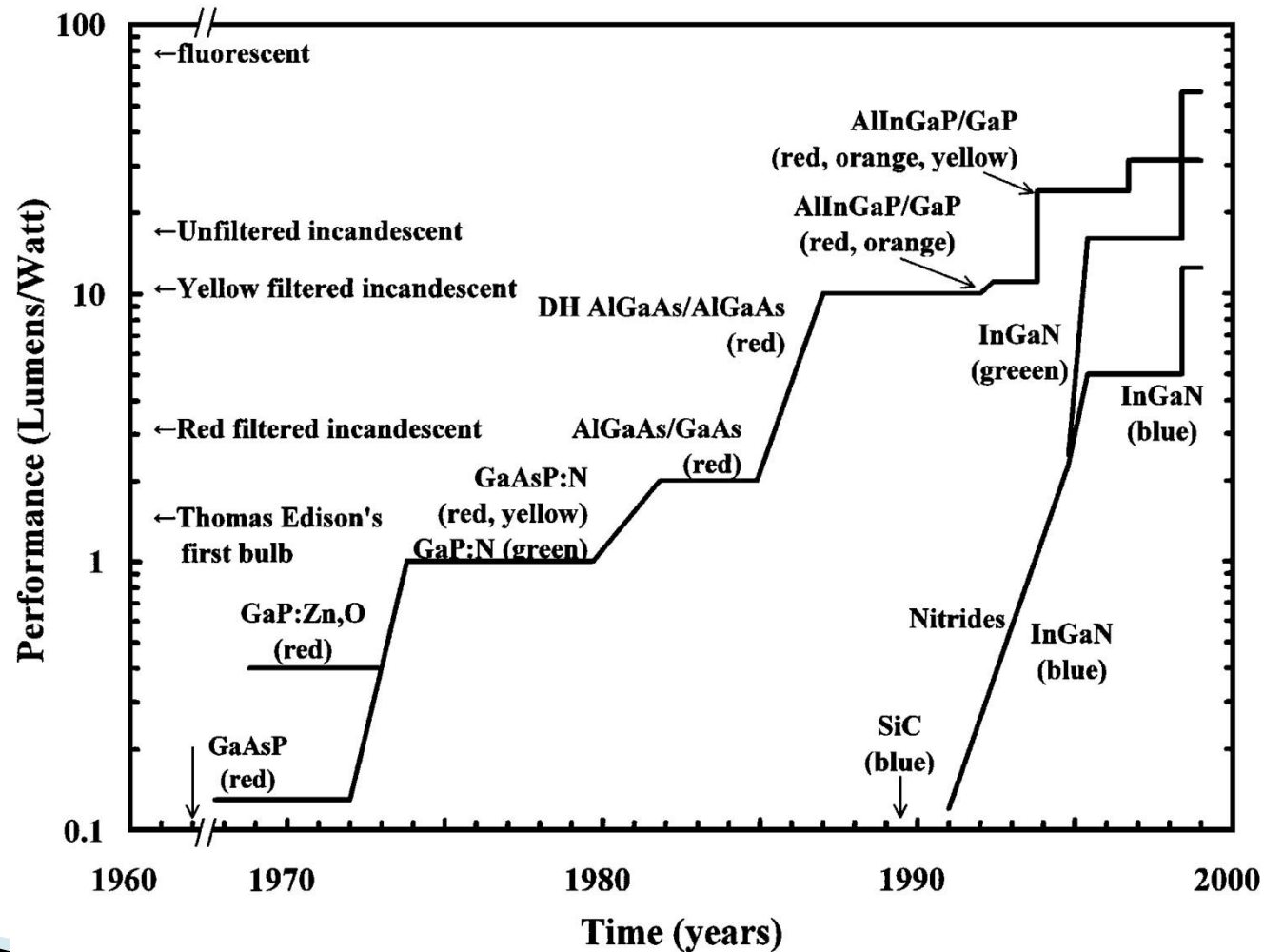
Aplicatii majore LED

- ▶ Comunicatii
 - Infrarosu (InGaAsP)
- ▶ Vizibil
 - Spectru vizibil (GaAlAs)
- ▶ Iluminare
 - Putere ridicata, lumina alba (GaInN)

Eficienta

- ▶ Bec cu incandescenta
 - 16 lm/W
- ▶ Tub fluorescent
 - 100 lm/W
- ▶ LED
 - curent: 250 lm/W
 - curand: 300 lm/W

