

# Optoelectronică

Curs 2

2020/2021

# Disciplina 2020/2021

- ▶ 2C/1L Optoelectronică **OPTO**
- ▶ **Minim 7 prezente curs + laborator**
- ▶ Curs – conf. **Radu Damian**
  - an IV  $\mu E$
  - Miercuri 11–14, online, Microsoft Teams
  - E – 70% din nota (50+20), online, rf-opto
    - **20% test la curs**, saptamana 4–5?
  - probleme + (? 1 subiect teorie) + (2p prez. curs)
  - toate materialele permise
- ▶ Laborator – **sl. Daniel Matasaru**
  - an IV  $\mu E$ 
    - Marti 10-14 impar/par
  - L – 30% din nota (+Caiet de laborator)

# Orar 2020/2021

## ▶ Curs

- Miercuri 11–14, online
- **2C ⇒ 3C**
  - $14 * 2/3 \approx 9.33$
  - $9 \div 10 C \approx 9C + E$

# Online

- ▶ acces la **examene** necesita **parola** primita prin **email**

The screenshot shows a student profile for POPESCU GOPO ION. The page has a dark blue header with navigation links: Start, Didactic, Master, Colectiv, Cercetare, and Studii. Below the header is a sub-header with links: Note, Lista Studenti, Examene, and Fotografii. The main content area displays the student's name, a placeholder for a photo (Fotografia nu exista), and a table of personal data. A red circle highlights the text 'Acceseaza ca acest student' and a link 'Cere acces la licente'.

English | Romana |

Start Didactic Master Colectiv Cercetare Studii

Note Lista Studenti Examene Fotografii

## POPESCU GOPO ION

**Fotografia nu exista**

**Date:**

Grupa	5700 (2019/2020)
Specializarea	Inginerie electronica si telecomunicatii
Marca	7000021

Acceseaza ca acest student | [Cere acces la licente](#)

### Note obtinute

Inca nu a fost notat.

The screenshot shows a login page titled 'Identificare'. It has a dark blue header with navigation links: Start, Didactic, Master, Colectiv, and Cercetare. Below the header is a sub-header with links: Note, Lista Studenti, Examene, and Fotografii. The main content area contains a form for login. A red arrow points from the 'E-mail/Parola' field to the 'parola' word in the text above. The 'E-mail/Parola' field is circled in red. Below the form is a CAPTCHA image showing the code '4db4457' and a 'Trimite' button.

Start Didactic Master Colectiv Cercetare

Note Lista Studenti Examene Fotografii

## Identificare

Introduceti numele si adresa de email utilizata la inscriere

Nume  
POPESCU GOPO

**E-mail/Parola**

Introduceti codul afisat mai jos

4db4457

Trimite

# Online

## ► acces email/parola

Start Didactic Master Colectiv

Note Lista Studenti Examene Fotografii

### POPESCU GOPO ION

Fotografia nu exista

Date:

Grupa	5700 (2019/2020)
Specializarea	Inginerie electronica
Marca	7000021

Se acceseaza site-ul [ca acest student!](#)

Start Didactic Master Colectiv C

Note Lista Studenti Examene Fotografii

### POPESCU GOPO ION

Fotografia nu exista

Date:

Grupa	5700 (2019/2020)
Specializarea	Inginerie electronica s
Marca	7000021

Se acceseaza site-ul [ca acest student \(inclusiv examene\)!](#)

# Parola

## ▶ primita prin email

Important message from RF-OPTO

Inbox x



Radu-Florin Damian

to me, POPESCU

Romanian > English Translate message



Laboratorul de Microunde si Optoelectronica  
Facultatea de Electronica, Telecomunicatii si Tehnologia Informatiei  
Universitatea Tehnica "Gh. Asachi" Iasi

**In atentie: POPESCU GOPO ION**

Parola pentru a accesa examenele pe server-ul **rf-opto** este

Parola: [REDACTED]

Identificati-va pe [server](#), cu parola, cat mai rapid, pentru confirmare.

**Memorati** acest mesaj intr-un loc sigur, pentru utilizare ulterioara

**Attention: POPESCU GOPO ION**

The password to access the exams on the **rf-opto** server is

Password: [REDACTED]

Login to the [server](#), with this password, as soon as possible, for confirmation.

**Save** this message in a safe place for later use

Reply

Reply all

Forward

Subject

Important message from RF-OPTO

Validation of MIDCR exam from 02/05/2020

From: Me <rdamian@etti.tuiasi.ro>

Subject: Important message from RF-OPTO

To: [REDACTED]

Cc: Me <rdamian@etti.tuiasi.ro>

Correspondents

POPESCU GOPO ION

[REDACTED]

[REDACTED]

Laboratorul de Microunde si Optoelectronica  
Facultatea de Electronica, Telecomunicatii si Tehnologia Informatiei  
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**Save** this message in a safe place for later use



# Manual examen online

- ▶ Aplicatia de examen online utilizata intens la:
  - curs (prezenta)
  - miniteste
  - examen

## Materials

### Other data

[Manual examen on-line](#) (pdf, 2.65 MB, ro, 🇷🇴)

[Simulare Examen](#) (video) (mp4, 65.12 MB, ro, 🇷🇴)

## Microwave Devices and Circuits (Englis

# Examen online

- ▶ intotdeauna **contratimp**
  - perioada lunga (prezenta curs/rezultate laborator)
  - perioada scurta (teste: 15min, examen: 2h)

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti **Examene** Fotografii

**Anunț**  
17:28 (29/04/2020)

**Material suport**  
17:30 (29/04/2020)

**Subiecte**  
17:32 (29/04/2020)

**Rezultate**  
17:35 (29/04/2020)

**Finalizare**  
17:45 (29/04/2020)

**Confirmare**  
17:45 (30/04/2020)

Urmatorul interval de timp in:  
**01 m 08 s**  
[Reincarca acum](#)

## Anunț

In acest examen se verifica diverse actiuni ale studentilor pentru examen

## Ora pe server

Toate examenele sunt bazate pe fusul orar al server-ului (ar putea sa fie diferit de timpul local). Pentru referinta ora pe server este acum:

**29/04/2020 17:28:51**



# Introducere

## Capitolul 1

# Aplicatii majore

## ▶ Comunicatii

- Infrarosu (InGaAsP)

## ▶ Vizibil

- Spectru vizibil (GaAlAs)

## ▶ Iluminare

- Putere ridicata, lumina alba (GaInN)

# 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
  - 159 Tb/s @ 1045 km
  - 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

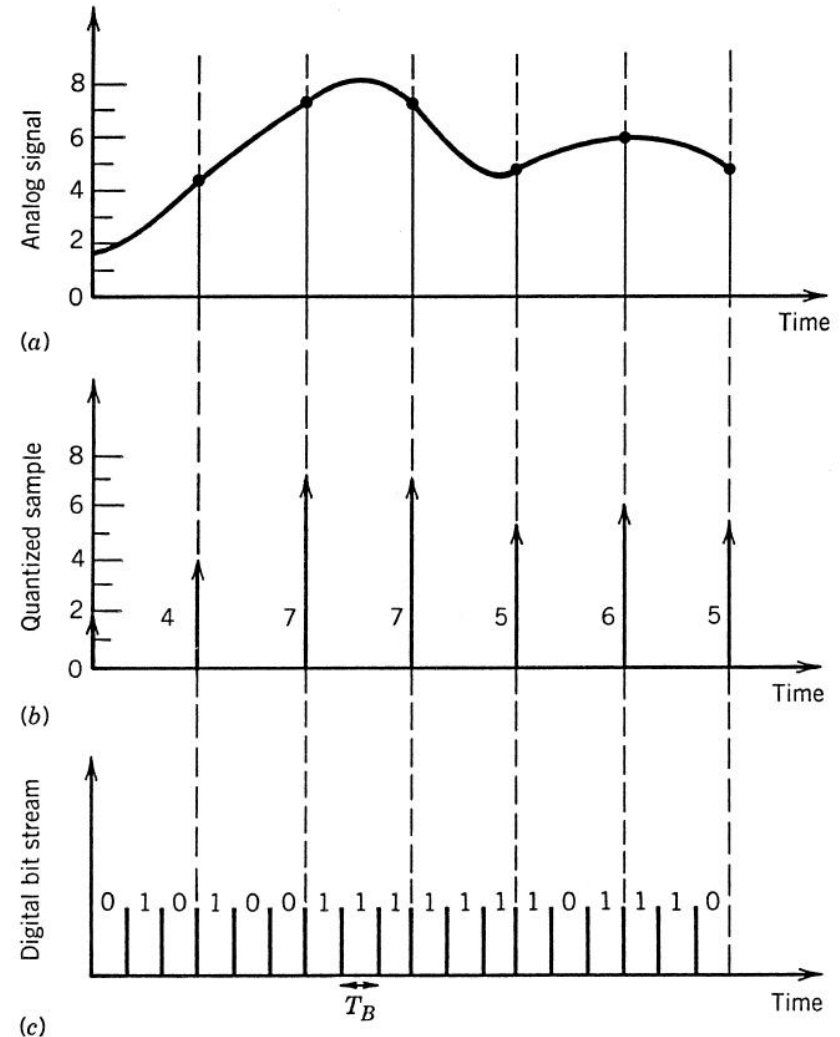
- ▶ pulse–position modulation
- ▶ pulse–duration modulation
- ▶ pulse–code modulation (PCM)

- ▶ 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

$$M = 2^m$$

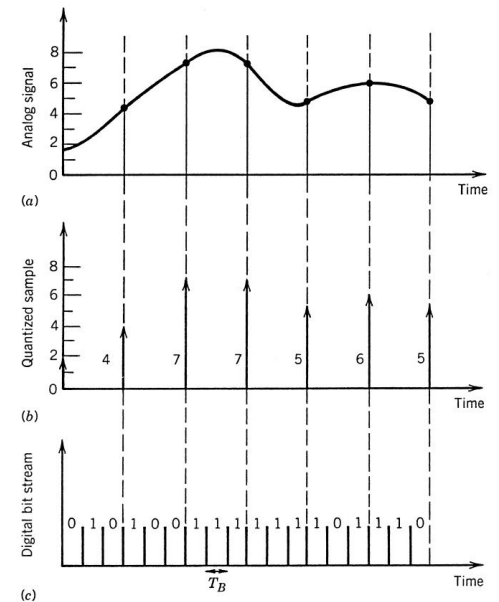
- ▶ viteza necesara (bit rate) [b/s]

