Optoelectronică, structuri şi tehnologii

Curs 2

2016/2017

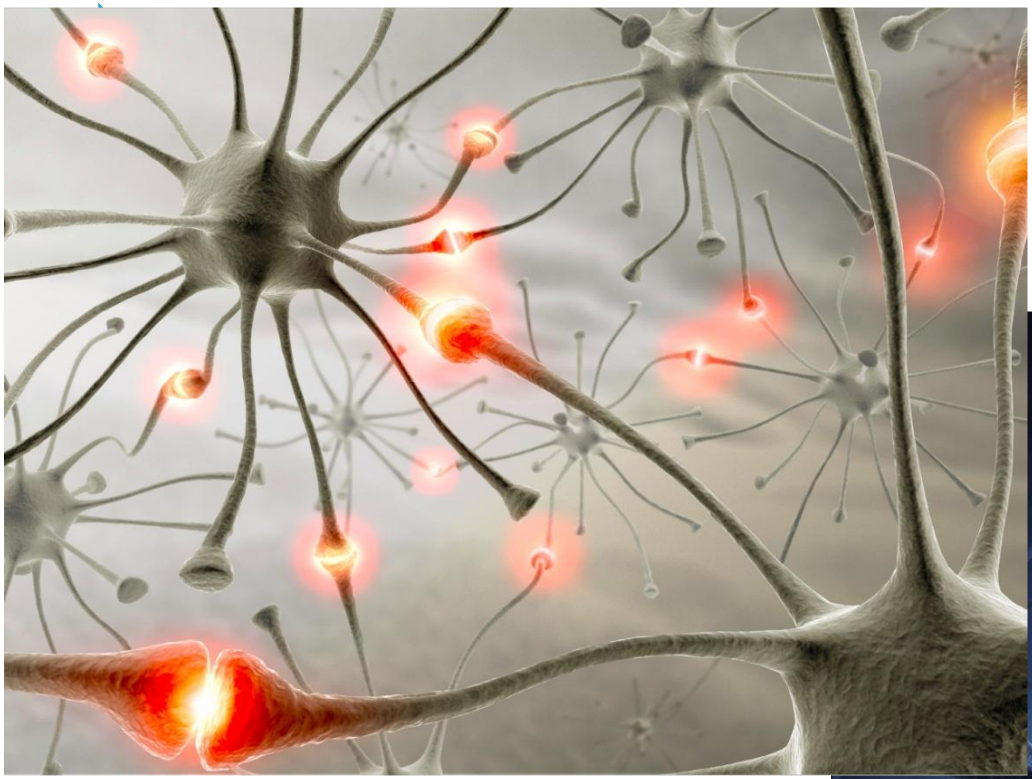
Disciplina 2016/2017

- 2C/1L Optoelectronică, structuri, tehnologii, circuite, OSTC
- **Minim 7 prezente curs + laborator**
- Curs – sl. Radu Damian
  - Joi 15-18, P5
  - E – 70% din nota
    - **20% test la curs**, saptamana 4-5?
  - probleme + (?1 subiect teorie) + (2p prez. Curs)
    - **2prez=0.5p**
  - toate materialele permise
- Laborator – sl. Daniel Matasaru
  - Joi 8-14 par
  - L – 15% din nota
  - C – 15% din nota

Orar 2016/2017

- Curs
  - Joi 15-18, P5
  - 2C ⇨ 3C
    - 14*2/3≈9.33
    - 9÷10 C

Scop 4



Sinapse
“inginerești”

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://rf-opto.etti.tuiasi.ro**
- Radu Damian, I Casian, D Matăsaru – „Comunicatii Optice" , Indrumar de laborator, 2005

Fotografii

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente **Observatii**

Finantare	Buget
Bursa	Fara Bursa

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5244

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente **Observatii**

Finantare	Buget
Bursa	Bursa de Studii

Date:

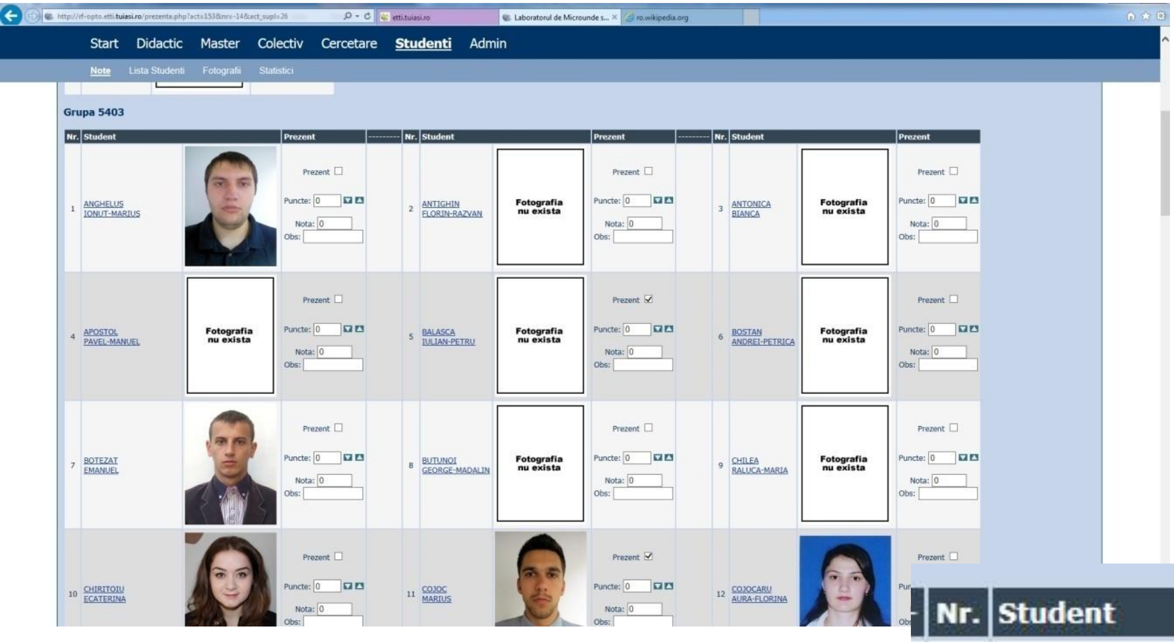
Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

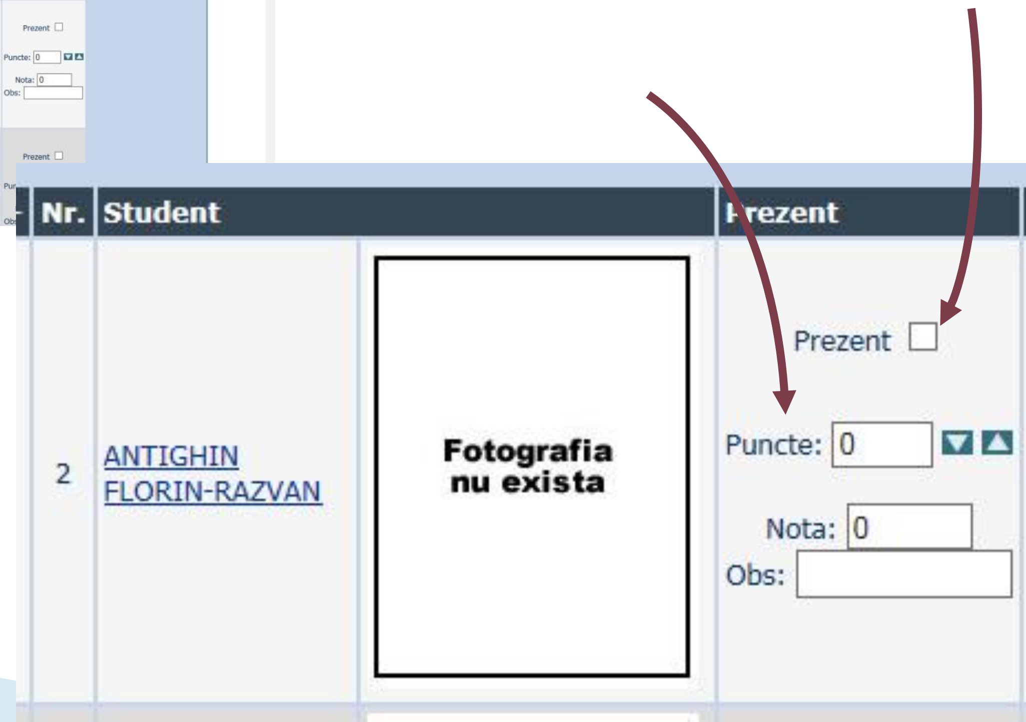
Acceseaza ca acest student

Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TW	Tehnologii Web					
	N	17/01/2014	Nota finala	10	-	
	A	17/01/2014	Colocviu Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

Fotografii


Start
Didactic
Master
Colectiv
Cercetare
Studenti
Admin
Note
Lista Studenti
Fotografii
Statistici
Grupa 5403
Nr.
Student
Prezent
ANGHELUS IONUT-MARIUS
ANTIGHIN FLORIN-RAZVAN
ANTONICA BIANCA
APOSTOL PAVEL-MANUEL
BALASCA IULIAN-PETRU
BOSTAN ANDREI-PETRICA
BOTEZAT EMANUEL
BUTUNOI GEORGE-MADALIN
CHILEA RALUCA-MARIA
CHIRITOIU ECATERINA
COJOC MARIUS
COJOCARU AURA-FLORINA
Fotografia nu exista
Puncte:
Nota:
Obs:


Nr.
Student
Prezent
2
ANTIGHIN FLORIN-RAZVAN
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:

Acces

- ~~Personalizat~~

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Acceseaza ca acest student

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	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

Examen

- subiecte **individuale**

Examen

- 2015/2016

Optoelectronica, structuri, tehnologii, circuite

Disciplina: OSTC (2015-2016)

Coordonator Disciplina: sl. dr. Radu-Florin Damian
Cod: DIS405M
Tip Disciplina: DIS; Disciplina Impusa, Disciplina de Specialitate
Credite: 4
An de Studiu: 4, **Sem.** 7

Activitati

Curs: Cadru Didactic: sl. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:
Laborator: Cadru Didactic: sl. dr. Petre-Daniel Matasaru, 1 Ore/Saptamana, Semigrupa, Orar:

Evaluare

Tip: **Colocviu**

A: 66%, (Examen/Colocviu)
B: 17%, (Activitate Seminar/Laborator/Proiect)
D: 17%, (Teme de casa/Lucrari de specialitate)

Note

Rezultate totale

Prezenta

Curs
Laborator

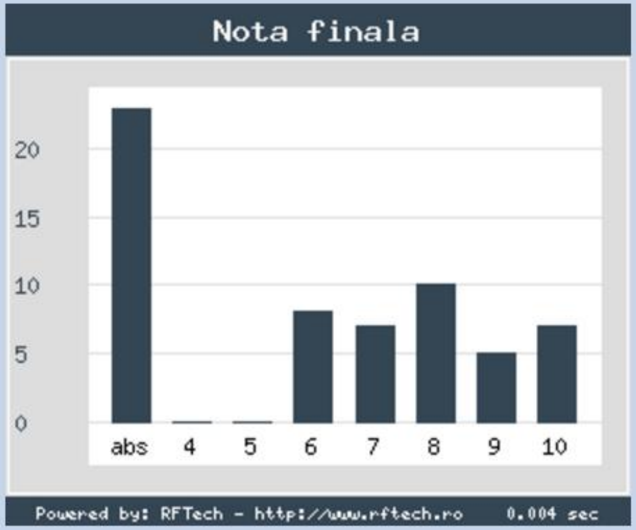
Liste

Studenti care nu pot intra in examen
Bonus-uri acumulate

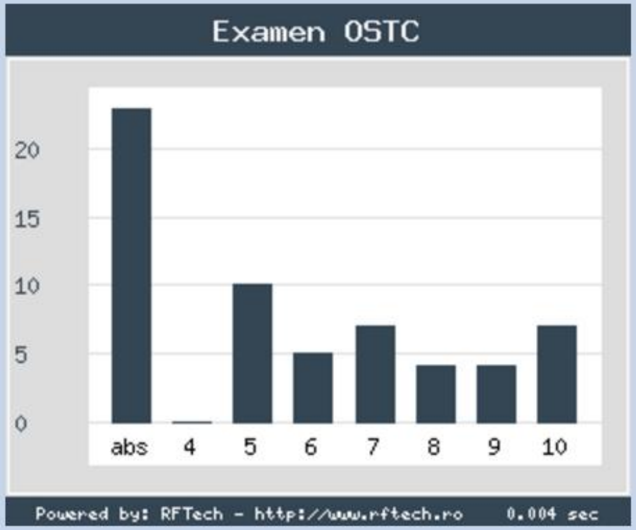
Note

Rezultate totale

Nota.	Numar
abs	23
4	0
5	0
6	8
7	7
8	10
9	5
10	7
TOTAL	60



Exam.	Numar
abs	23
4	0
5	10
6	5
7	7
8	4
9	4
10	7
TOTAL	60



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]

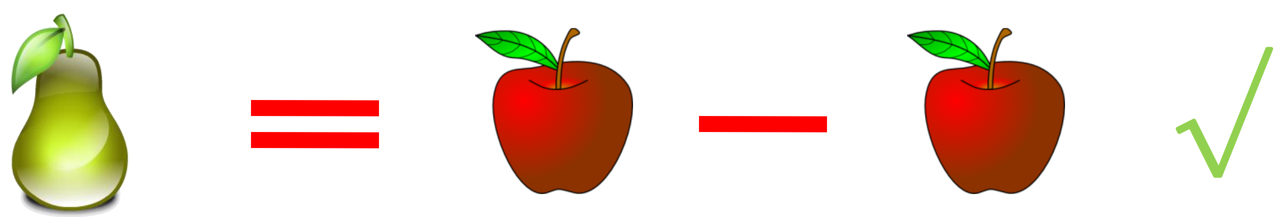
[x] + [dB] = [x]

Calculul atenuarii

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

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

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



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

Bonus

Disciplina: Optoelectronica, structuri, tehnologii, circuite
An: 2015/2016

Bonus-uri care se aplica la nota de la teza obtinute prin:
- prezenta la curs (0.5p / 3pr)
- 3 miniteste aplicate la curs (max. 3 X 1.5p)
- contributie la site rf-opto (foto <C5=1p, >C5=0.5p)

Nr.	Student	Grupa	Prezente curs	Bonus prezenta	Bonus foto	Bonus T1	Bonus T2	Bonus T3	Total Bonus	Obs.
1	CIOLPAN OCTAVIAN	5306	3	0.5					0.5	-
2	NITA COSTEL-CATALIN	5307	4	0.5	1				1.5	-
3	BARON BOGDAN-IONUT	5405	12	2	1	0.5		0.75	4.25	-