Eficienta in timp



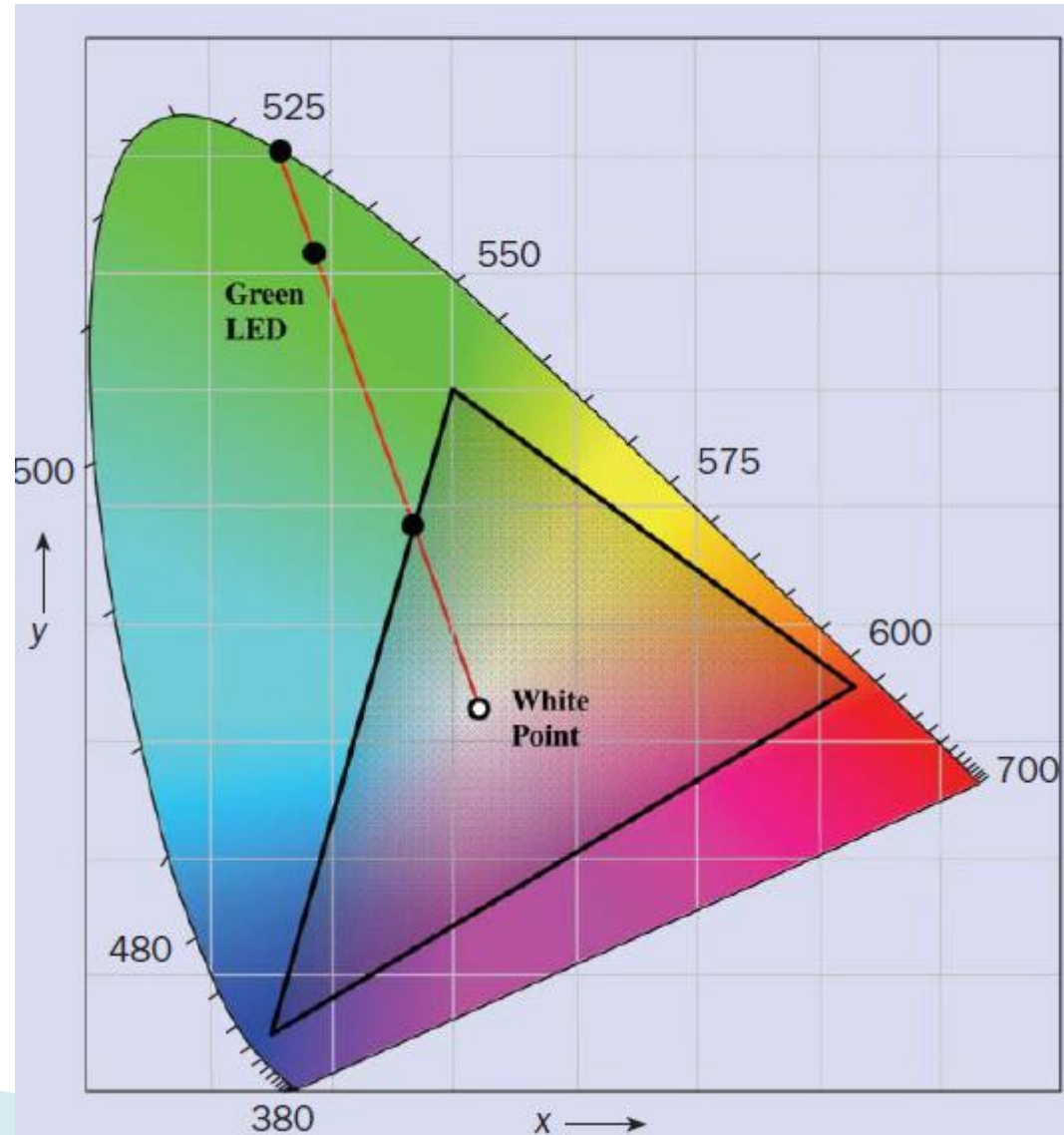
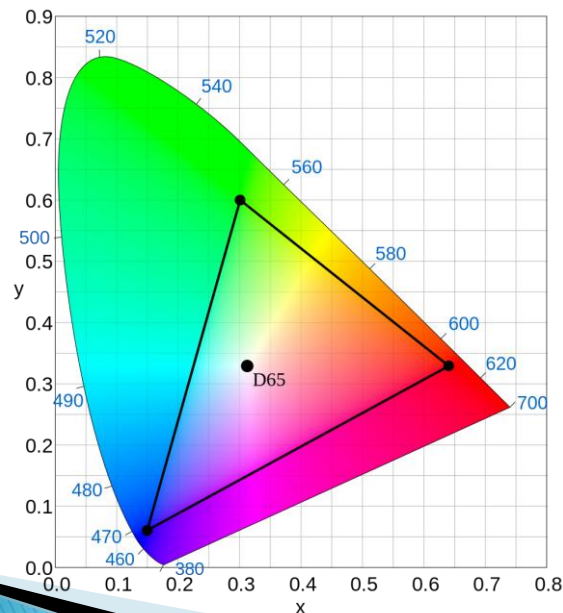
ITU-R BT.709



