

# Optoelectronică, structuri și tehnologii

Curs 1  
2015/2016

▶ La facultate, profesorul intreaba:

– Intrebare de "nota 10": cum ma numesc?  
Toti tac.

– Intrebare de "nota 8": la ce obiect aveti examen?  
Toti tac.

– Intrebare de "nota 5": ce culoare are manualul  
(site-ul laboratorului)?

Din ultimele randuri se aude o voce:

– Vrea sa ne pice magaru'!

# Disciplina 2015/2016

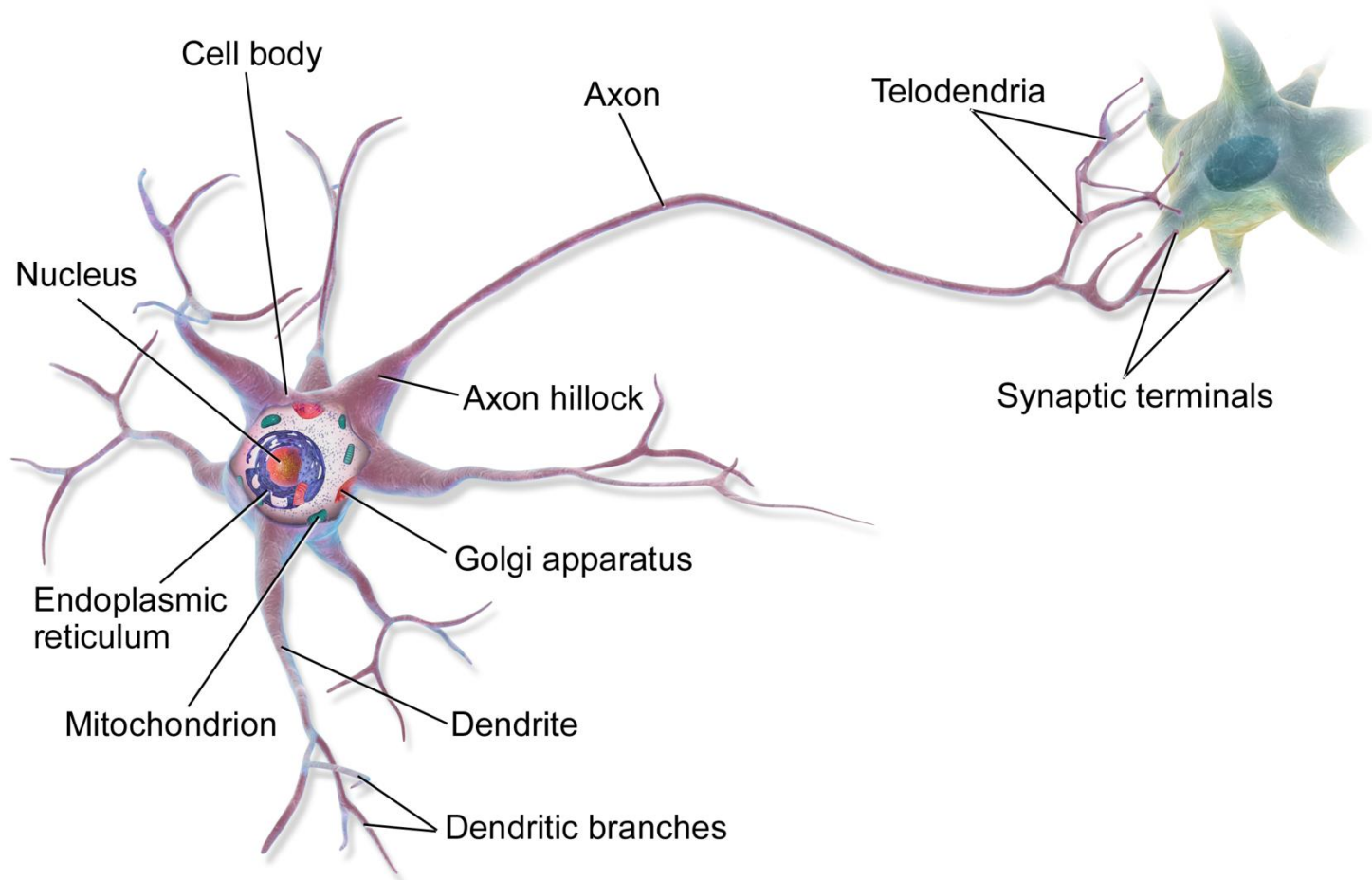
- ▶ 2C/1L Optoelectronică, structuri și tehnologii, **OSTC**
- ▶ Curs – **sl. Radu Damian**
  - an IV  $\mu$ E
  - Luni 18–20, P5
  - E – 66% din nota
  - probleme + (? 1 subiect teorie) + (2p prez. curs)
  - toate materialele permise
- ▶ Laborator – **sl. Daniel Matasaru**
  - an IV  $\mu$ E, an IV Tc
    - Luni 16-18 impar
    - Marti 18-20
    - Joi 8-12 impar
  - L – 17% din nota
  - T – 17% din nota