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

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

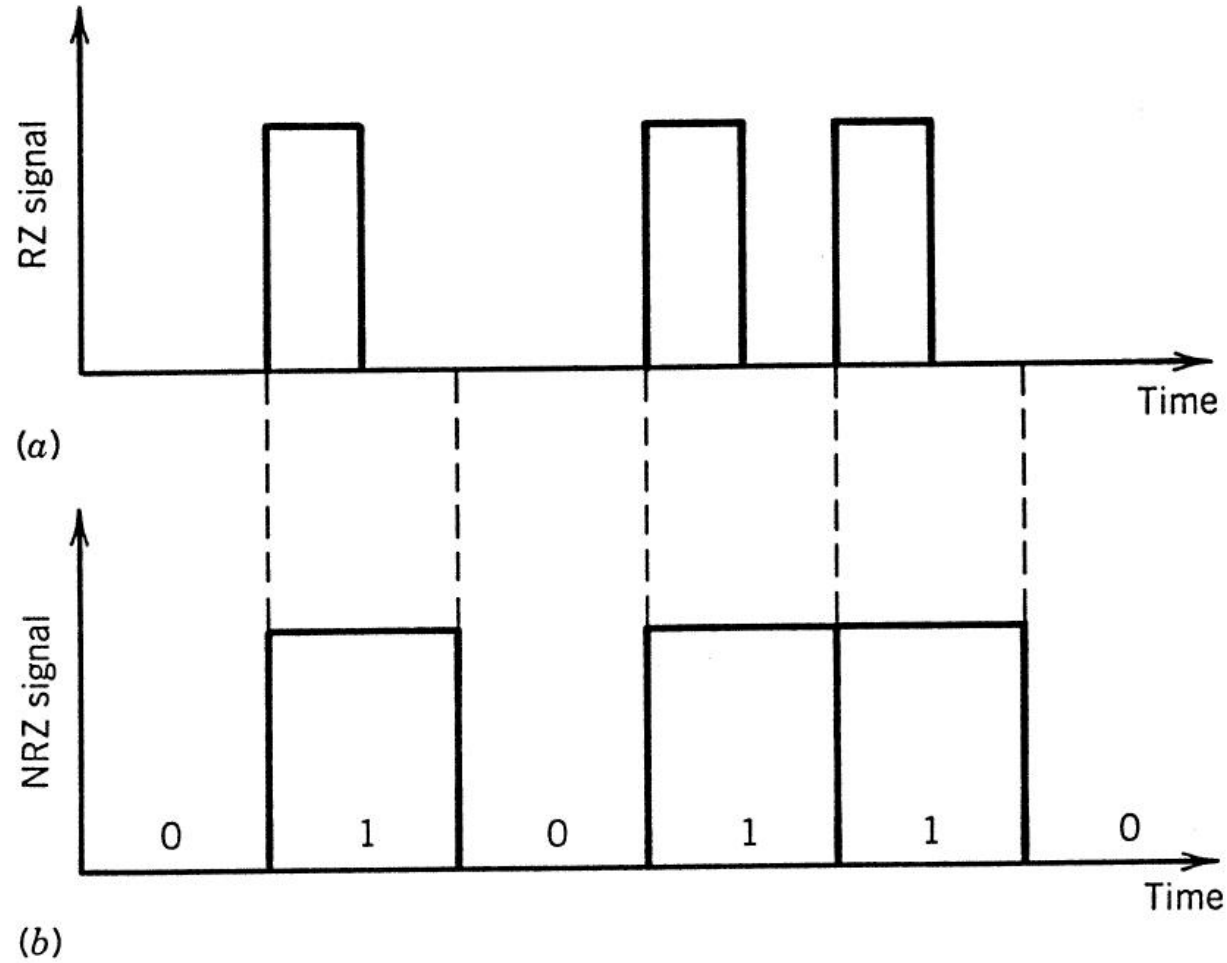
$$B > (\Delta f / 3) \cdot SNR$$

- ▶ 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)