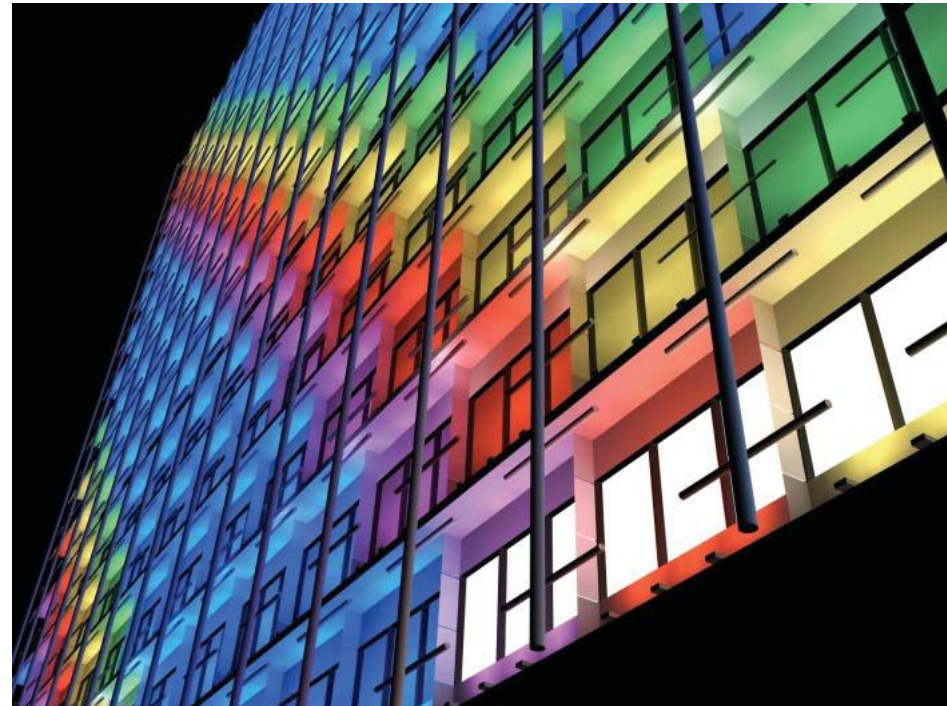
ITU-R BT.709 phosphor properties

Phosphor	x	y
Red	0.640	0.330
Green	0.300	0.600
Blue	0.150	0.060

Data refers to xy chromaticity co-ordinates of ITU-R BT.709 phosphors which are used in most CRT displays [1].



ITU-R BT.709



RGB values for Luxeon LEDs

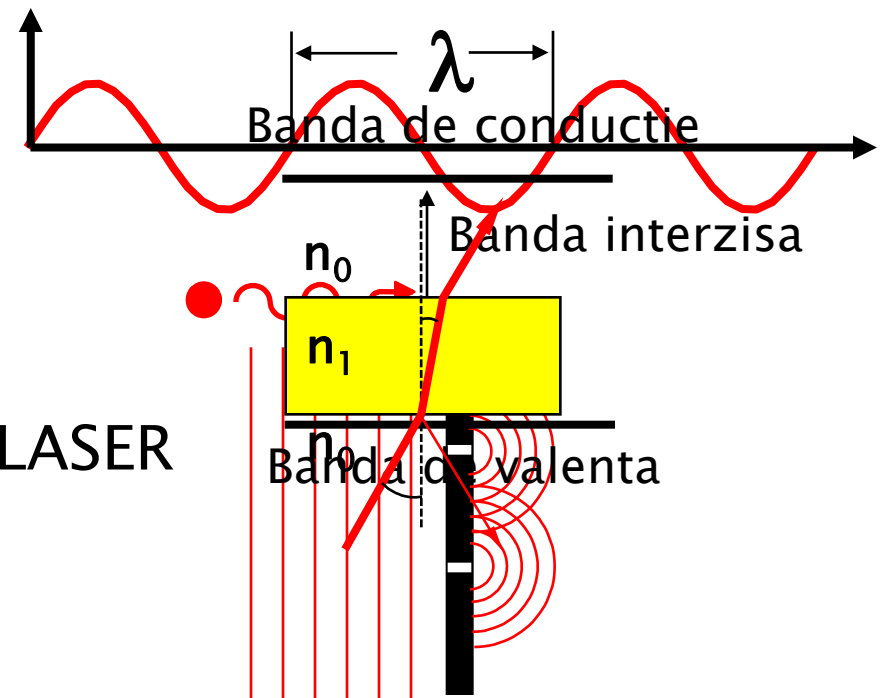
LED color	Dominant wavelength λ_D (nm)	RGB values
Royal blue	455	0.05, 0.00, 0.95
Blue	470	0.00, 0.11, 0.89
Cyan	505	0.00, 0.63, 0.37
Green	530	0.00, 0.77, 0.23
Amber	590	0.70, 0.30, 0.00
Red-orange	615	0.97, 0.00, 0.03
Red	625	0.92, 0.00, 0.08