Prezenta

Curs
Laborator

Liste

Studenti care nu pot intra in examen
Bonus-uri acumulate

- **Minim** 7 prezente
- 0.5p/2(3)prez
- 3 teste
- foto

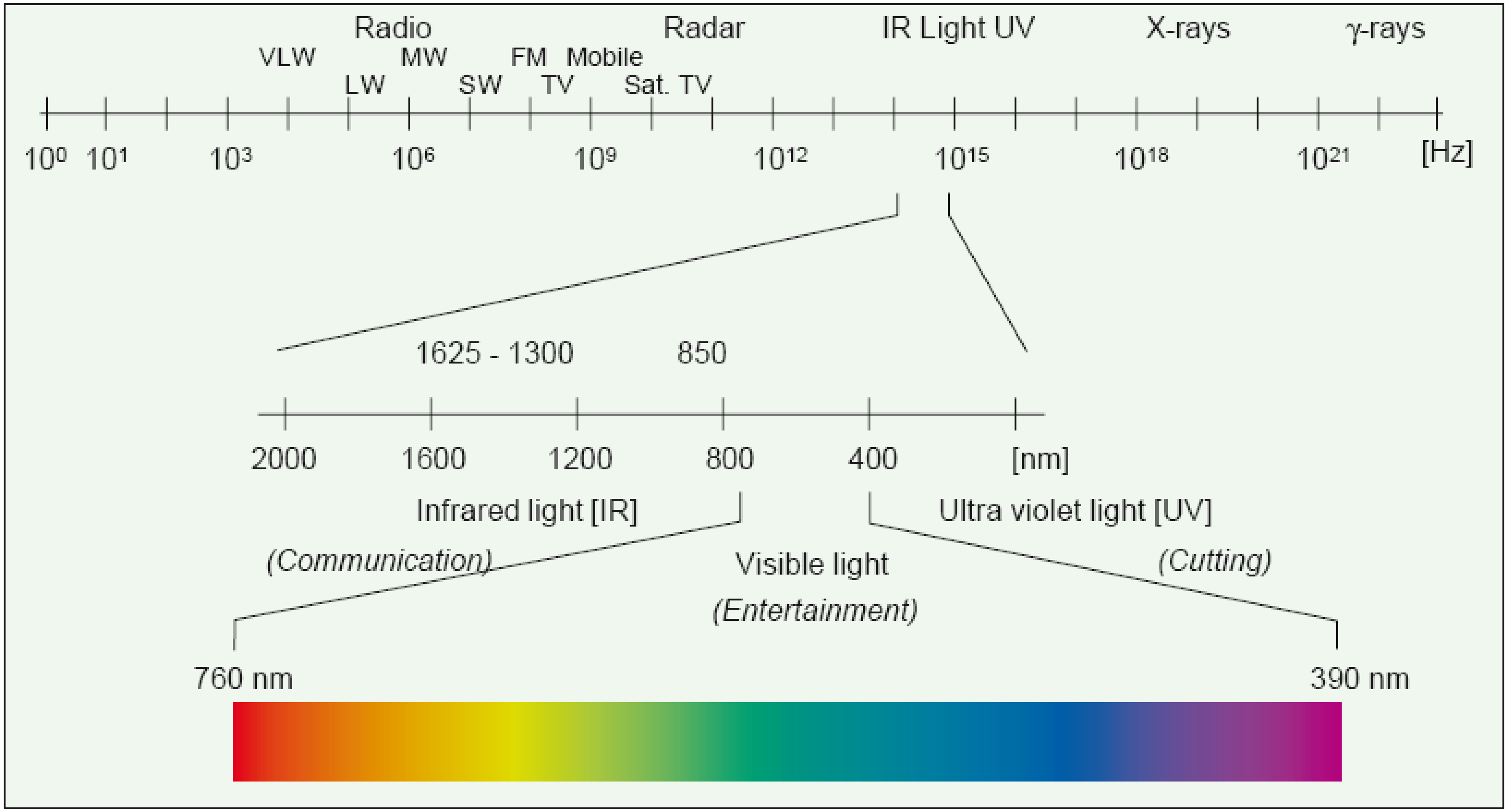
Introducere

Capitolul 1

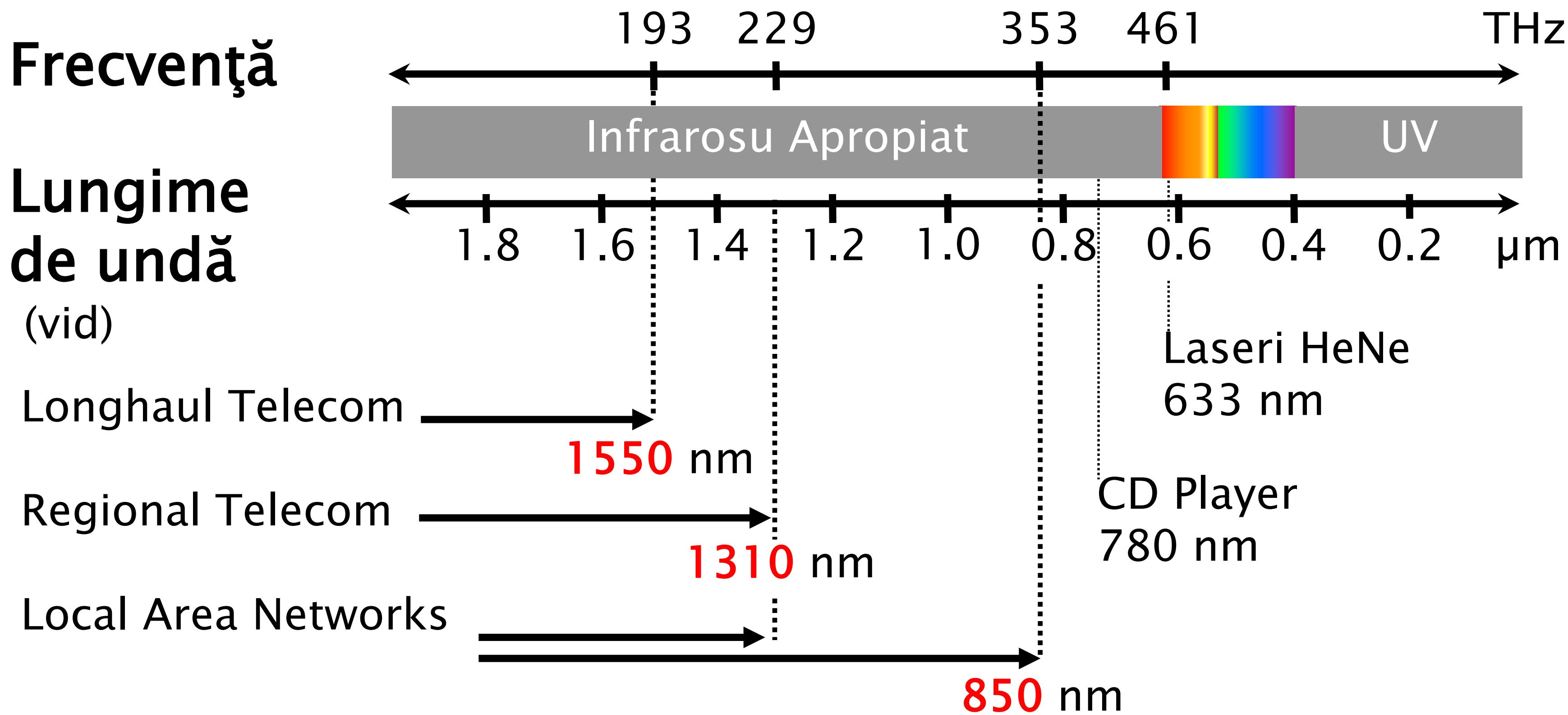
Aplicatii majore

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

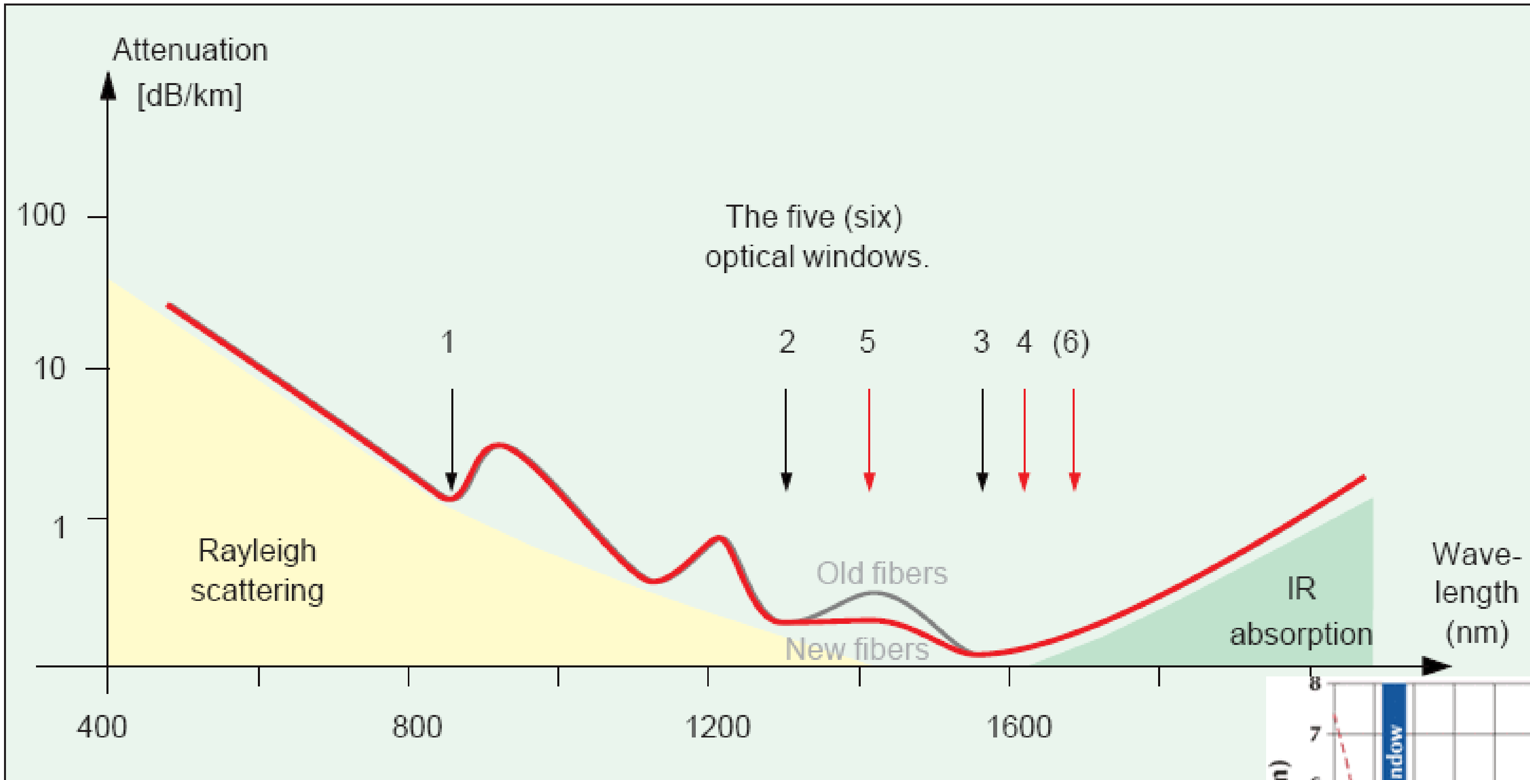
Spectrul electromagnetic

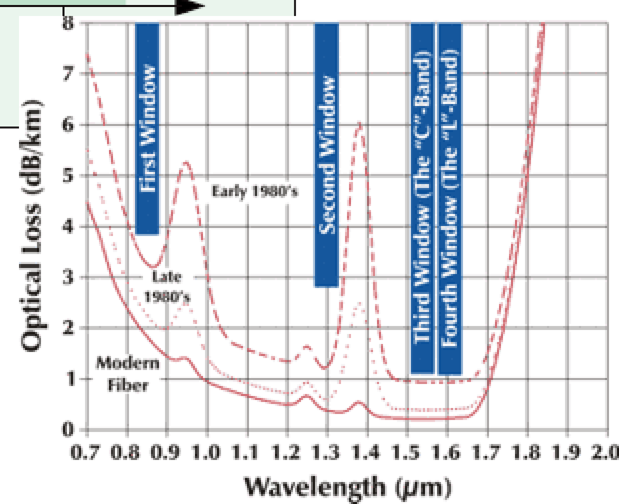


Benzi de lucru in comunicaţiile optice



Atenuarea în fibra optică (SiO_2)





850nm, 1310nm, 1550nm

Aplicatii majore

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

Premiul Nobel, Fizica, 2014

Aplicatii majore

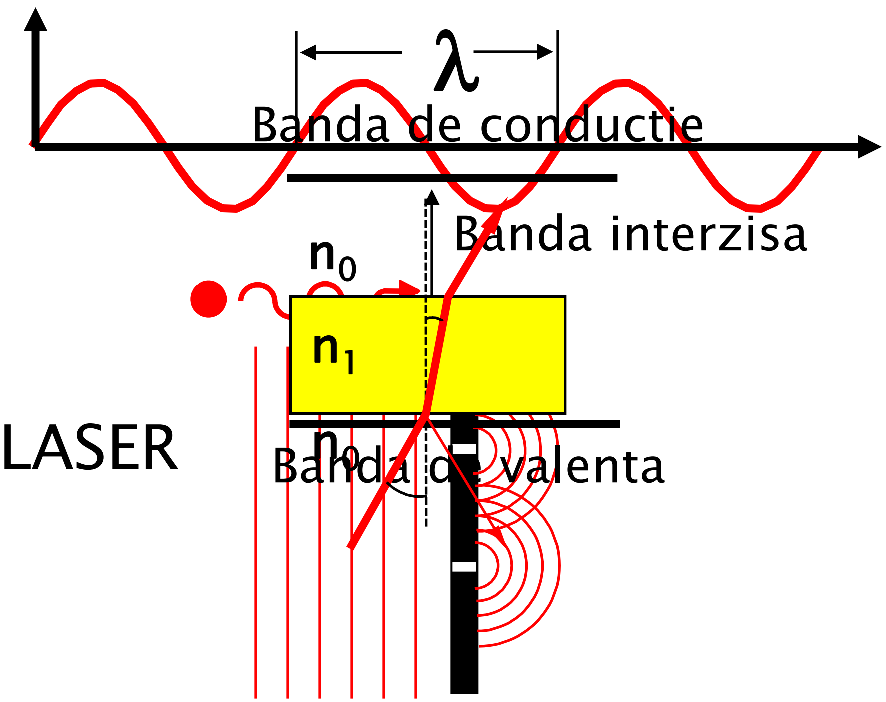
- Comunicatii
  - Infrarosu (InGaAsP)
- Vizibil
  - Spectru vizibil (GaAlAs)
- Iluminare
  - Putere ridicata, lumina alba (GaInN)