# Orar 2013/2014

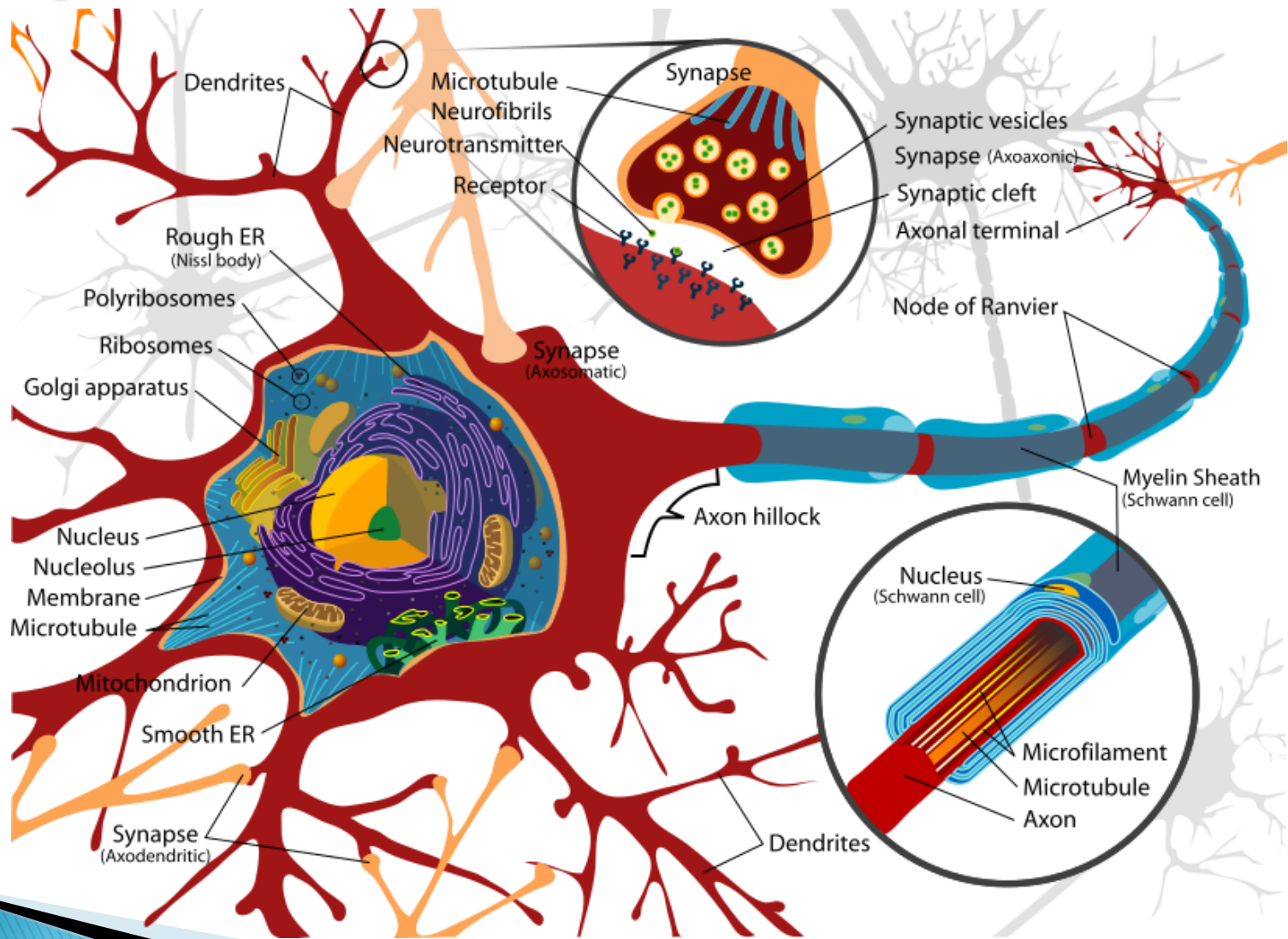
## ▶ Curs

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

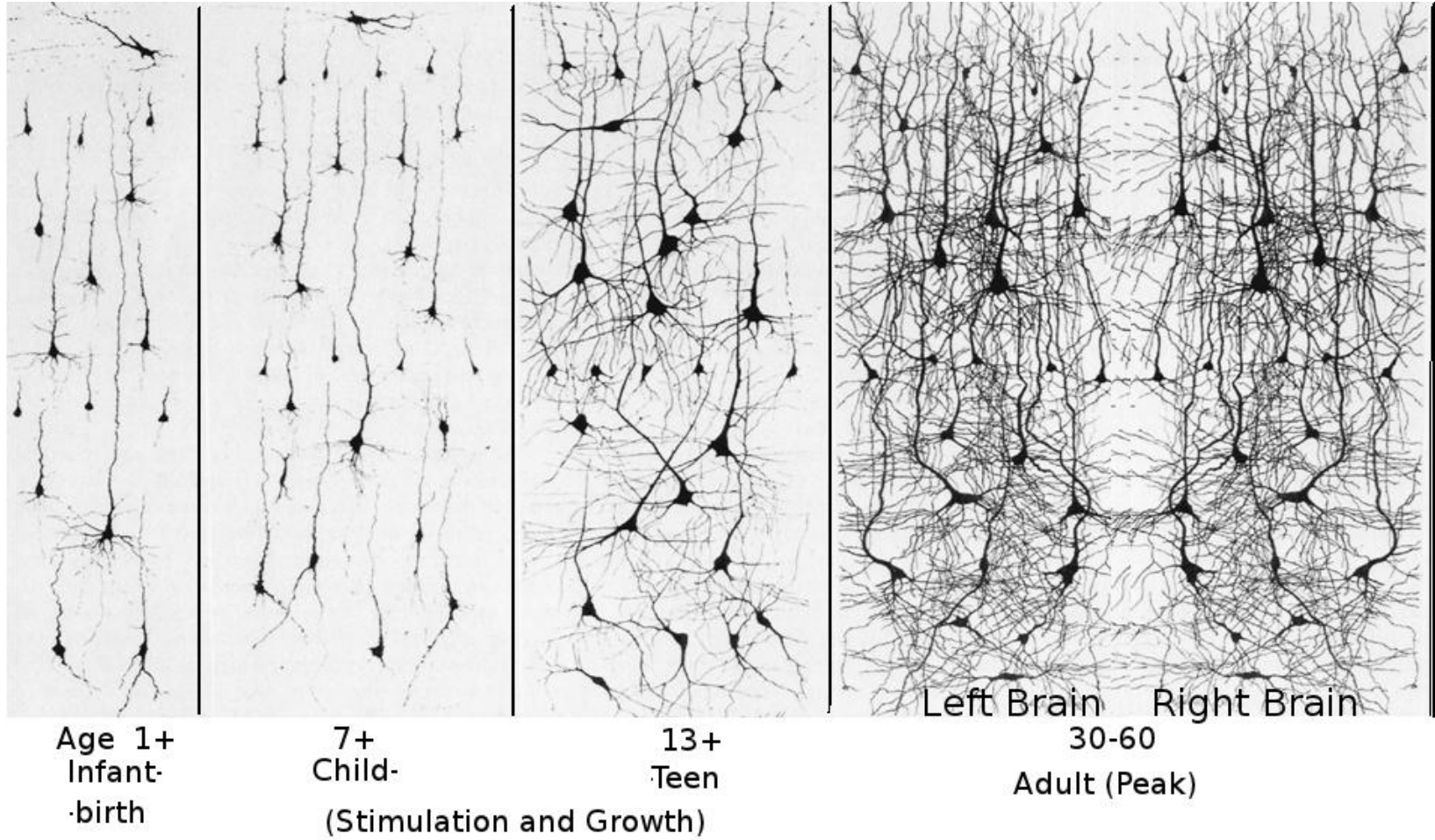
# Scop 1



# Scop 2



# Scop 3



# Scop 4

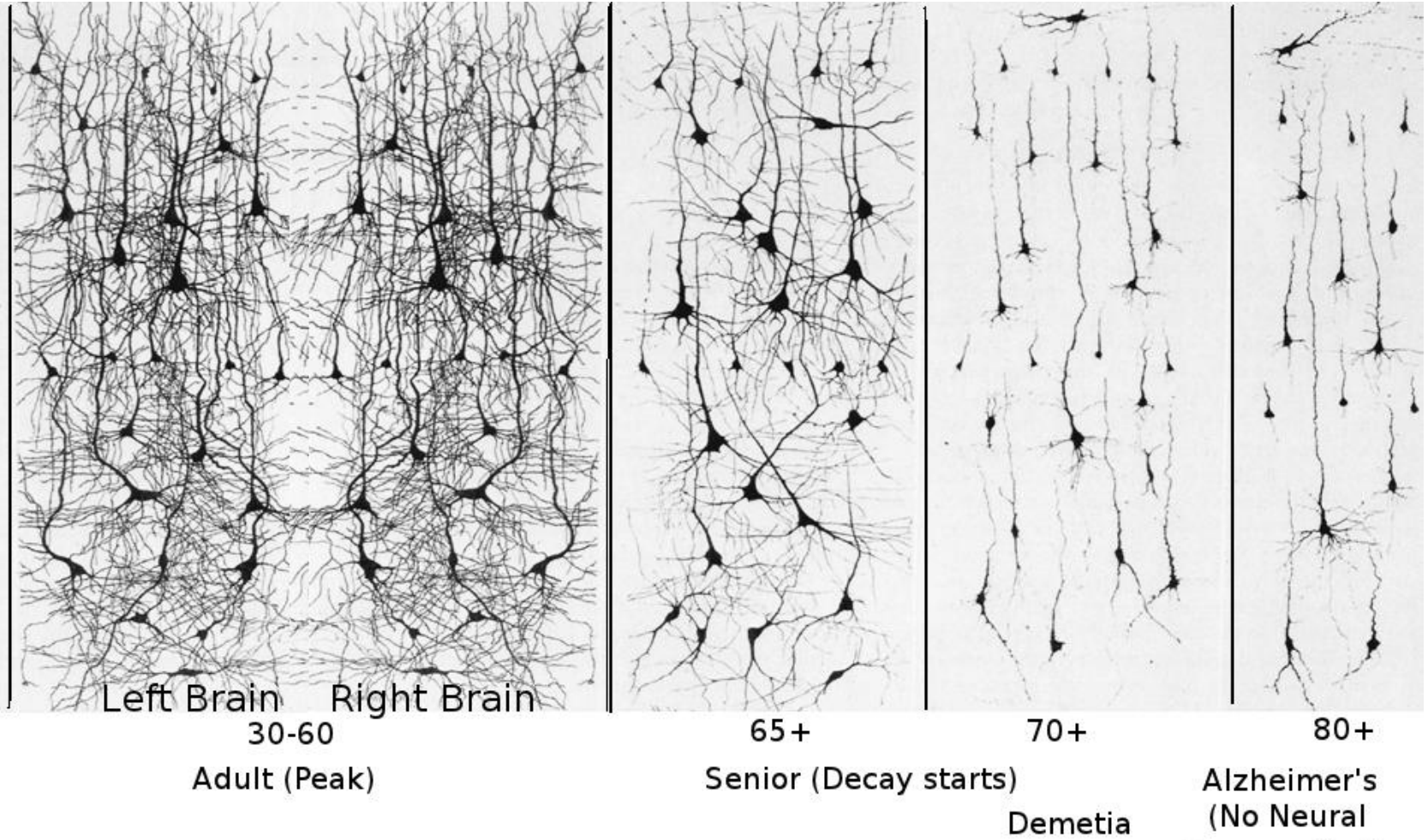


**Sinapse  
“ingineresti”**





# Termen



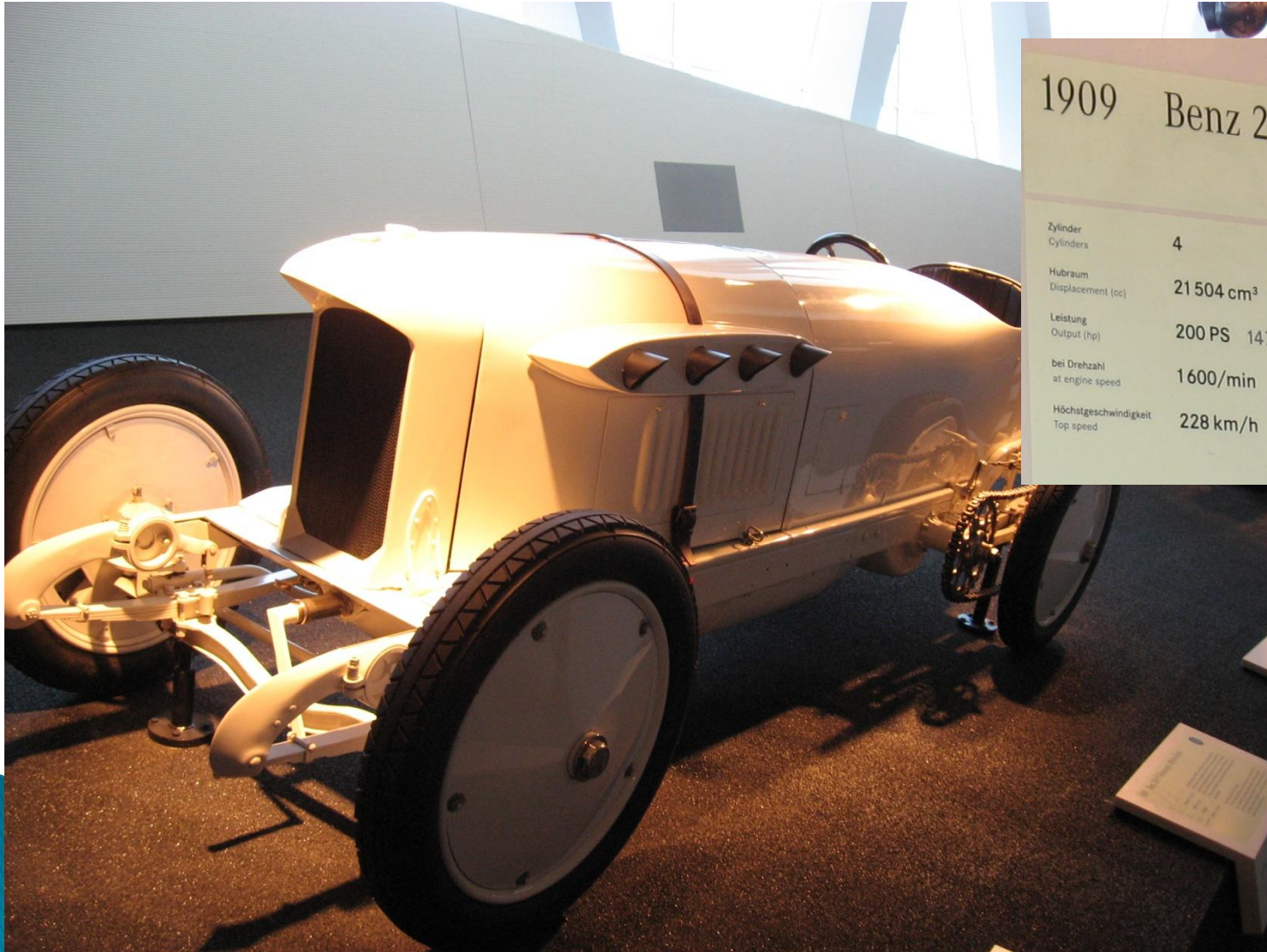
~1930



~1930



# 1909



## 1909 Benz 200 PS Rennwagen »Blitzen-Benz«

Zylinder Cylinders	4
Hubraum Displacement (cc)	21 504 cm <sup>3</sup> 1 312 cu in
Leistung Output (hp)	200 PS 147 kW
bei Drehzahl at engine speed	1 600/min
Höchstgeschwindigkeit Top speed	228 km/h 142 mph

Der »Blitzen-Benz« ist 1909 der erste 200 km/h fähige. Seine größten Erfolge feierte er mit dem 200 km/h zylindermotor ausgestattete Rekordfahrer Burman mit 228 km/h über die Saale. Er ist damit das schnellste Fahrzeug aller Zeiten auf jeder Eisenbahn.

Benz »Lightning Benz« 200 hp racing car  
In 1909 the Lightning Benz

# 1930-1950



# Tehnologie

> 2010

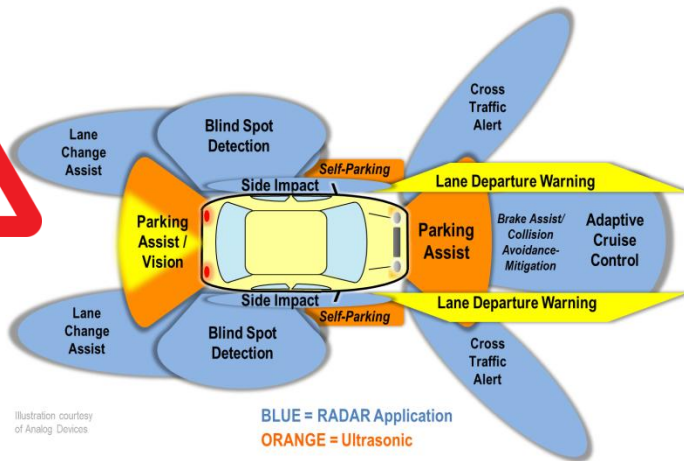


Illustration courtesy of Analog Devices

< 1950



# Tehnologie

<b>1x1 = 1</b>	<b>2x1 = 2</b>	<b>3x1 = 3</b>	<b>4x1 = 4</b>	<b>5x1 = 5</b>
<b>1x2 = 2</b>	<b>2x2 = 4</b>	<b>3x2 = 6</b>	<b>4x2 = 8</b>	<b>5x2 = 10</b>
<b>1x3 = 3</b>	<b>2x3 = 6</b>	<b>3x3 = 9</b>	<b>4x3 = 12</b>	<b>5x3 = 15</b>
<b>1x4 = 4</b>	<b>2x4 = 8</b>	<b>3x4 = 12</b>	<b>4x4 = 16</b>	<b>5x4 = 20</b>
<b>1x5 = 5</b>	<b>2x5 = 10</b>	<b>3x5 = 15</b>	<b>4x5 = 20</b>	<b>5x5 = 25</b>
<b>1x6 = 6</b>	<b>2x6 = 12</b>	<b>3x6 = 18</b>	<b>4x6 = 24</b>	<b>5x6 = 30</b>
<b>1x7 = 7</b>	<b>2x7 = 14</b>	<b>3x7 = 21</b>	<b>4x7 = 28</b>	<b>5x7 = 35</b>
<b>1x8 = 8</b>	<b>2x8 = 16</b>	<b>3x8 = 24</b>	<b>4x8 = 32</b>	<b>5x8 = 40</b>
<b>1x9 = 9</b>	<b>2x9 = 18</b>	<b>3x9 = 27</b>	<b>4x9 = 36</b>	<b>5x9 = 45</b>
<b>1x10 = 10</b>	<b>2x10 = 20</b>	<b>3x10 = 30</b>	<b>4x10 = 40</b>	<b>5x10 = 50</b>
<b>6x1 = 6</b>	<b>7x1 = 7</b>	<b>8x1 = 8</b>	<b>9x1 = 9</b>	<b>10x1 = 10</b>
<b>6x2 = 12</b>	<b>7x2 = 14</b>	<b>8x2 = 16</b>	<b>9x2 = 18</b>	<b>10x2 = 20</b>
<b>6x3 = 18</b>	<b>7x3 = 21</b>	<b>8x3 = 24</b>	<b>9x3 = 27</b>	<b>10x3 = 30</b>
<b>6x4 = 24</b>	<b>7x4 = 28</b>	<b>8x4 = 32</b>	<b>9x4 = 36</b>	<b>10x4 = 40</b>
<b>6x5 = 30</b>	<b>7x5 = 35</b>	<b>8x5 = 40</b>	<b>9x5 = 45</b>	<b>10x5 = 50</b>
<b>6x6 = 36</b>	<b>7x6 = 42</b>	<b>8x6 = 48</b>	<b>9x6 = 54</b>	<b>10x6 = 60</b>
<b>6x7 = 42</b>	<b>7x7 = 49</b>	<b>8x7 = 56</b>	<b>9x7 = 63</b>	<b>10x7 = 70</b>
<b>6x8 = 48</b>	<b>7x8 = 56</b>	<b>8x8 = 64</b>	<b>9x8 = 72</b>	<b>10x8 = 80</b>
<b>6x9 = 54</b>	<b>7x9 = 63</b>	<b>8x9 = 72</b>	<b>9x9 = 81</b>	<b>10x9 = 90</b>
<b>6x10 = 60</b>	<b>7x10 = 70</b>	<b>8x10 = 80</b>	<b>9x10 = 90</b>	<b>10x10 = 100</b>

$$2 \times 1 = 2$$

$$2 \times 2 = 4$$

$$2 \times 3 = 6$$

$$2 \times 4 = 8$$

$$2 \times 5 = 10$$

$$2 \times 6 = 12$$

$$2 \times 7 = 14$$

$$2 \times 8 = 16$$

$$2 \times 9 = 18$$

$$2 \times 10 = 20$$

# 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 de captare a energiei solare** (principiu de funcționare, utilizare, proiectare )



# Bibliografie

- ▶ <http://rf-opto.etti.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.etti.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

# Documentatie

http://rf-opto.etti.tuiasi.ro/optical\_comm.php

etti.tuiasi.ro

Laboratorul de Microunde s...

ro.wikipedia.org

English | Romana |

Main **Courses** Master Staff Research Students

Microwave CD **Optical Communications** Optoelectronics Internet Practica Networks

## Optical Communications

**Course: CO (2014-2015)**

**Course Coordinator:** Prof. Dr. Irinel Casian Botez  
**Code:** DOS410T  
**Discipline Type:** DOS; Alternative, Specialty  
**Credits:** 4  
**Enrollment Year:** 4, Sem. 7

### Activities

**Course:** Instructor: Prof. Dr. Irinel Casian Botez, 3 Hours/Week, Specialization Section, Timetable:  
**Laboratory:** Instructor: Assist.P. Dr. Petre-Daniel Matasaru, 1 Hours/Week, Half Group, Timetable:

### Evaluation

Type: **Colocviu**

**A:** 70%, (Test/Colloquium)  
**B:** 30%, (Seminary/Laboratory/Project Activity)

### Grades

[Aggregate Results](#)

### Attendance

Not yet

### Materials

**Course Slides**

[Raze de lumina slides \(pdf, 232.99 KB, ro, IT\)](#)  
[Fibre optic slides \(pdf, 902.07 KB, ro, IT\)](#)  
[LED \(pdf, 664.51 KB, ro, IT\)](#)

# Documentatie

- ▶ RF-OPTO

- <http://rf-opto.etti.tuiasi.ro>

- ▶ Fotografie

- de trimis prin email: [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)

- necesara la laborator/curs

# Fotografii

## Studentii care au trimis fotografiile 🙌👍

Grupa: 5402

Nr.	Nume
1	<a href="#">APETRII MARIA</a>

Grupa: 5403

Nr.	Nume
1	<a href="#">ALEXANDRESCU SEBASTIAN</a>

Grupa: 5404

Nr.	Nume
1	<a href="#">APERGHIS MIHAI-ALIN</a>

Grupa: 5405

Nr.	Nume
1	<a href="#">ANGHELUS MARIU</a>

## 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

# Fotografii

Start Didactic Master Colectiv Cercetare **Studenti** Admin

Note Lista Studenti Fotografii Statistici

Grupa 5403

Nr.	Student	Prezent	Nr.	Student	Prezent	Nr.	Student	Prezent
1	ANGHELUS IONUT-MARKUS	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	2	ANTIGHIN FLORIN-RAZVAN	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	3	ANTONICA BIANCA	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>
4	APOSTOL PAVEL-MANUEL	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	5	BALASCA BULIAN-PETRU	Prezent <input checked="" type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	6	BOSTAN ANDREI-PETRICIA	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>
7	BOTESZAT EMANUEL	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	8	BUTUNOI GEORGE-MADALIN	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	9	CHILEA SALUCA-MARIA	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>
10	CHERITOIU ECATERINA	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	11	COJOC MARIUS	Prezent <input checked="" type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>	12	COJOCARIU AURA-FLORINA	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>

Nr.	Student	Prezent
2	ANTIGHIN FLORIN-RAZVAN	Prezent <input type="checkbox"/> Puncte: 0 <input type="text"/> Nota: 0 <input type="text"/> Obs: <input type="text"/>

# 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:  $5.10 \pm 1.46$
  - 2010:  $3.89 \pm 1.32$
- ▶ 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

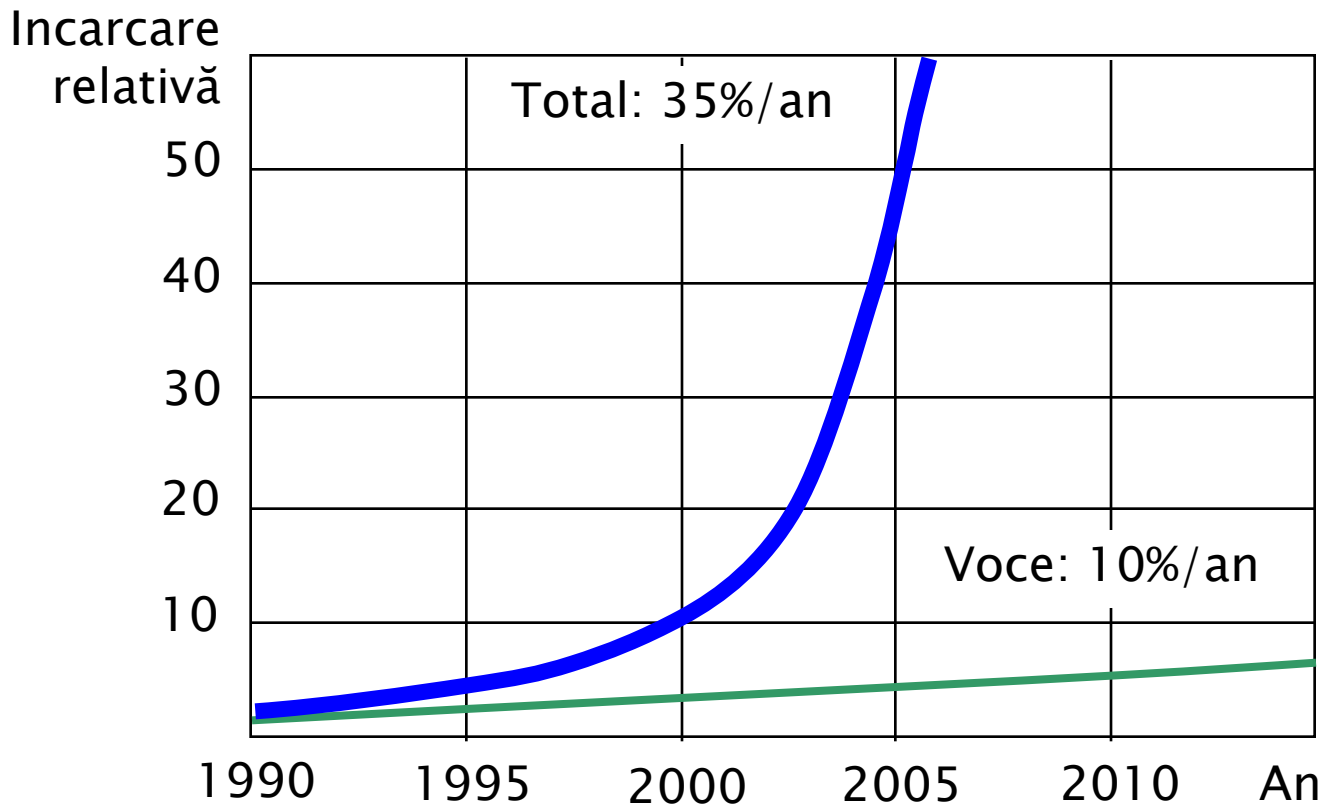




# Introducere

## Capitolul 1

# Evoluția lățimii de bandă utilizată în rețelele de telecomunicații

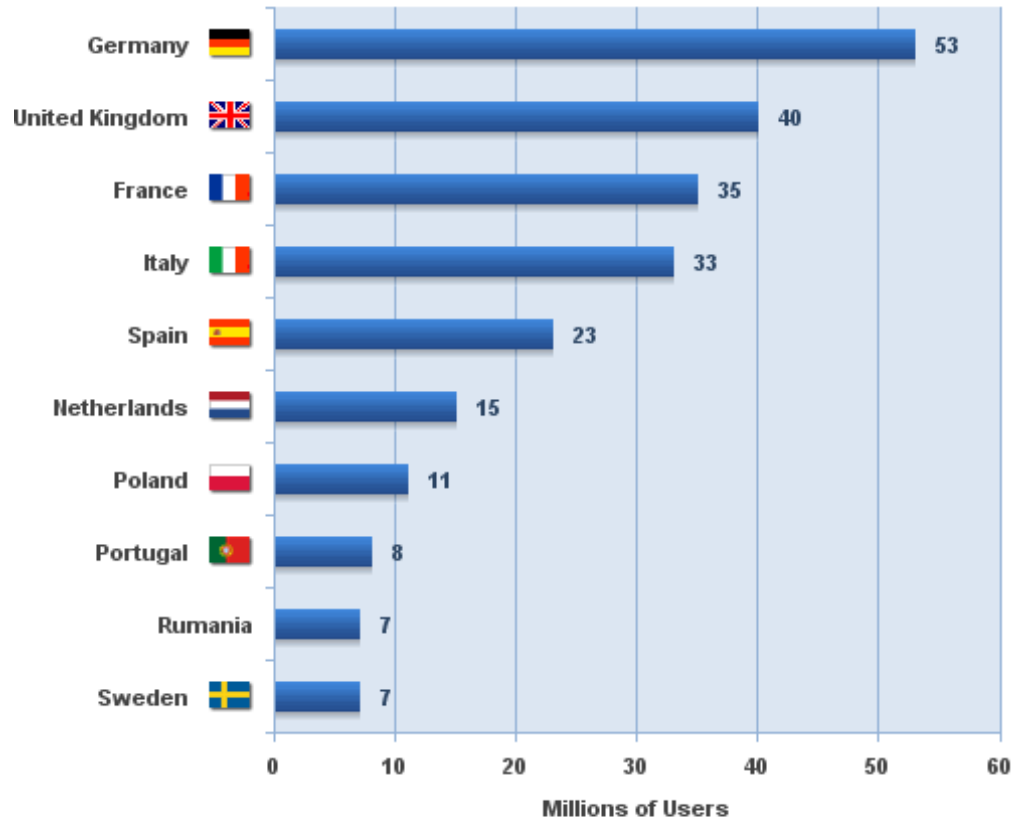


Sursa:

**EC** ELECTRONICAST  
CORPORATION

# Utilizzatori Internet in EU

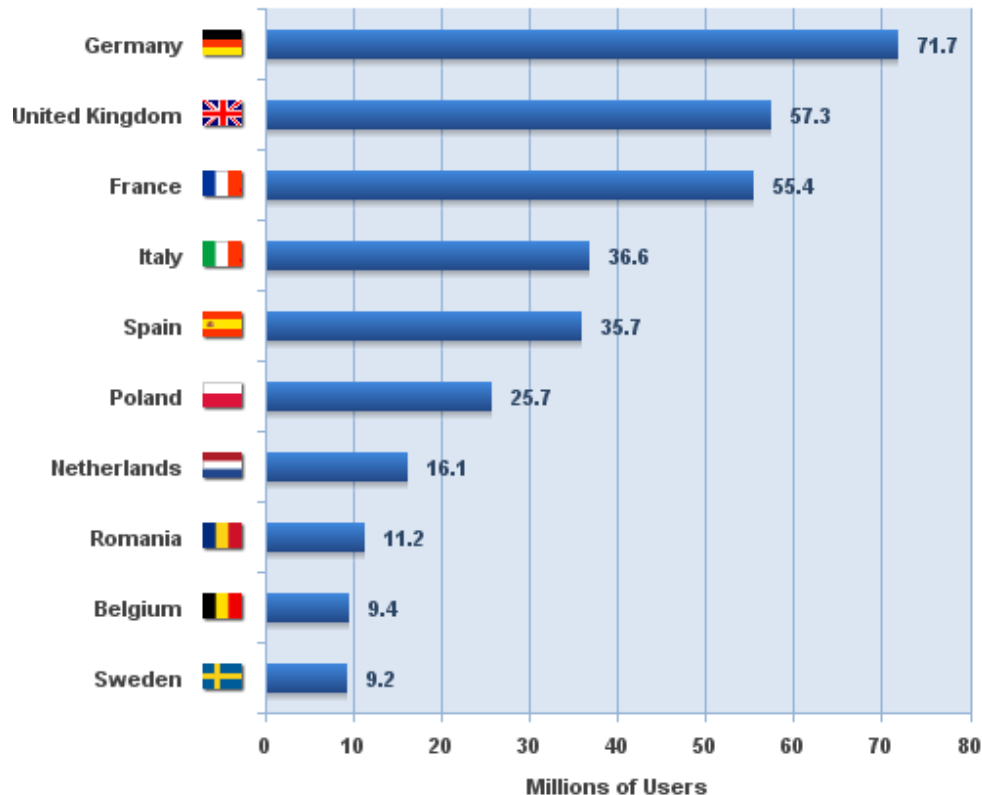
## European Union Top 10 Internet Users November 2007



Source: [www.internetworldstats.com](http://www.internetworldstats.com)  
Copyright © 2008, Miniwatts Marketing Group

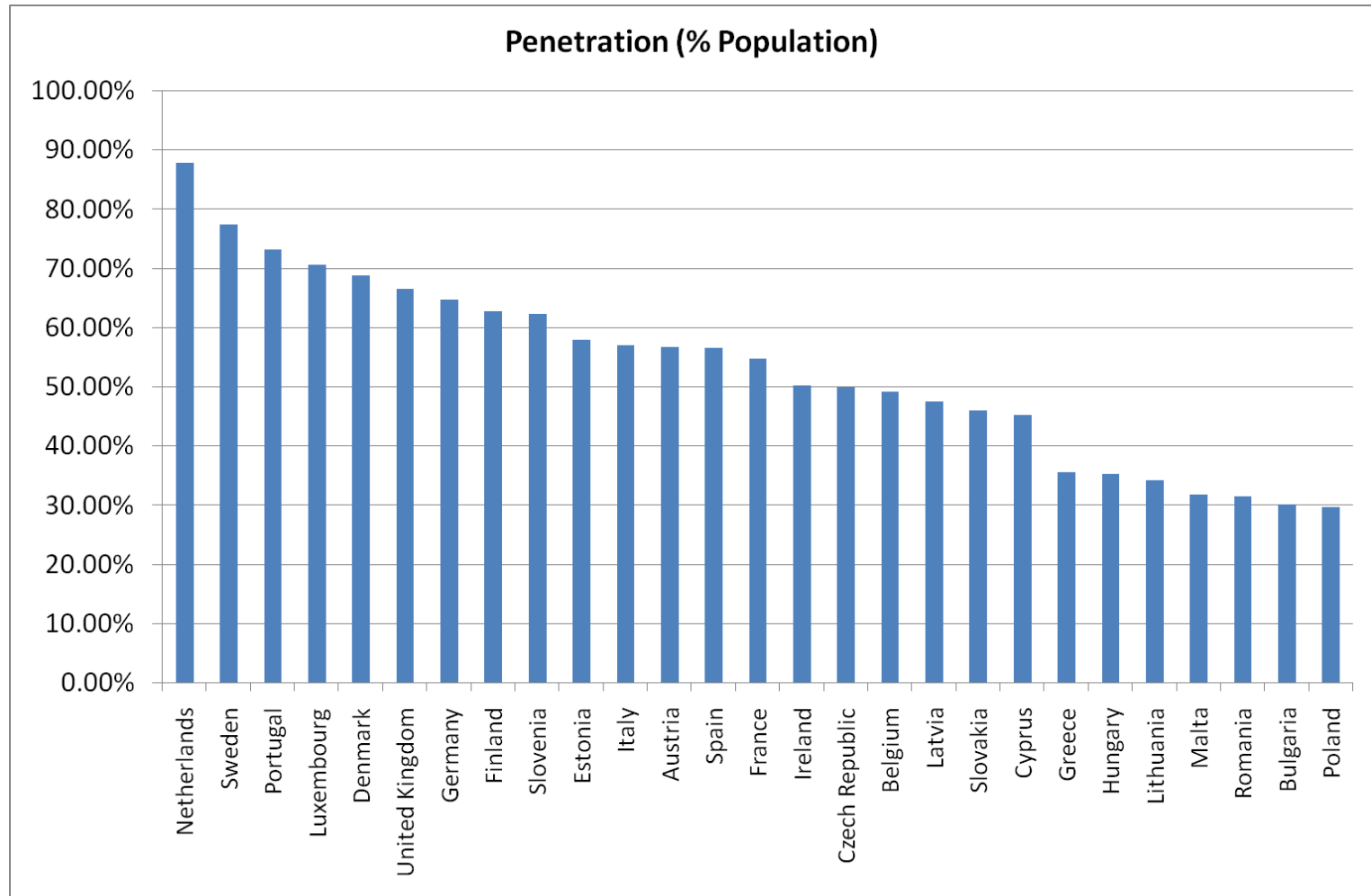
# Utilizzatori Internet in EU

## European Union - Top 10 Internet Countries December 31, 2014

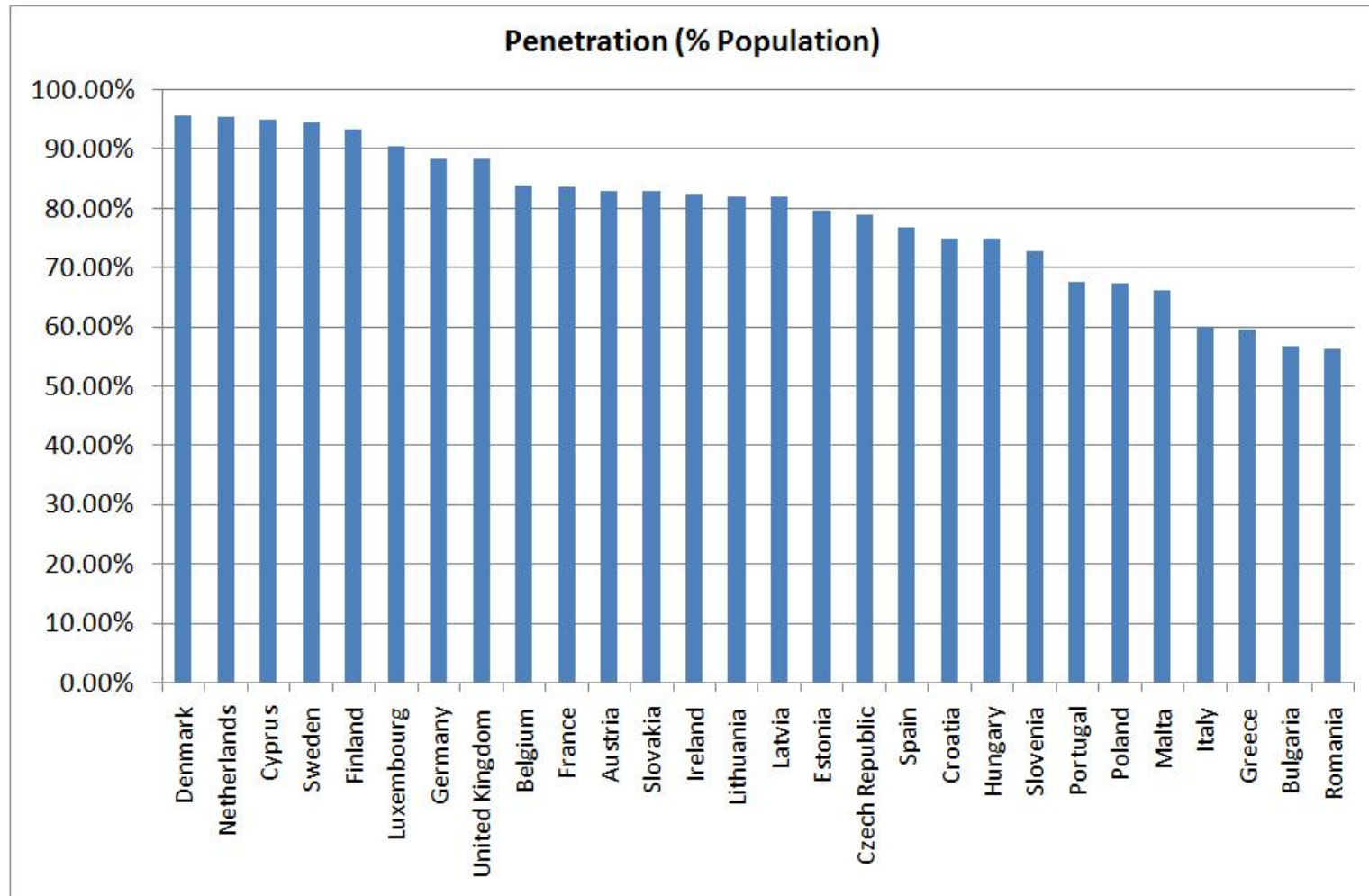


Source: Internet World Stats - [www.internetworldstats.com/stats9.htm](http://www.internetworldstats.com/stats9.htm)  
398,972,533 estimated EU Internet users for 2014Q4  
Copyright © 2015, Miniwatts Marketing Group