Modelarea luminii

(tot) Capitolul 1

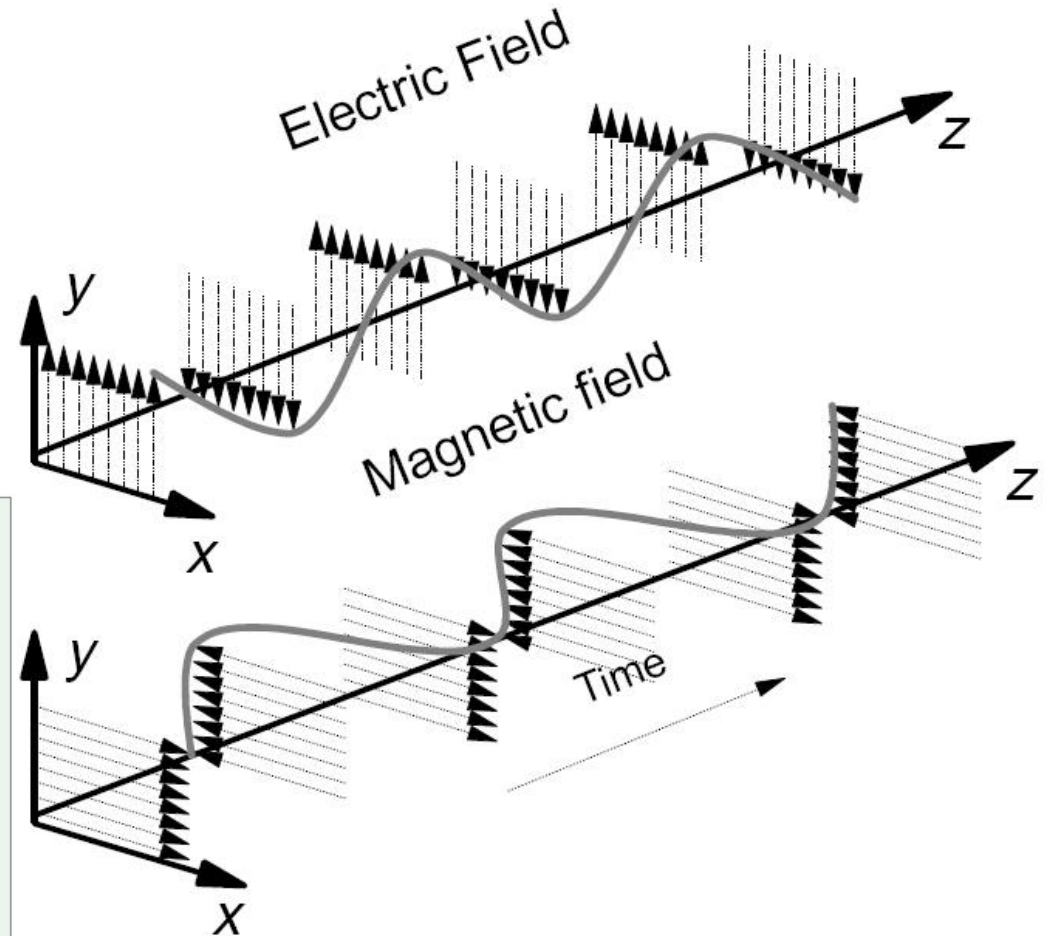
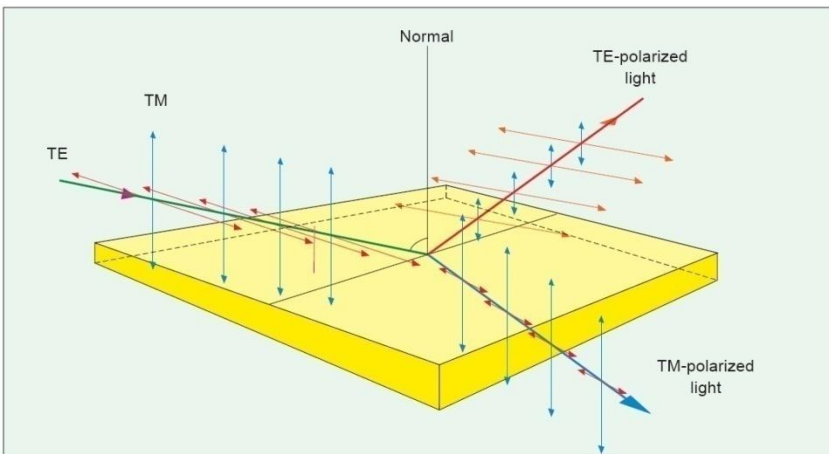
Modelarea luminii

- ▶ Undă electromagnetică
 - Ecuațiile 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

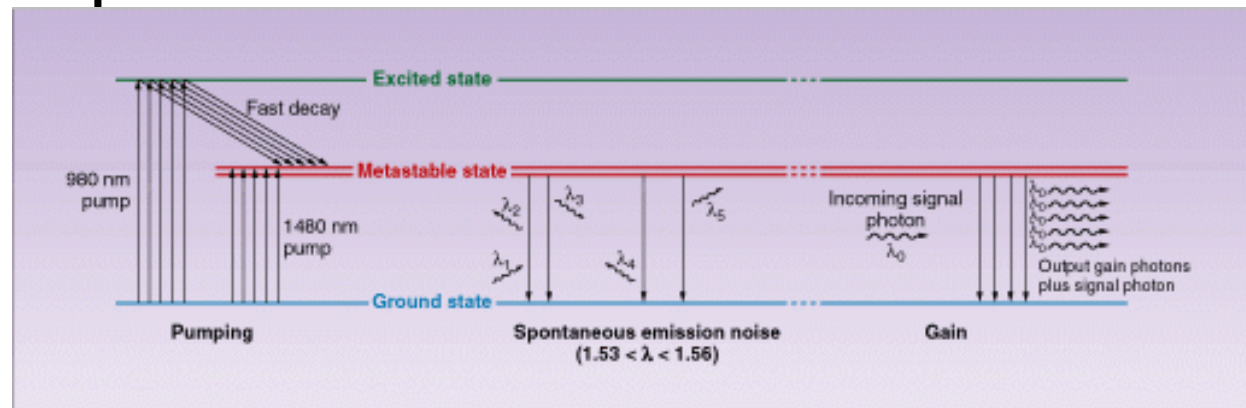
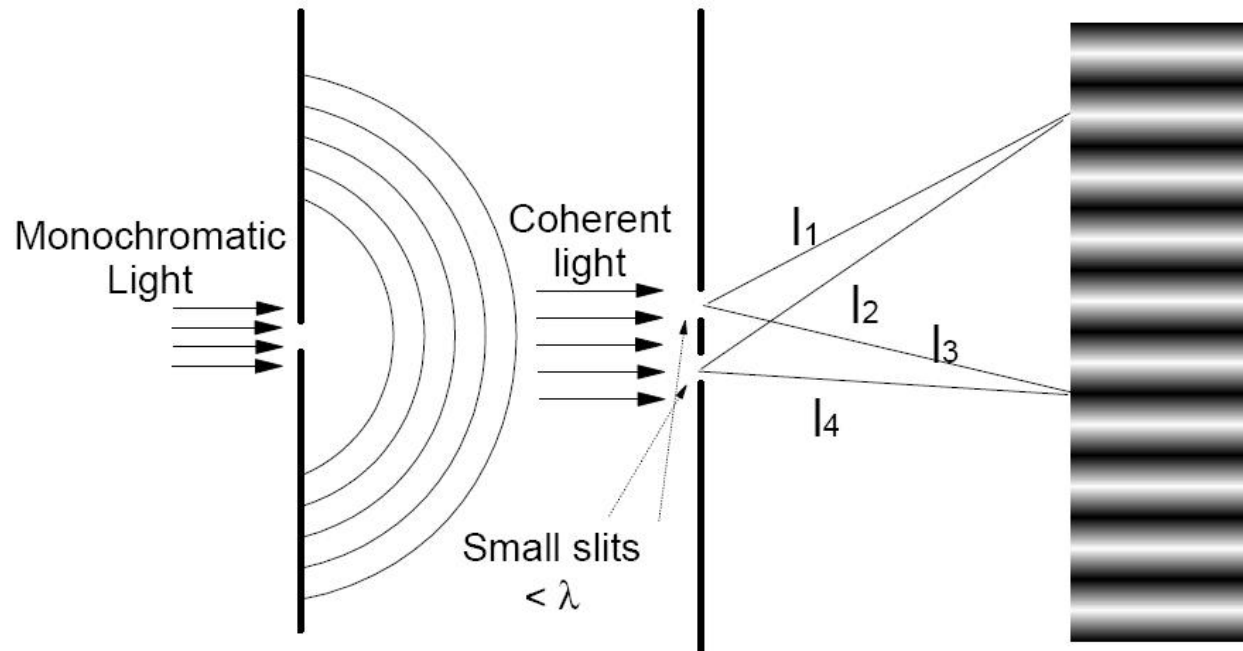