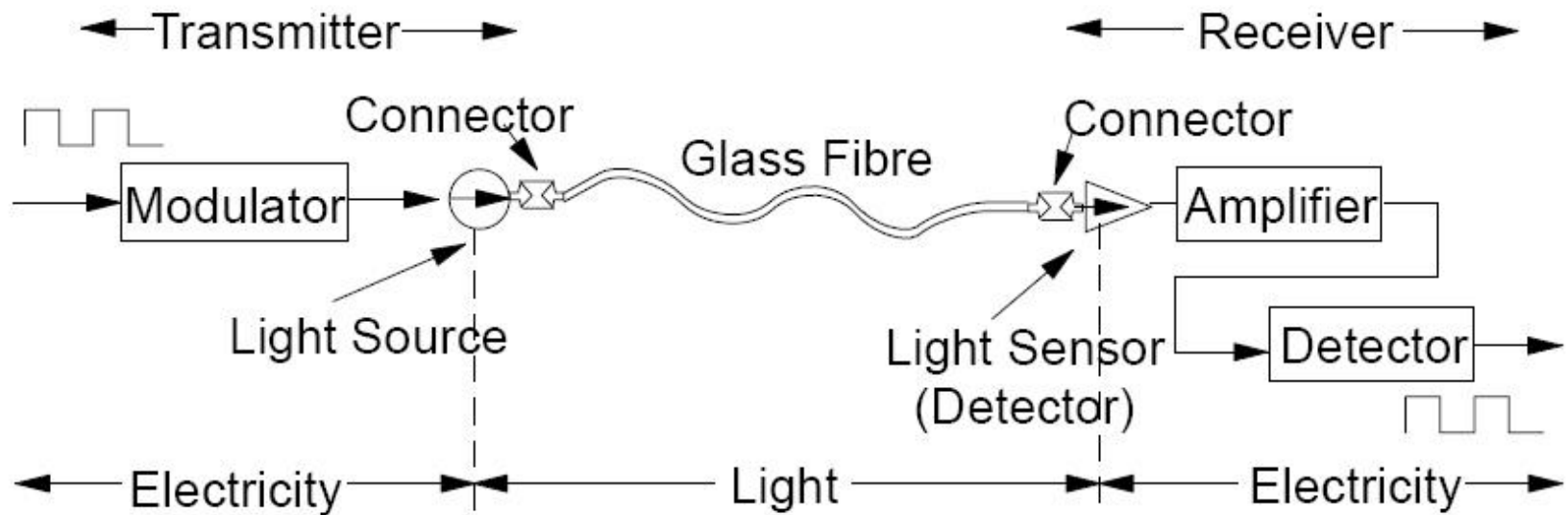


# Modulare

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

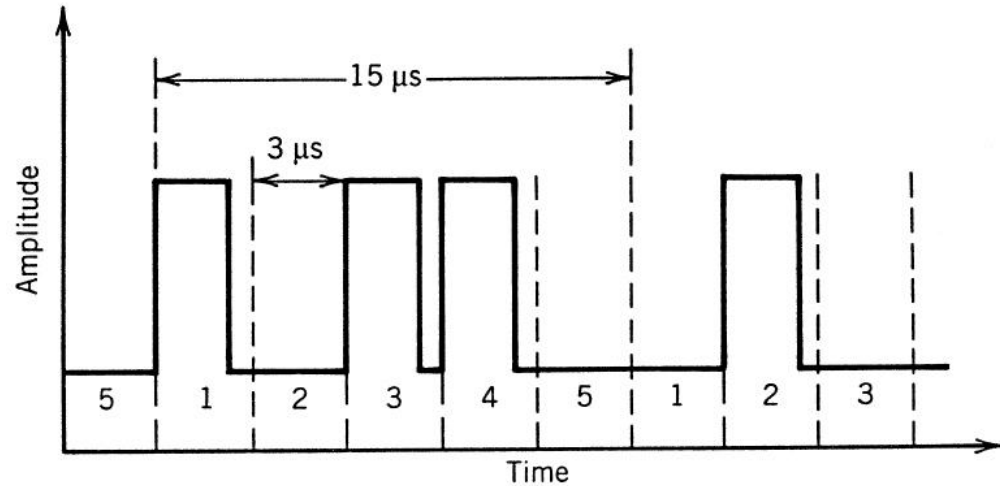


# Transmisia optica

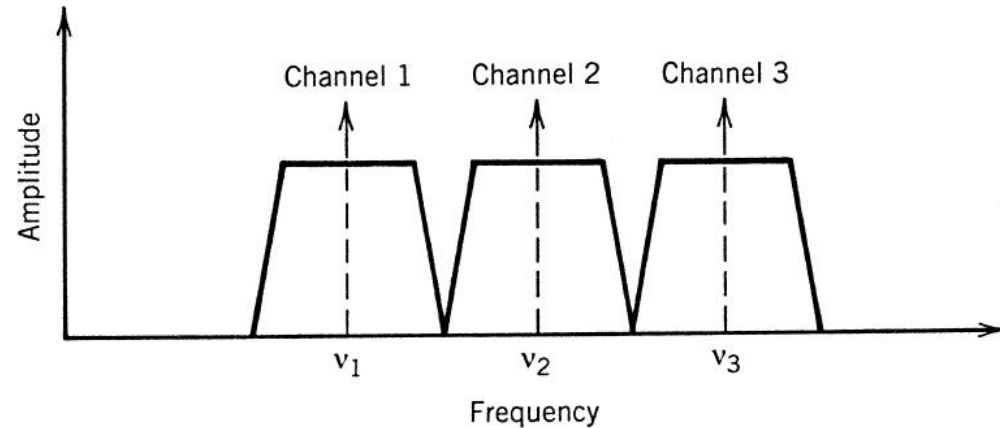


# Multiplexare

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

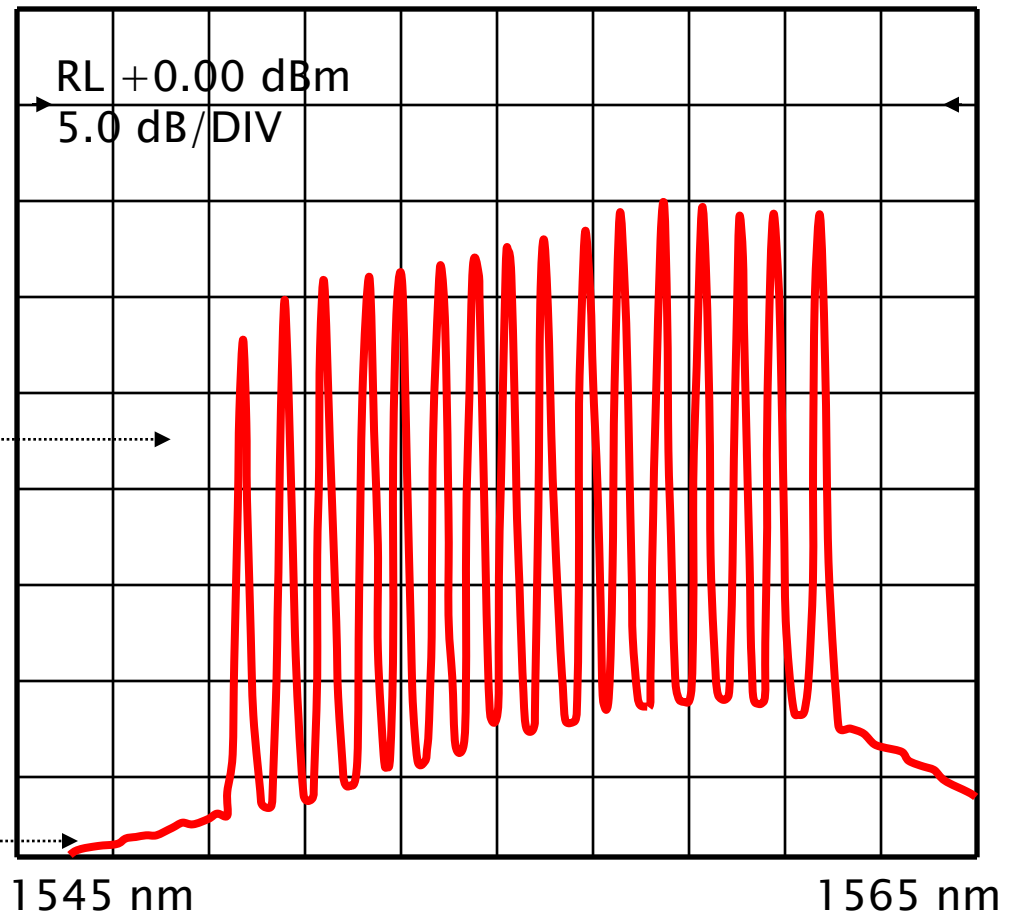


(a)



(b)

# Spectrul WDM – Wavelength Division Multiplexing



Canale: 16  
Spațiere: 0.8 nm

Emisie spontană  
Amplificată (ASE)

# Standardde

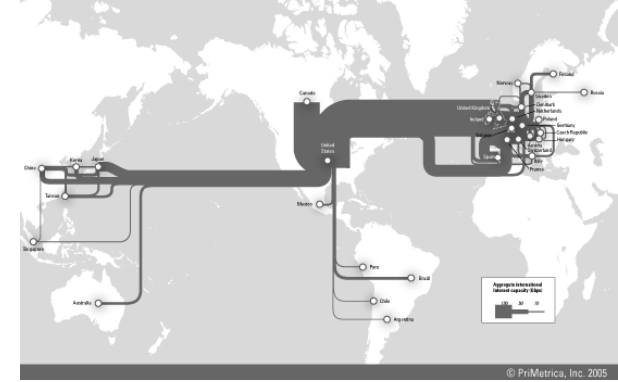
- ▶ SUA, Japonia

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

## ▶ Europa

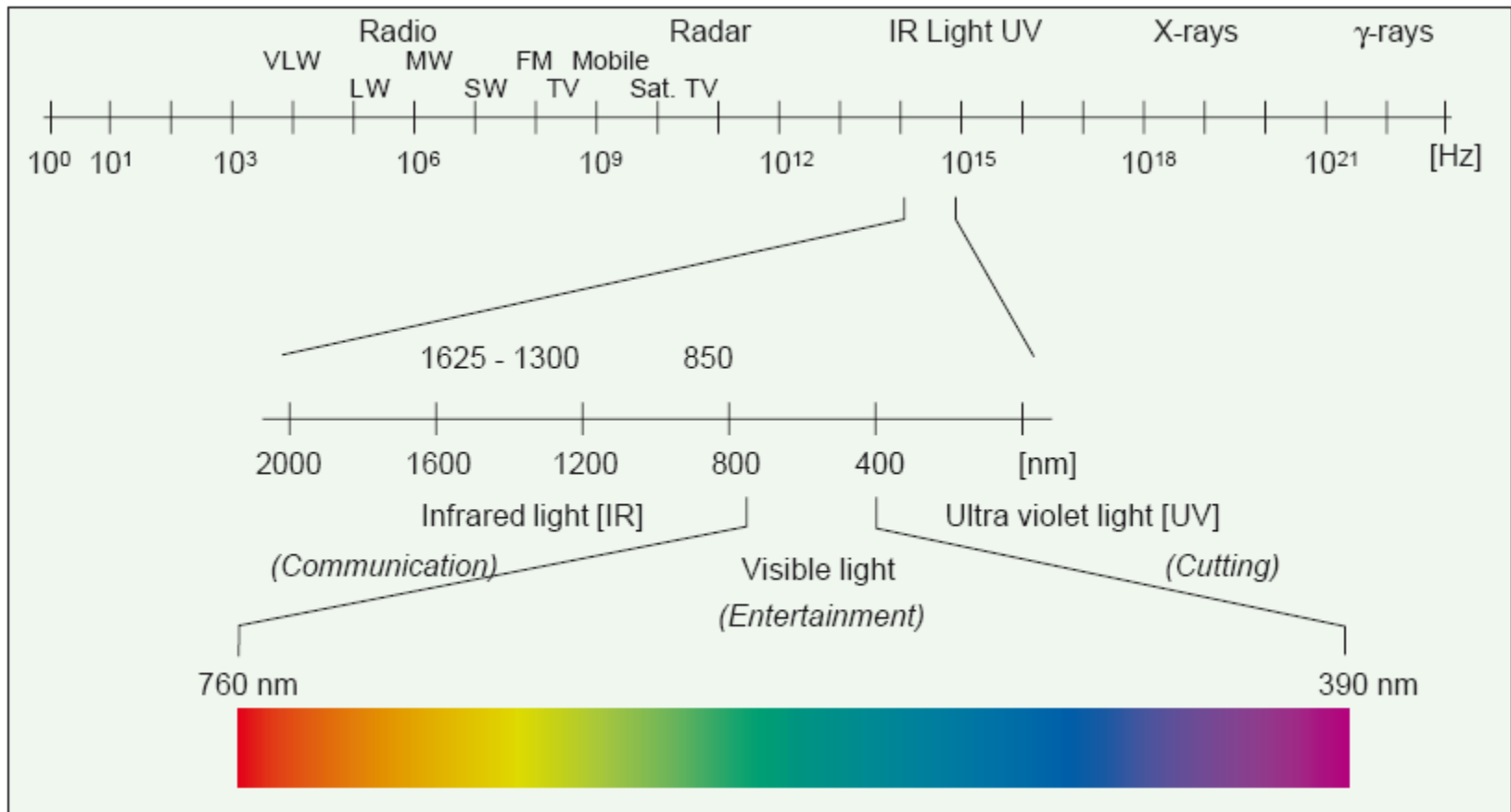
E0	64 Kb/s	
E1	2.048 Mb/s	
E2	8.448 Mb/s	4 E1s
E3	34.364 Mb/s	16 E1s
E4	139.264 Mb/s	64 E1s