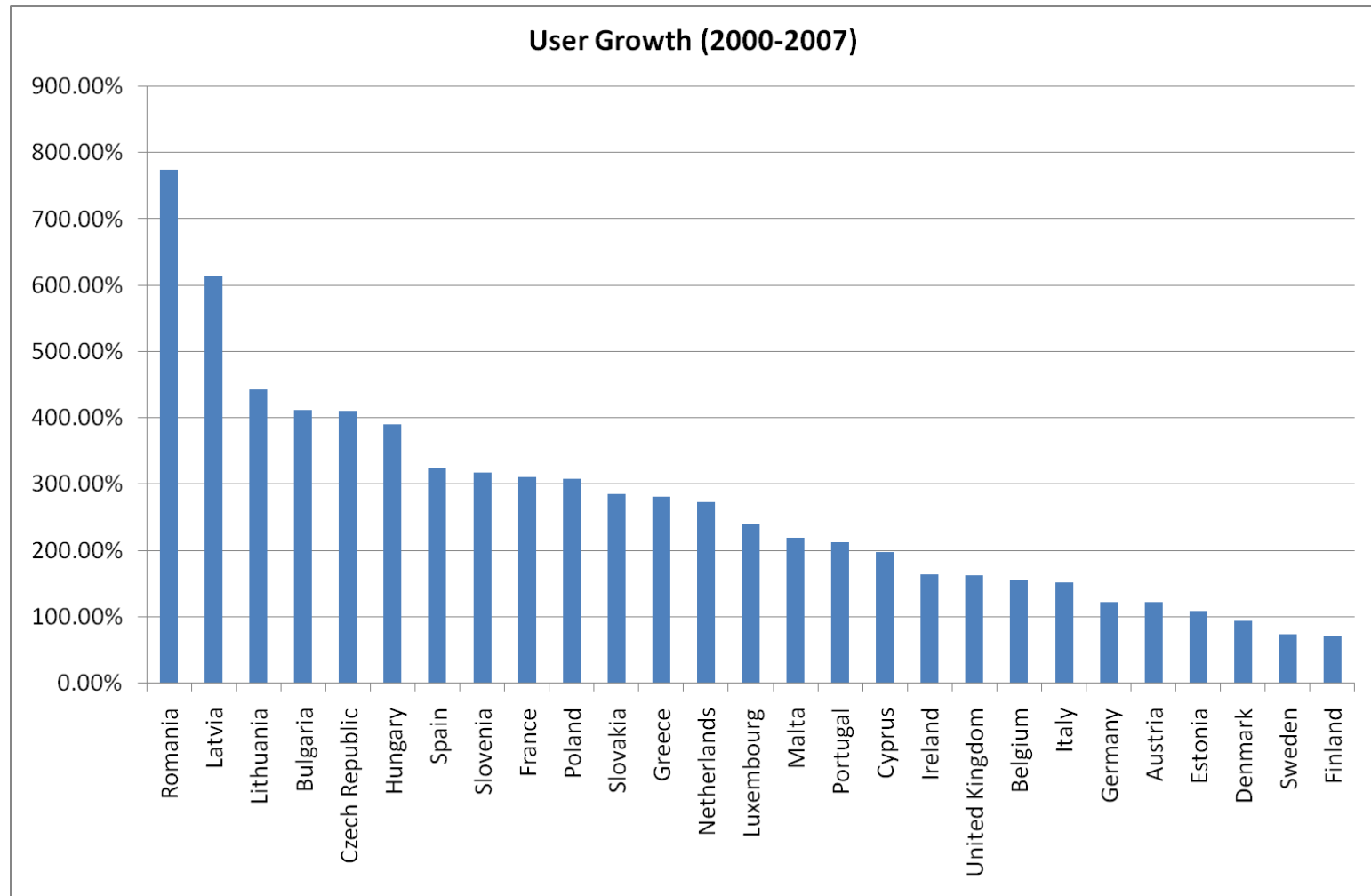
# Rata de penetrare in EU 2007



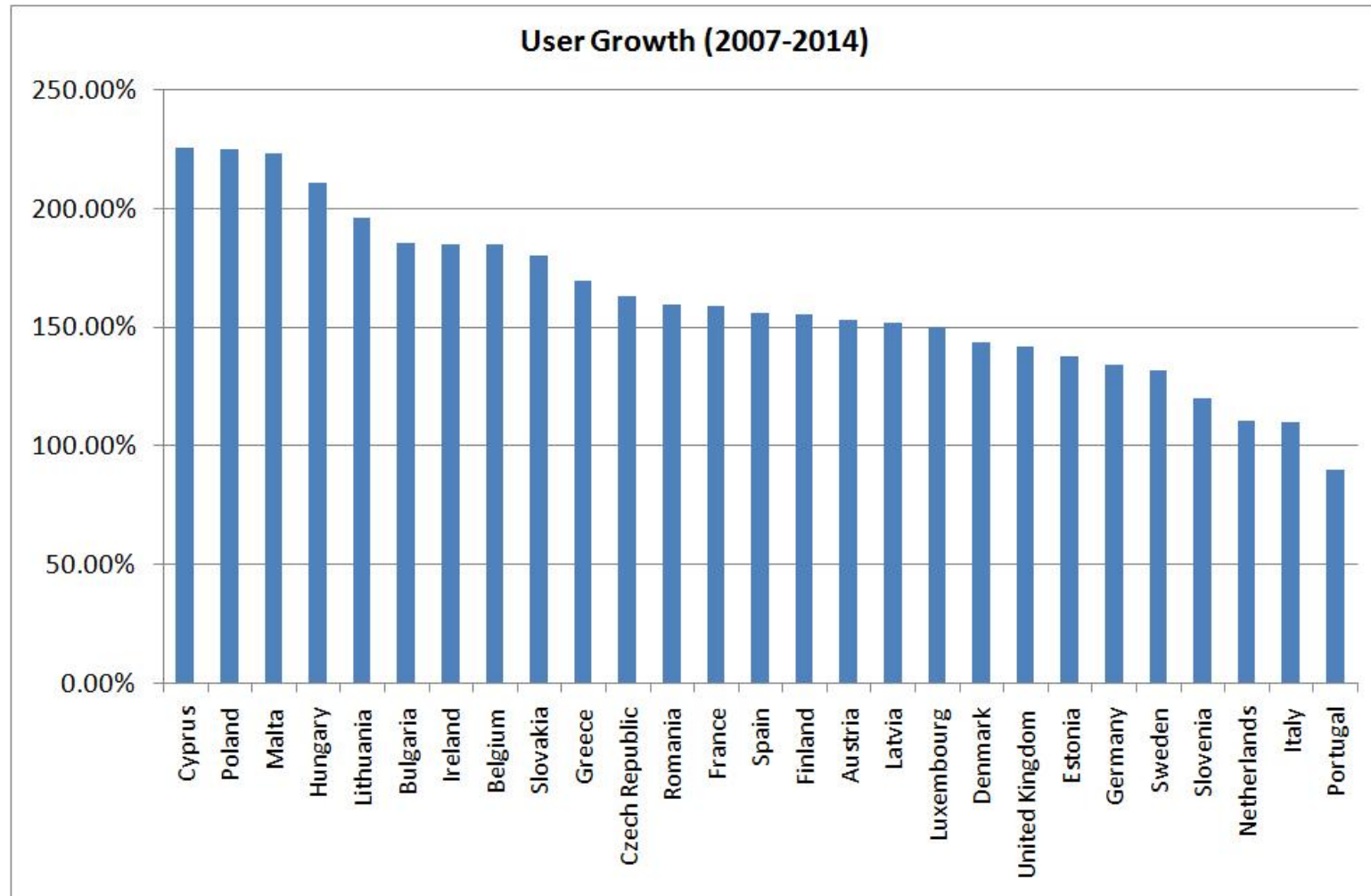
# Rata de penetrare in EU 2014



# Crestere 2000-2007

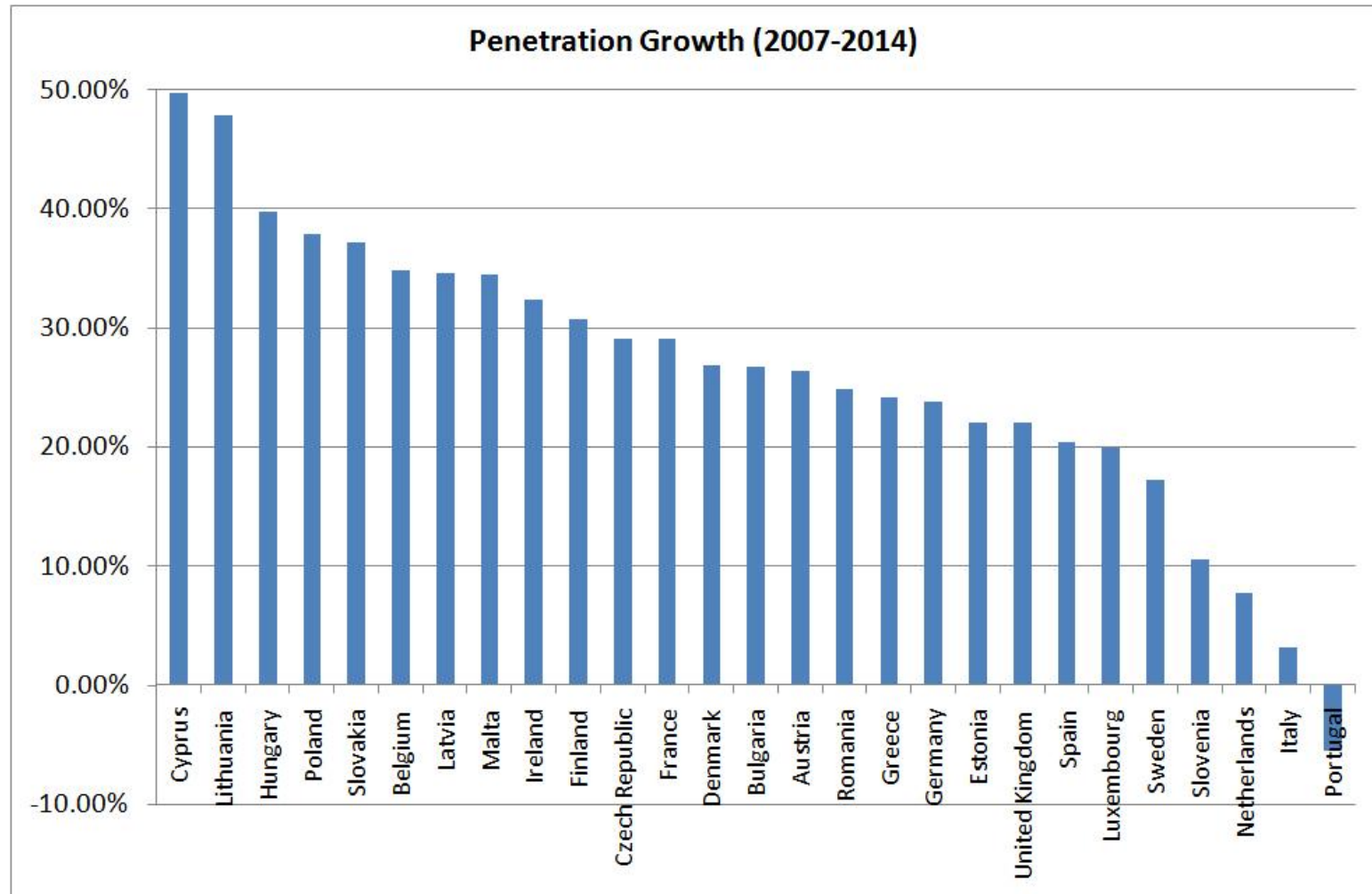


# Crestere 2007-2014

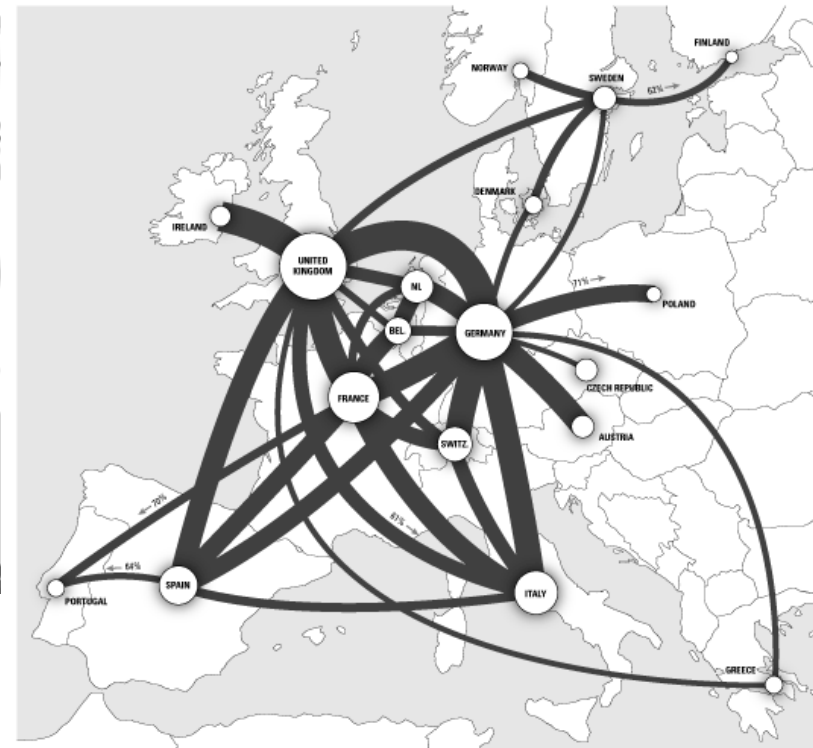
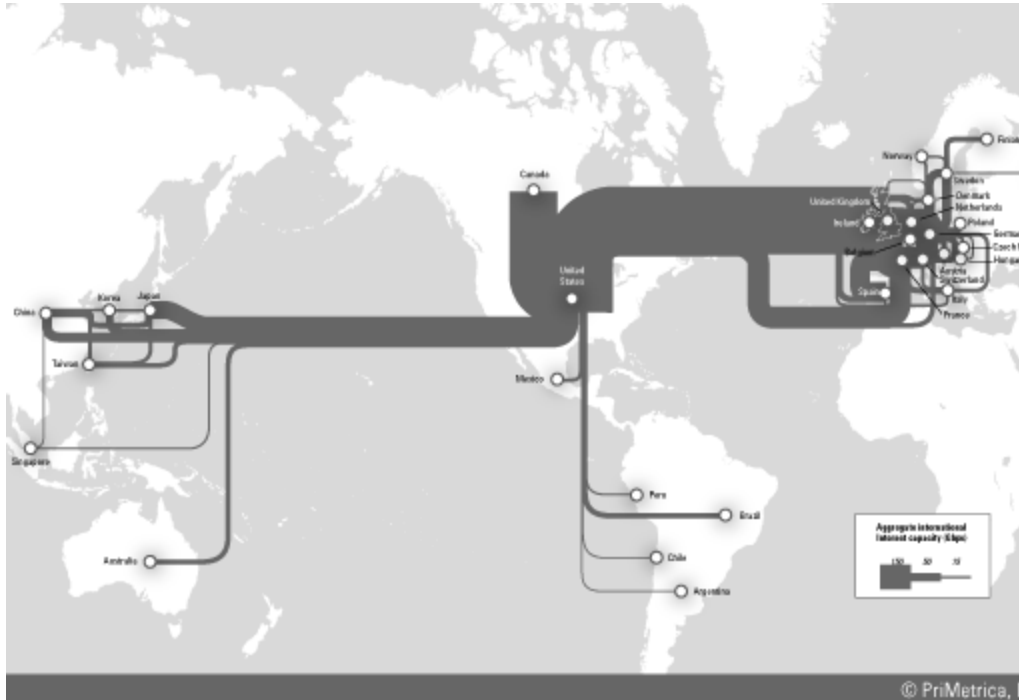




# Crestere 2007-2014



# Internet Backbone

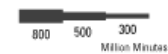


## Key

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 80 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
  - $\text{SiO}_2/\text{Cu}$
- ▶ Capacitate de transmisie a informației  **$f \sim 200\text{THz}$** 
  - 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 repeatoare
  - 100km/2–5km
- ▶ Posibilitate de creștere a capacității de transmisie a informației
  - Teoretic extrem de mare (aproape infinită) **f~200THz**
  - Reutilizarea cablurilor existente
- ▶ Securitate
  - Interceptare dificilă și detectabilă
  - Inserare de semnal practic imposibilă

# 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

# Esantionare

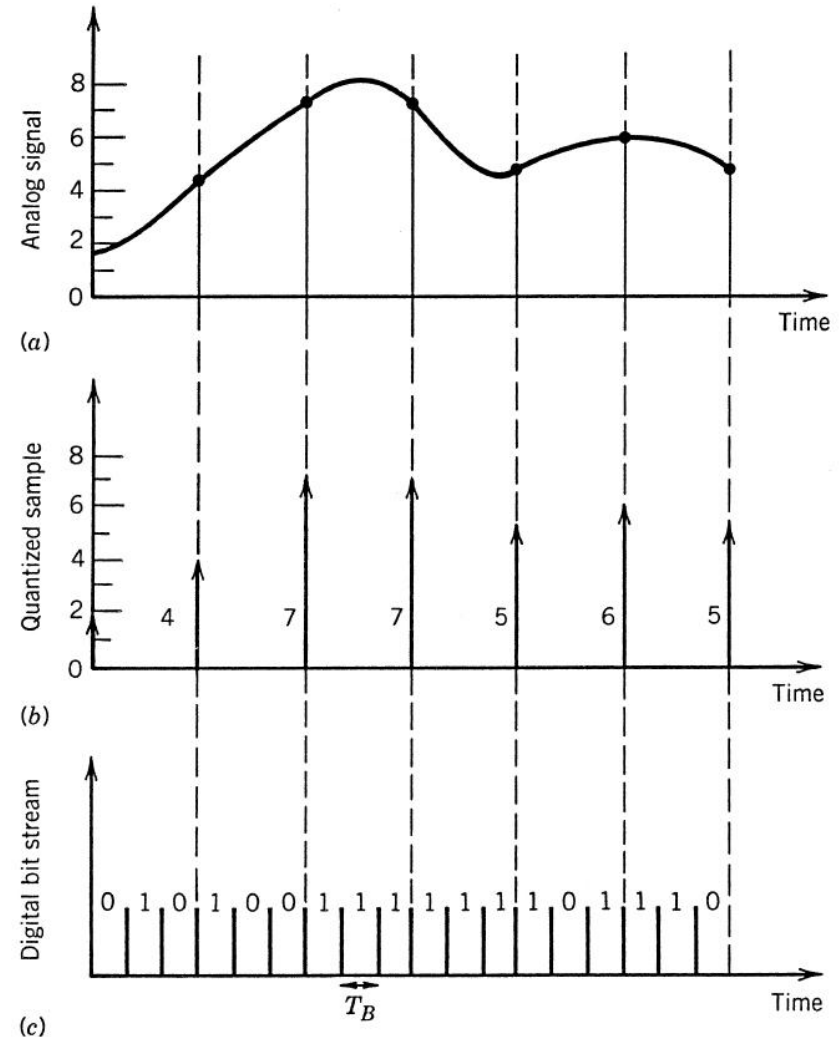
- ▶ pulse–position modulation
- ▶ pulse–duration modulation
- ▶ pulse–code modulation (PCM)

- ▶ esantionare (Nyquist)

$$f_s \geq 2 \cdot \Delta f$$

- ▶ cuantizare **M** intervale discrete
- ▶ zgomot de cuantizare
- ▶ minimizat

$$M \geq \frac{A_{\max}}{A_N}$$



# Esantionare

- ▶ pulse-code modulation (PCM)
- ▶ cuantizare  $M$  intervale discrete, codificate cu  $m$  biți

$$M = 2^m$$

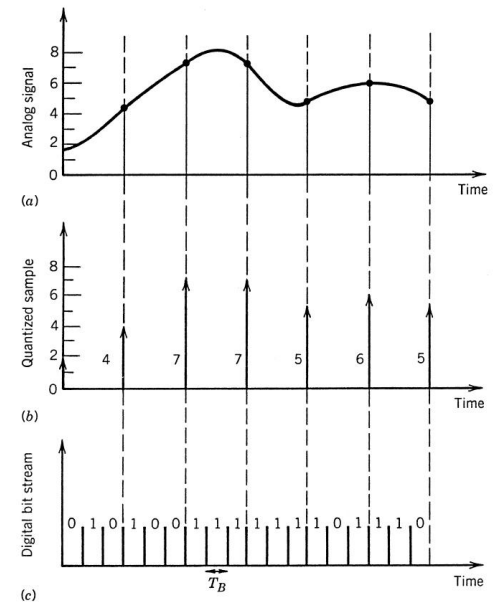
- ▶ viteza necesara (bit rate) [b/s]

$$B = m \cdot f_s \geq (2\Delta f) \cdot \log_2 M$$

$$M \geq \frac{A_{\max}}{A_N} \quad SNR [\text{dB}] = 10 \cdot \log_{10} \left( \frac{P_{\max}}{P_N} \right) = 20 \cdot \log_{10} \left( \frac{A_{\max}}{A_N} \right) \quad \log_2 10 \approx 3.33$$