Unda electromagnetica

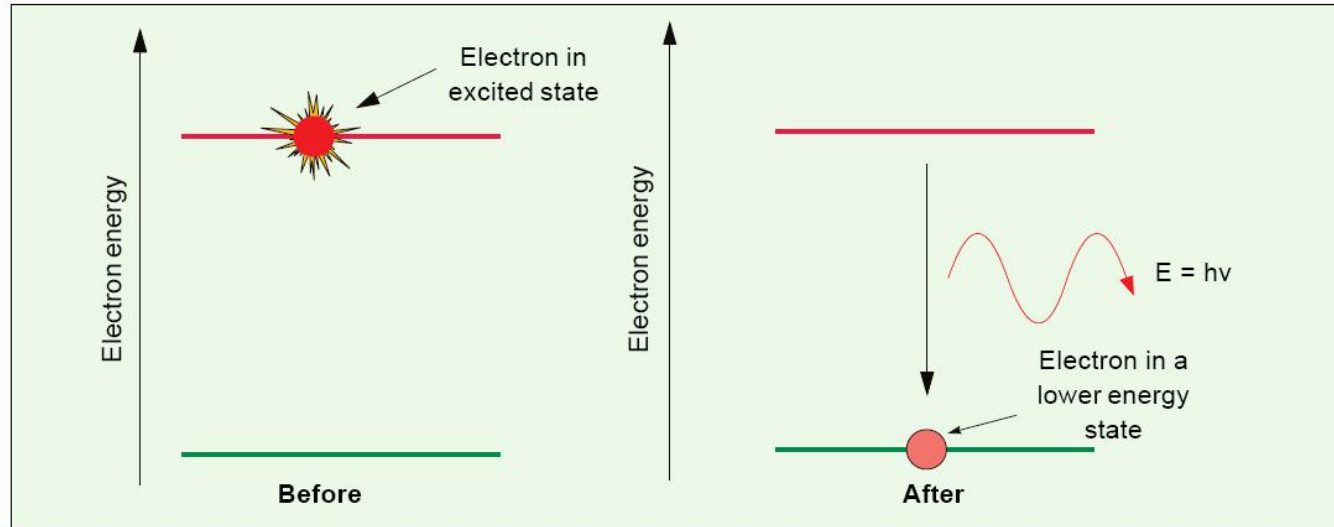
- ▶ Dispersie
- ▶ Fibre monomod
- ▶ Interferenta
- ▶ Polarizare