1 mile = 1760 yards

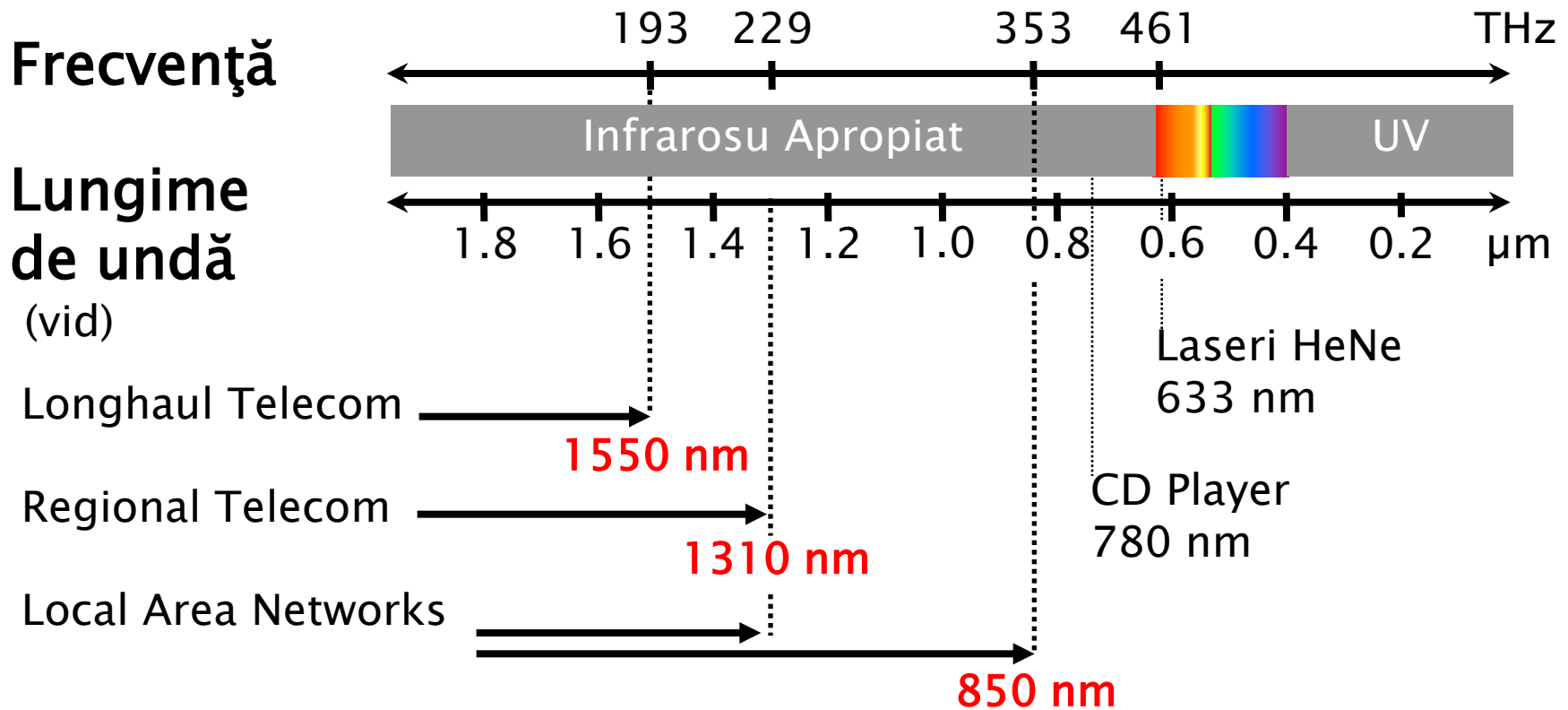
1 yards = 3 feet

1 mile ≈ 1609.34 m

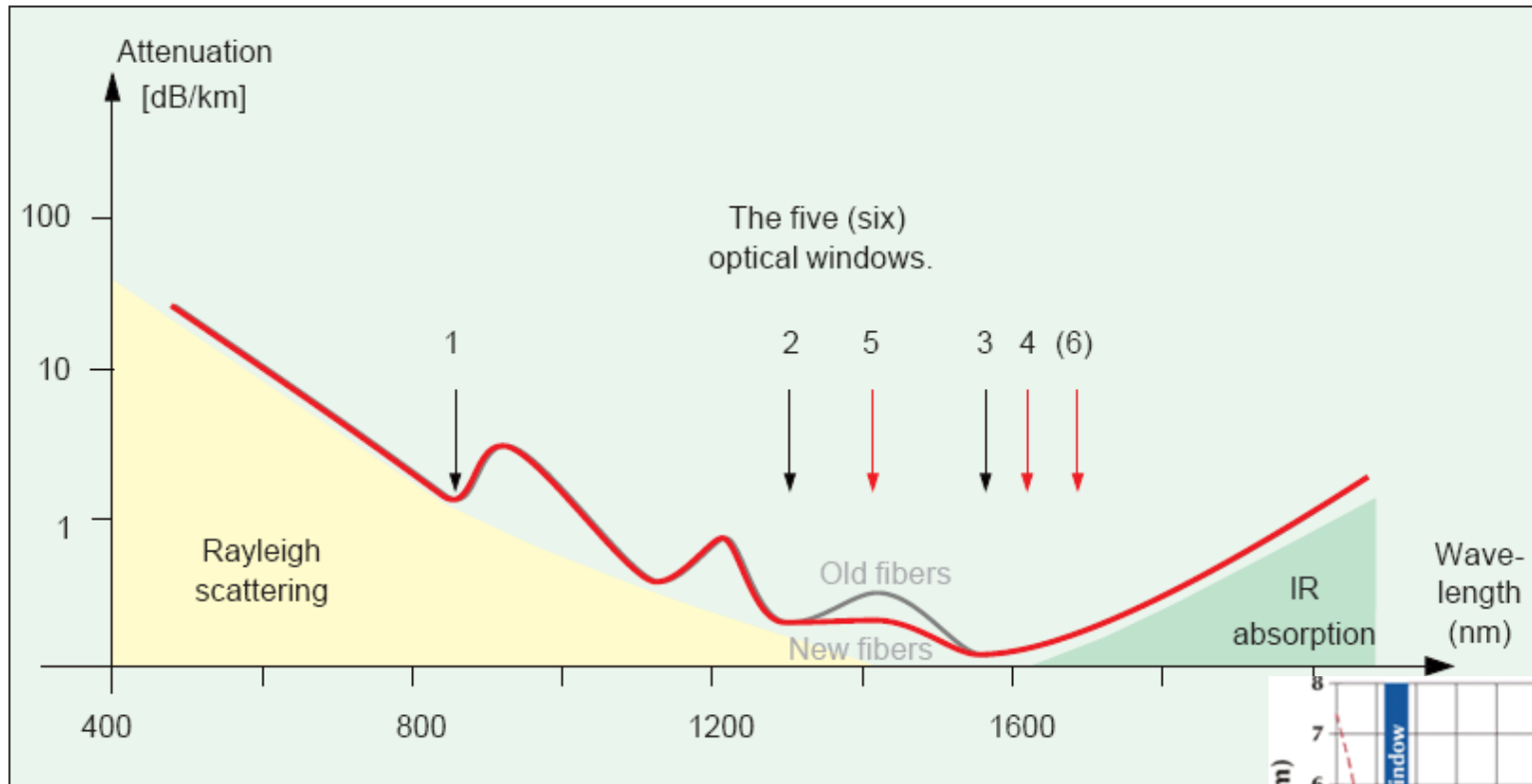
# Spectrul electromagnetic



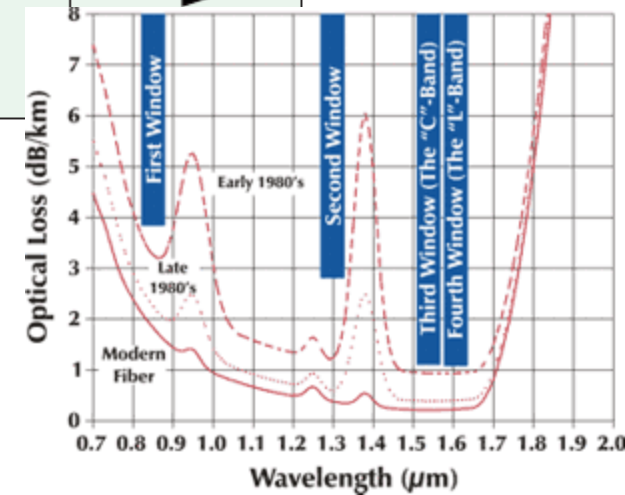
# Benzi de lucru in comunicațiile optice



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



850nm, 1310nm, 1550nm



# Aplicatii majore

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

# 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

Physics



The Nobel Prize in Physics 2014

Summary



The Nobel Prize in Physics 2014

Isamu Akasaki  
Hiroshi Amano  
Shuji Nakamura

Share this



## The Nobel Prize in Physics 2014



© Nobel Media AB. Photo: A. Mahmoud

**Isamu Akasaki**

Prize share: 1/3



© Nobel Media AB. Photo: A. Mahmoud

**Hiroshi Amano**

Prize share: 1/3



© Nobel Media AB. Photo: A. Mahmoud

**Shuji Nakamura**

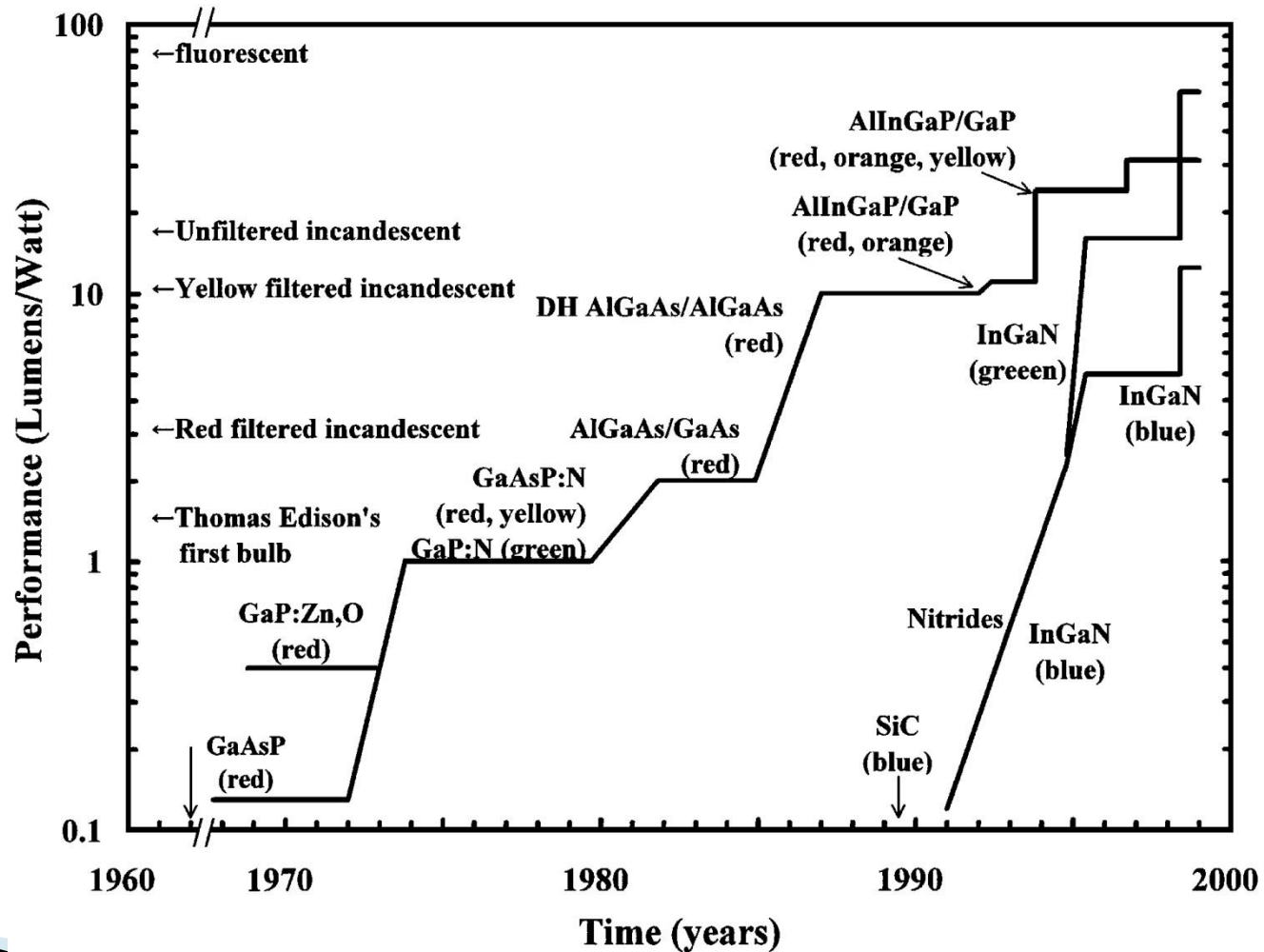
Prize share: 1/3

The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources."