Modelarea luminii

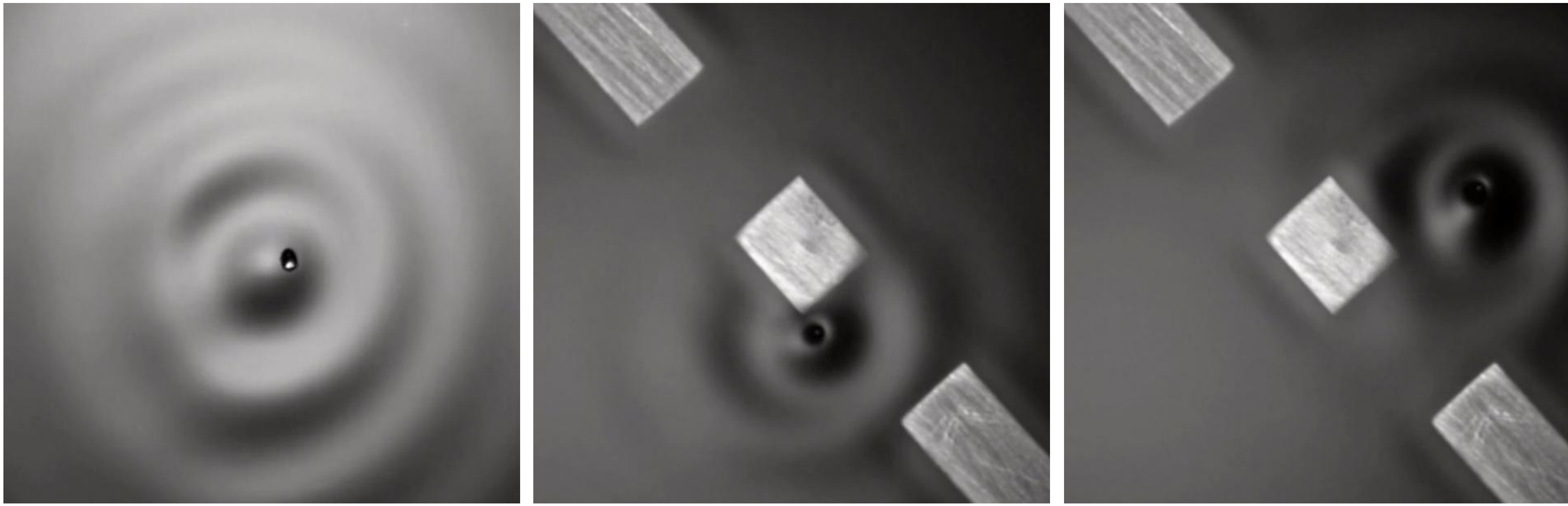
(tot) Capitolul 1

Modelarea luminii

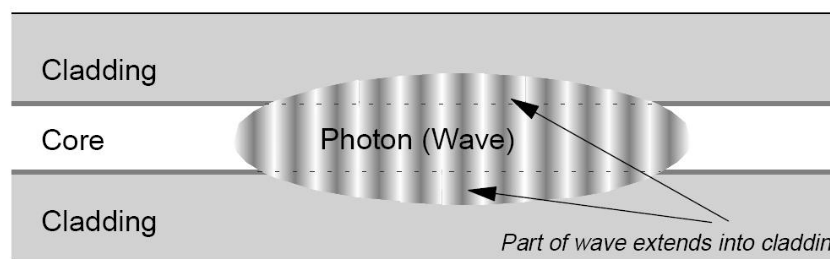
- Undă electromagnetică
  - Ecuaţiile lui Maxwell
  - λ, ε, ω, f
- Teoria cuantică
  - Benzi energetice $E = h\nu$
  - fotoni, emisie stimulată, LASER
- Optică geometrică
  - n, θ
  - raze de lumină
  - intuitivă



Modelare



Through the Wormhole
S02E07 How Does the Universe Work



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

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

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

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8 \; m/s$$

Câmpuri electromagnetic cu variaţie armonică în timp

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

- 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

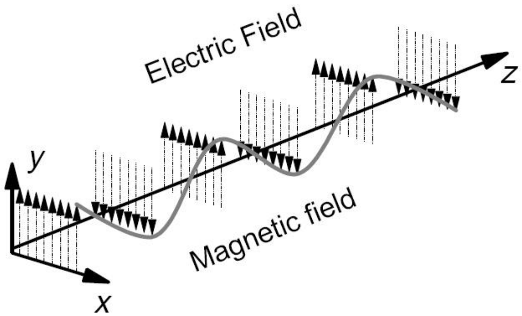
$$\nabla^2 E - \gamma^2 E = 0$$

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

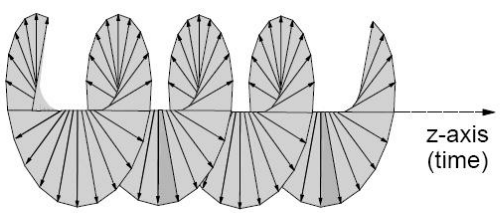
$$\gamma^2 = -\omega^2\varepsilon\mu + j\omega\mu\sigma$$

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_+ => A

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

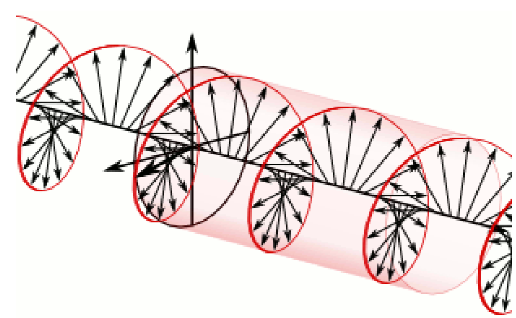
Camp armonic

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

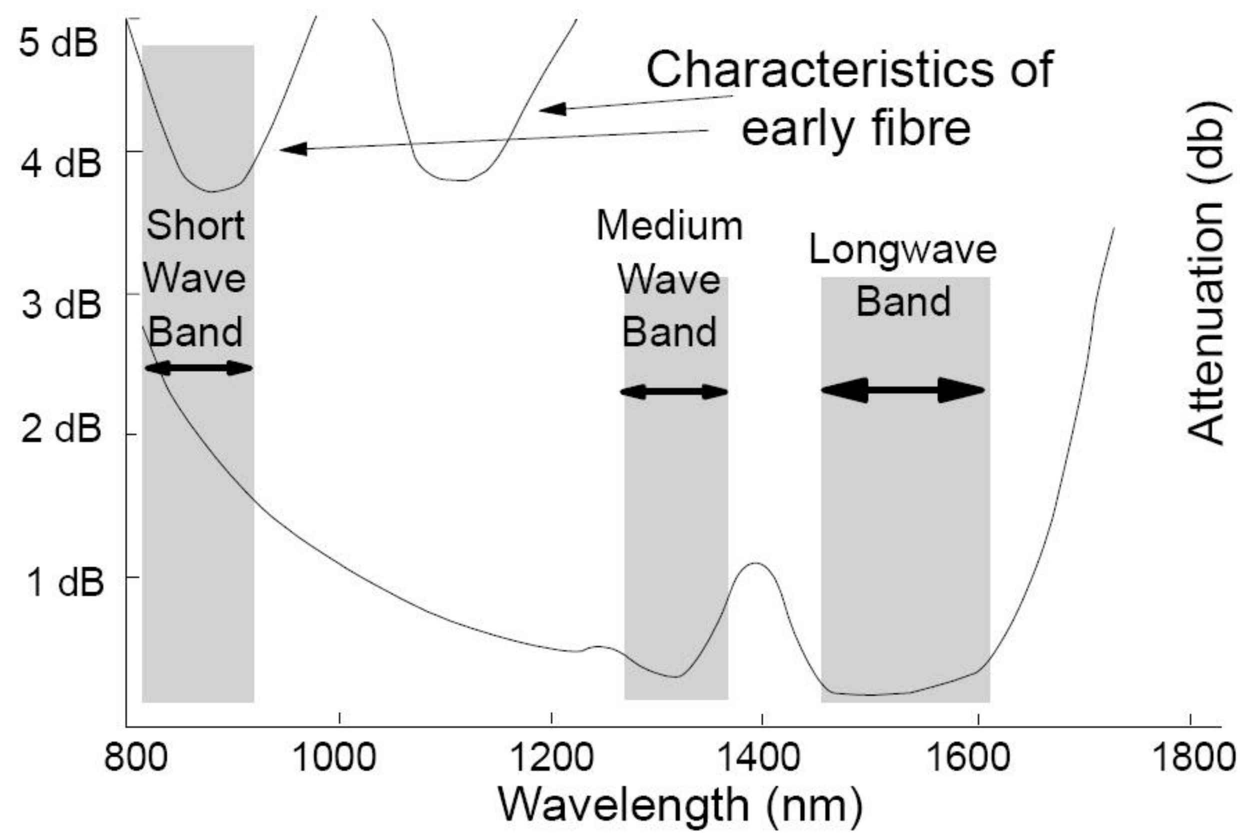
Amplitudine

Atenuare

Propagare (variatie in timp si spatiu)



Atenuarea pe 1 km in SiO_2



Atenuare

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

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

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

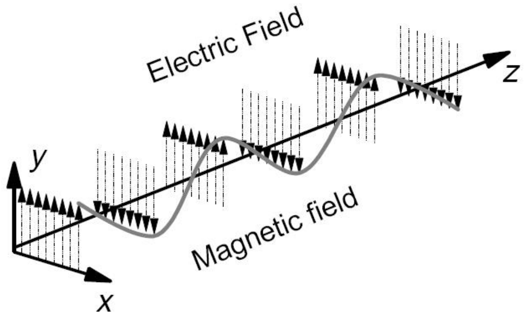
$$A[dB] = 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \left[e^{-2\alpha \cdot (z_2 - z_1)} \right]$$

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

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

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

Parametri de propagare



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

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

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

$$\eta = \frac{E_y}{H_x} = \sqrt{\frac{\mu}{\varepsilon}}$$ 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 $\quad v_g = \frac{dz}{dt} = \frac{d\omega}{d\beta}$ $\quad$ in medii dispersive unde $\beta = \beta(\omega)$

Parametri de propagare

- In vid

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\Omega \qquad v = v_g = c_0 \qquad c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8 \ m/s$$

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

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 $c = \frac{c_0}{n}$

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

Parametri, dependenta de mediu

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\Omega$$

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8 \ m/s$$

$n = 1$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\lambda_0 = \frac{2\pi}{\beta} = \frac{c_0}{f}$$

$$\eta = \frac{\eta_0}{n}$$

$$c = \frac{c_0}{n}$$

$n = \sqrt{\varepsilon_r}$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\lambda = \frac{c_0}{n \cdot f} = \frac{\lambda_0}{n}$$

$$\lambda = \lambda(n)$$
$$f = \text{indep.}$$

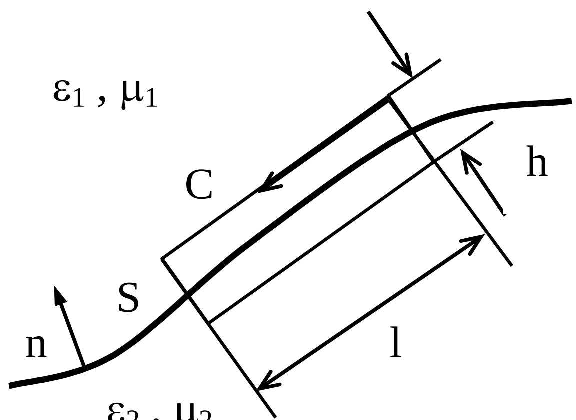
ITU G.692

"the allowed channel frequencies are based on a 50 GHz grid with the reference frequency at 193.10 THz"

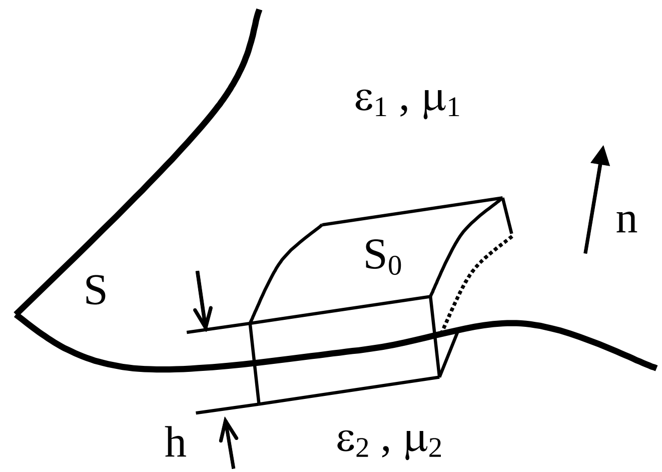
SI

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

Condiţii la limita de separaţie între două medii



a)



b)

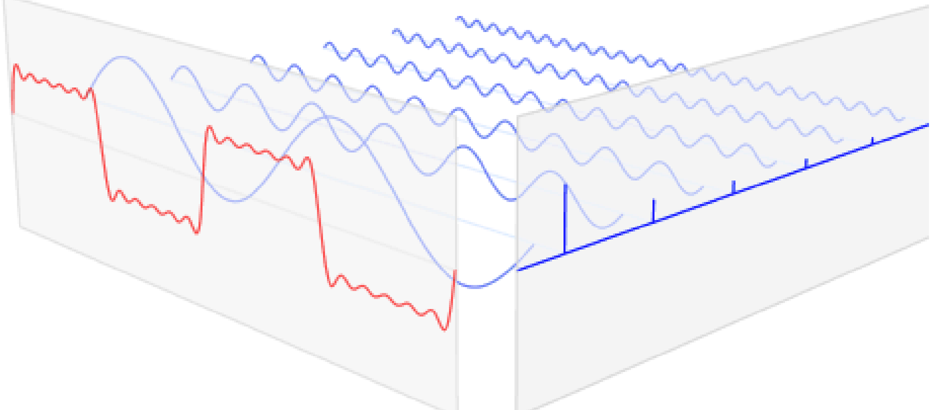
$$n \times \left(E_1 - E_2\right) = 0 \qquad n \cdot \left(D_1 - D_2\right) = \rho_S$$

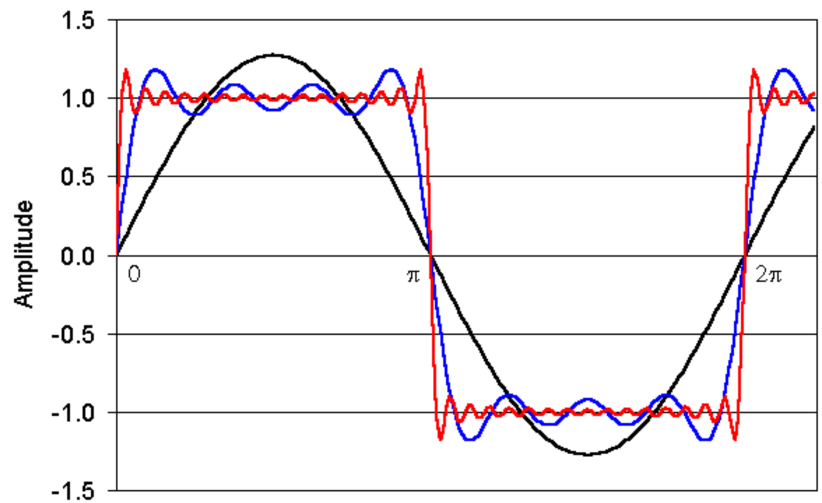
$$n \times \left(H_1 - H_2\right) = J_S \qquad n \cdot \left(B_1 - B_2\right) = 0$$

Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - semnale cu variaţie armonică în timp, transformata Fourier, spectru

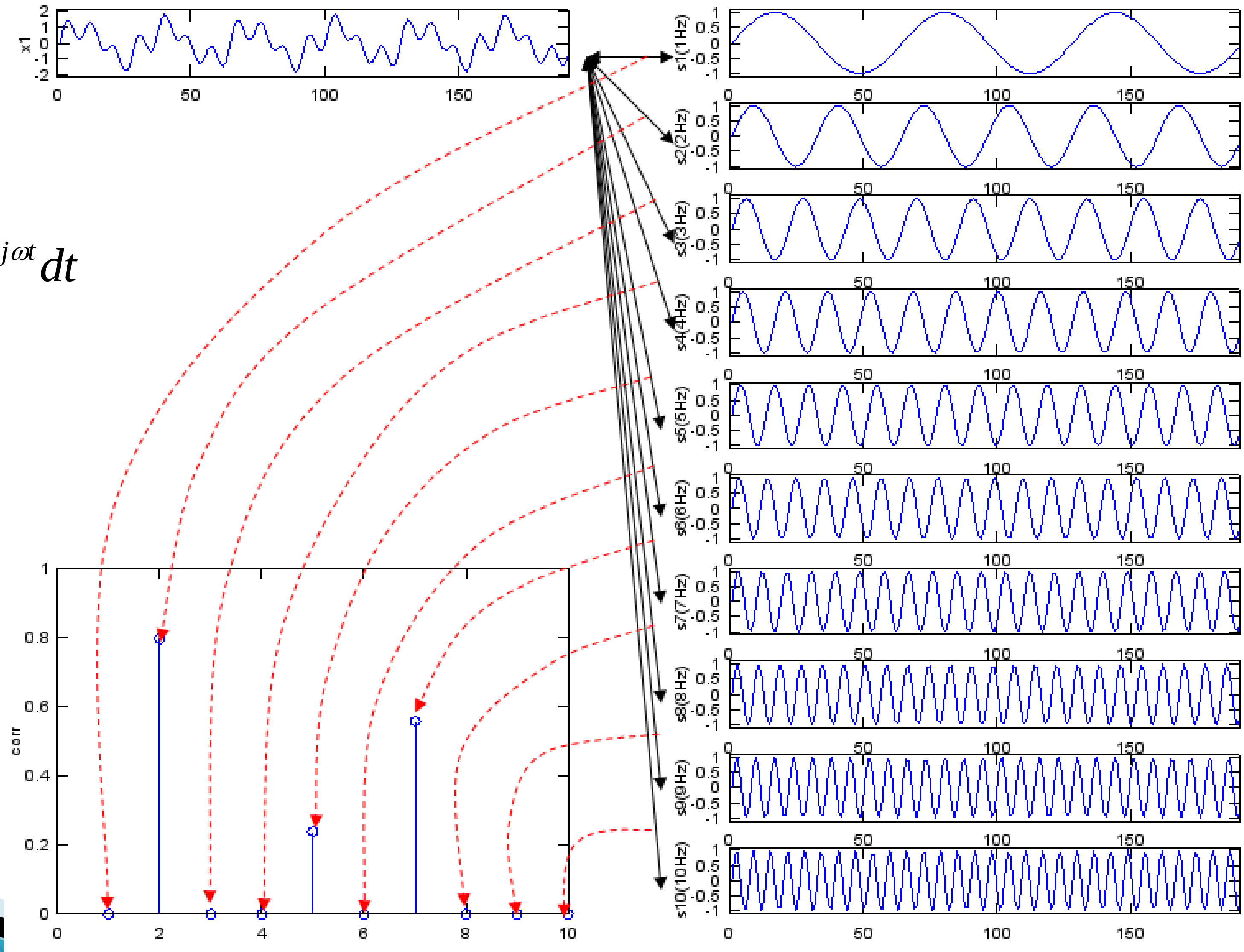
$$X = X_0 e^{j\cdot\omega\cdot t} \qquad \frac{\partial X}{\partial t} = j\cdot\omega\cdot X \qquad g(\omega) = \int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}dt \qquad f(t) = \int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$$



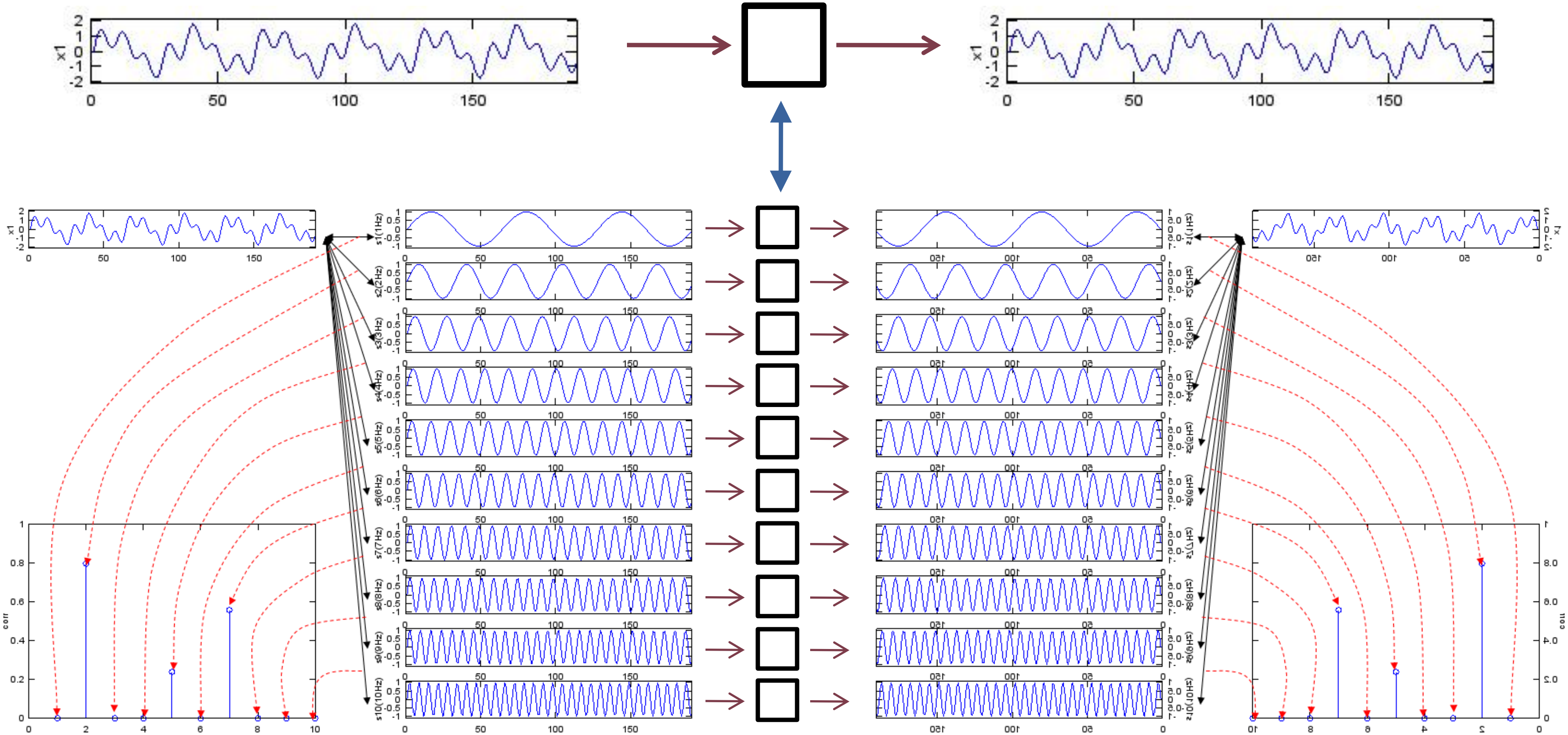


Modele matematice

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



Modele matematice

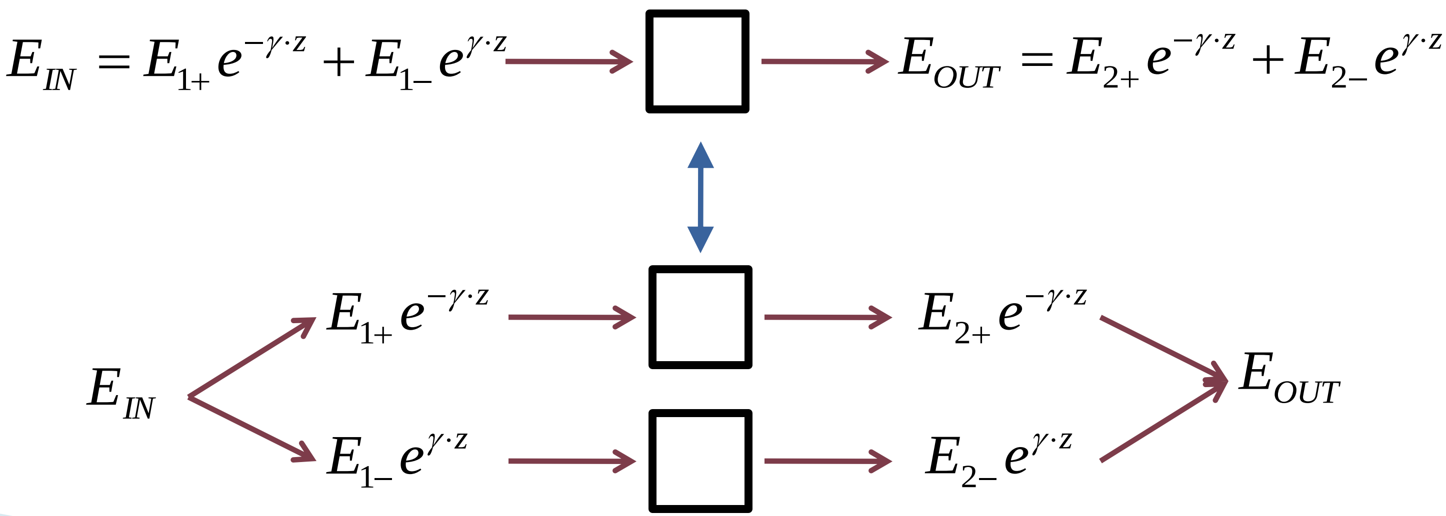


$$g(\omega)=\int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}dt \qquad f(t)=\int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}d\omega$$

Modele matematice

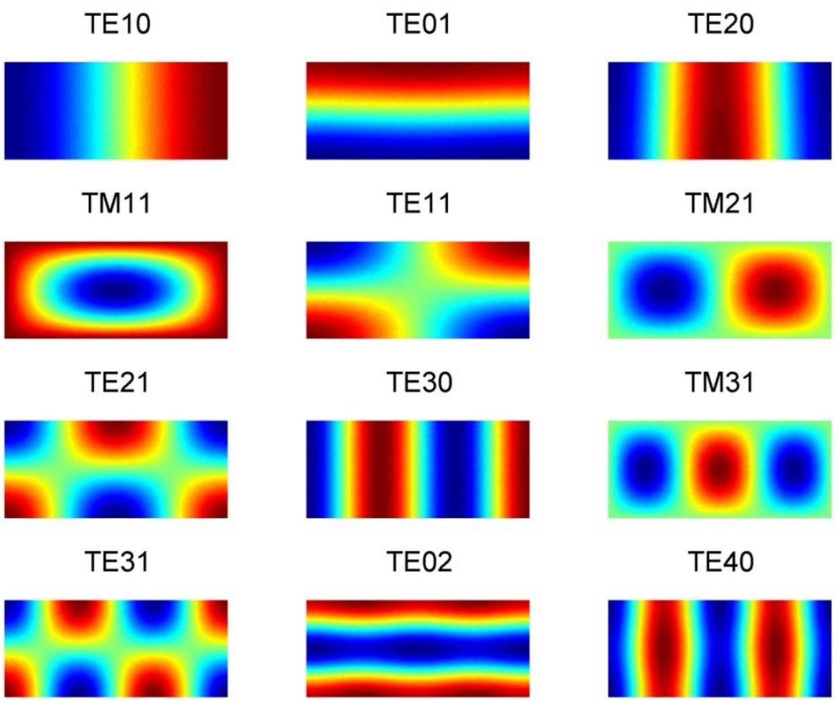
- cazuri particulare in care exista rezolvare analitica
  - unda
    - incidenta
    - reflectata
  - unda
    - directa
    - inversa

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



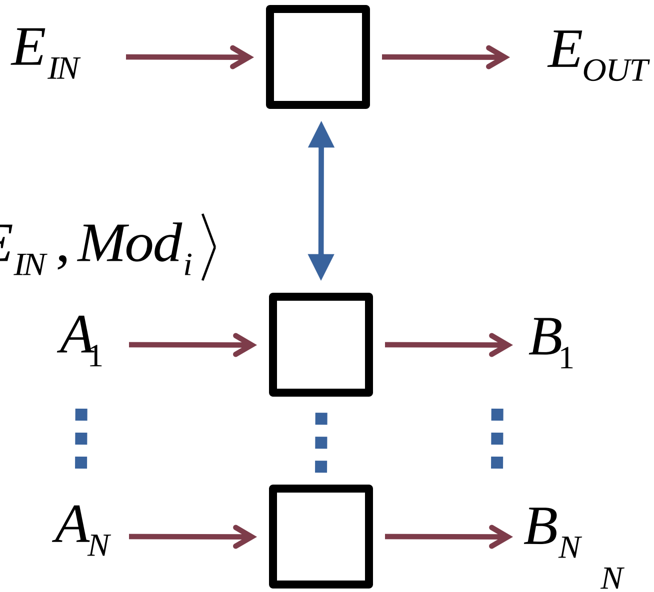
Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - moduri in medii delimitate



$$E = \sum_{1}^{\infty} A_i \cdot Mod_i \qquad A_i = \langle E, Mod_i \rangle$$

$$A_i = \langle E_{IN}, Mod_i \rangle$$



$$E_{OUT} = \sum_{1}^{N} B_i \cdot Mod_i$$

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)