Fotoni/Unda

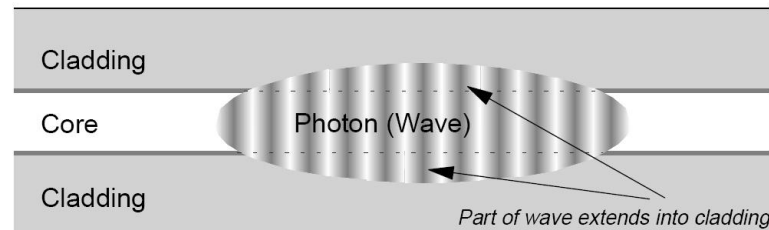


Model cuantic – foton

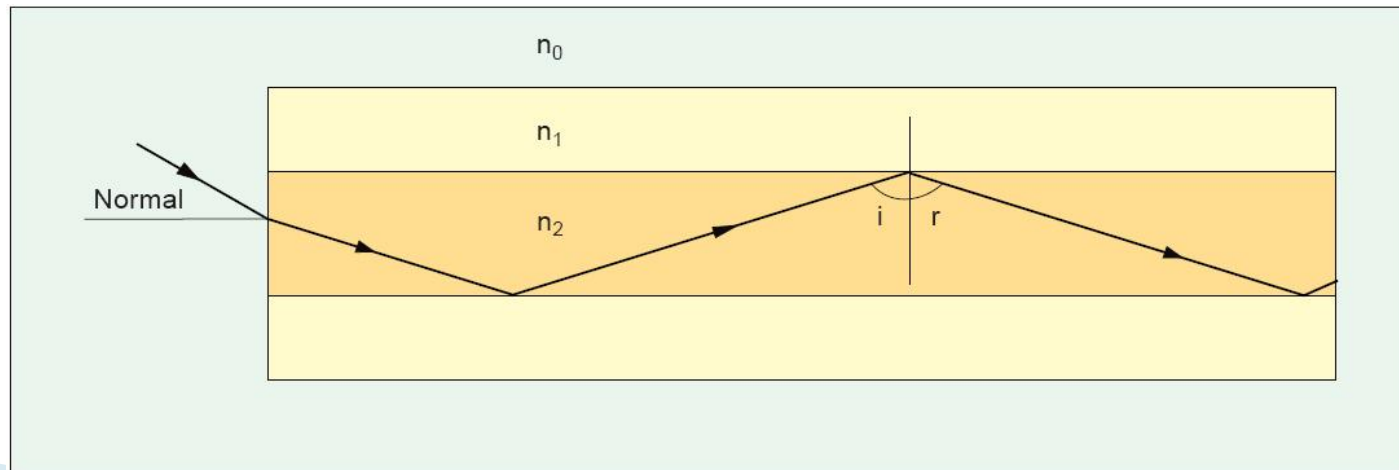
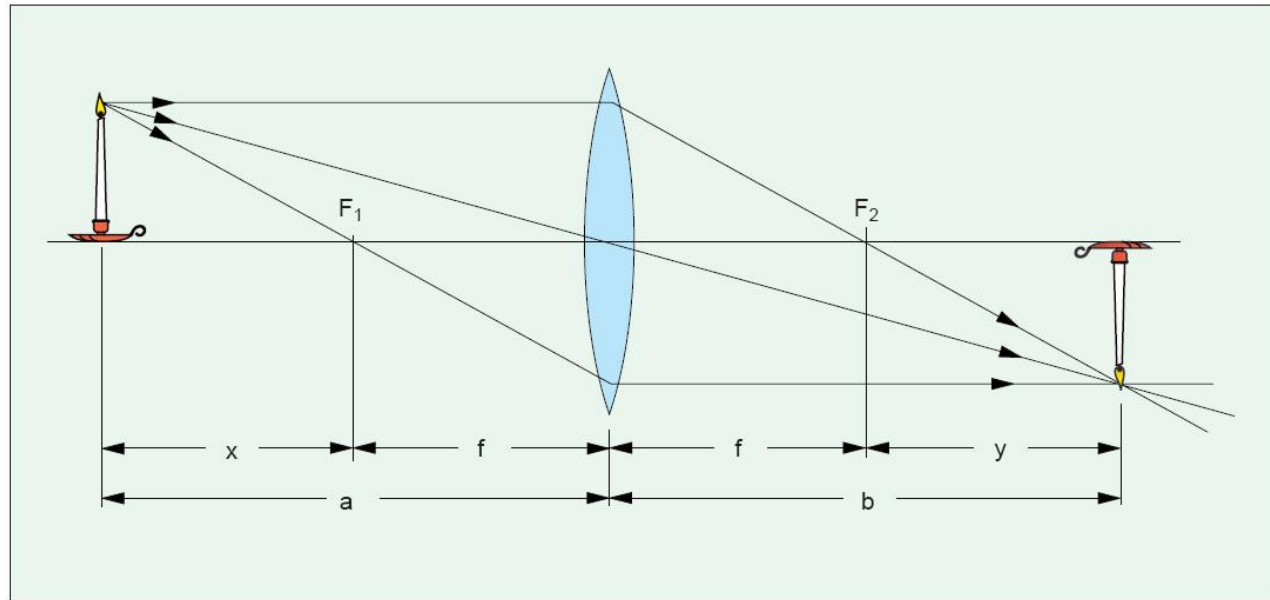


$$E_g = h\nu; \quad \lambda = \frac{hc}{E_g}; \quad \lambda[\mu\text{m}] = \frac{1.240}{E_g[\text{eV}]}$$