To cite this section

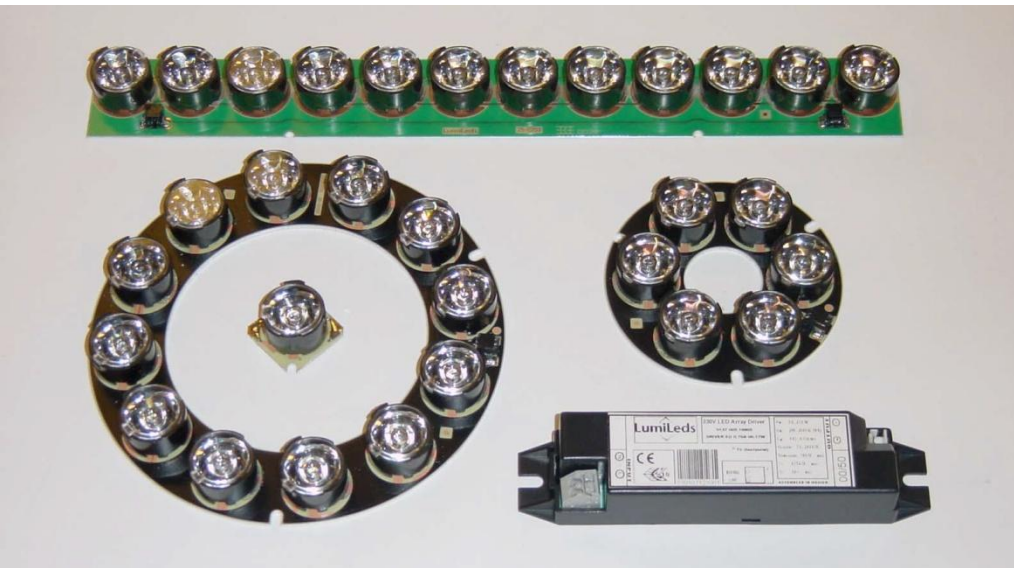
MLA style: The Nobel Prize in Physics 2014, NobelPrize.org, Nobel Media AB 2021. Tue, 2 Mar 2021.

# Eficienta in timp



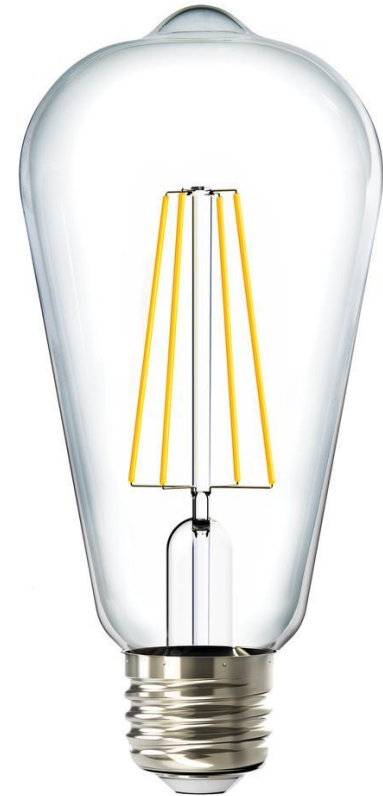
# Aplicatii

## ▶ auto



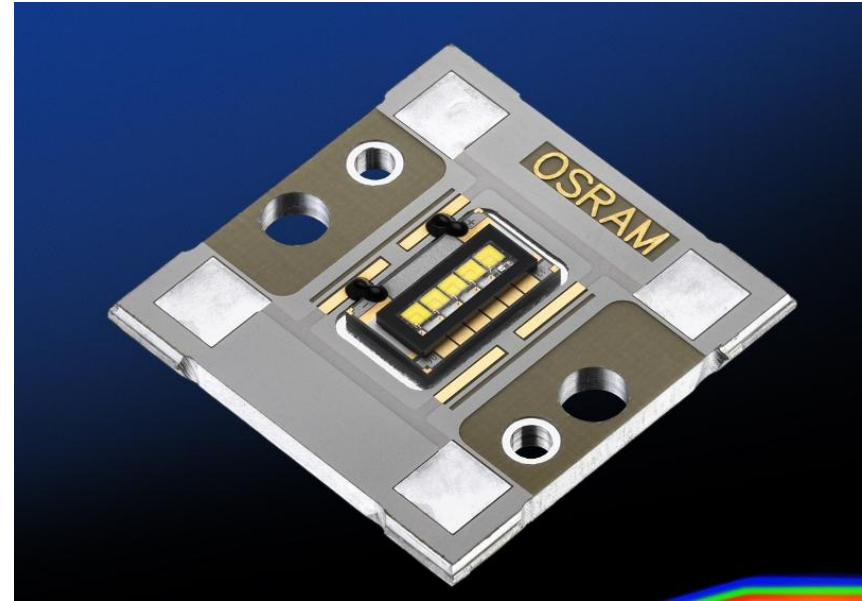
# Aplicatii

- ▶ casnic





# Aplicatii



# Aplicatii majore

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



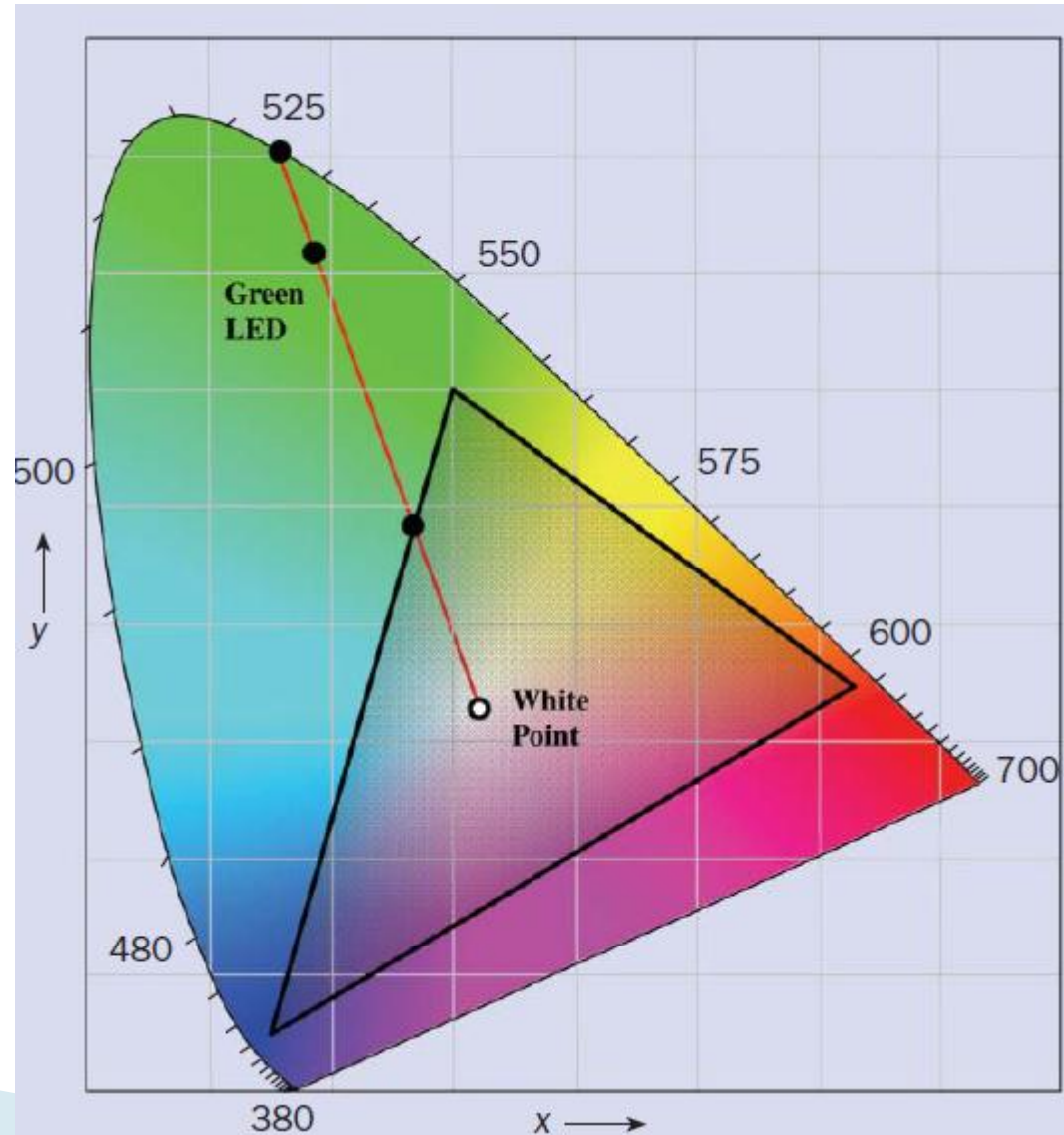
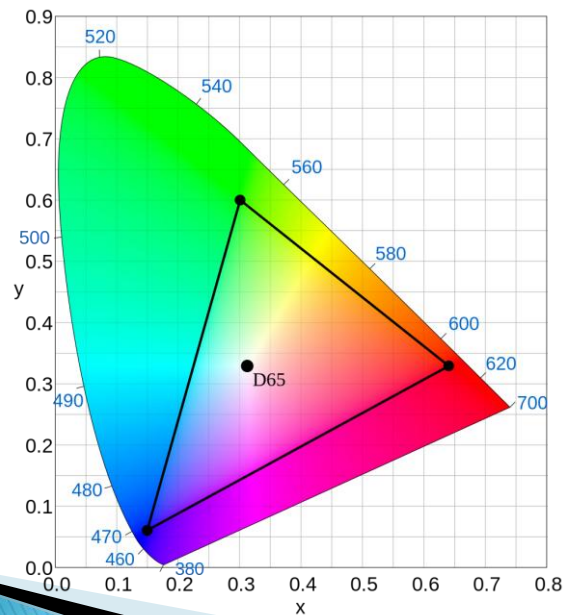
# ITU-R BT.709