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

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

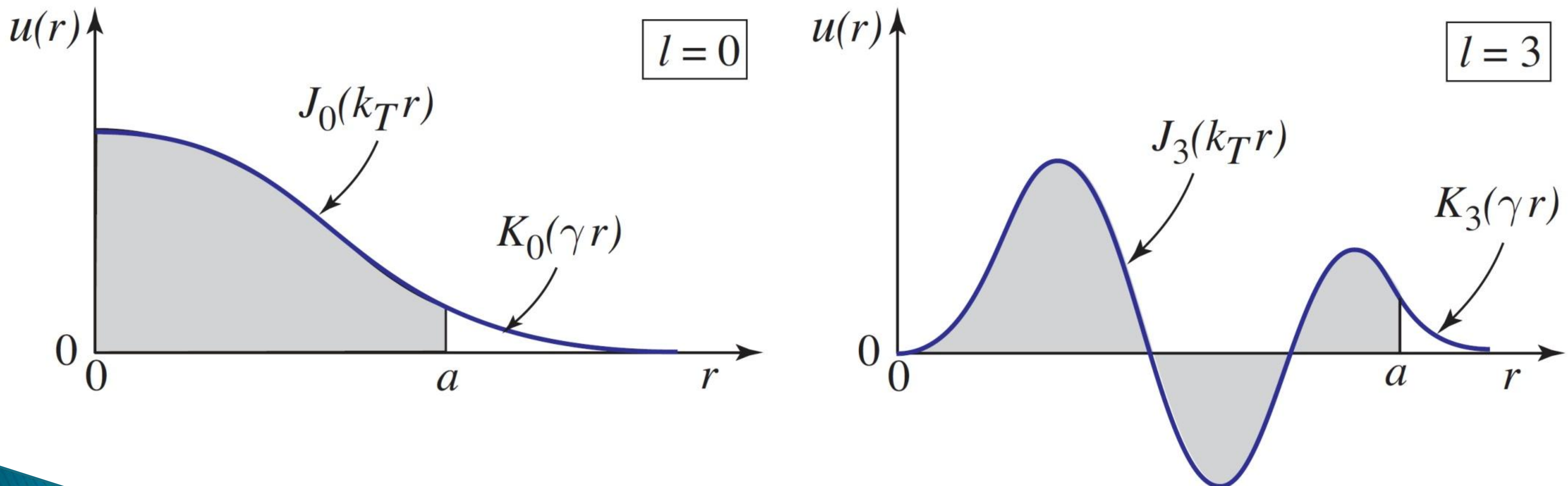
$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \left(k_T^2 - \frac{l^2}{r^2} \right) u = 0, \qquad r < a$$

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

Ghid cilindric dielectric

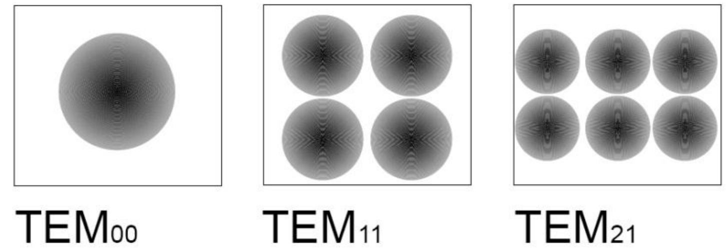
- solutii proportionale cu functii Bessel

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

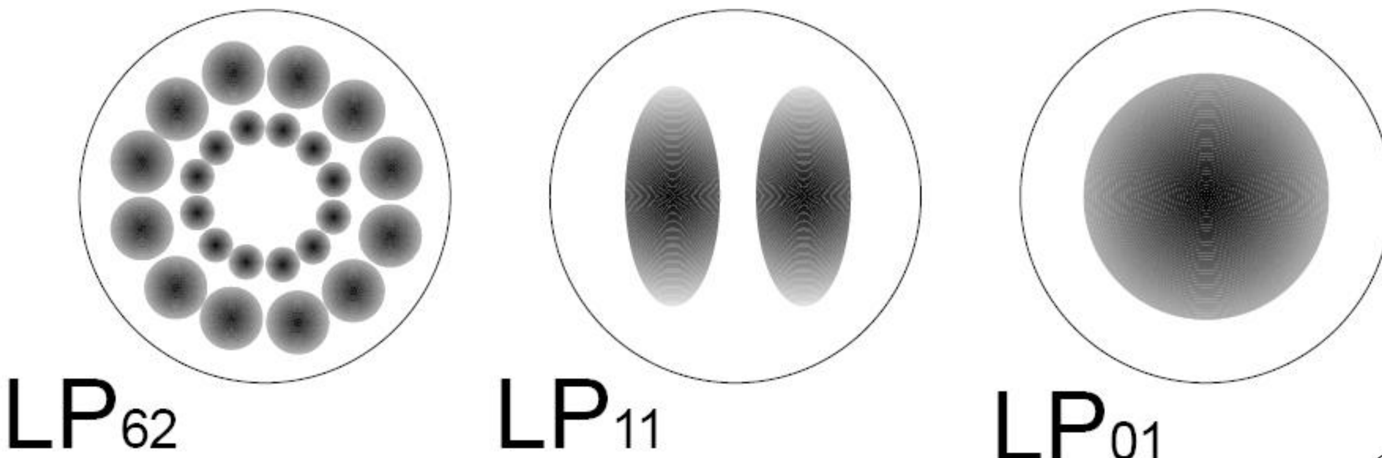


Moduri in fibra

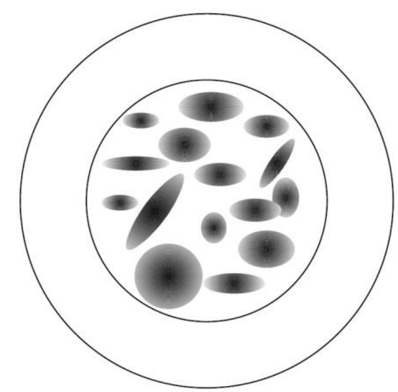
- Moduri in ghid rectangular



- Moduri linear polarizate in fibra



“Sparkle” pattern



Dispersia

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

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

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

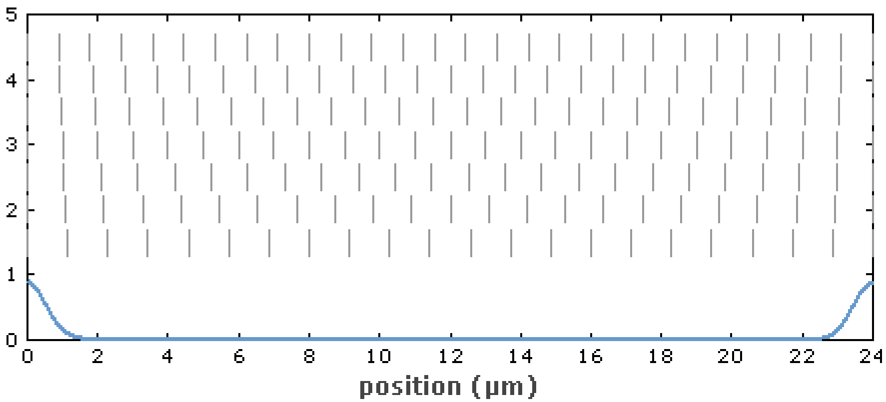
$$D = \frac{d\tau}{d\lambda} = \frac{1}{c}\left(\frac{dn}{d\lambda} - \lambda \frac{d^2 n}{d\lambda^2} - \frac{dn}{d\lambda}\right) = -\frac{\lambda}{c}\frac{d^2 n}{d\lambda^2} \quad (s/m^2)$$

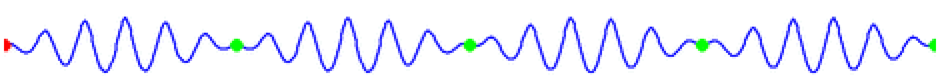
- Dispersia se exprima de obicei in **ps/nm/km** si permite aflarea intarzierilor aparute intre "moduri" (latirea impulsurilor) pentru o anumita latime spectrala si o anumita distanta parcursa

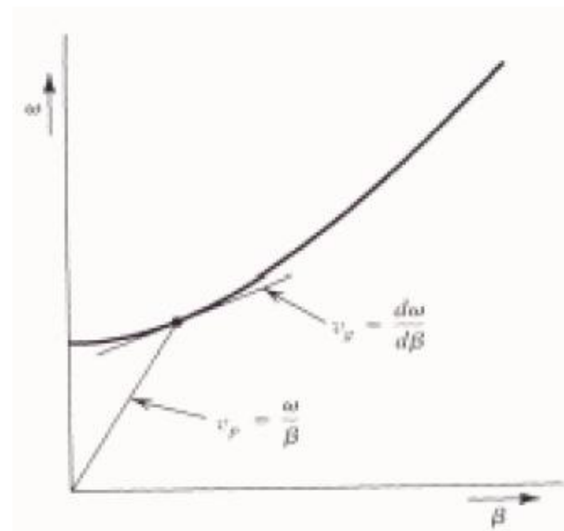
$$\Delta\tau = D \cdot \Delta\lambda \cdot L$$

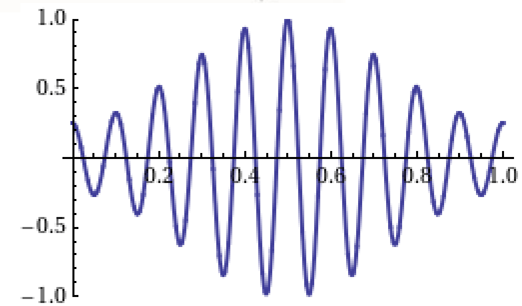
Viteze de grup si faza

- Viteza de faza – viteza virtuala cu care circula punctul cu o anumita faza
- Viteza de grup – viteza cu care circula informatia (energia) – in medii cu dispersie normala

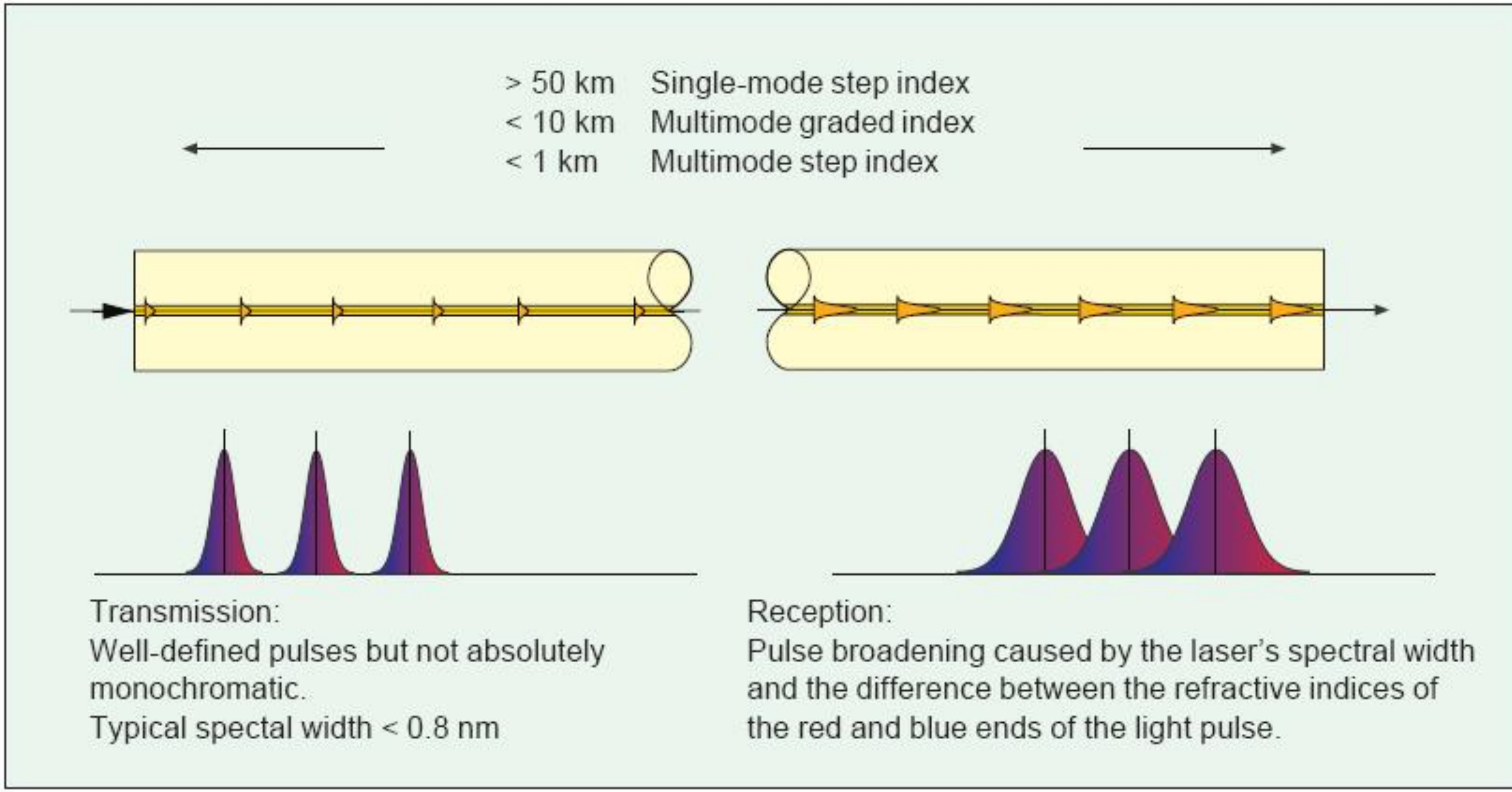








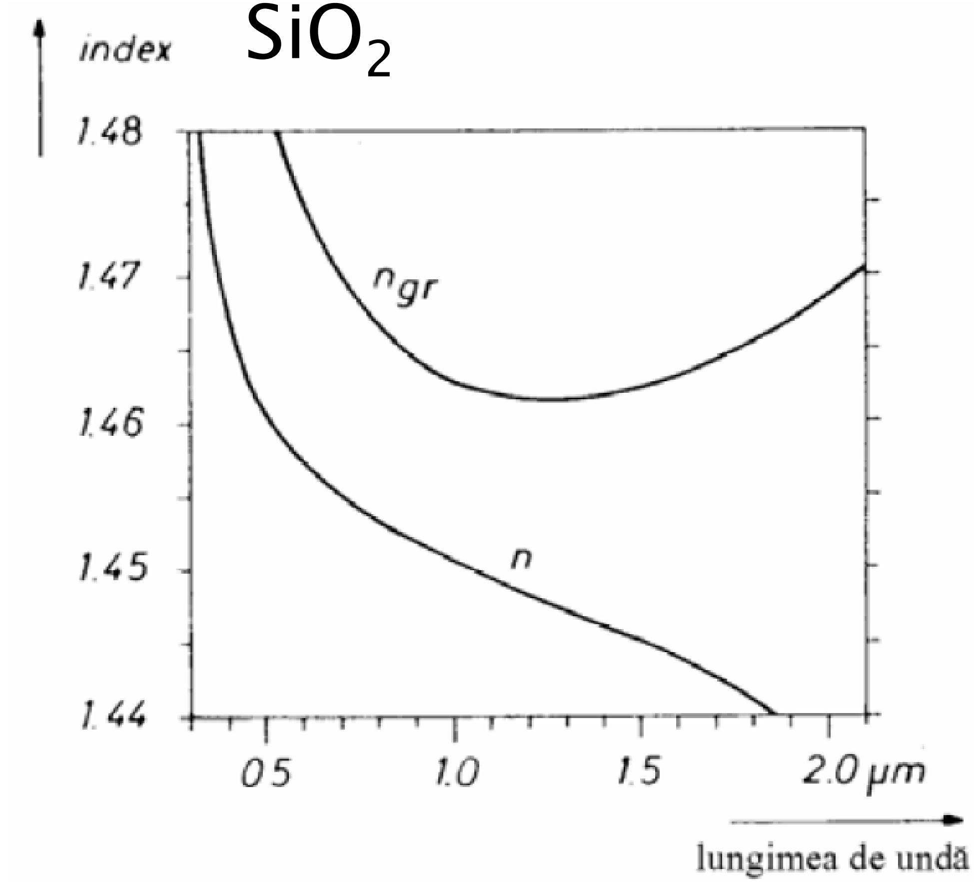
Dispersie


> 50 km Single-mode step index
< 10 km Multimode graded index
< 1 km Multimode step index
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.