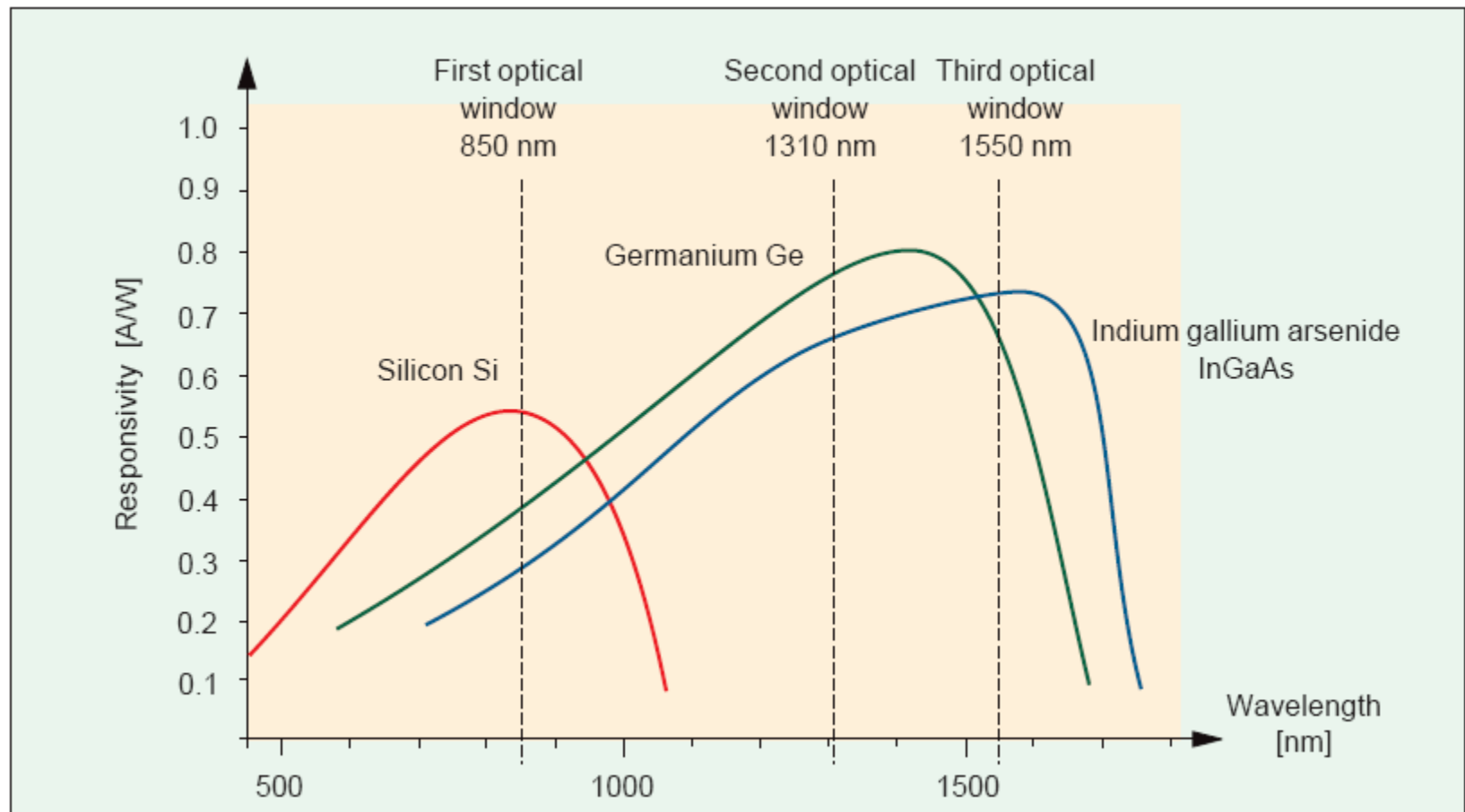
- ▶ h constanta lui Plank
 $6.62 \cdot 10^{-32} \text{ Ws}^2$
- ▶ c viteza luminii in vid
 $2.998 \cdot 10^8 \text{ m/s}$