$$B > (\Delta f / 3) \cdot SNR$$

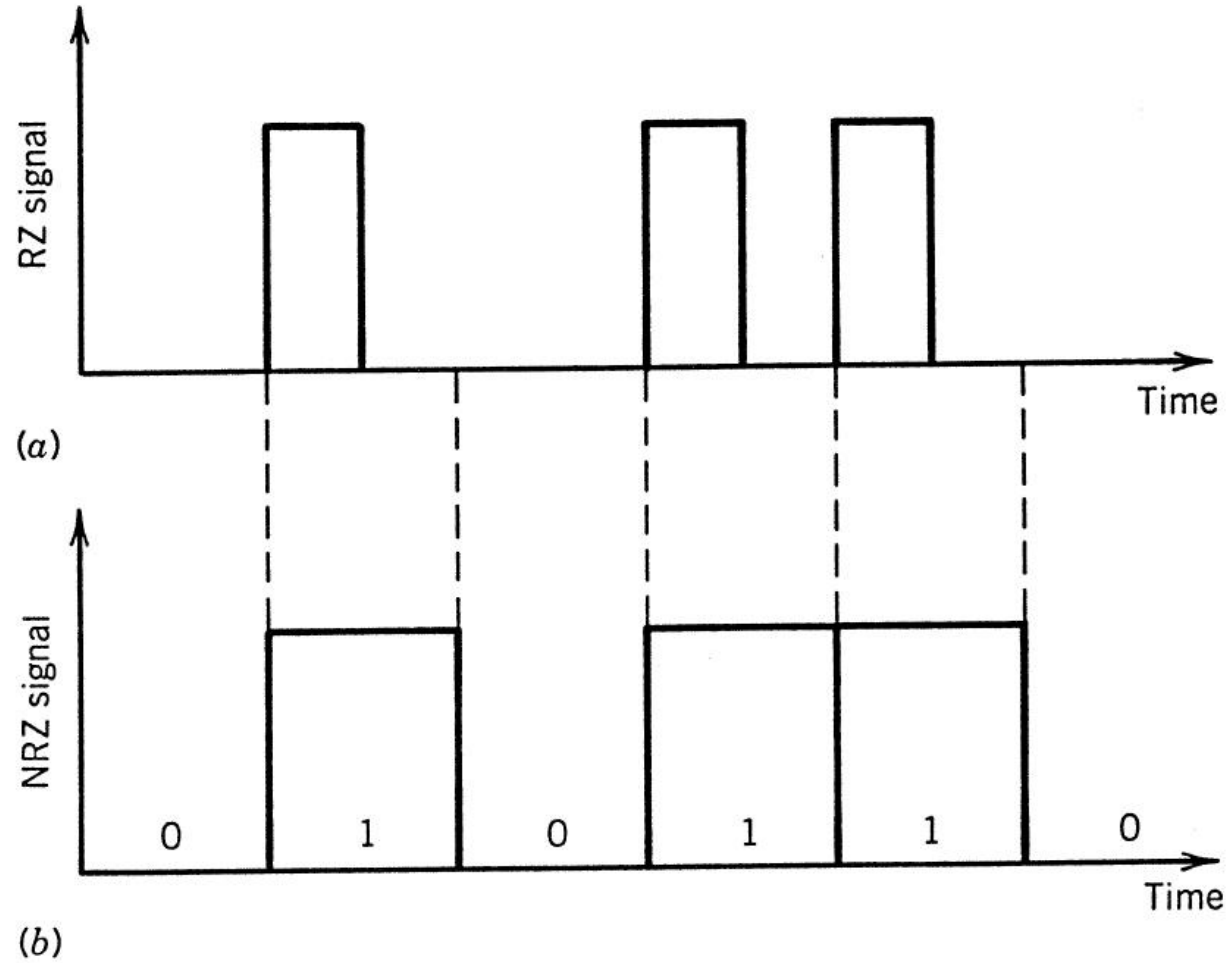
- ▶ telefonie: 3.1 kHz @ SNR=30dB
  - ▶ B=31 kb/s (64 kb/s)
- ▶ televiziune: 4 MHz @ SNR=50dB
  - ▶ B=66 Mb/s (100 Mb/s)



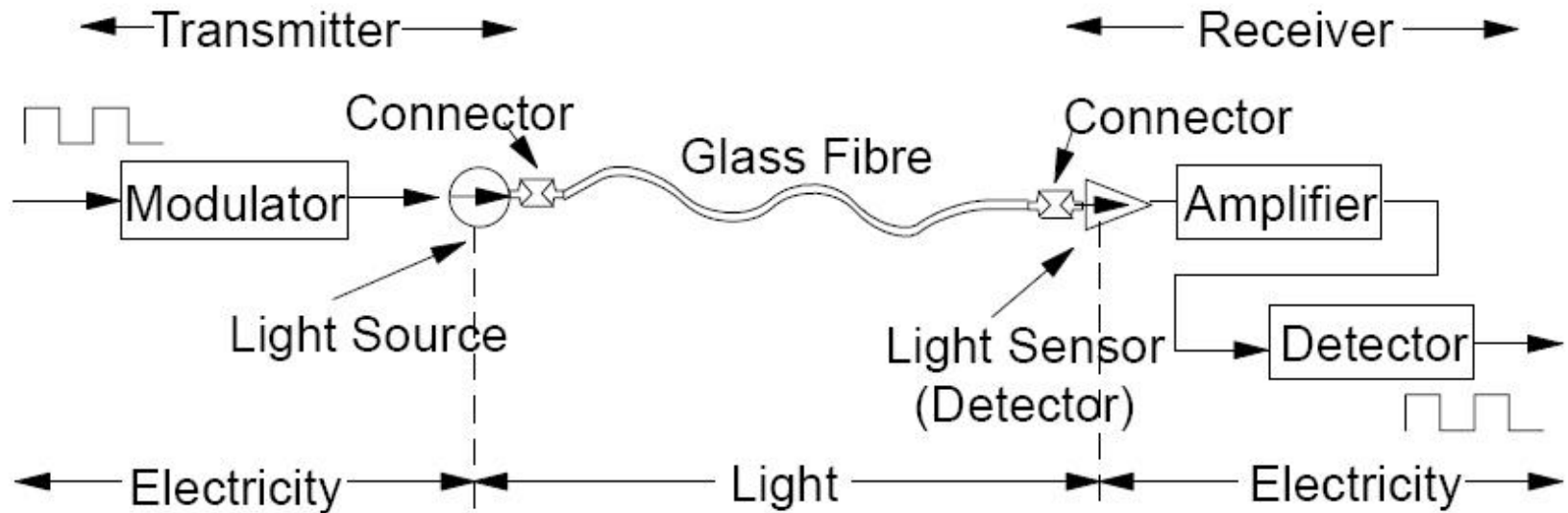


# Modulare

- ▶ return-to-zero (RZ)
- ▶ nonreturn-to-zero (NRZ)

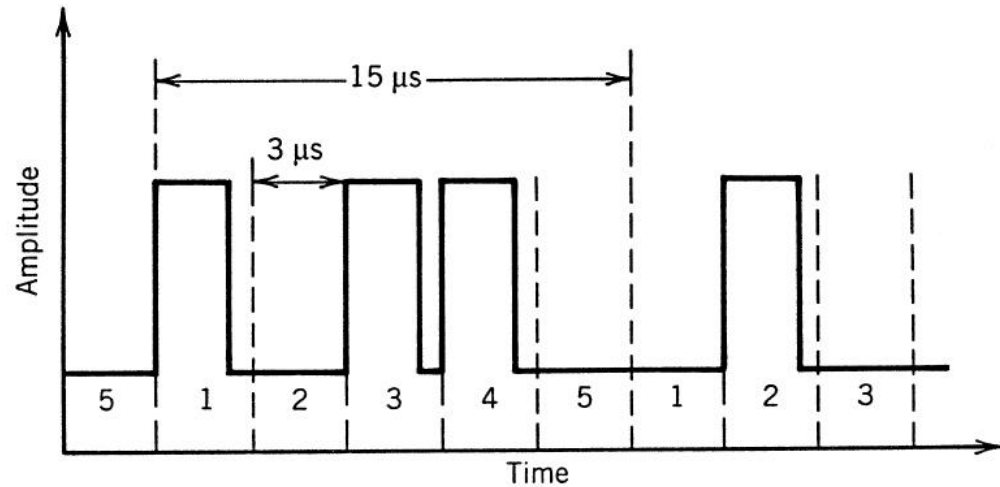


# Transmisia optica

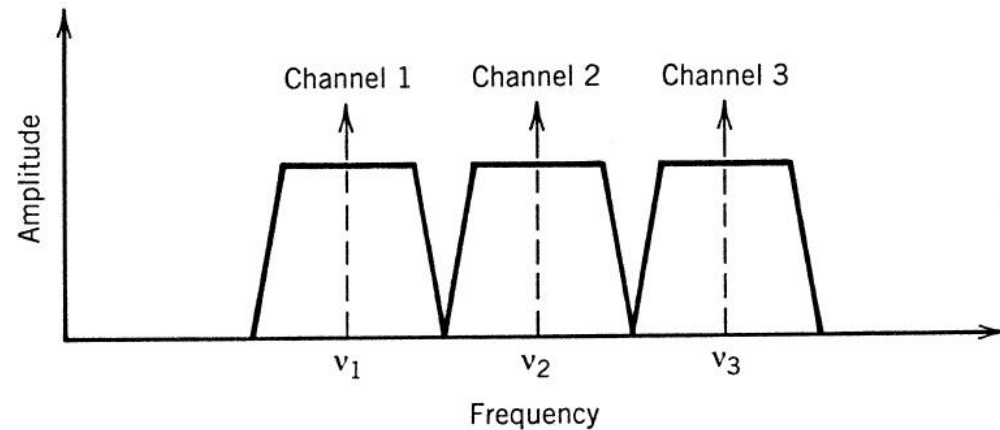


# Multiplexare

- ▶ TDM
  - time-division multiplexing
- ▶ FDM
  - frequency-division multiplexing
- ▶ Realizabila in domeniul **electric/optic**
- ▶ WDM
  - wavelength division multiplexing

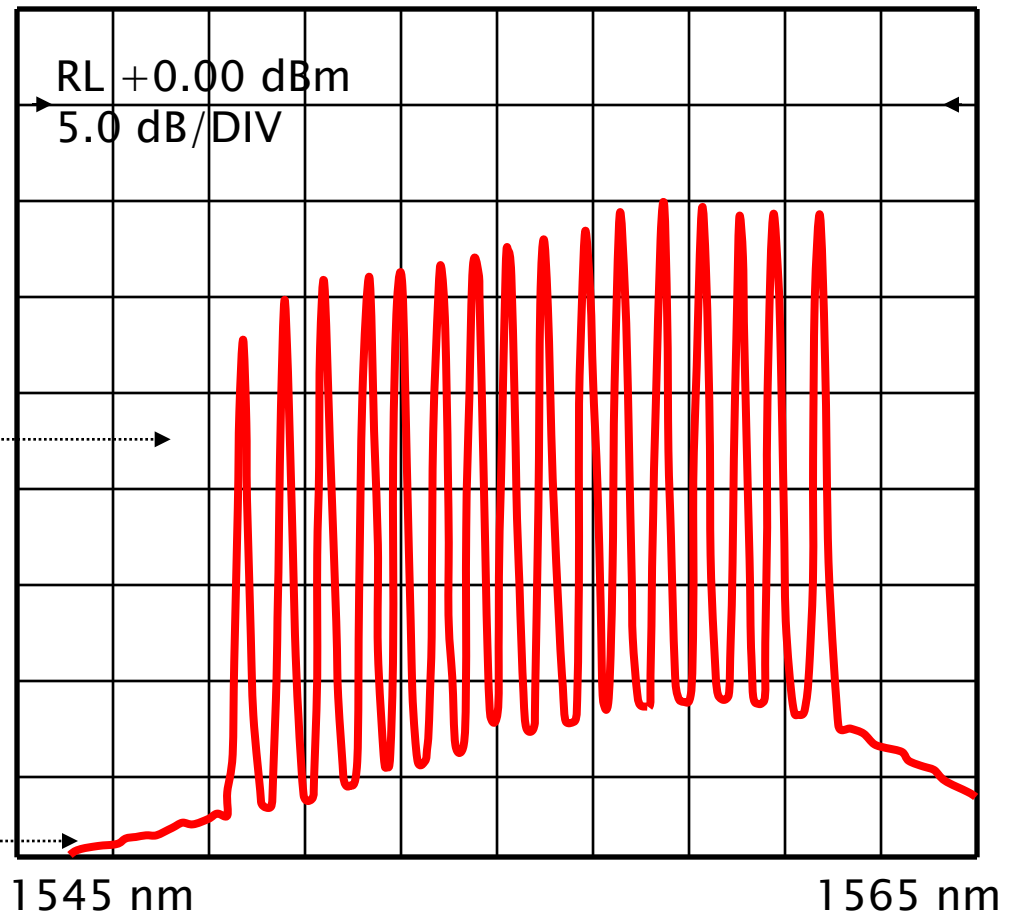


(a)



(b)

# Spectrul WDM – Wavelength Division Multiplexing



Canale: 16  
Spațiere: 0.8 nm

Emisie spontană  
Amplificată (ASE)

# Standardde

- ▶ SUA, Japonia

SONET	SDH	$B$ (Mb/s)	Channels
OC-1		51.84	672
OC-3	STM-1	155.52	2,016
OC-12	STM-4	622.08	8,064
OC-48	STM-16	2,488.32	32,256
OC-192	STM-64	9,953.28	129,024
OC-768	STM-256	39,813.12	516,096

- ▶ SONET – synchronous optical network
  - ▶ inlocuit de
- ▶ SDH – synchronous digital hierarchy

# Standard

## ▶ 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

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## ▶ Europa

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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

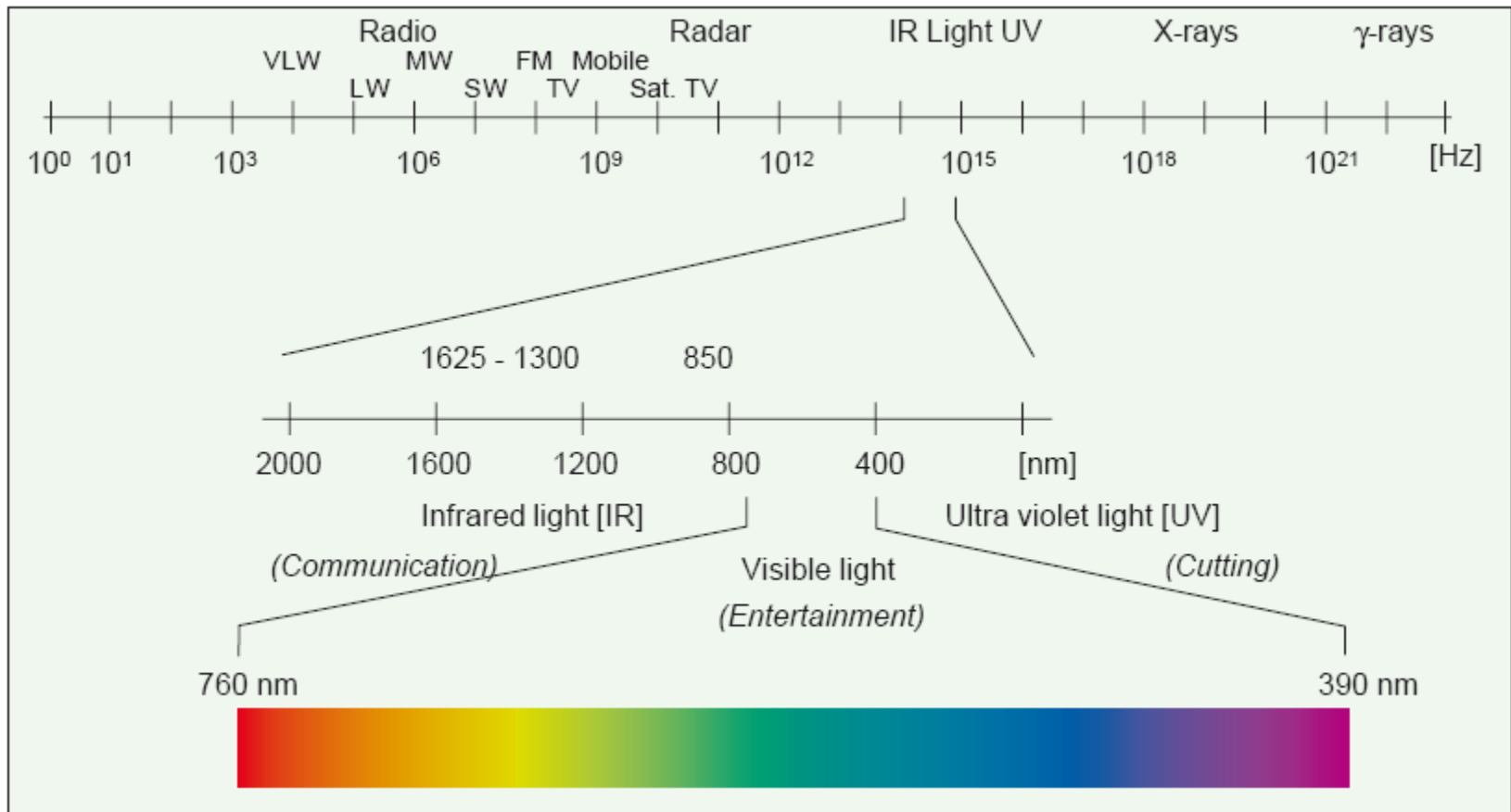
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1 mile = 1760 yards