## 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].

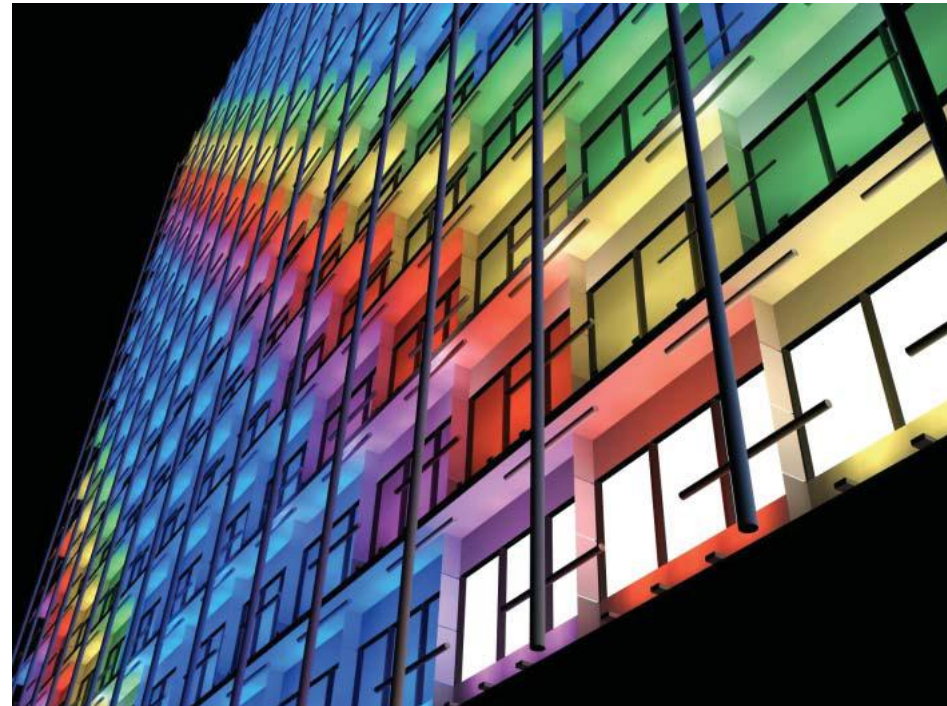


# Spectru vizibil





# 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

# Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

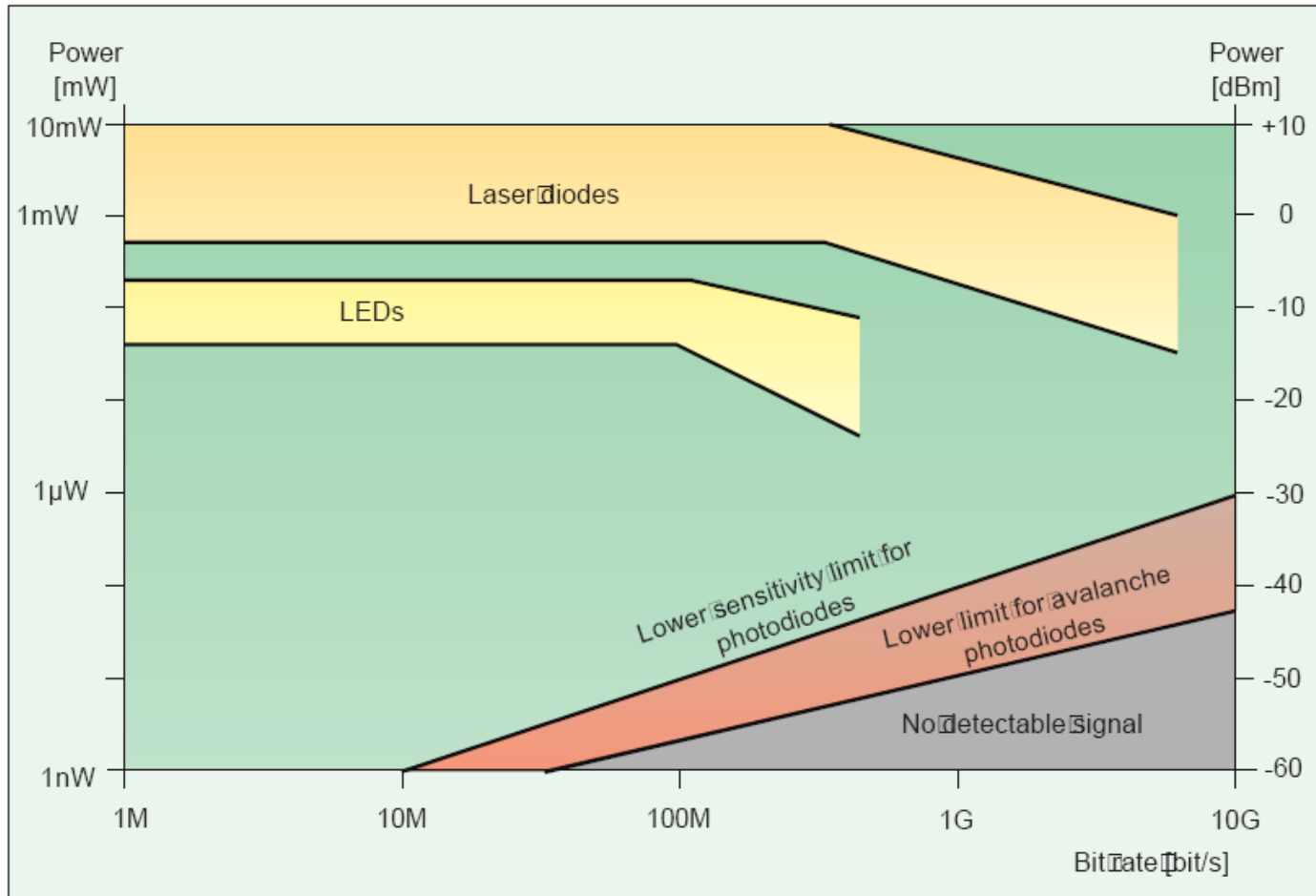
$$-60 \text{ dBm} = 1 \text{ nW}$$

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

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

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

# Limite putere/bandă a dispozitivelor optoelectronice



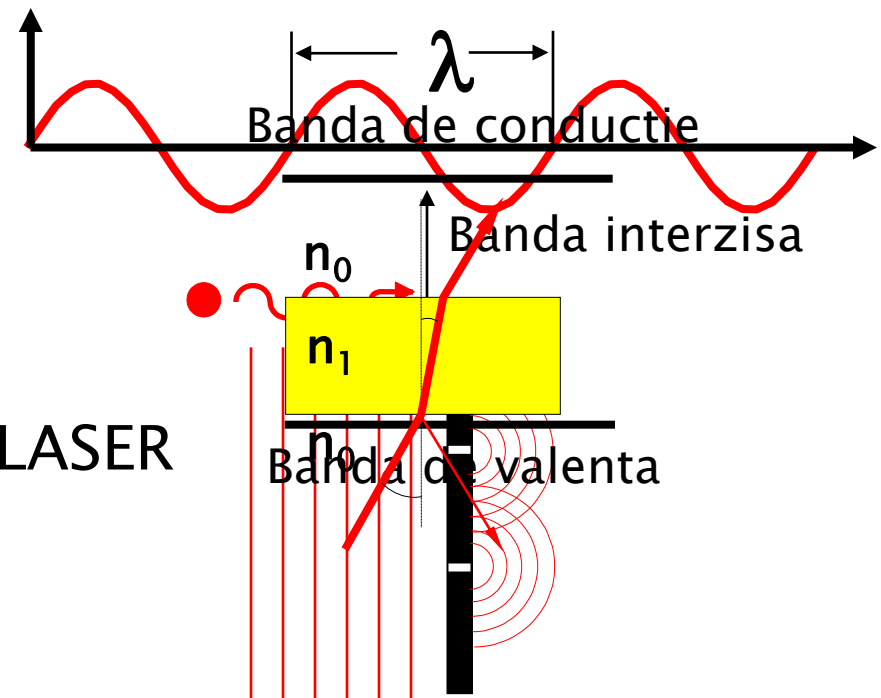
# Modelarea luminii

(tot) Capitolul 1



# Modelarea luminii

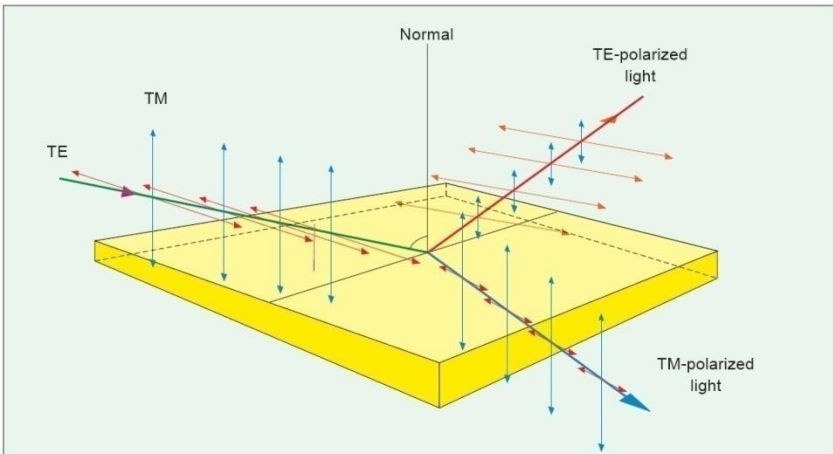
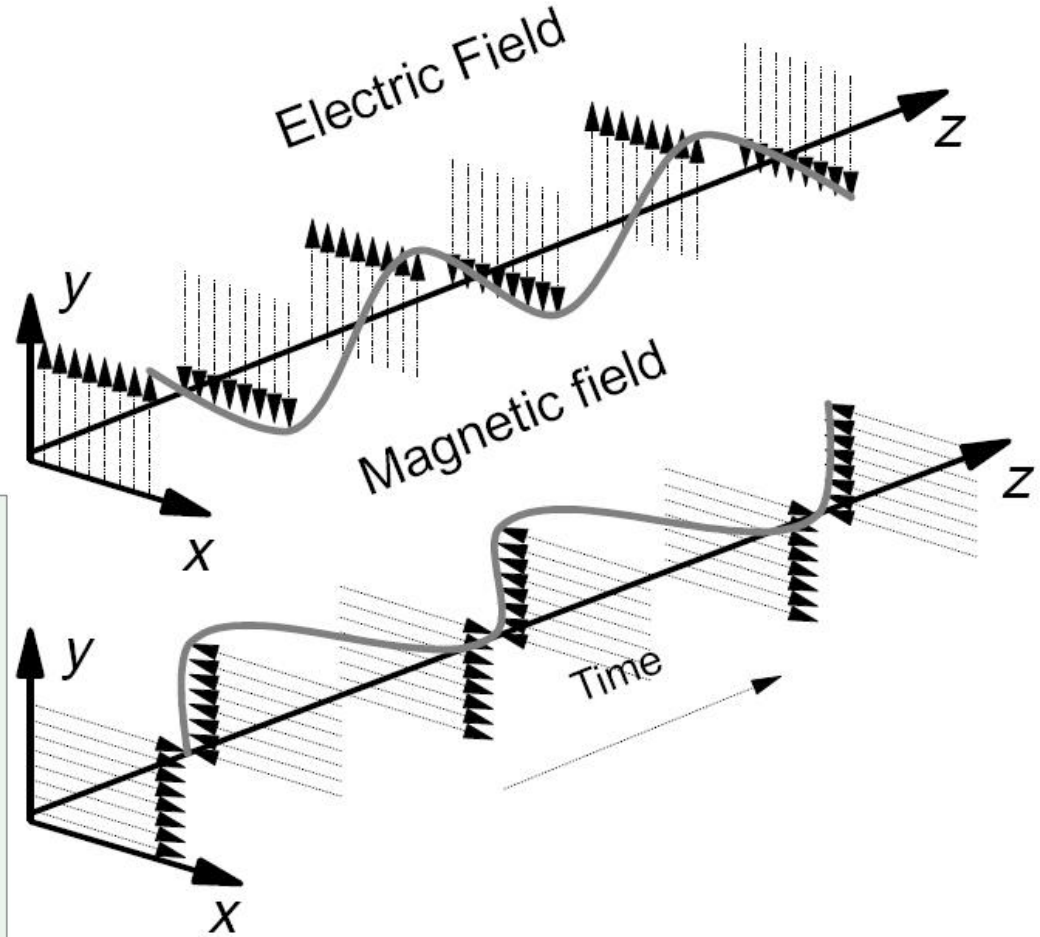
- ▶ Undă electromagnetică
  - Ecuațiile lui Maxwell
  - $\lambda$ ,  $\epsilon$ ,  $\omega$ ,  $f$
- ▶ Teoria cuantică
  - Benzi energetice  $E = h \nu$
  - fotoni, emisie stimulată, LASER
- ▶ Optică geometrică
  - $n$ ,  $\theta$
  - raze de lumină
  - intuitivă