Optica geometrica



Materiale semiconductoare utilizate in optoelectronică



Lățimea benzii interzise/lungime de undă pentru materialele uzuale

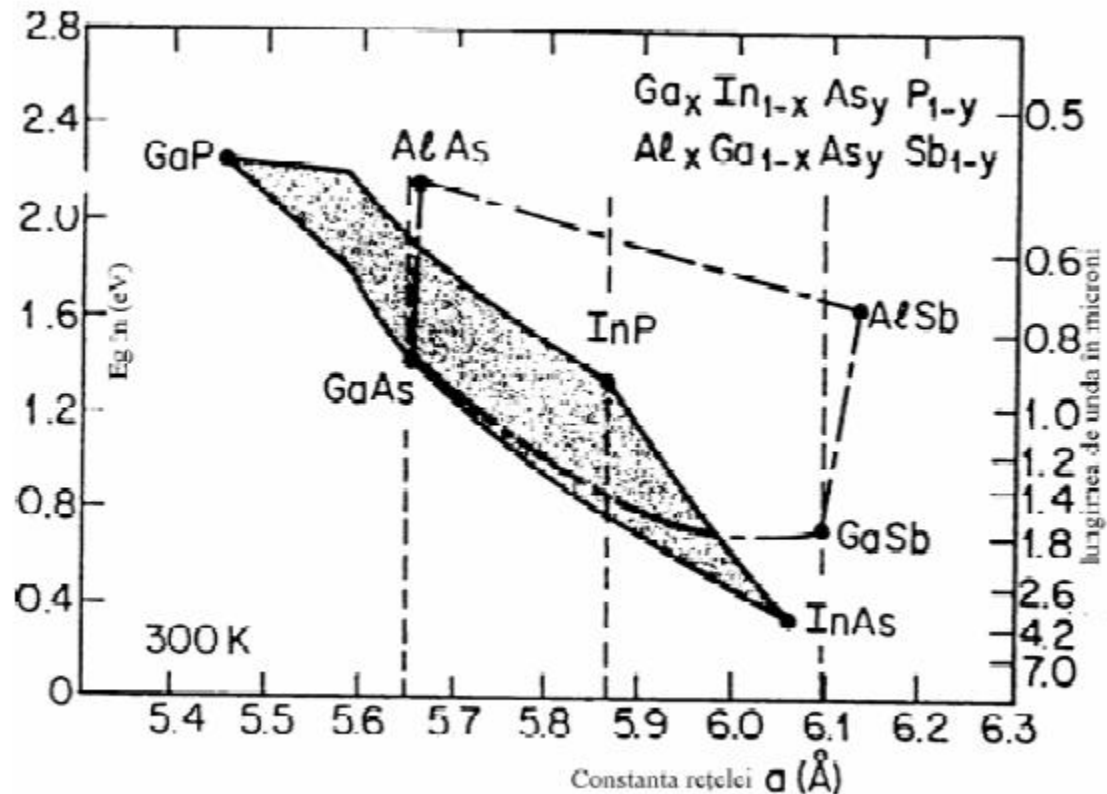
$$\lambda = \frac{hc}{E_g}$$

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

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

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

Dependența benzii interzise de constanta rețelei



Reprezentare logaritmică

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

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

$$0 \text{ dB} = 1$$

$$+ 0.1 \text{ dB} = 1.023 (+2.3\%)$$

$$+ 3 \text{ dB} = 2$$

$$+ 5 \text{ dB} = 3$$

$$+ 10 \text{ dB} = 10$$

$$-3 \text{ dB} = 0.5$$

$$-10 \text{ dB} = 0.1$$

$$-20 \text{ dB} = 0.01$$

$$-30 \text{ dB} = 0.001$$

$$0 \text{ dBm} = 1 \text{ mW}$$

$$3 \text{ dBm} = 2 \text{ mW}$$

$$5 \text{ dBm} = 3 \text{ mW}$$

$$10 \text{ dBm} = 10 \text{ mW}$$

$$20 \text{ dBm} = 100 \text{ mW}$$

$$-3 \text{ dBm} = 0.5 \text{ mW}$$

$$-10 \text{ dBm} = 100 \text{ }\mu\text{W}$$

$$-30 \text{ dBm} = 1 \text{ }\mu\text{W}$$

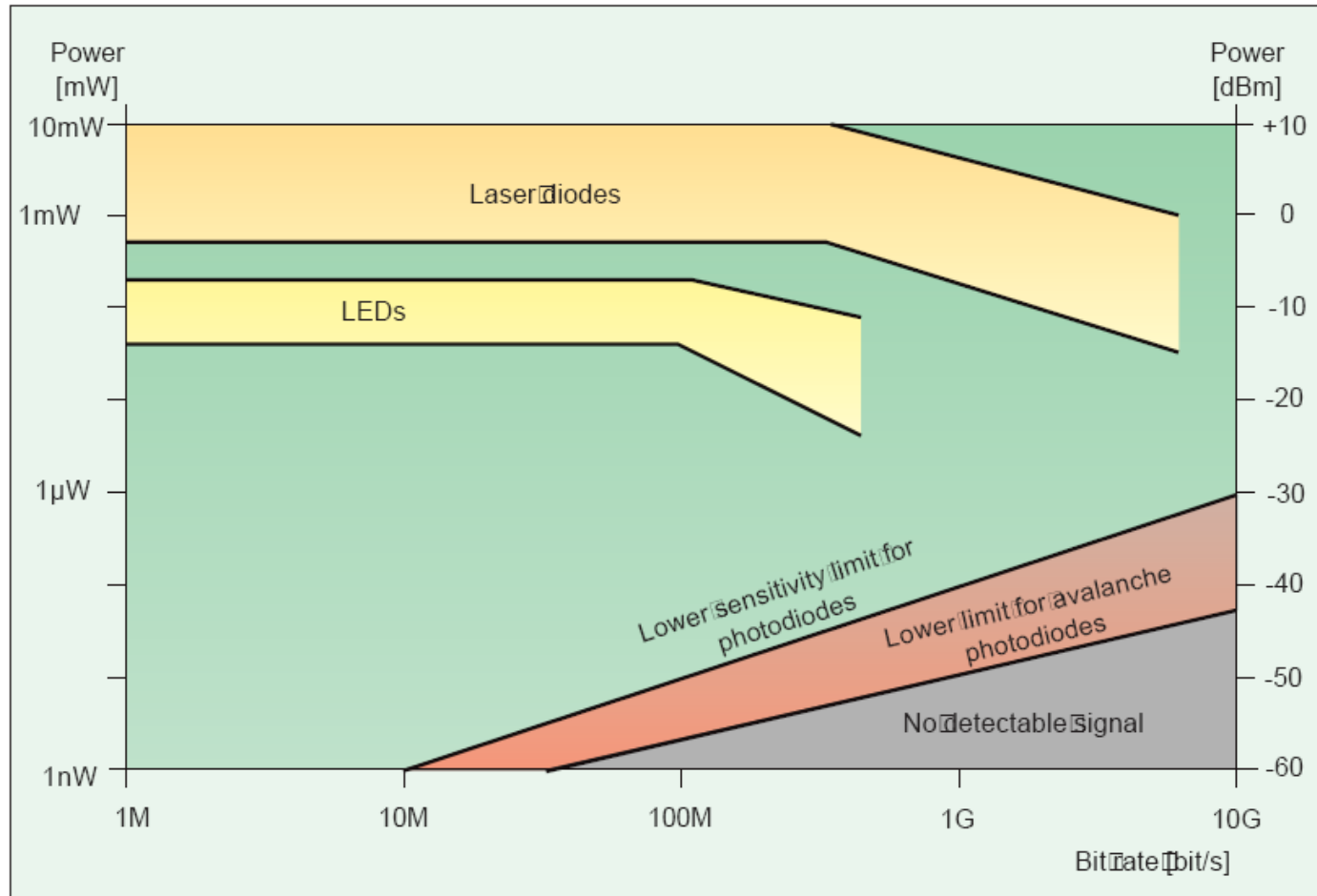
$$-60 \text{ dBm} = 1 \text{ nW}$$

$$[\text{dBm}] + [\text{dB}] = [\text{dBm}]$$

$$[\text{dBm/Hz}] + [\text{dB}] = [\text{dBm/Hz}]$$

$$[\text{x}] + [\text{dB}] = [\text{x}]$$

Limite putere/bandă a dispozitivelor optoelectronice



Contact

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- ▶ rdamian@etti.tuiasi.ro