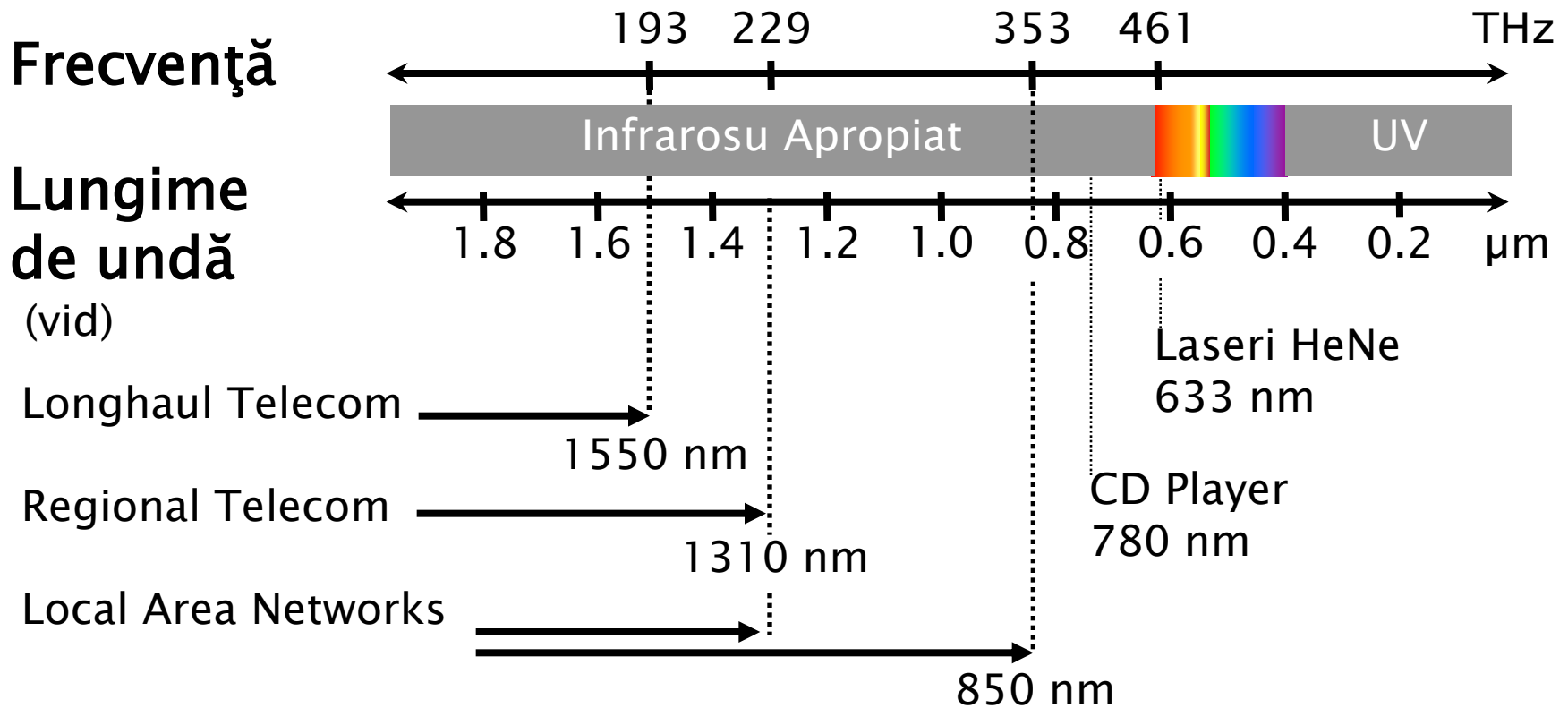
1 yards = 3 feet

1 mile  $\approx$  1609.34 m

# Spectrul electromagnetic

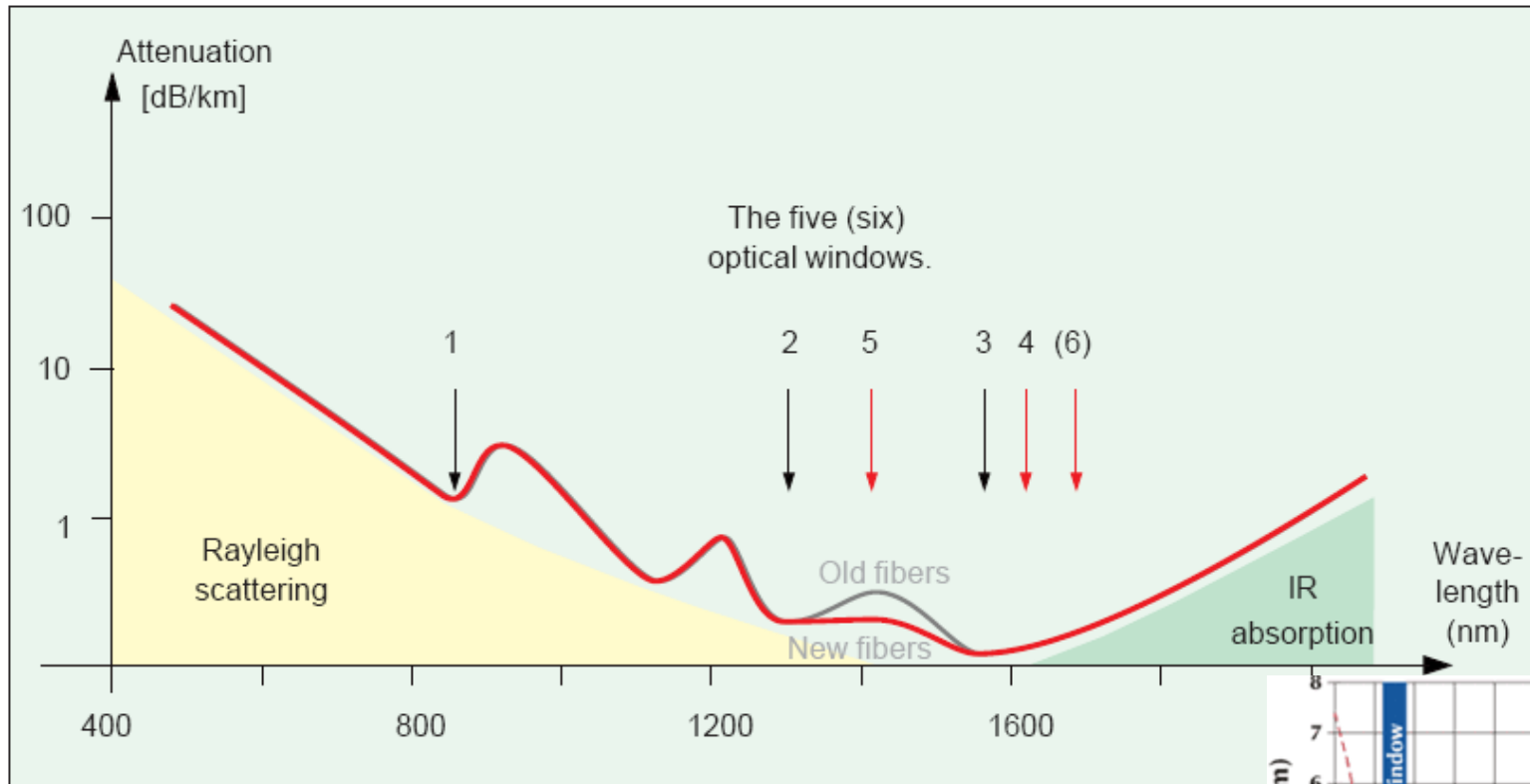


# Benzi de lucru in comunicațiile optice

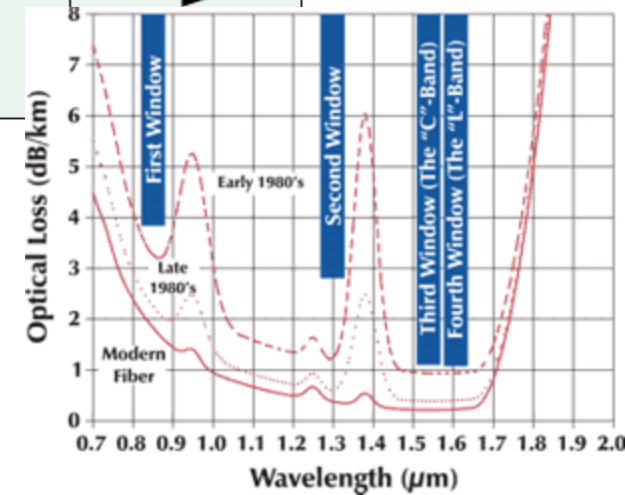




# Atenuarea în fibra optică (SiO<sub>2</sub>)



850nm, 1310nm, 1550nm



# Aplicatii majore LED

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

# Eficiența

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

# Premiul Nobel, Fizica, 2014



The image is a graphic announcement for the Nobel Prize in Physics 2014. It features a blue background with a gold Nobel Prize medal icon in the top left. The text is in both Swedish and English. At the top, it says "Nobelpriset i fysik 2014" and "The Nobel Prize in Physics 2014". Below this, the Swedish text "Nobelpriset i fysik 2014" is prominently displayed. To the right is the logo of the Royal Swedish Academy of Sciences, "KUNGL. VETENSKAPSKAS AKADEMIEN". Three portraits of the laureates are shown in a row: Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura. Below each portrait is their name and affiliation. At the bottom, the award citation is given in Swedish and English. The date "2014-10-07" and the copyright notice "© Kungl. Vetenskapsakademien" are at the very bottom.

Nobelpriset i fysik 2014

The Nobel Prize in Physics 2014

KUNGL. VETENSKAPSKAS AKADEMIEN  
THE ROYAL SWEDISH ACADEMY OF SCIENCES



**Isamu Akasaki**  
Meijo University, Nagoya, Japan  
Nagoya University, Japan



**Hiroshi Amano**  
Nagoya University, Japan



**Shuji Nakamura**  
University of California,  
Santa Barbara, CA, USA

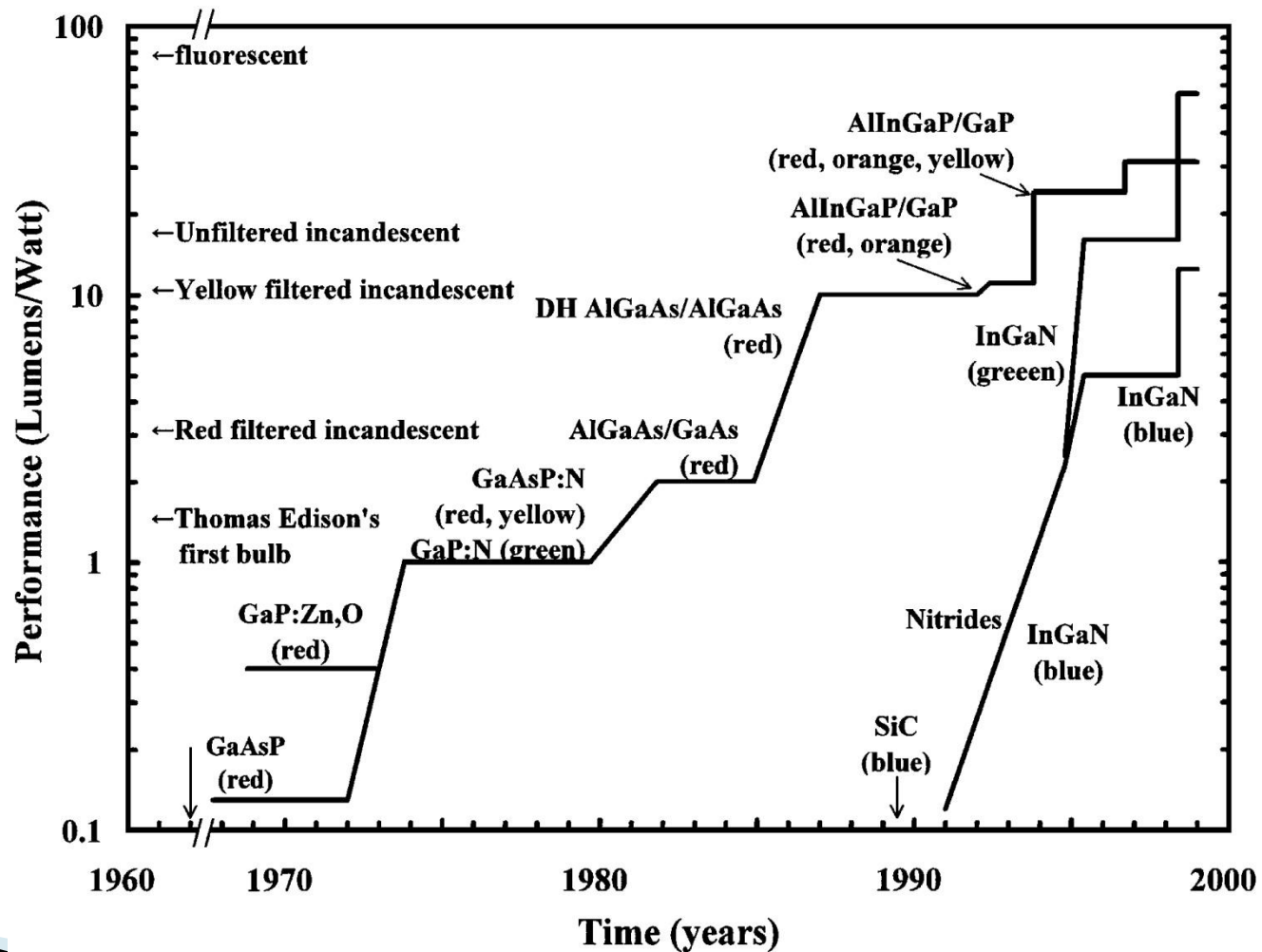
*"För uppfinningen av effektiva blå lysdioder vilka möjliggjort ljusstarka och energisnåla vita ljuskällor"*