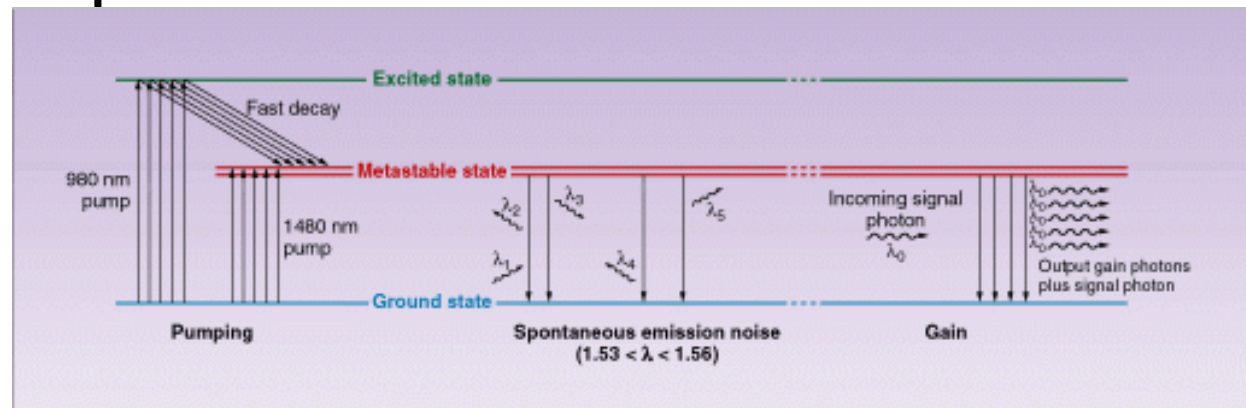
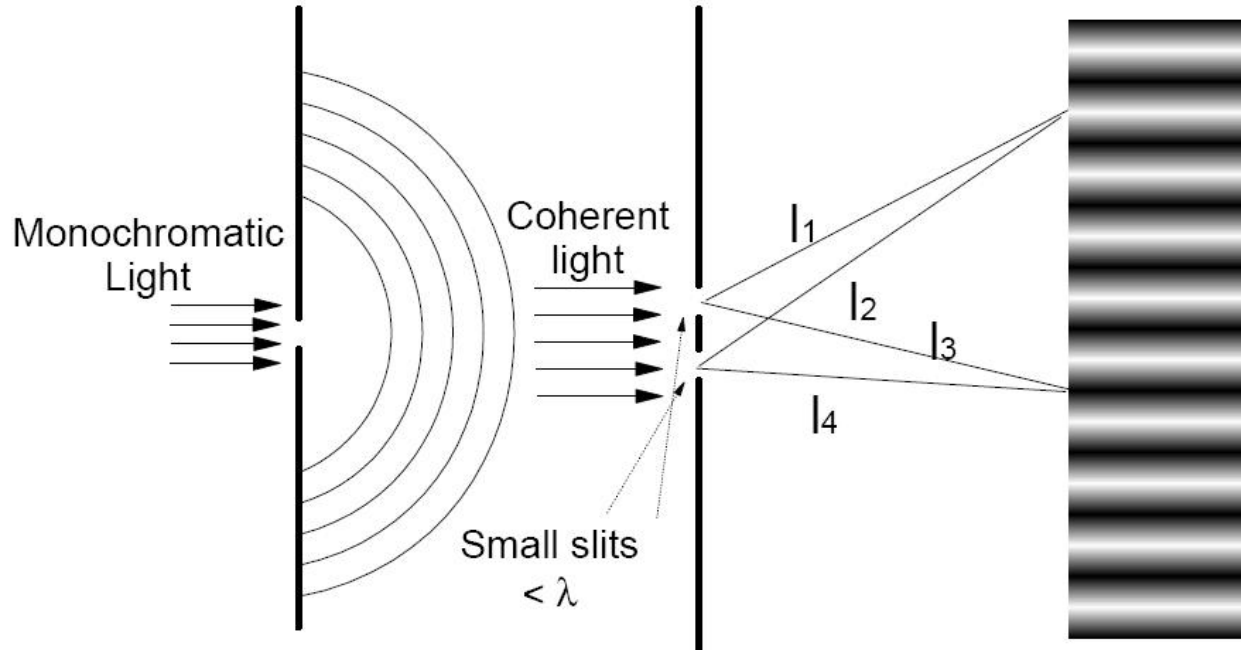