Dispersie normala

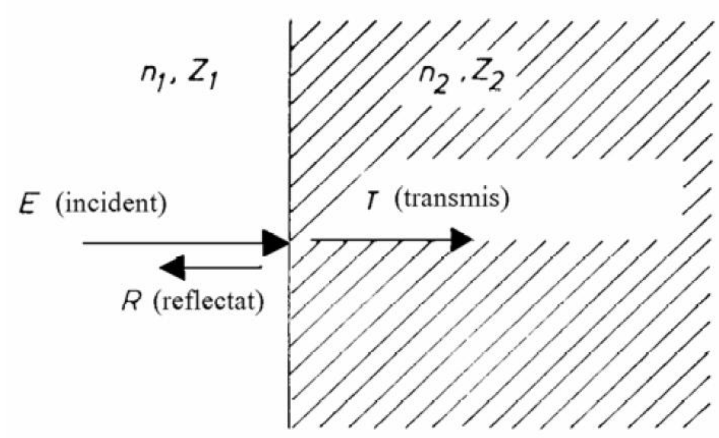
$$n_{gr} = n - \lambda \frac{dn}{d\lambda}$$

$$D = \frac{d\tau}{d\lambda} = \frac{1}{c} \cdot \frac{d n_{gr}}{d\lambda}$$



Transmisia puterii intre medii

- incidenta normala
- reflexia in amplitudine



$$Z = \frac{Z_0}{n} \qquad \Gamma = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{n_1 - n_2}{n_1 + n_2}$$

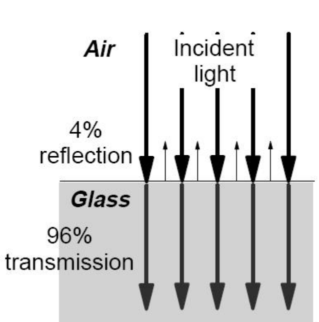
- densitatea de putere proportionala cu patratul amplitudinii câmpului

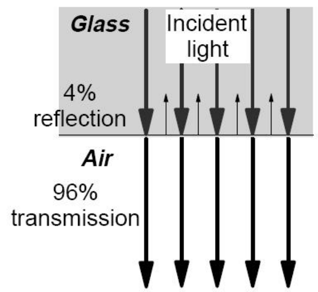
$$r = \left(\frac{n_1 - n_2}{n_1 + n_2} \right)^2 \qquad t = \left(\frac{2n_1}{n_1 + n_2} \right)^2$$

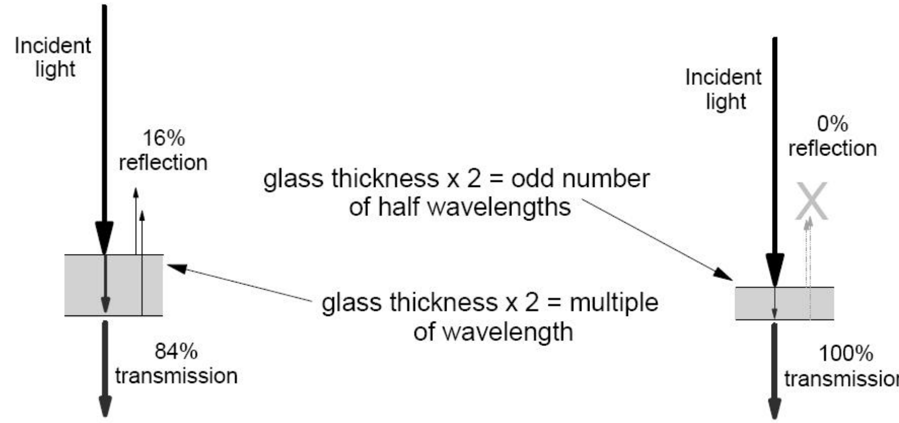
- interfata aer-sticla (n_1 = 1, n_2 = 1.5)

$$r = 0.04 = 4\%$$

Transmisia printr-o lamela

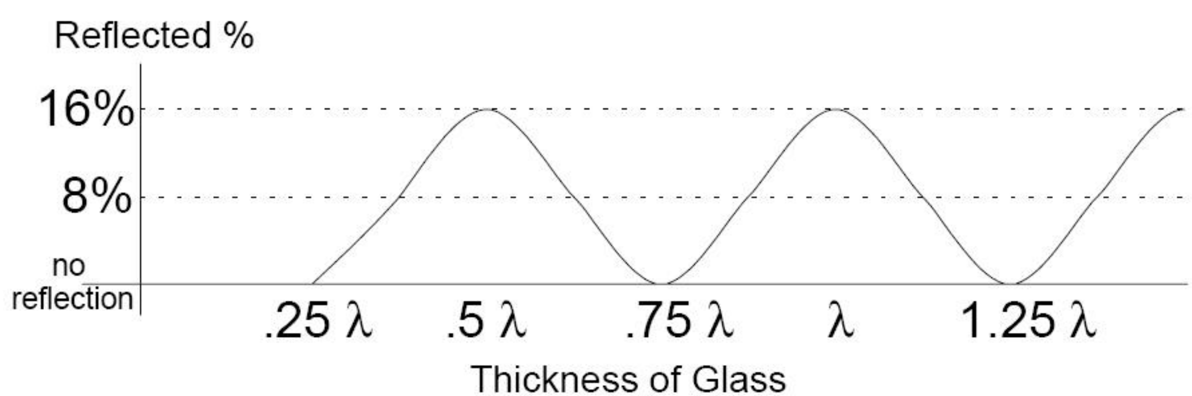






$$\Gamma = \frac{1.5-1}{1.5+1} = 0.2; \quad r = \Gamma^2 = 0.04 = 4\% \quad \Gamma_{max} = 0.2 + 0.2; \quad r_{max} = \Gamma_{max}^2 = 0.16 = 16\%$$

- apare interferenta intre diversele unde reflectate
- se aduna campurile nu puterile
- lamele antireflexive

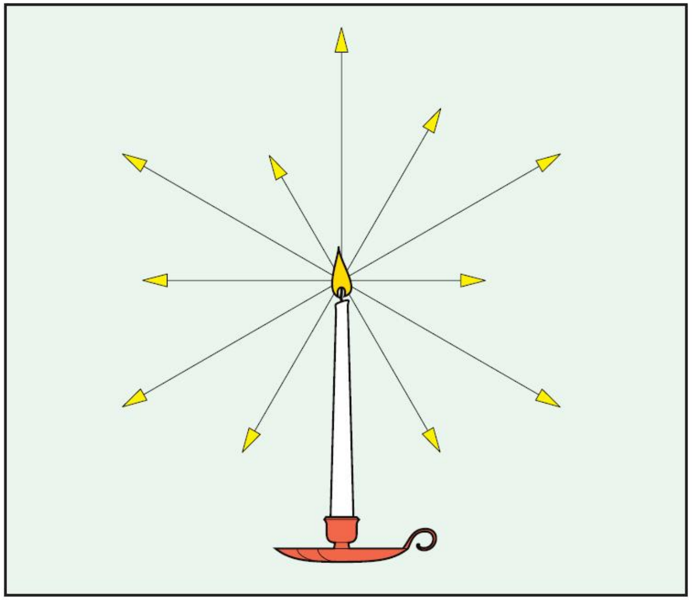


Optică geometrică

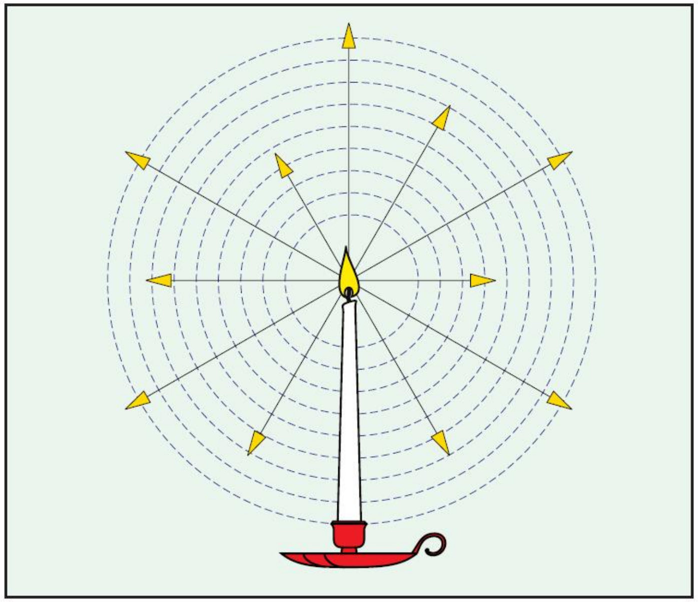
(tot) Capitolul 2

Raze de lumina

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



- Energia luminoasa descreste invers proportional cu patratul distantei fata de sursa (energia se imparte uniform pe suprafata intregii sfere)



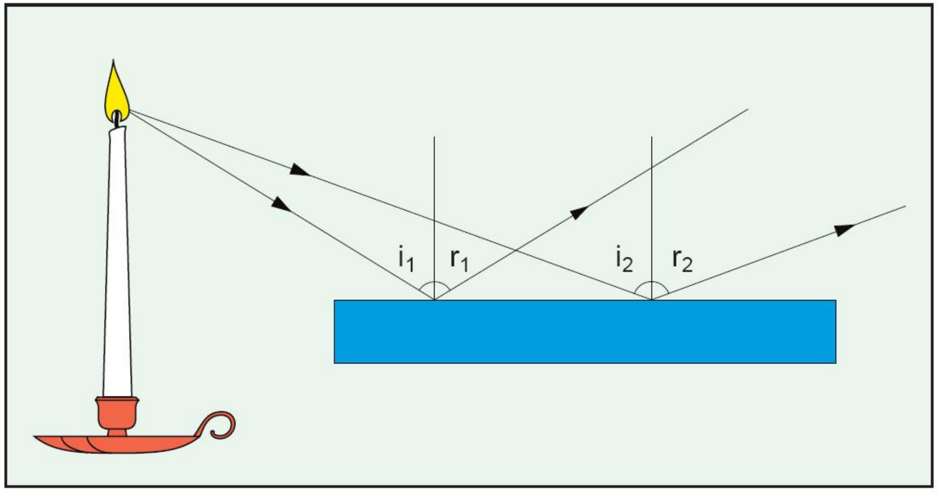
$$P = \frac{P_0}{r^2}$$

Reflexia luminii

- la suprafata de separatie dintre doua medii, (o parte din) lumina se intoarce in mediul de incidenta
- unghiul facut de raza incidenta cu normala (ϕ_i) este egal cu unghiul facut de raza reflectata cu normala (ϕ_r)

- Legea reflexiei

$$\phi_i = \phi_r$$

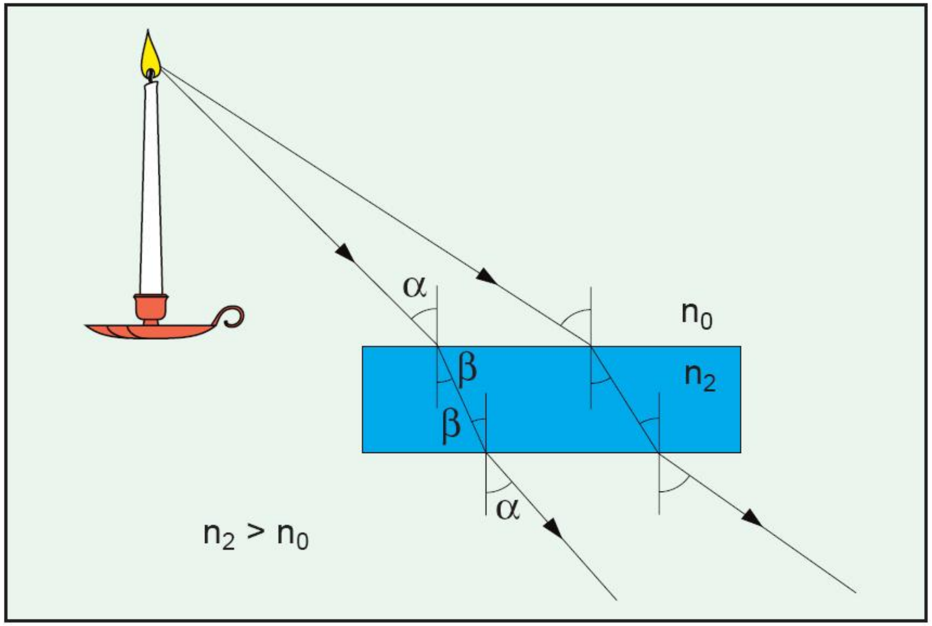


Refractia luminii

- la suprafața de separație dintre doua medii, (o parte din) lumina se (poate) propaga in mediul de transmisie sub un unghi diferit de unghiul incident
- la trecerea in medii mai “dense” (optic) lumina se apropie de normala
- la trecerea in medii mai “puțin dense” (optic) lumina se depărtează de normala
- Legea lui Snell (a refracției)

$$n_1 \cdot \sin \phi_i = n_2 \cdot \sin \phi_R$$

ϕ_i – unghi incident (in n_1)
ϕ_R – unghi de refracție (in n_2)