*"For the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"*

2014-10-07

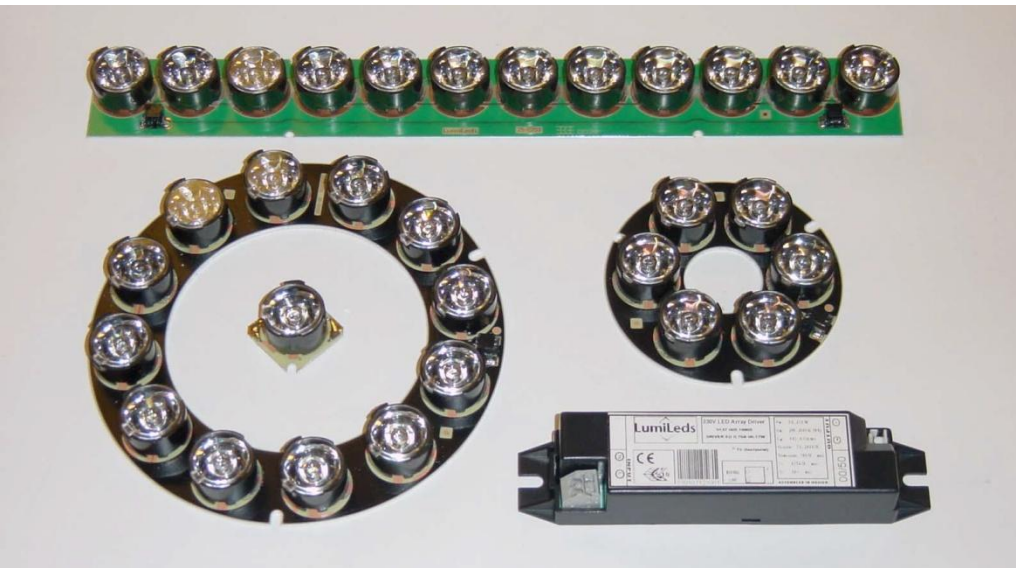
© Kungl. Vetenskapsakademien

# Eficienta in timp

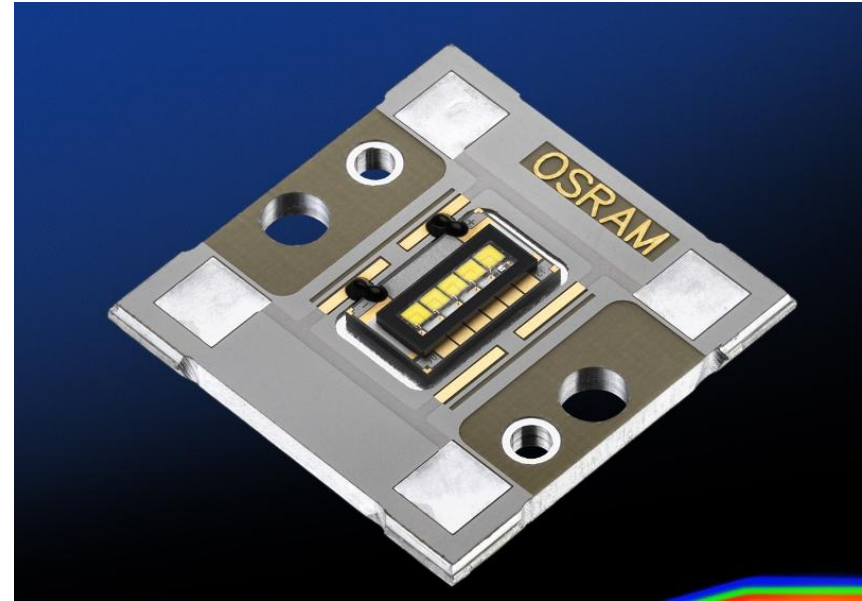


# Aplicatii

## ▶ auto



# Aplicatii



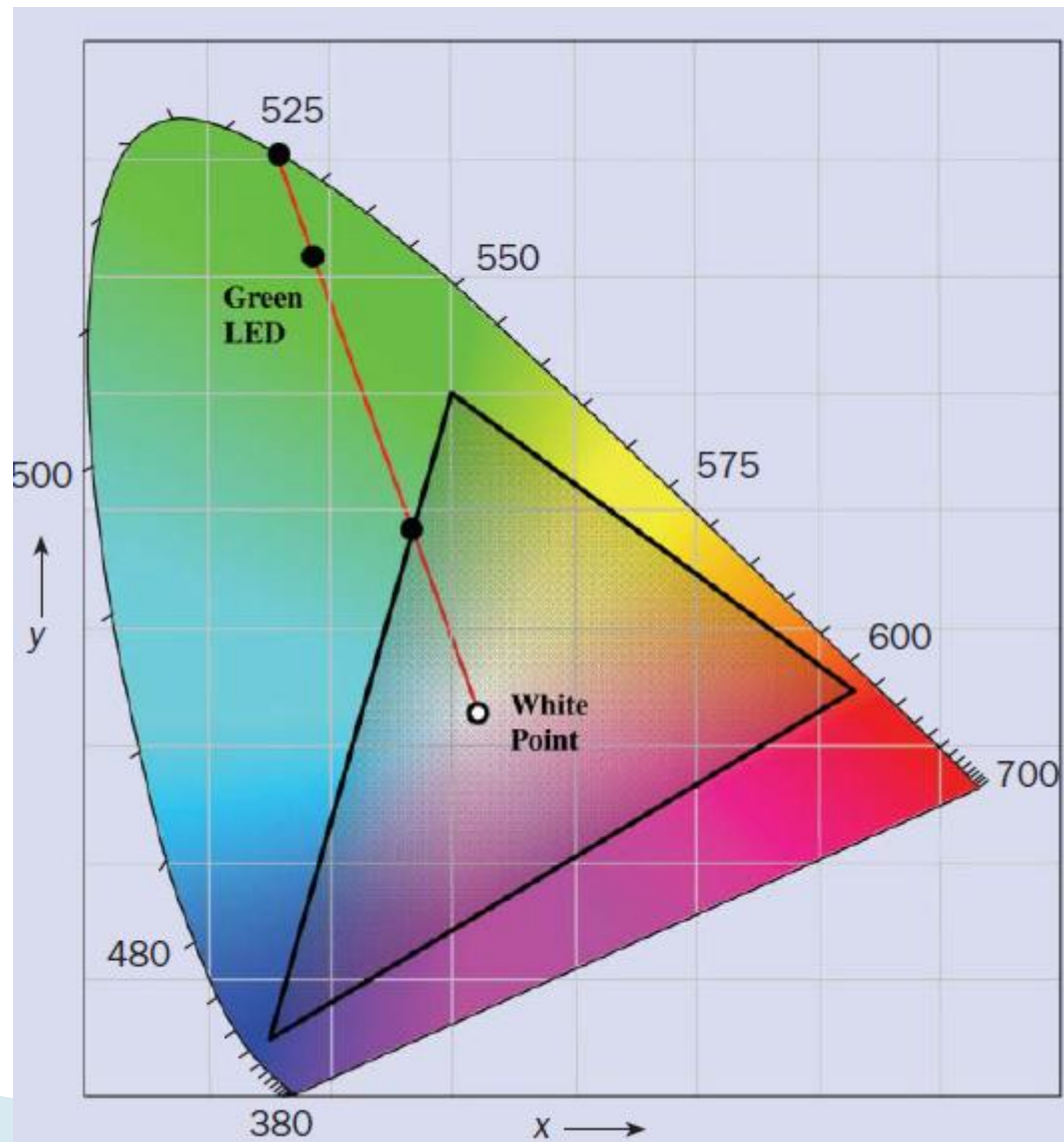
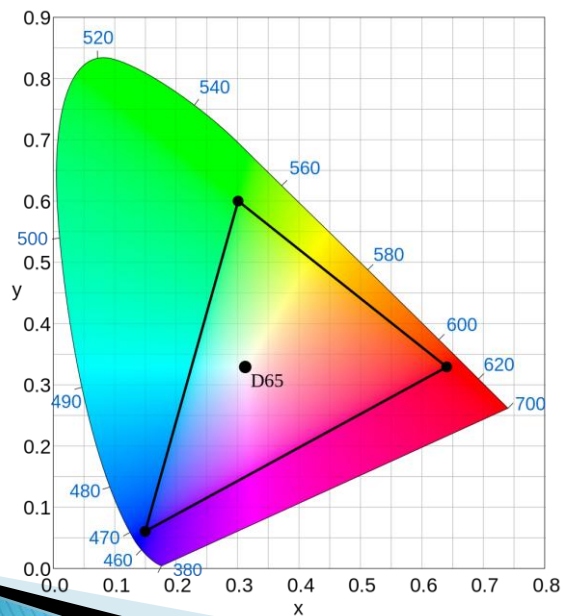
# ITU-R BT.709



## ITU-R BT.709 phosphor properties

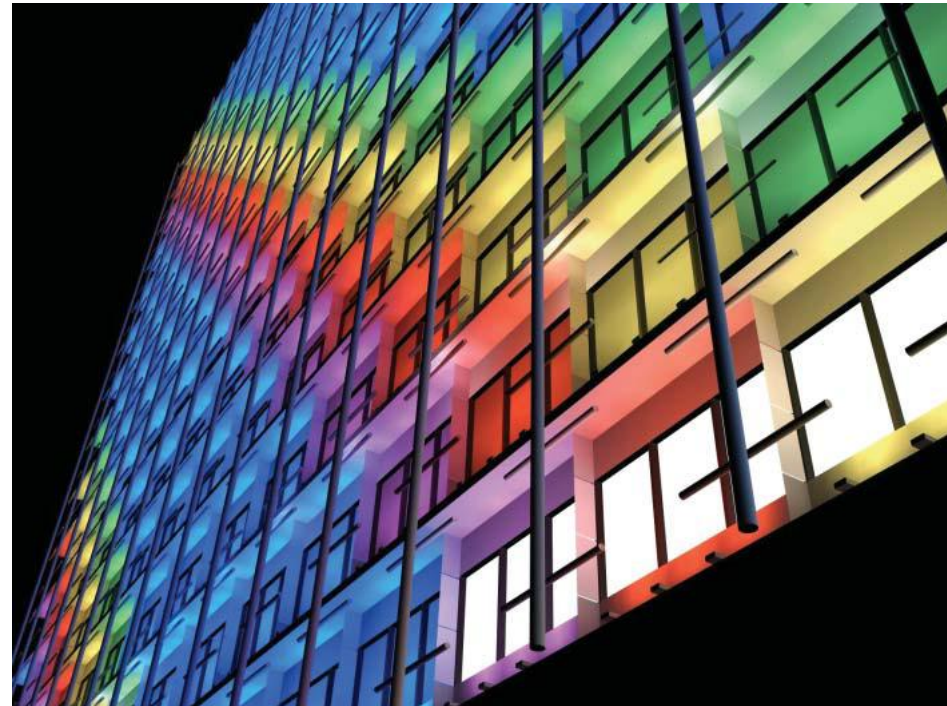
Phosphor	x	y
Red	0.640	0.330
Green	0.300	0.600
Blue	0.150	0.060

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

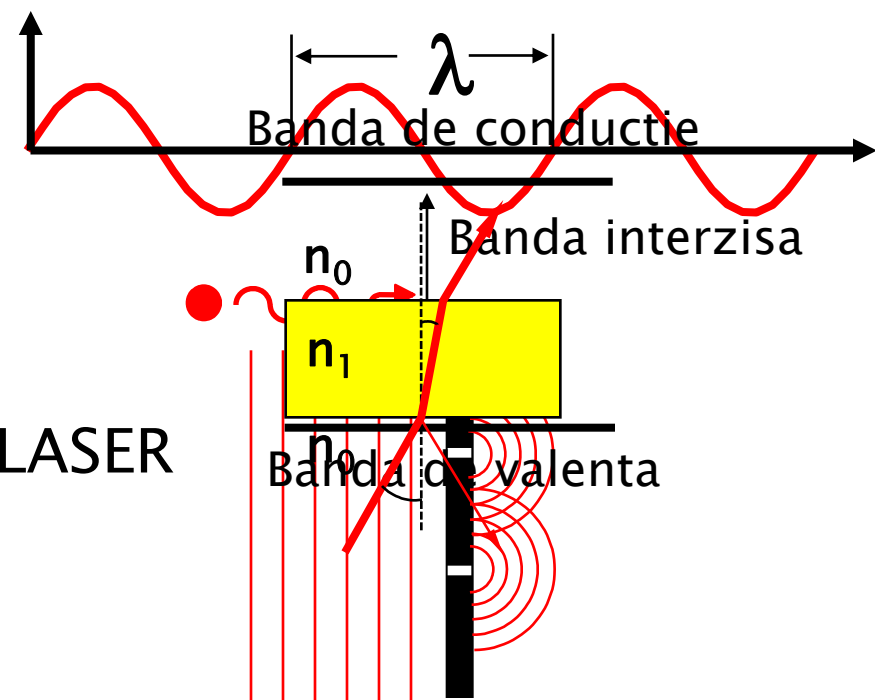
LED color	Dominant wavelength $\lambda_D$ (nm)	RGB values
Royal blue	455	0.05, 0.00, 0.95
Blue	470	0.00, 0.11, 0.89
Cyan	505	0.00, 0.63, 0.37
Green	530	0.00, 0.77, 0.23
Amber	590	0.70, 0.30, 0.00
Red-orange	615	0.97, 0.00, 0.03
Red	625	0.92, 0.00, 0.08

# Modelarea luminii

(tot) Capitolul 1

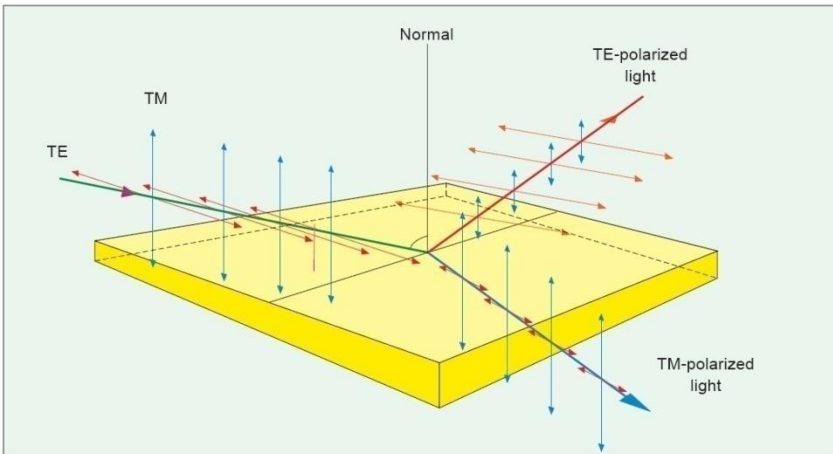
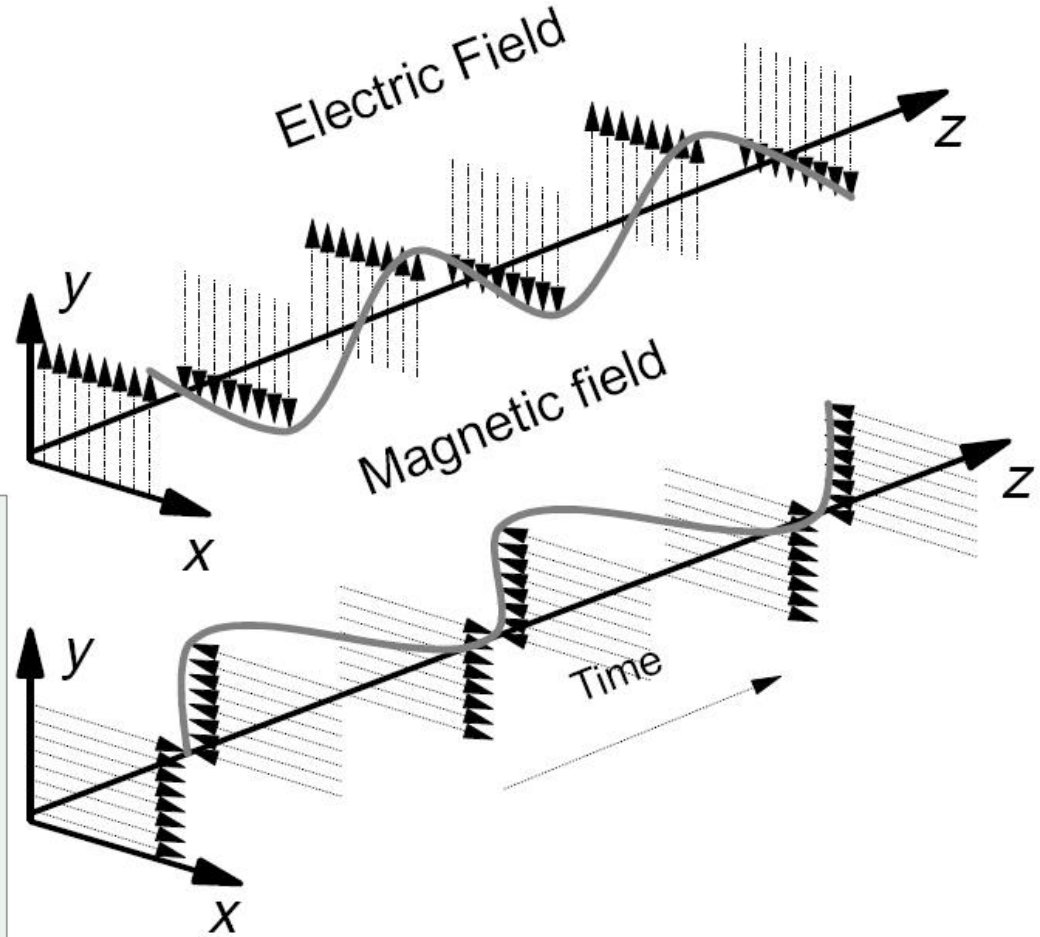
# Modelarea luminii

- ▶ Undă electromagnetică
  - Ecuațiile lui Maxwell
  - $\lambda$ ,  $\epsilon$ ,  $\omega$ ,  $f$
- ▶ Teoria cuantică
  - Benzi energetice  $E = h \nu$
  - fotoni, emisie stimulată, LASER
- ▶ Optică geometrică
  - $n$ ,  $\theta$
  - raze de lumină
  - intuitivă

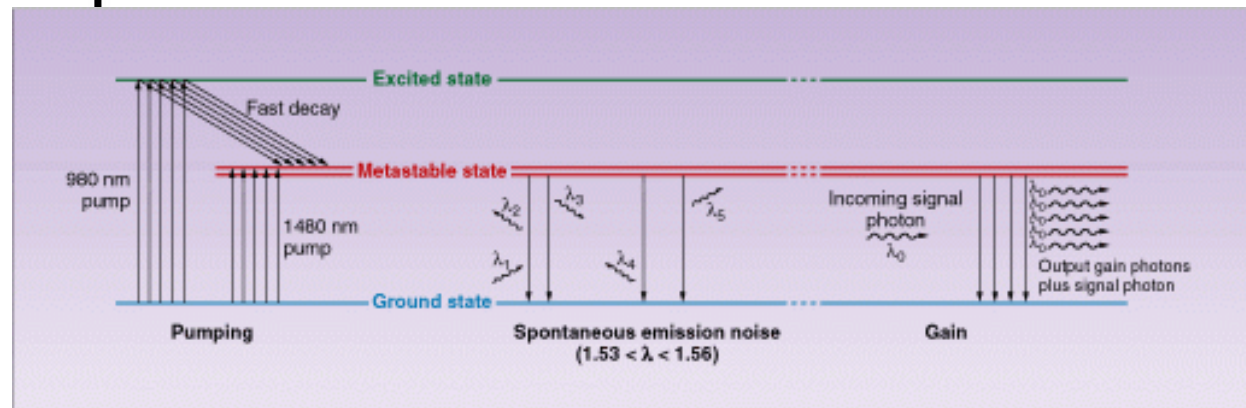
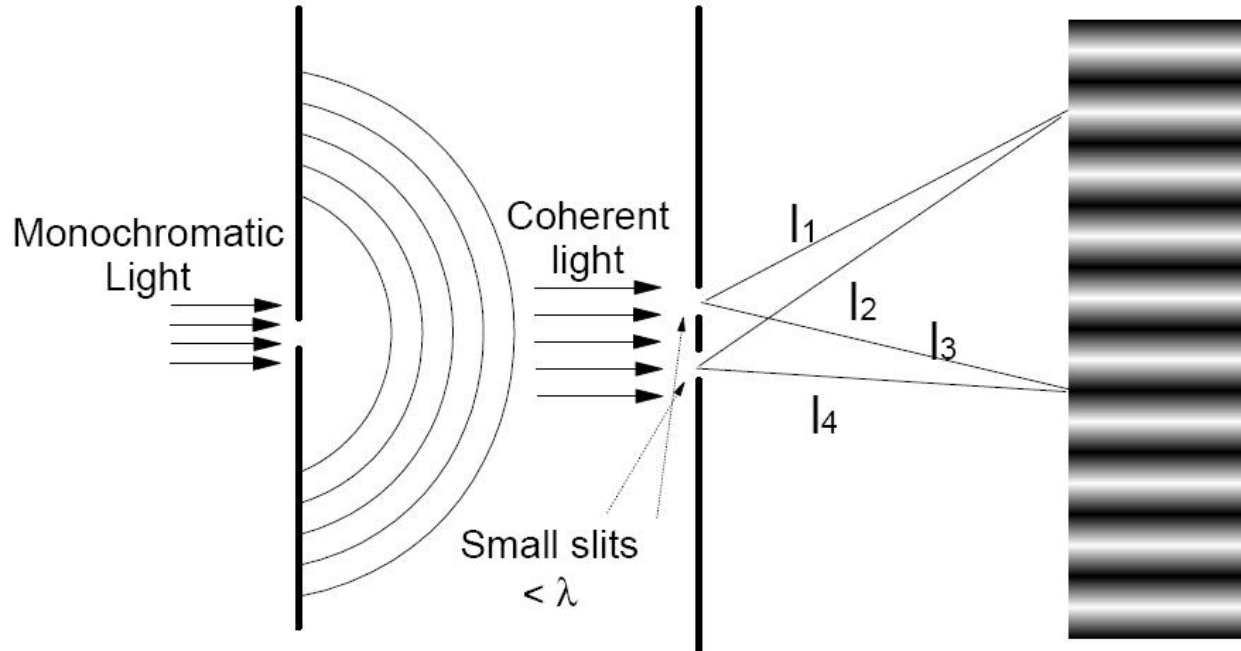