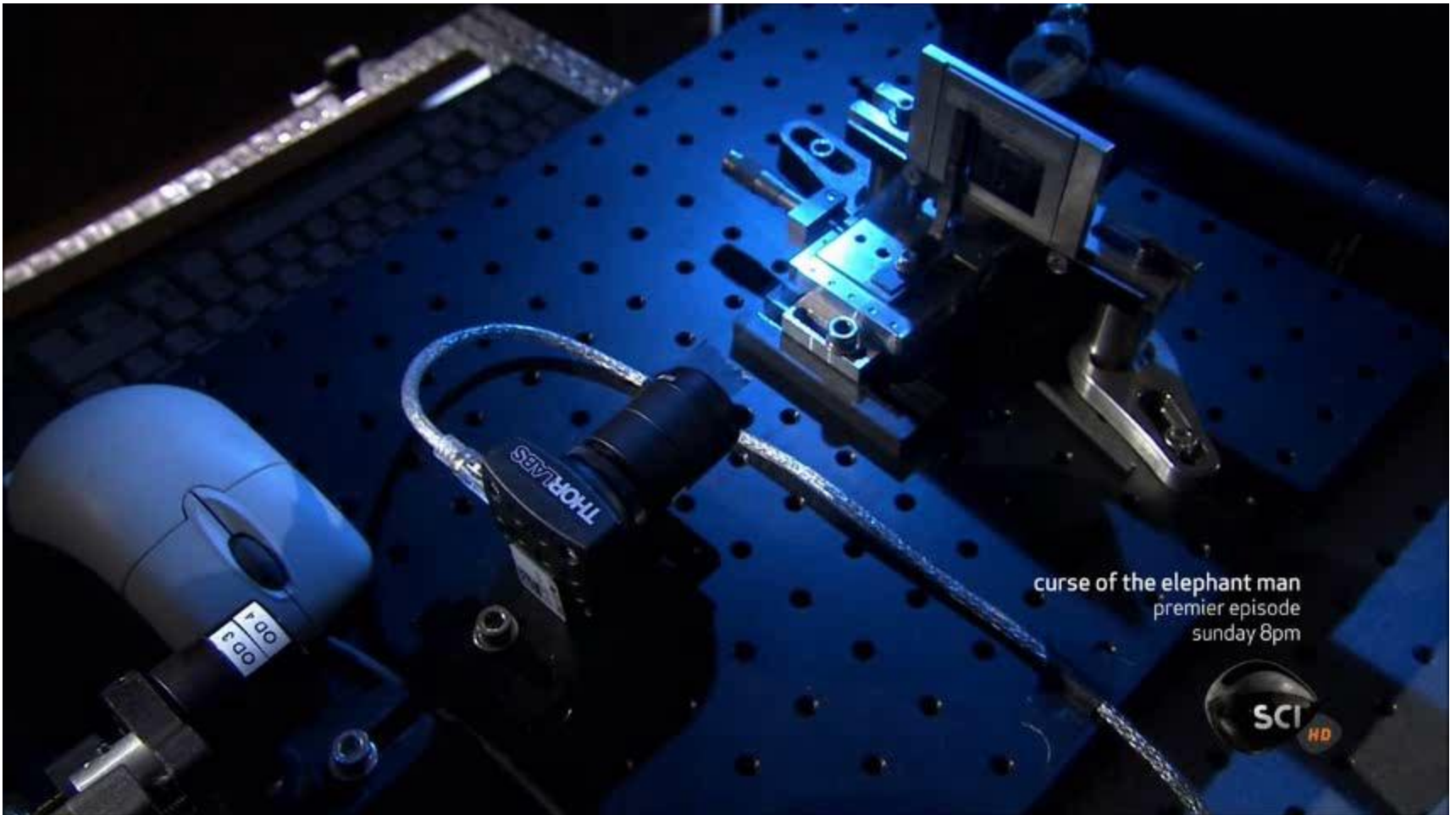
# Unda electromagnetica

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



# Fotoni/Unda



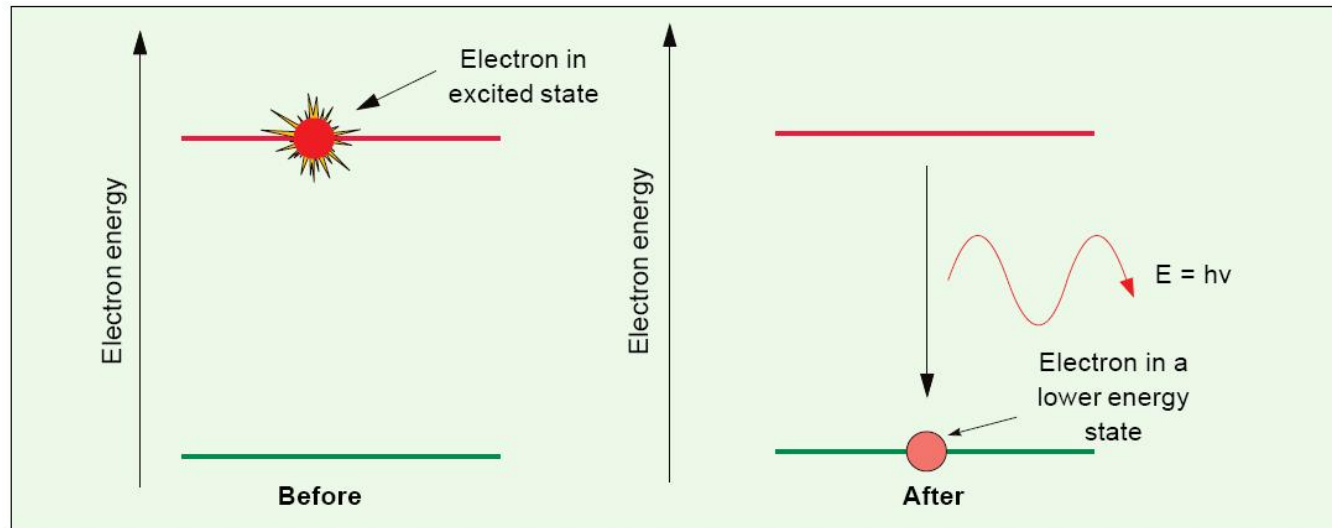


curse of the elephant man  
premier episode  
sunday 8pm

SCI  
HD

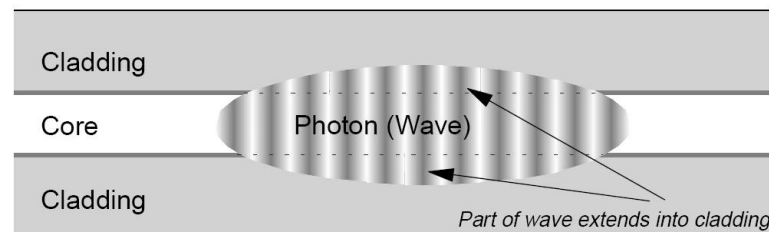
Through the Wormhole  
S02E07 How Does the Universe Work

# 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  
 $6.62 \cdot 10^{-32} \text{ W s}^2$
- ▶  $c$  viteza luminii **in vid**  
 $2.998 \cdot 10^8 \text{ m/s}$

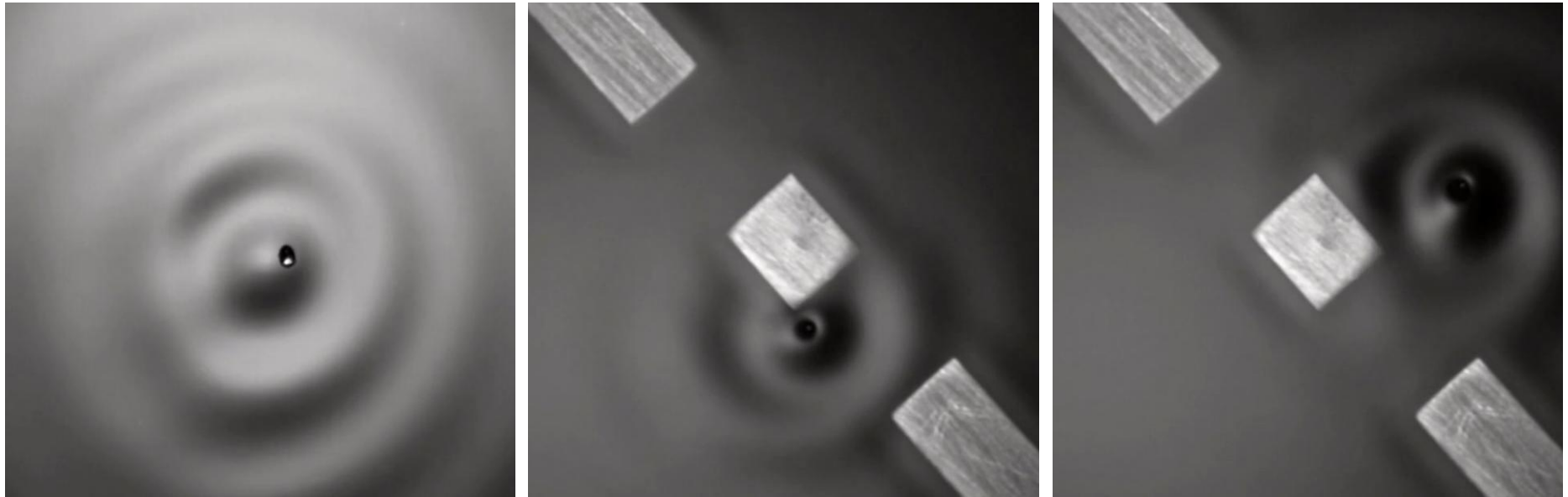




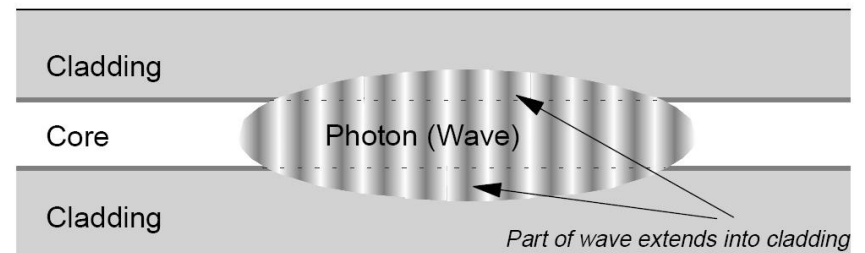


Through the Wormhole  
S02E07 How Does the Universe Work

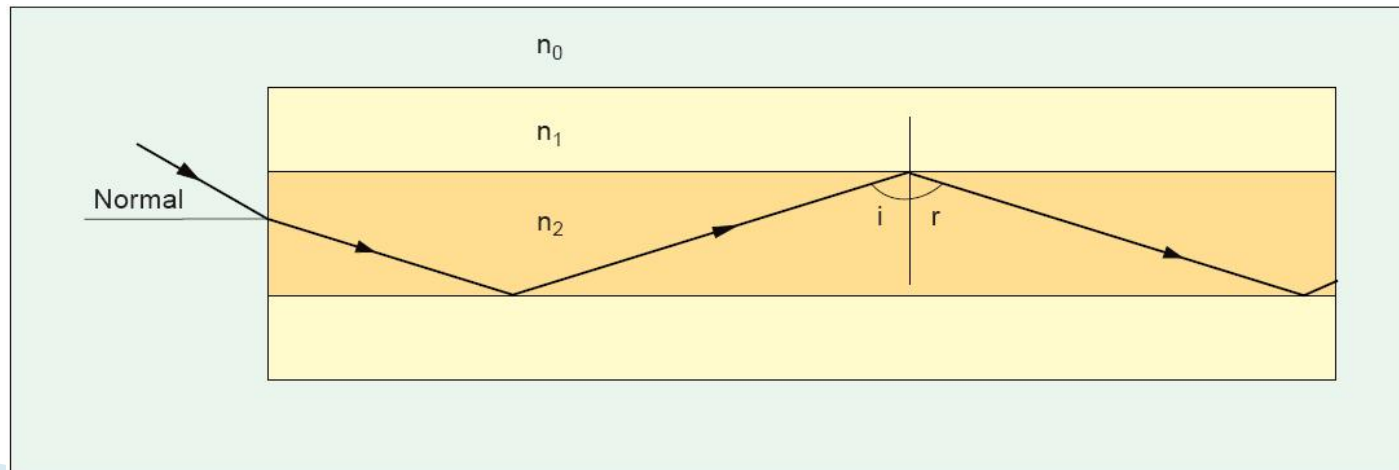
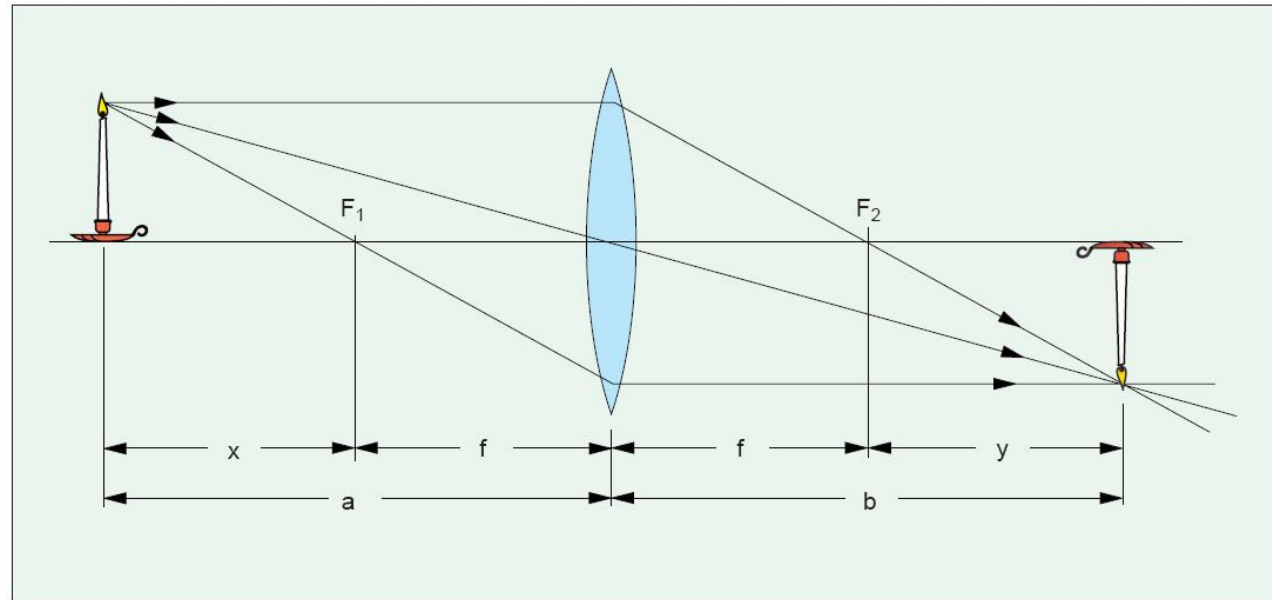
# Modelare



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# Optica geometrica



# Contact

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