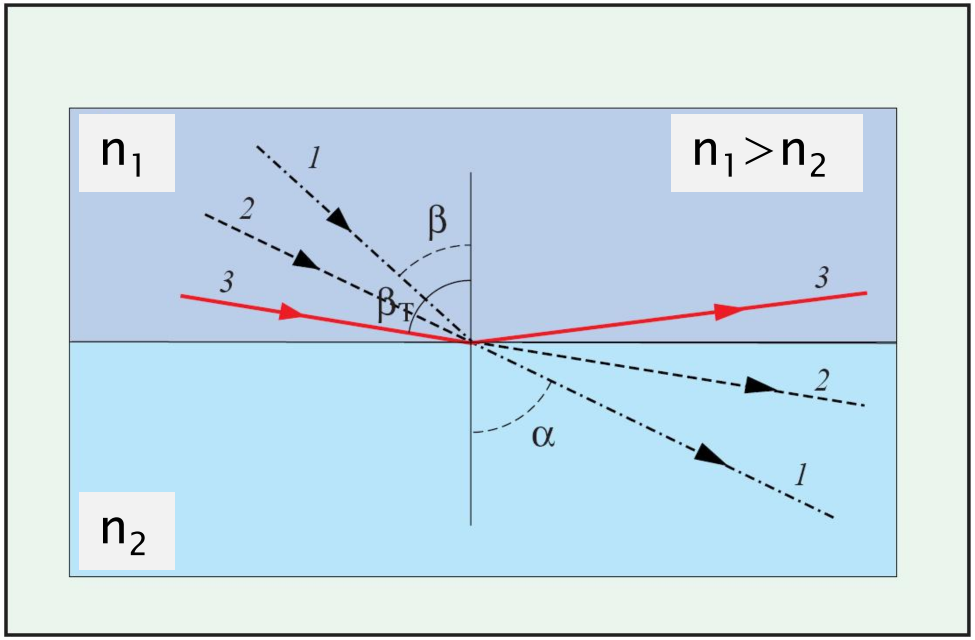
Reflexia totala

- 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

$$n_1 > n_2; \quad \phi_R = 90°$$

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

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

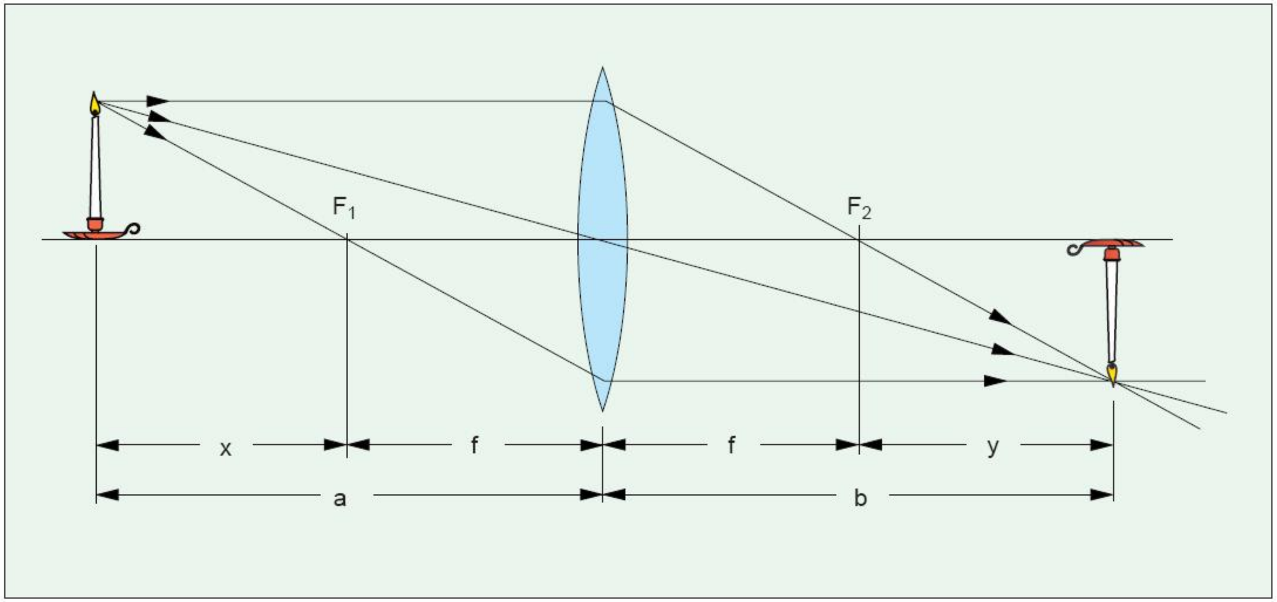


Lentile

- Razele de lumina paralele sunt concentrate intr-un punct numit focar, aflat la **distanta focala** de planul lentilei
- O sursa omnidirectionala pozitionata in focar va permite obtinerea unui fascicul paralel