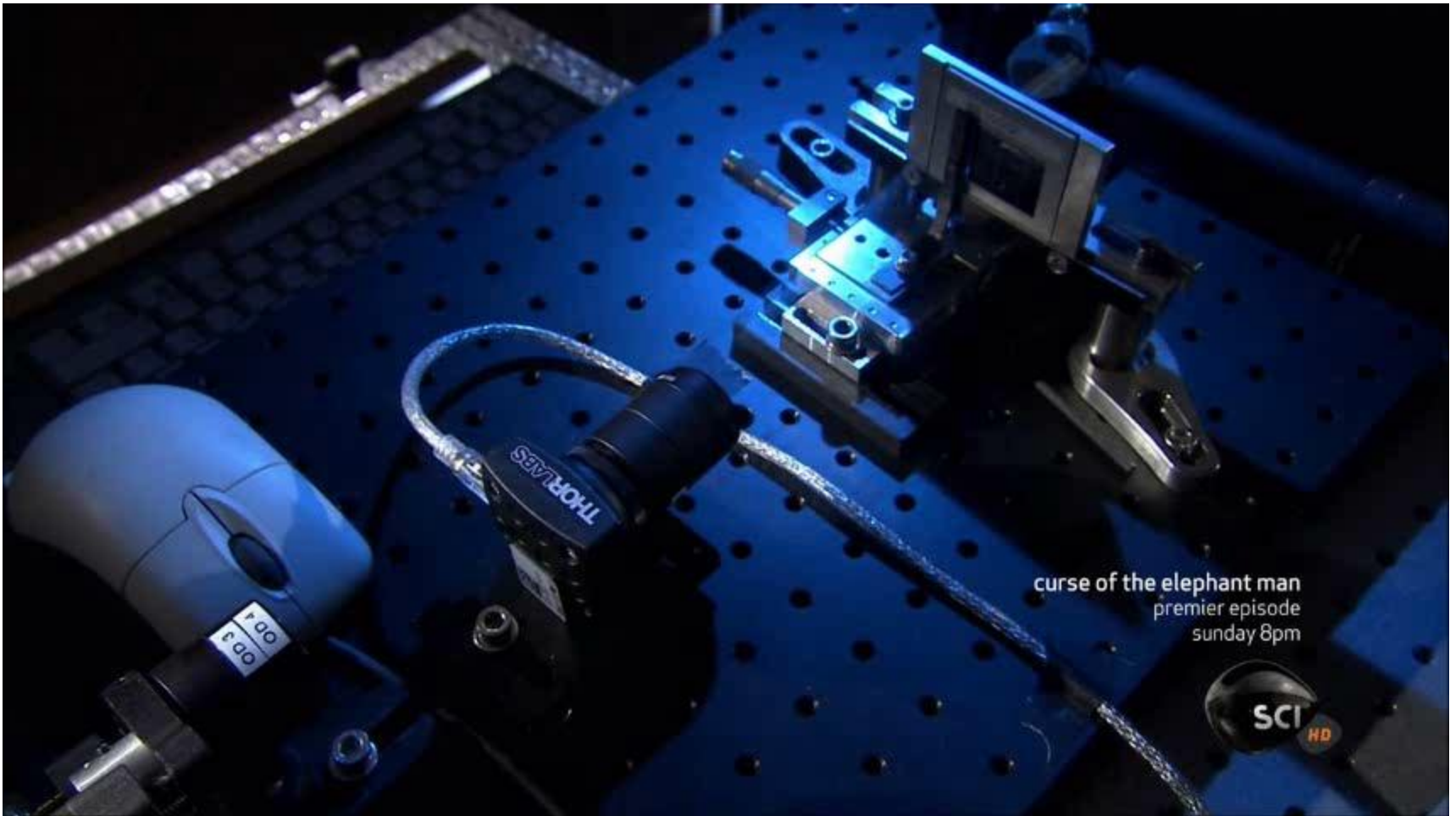
# Unda electromagnetica

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



# Fotoni/Unda



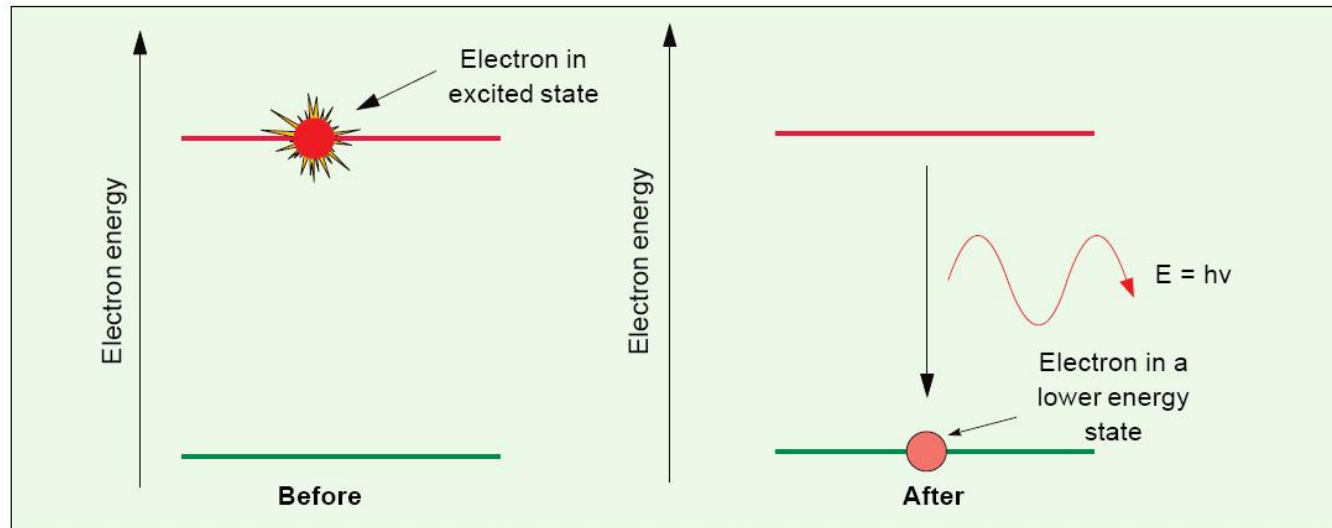


curse of the elephant man  
premier episode  
sunday 8pm



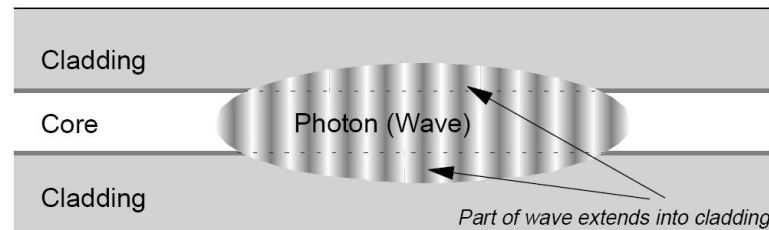
## Through the Wormhole S02E07 How Does the Universe Work

# 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**  
 $2.998 \cdot 10^8 \text{ m/s}$

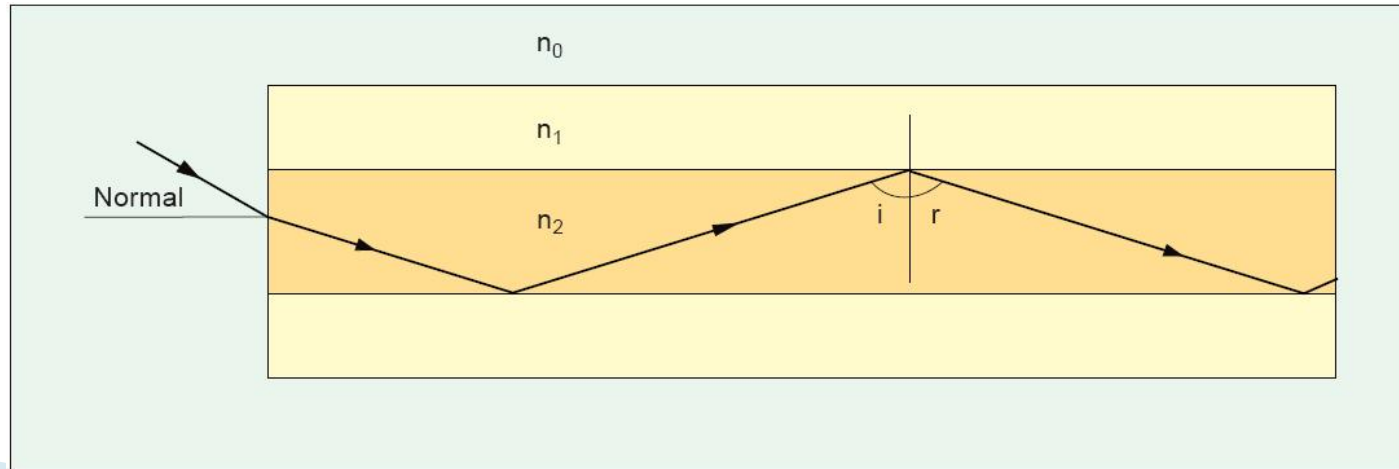
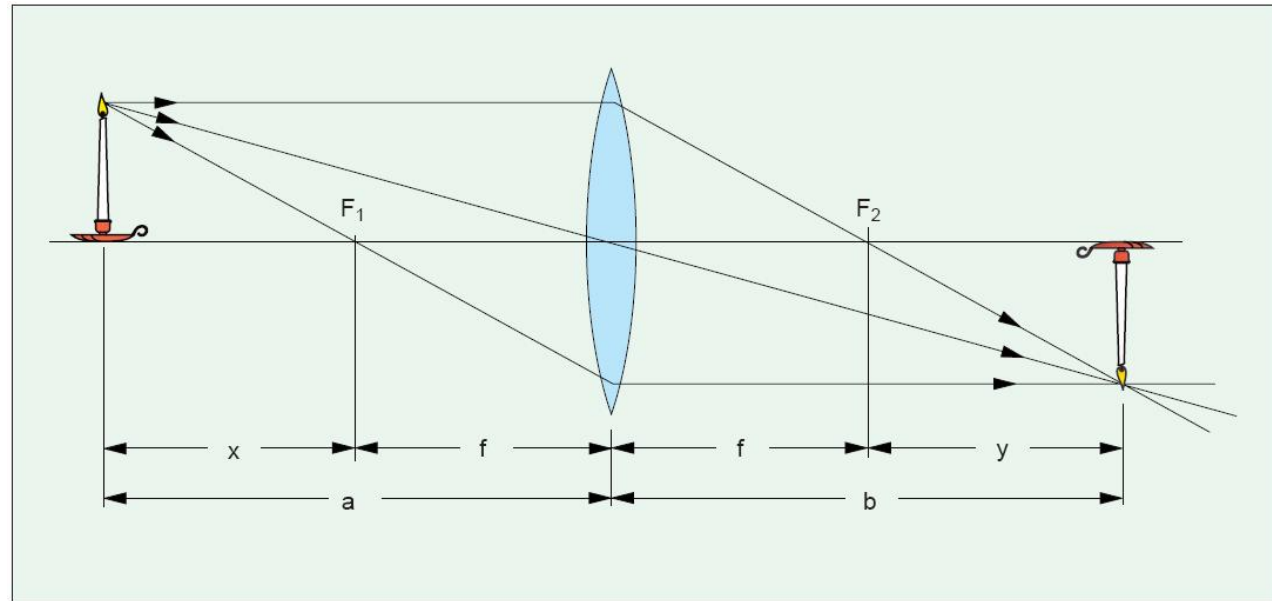
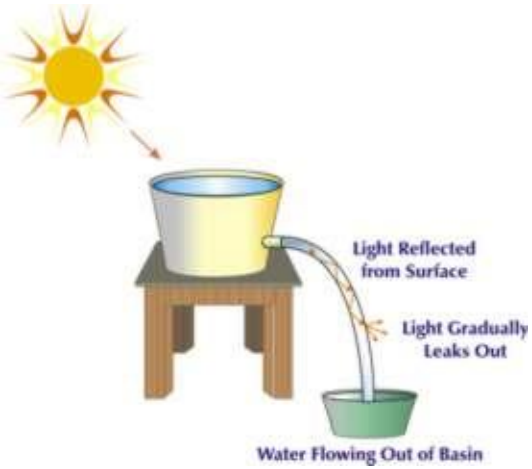




Through the Wormhole  
S02E07 How Does the Universe Work



# Optica geometrica



# Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# Calculul atenuarii

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

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

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



=

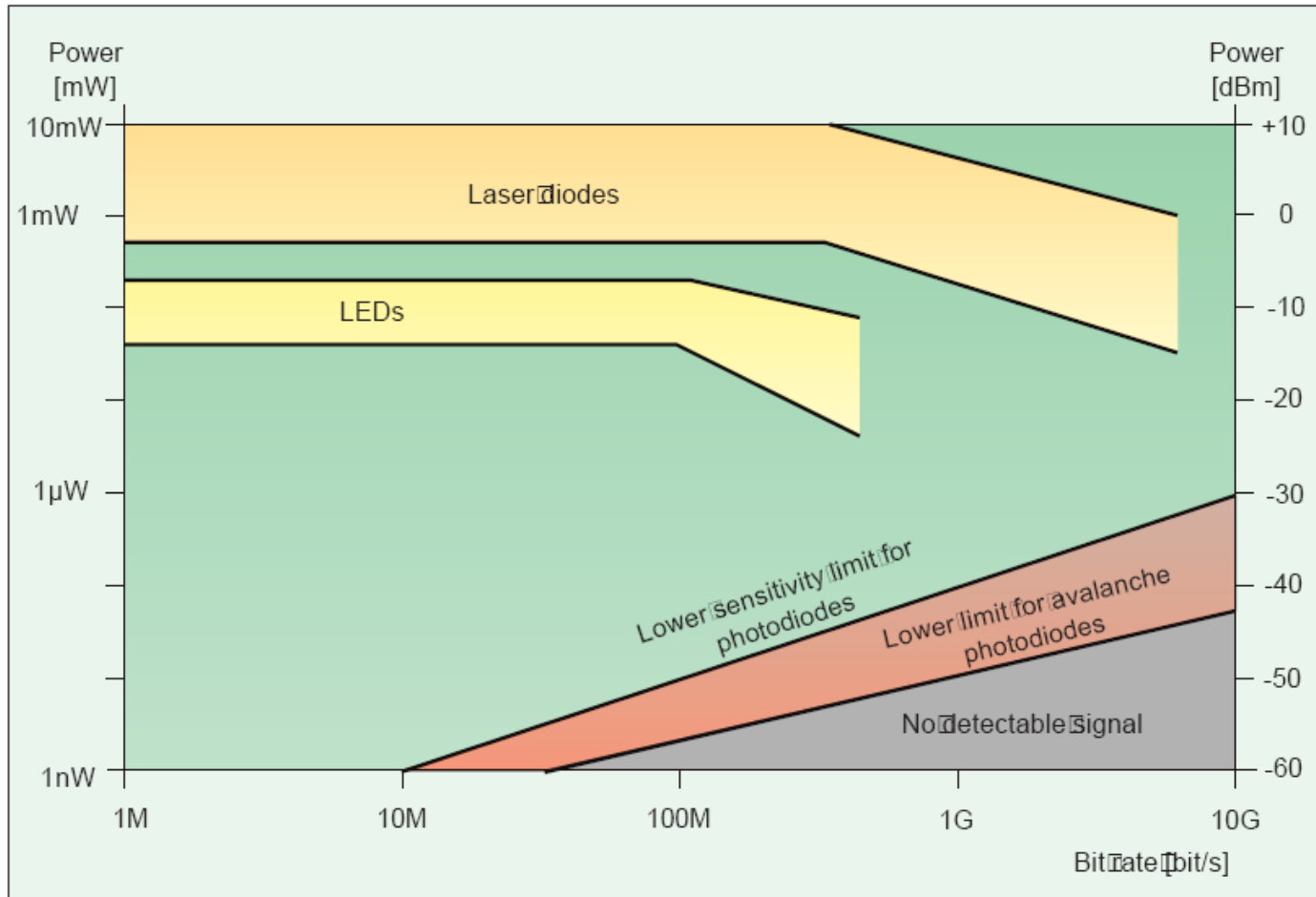


-



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

# Limite putere/bandă a dispozitivelor optoelectronice



# Contact

- ▶ Laboratorul de microunde si optoelectronica
- ▶ <http://rf-opto.etti.tuiasi.ro>
- ▶ [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)