$$\frac{1}{a}+\frac{1}{b}=\frac{1}{f}$$

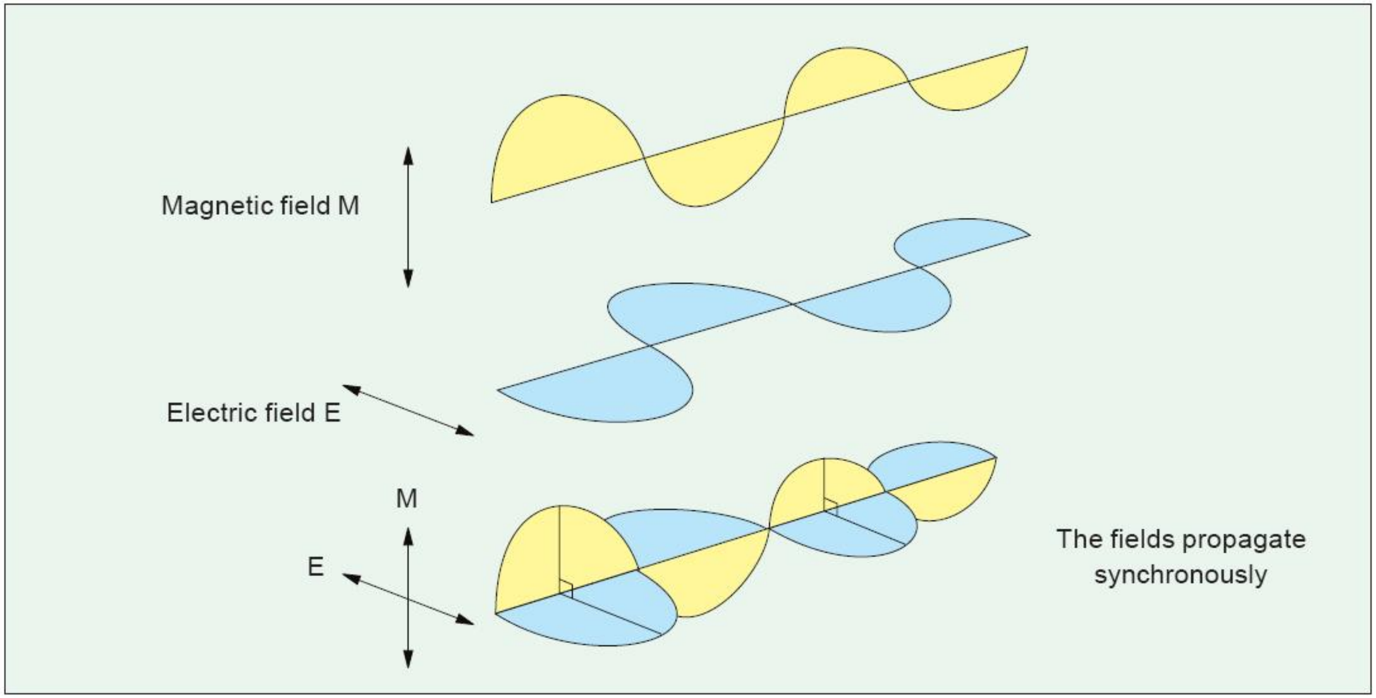
$$x \cdot y = f^2$$

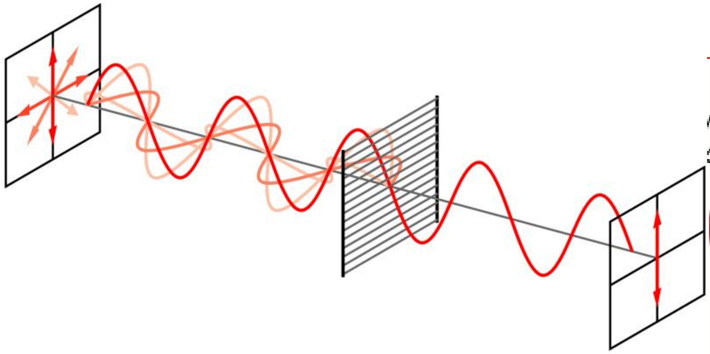


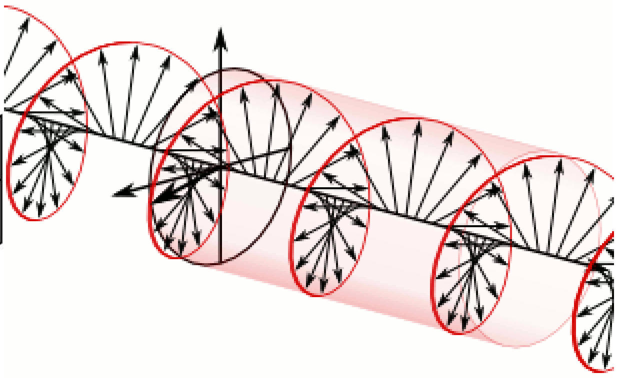
Lumina ca undă electromagnetică

(tot) Capitolul 2

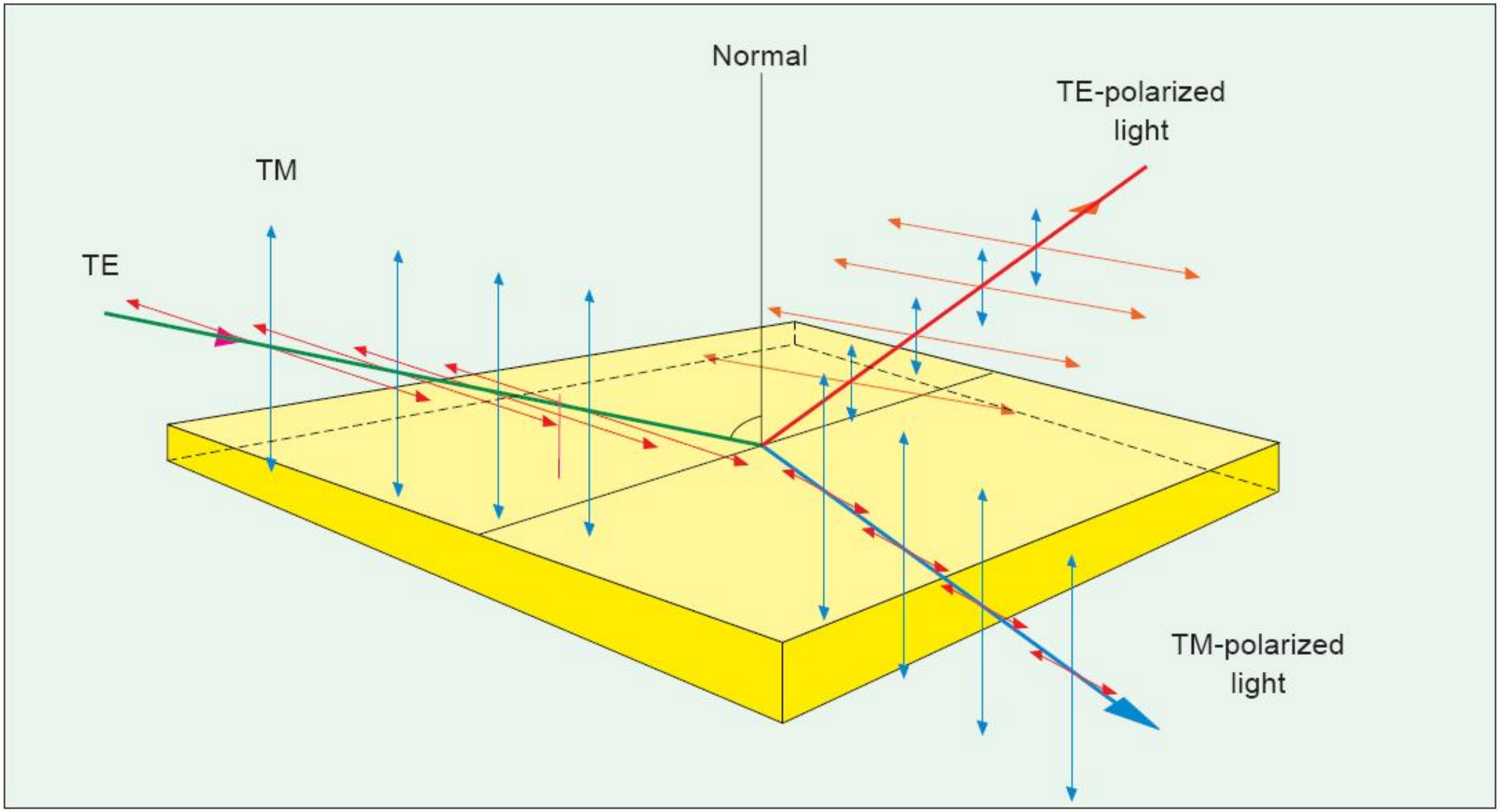
Polarizarea luminii



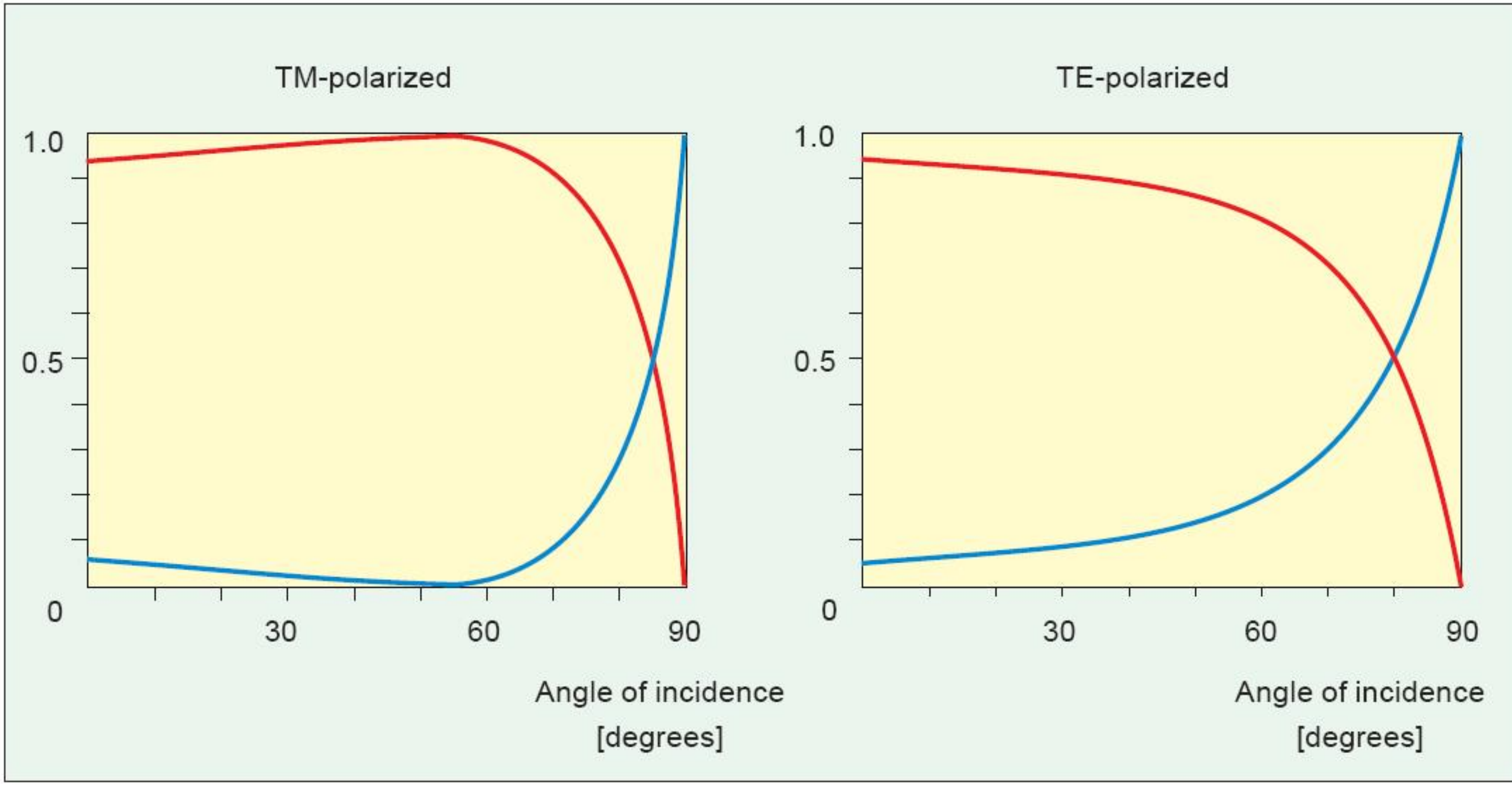




Polarizarea luminii



Polarizarea luminii



(revenire) Polarizarea luminii

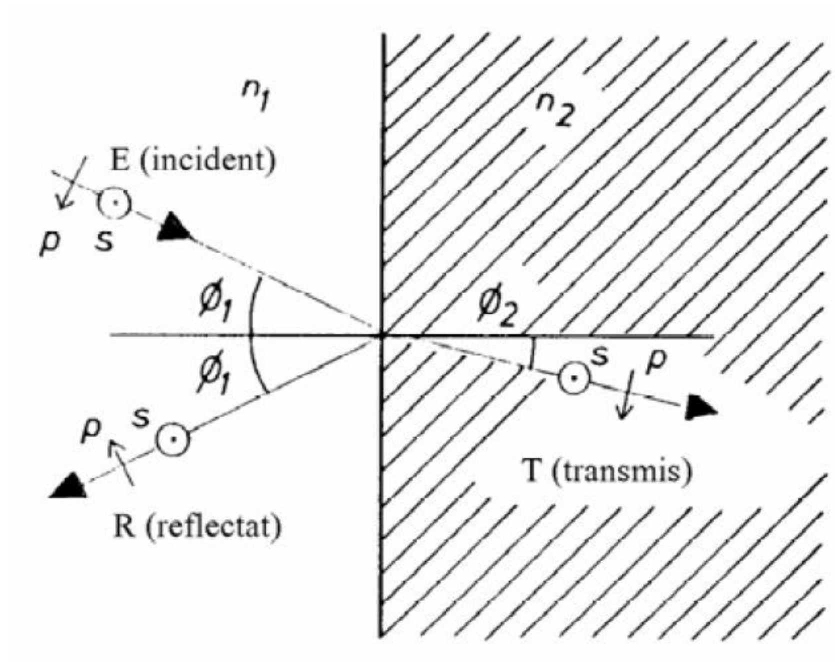
- incidenta oblica
- reflexiile in amplitudine a campului:

$$r_s = -\frac{\sin(\phi_1 - \phi_2)}{\sin(\phi_1 + \phi_2)}$$

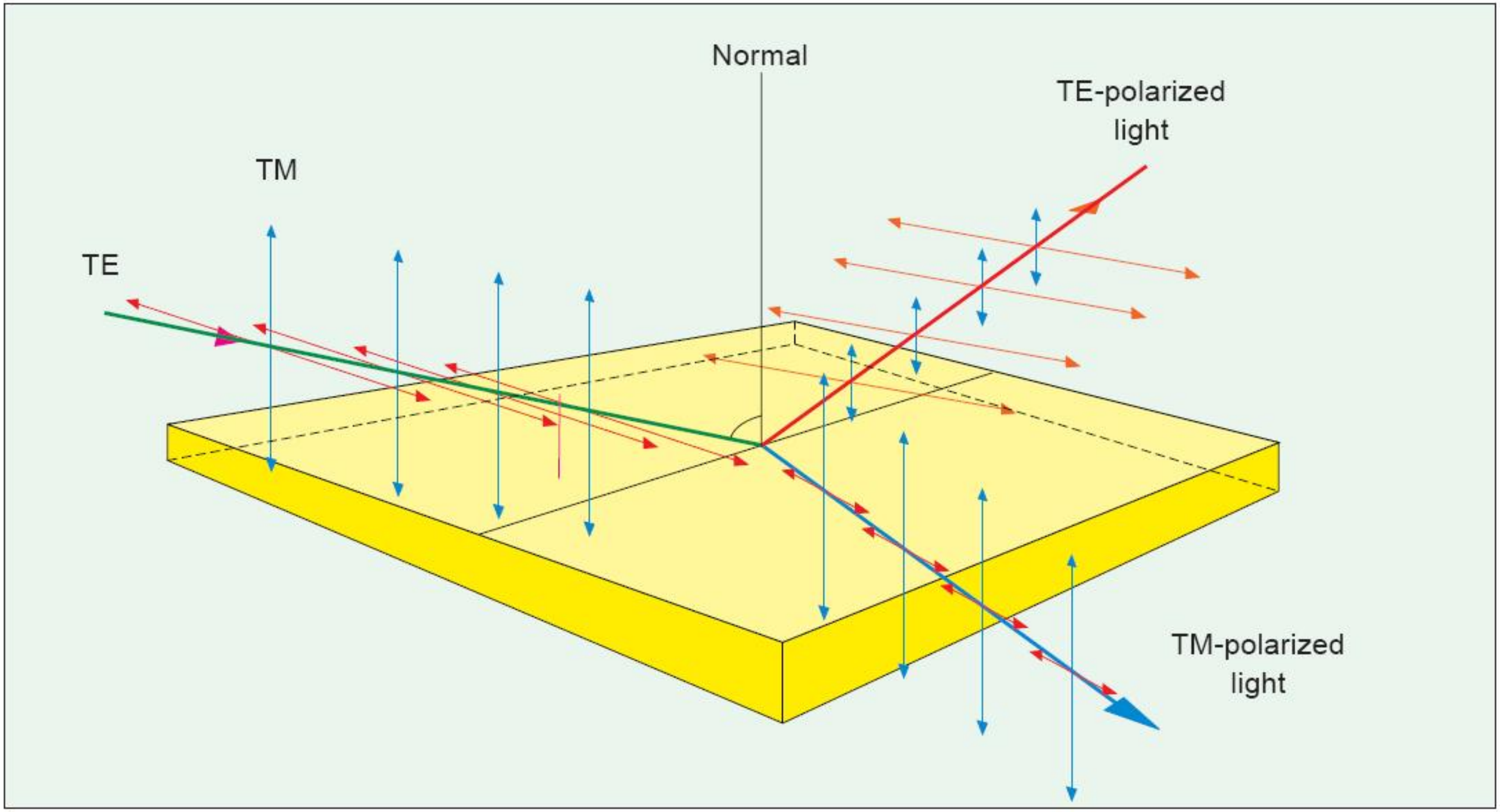
$$r_p = \frac{\tan(\phi_1 - \phi_2)}{\tan(\phi_1 + \phi_2)}$$

$$t_s = \frac{2\sin\phi_2 \cos\phi_1}{\sin(\phi_1 + \phi_2)}$$

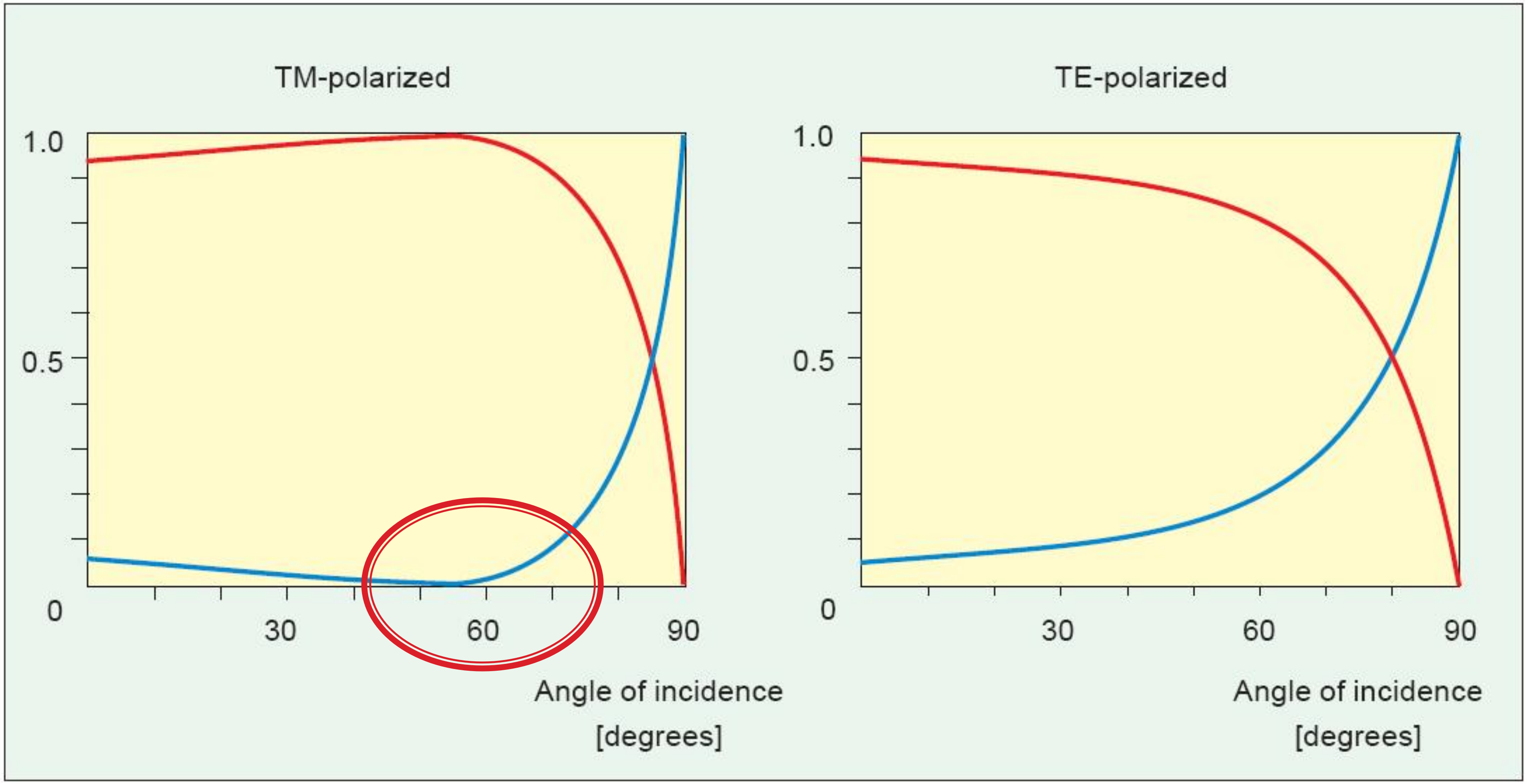
$$t_p = \frac{2\sin\phi_2 \cos\phi_1}{\sin(\phi_1 + \phi_2)\cos(\phi_1 - \phi_2)}$$



Polarizarea luminii



Polarizarea luminii



Unghi Brewster

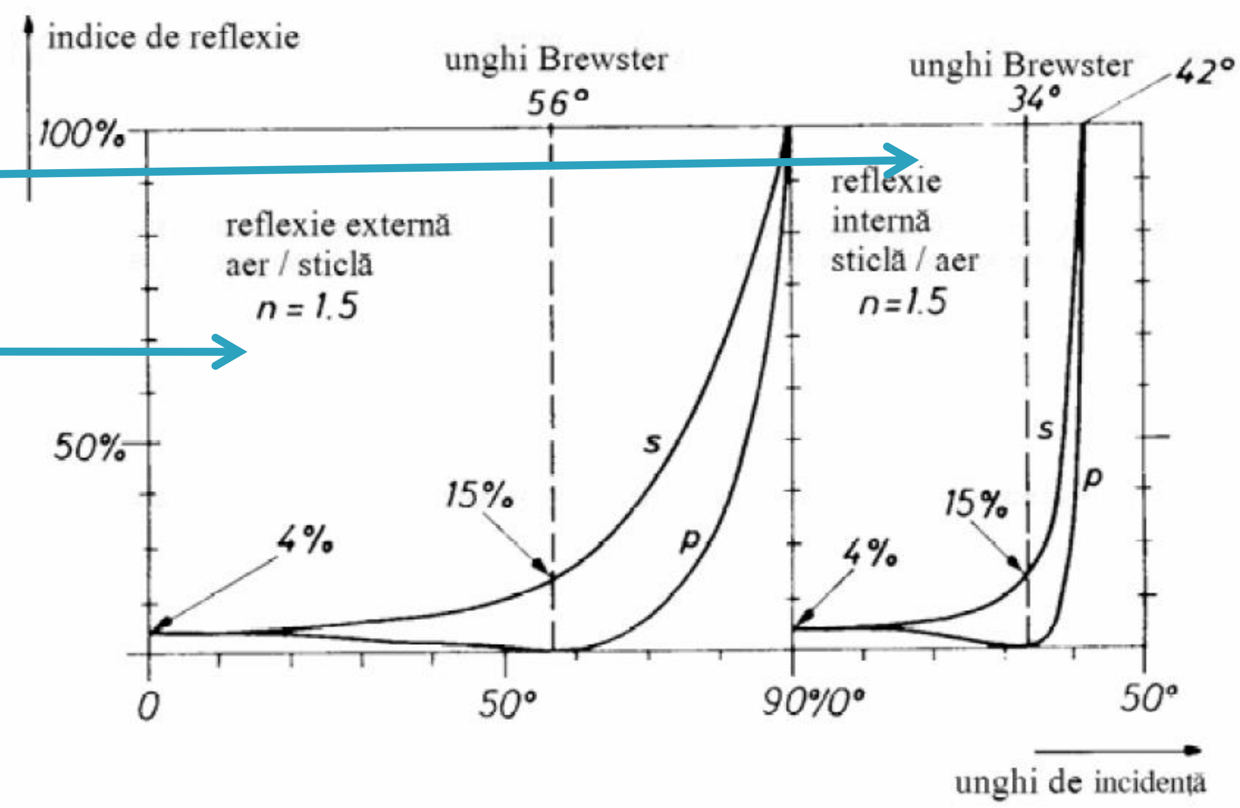
$$r_p = 0 \quad \Rightarrow \quad \tan(\phi_1 + \phi_2) \to \infty \quad \Rightarrow \quad \phi_1 + \phi_2 = \frac{\pi}{2}$$

$$n_1 \cdot \sin\phi_1 = n_2 \cdot \sin\phi_2 = n_2 \cdot \cos\phi_1$$

$$\phi_B = \arctan\left(\frac{n_2}{n_1}\right)$$

$$\phi_B = 34°$$

$$\phi_B = 56°$$



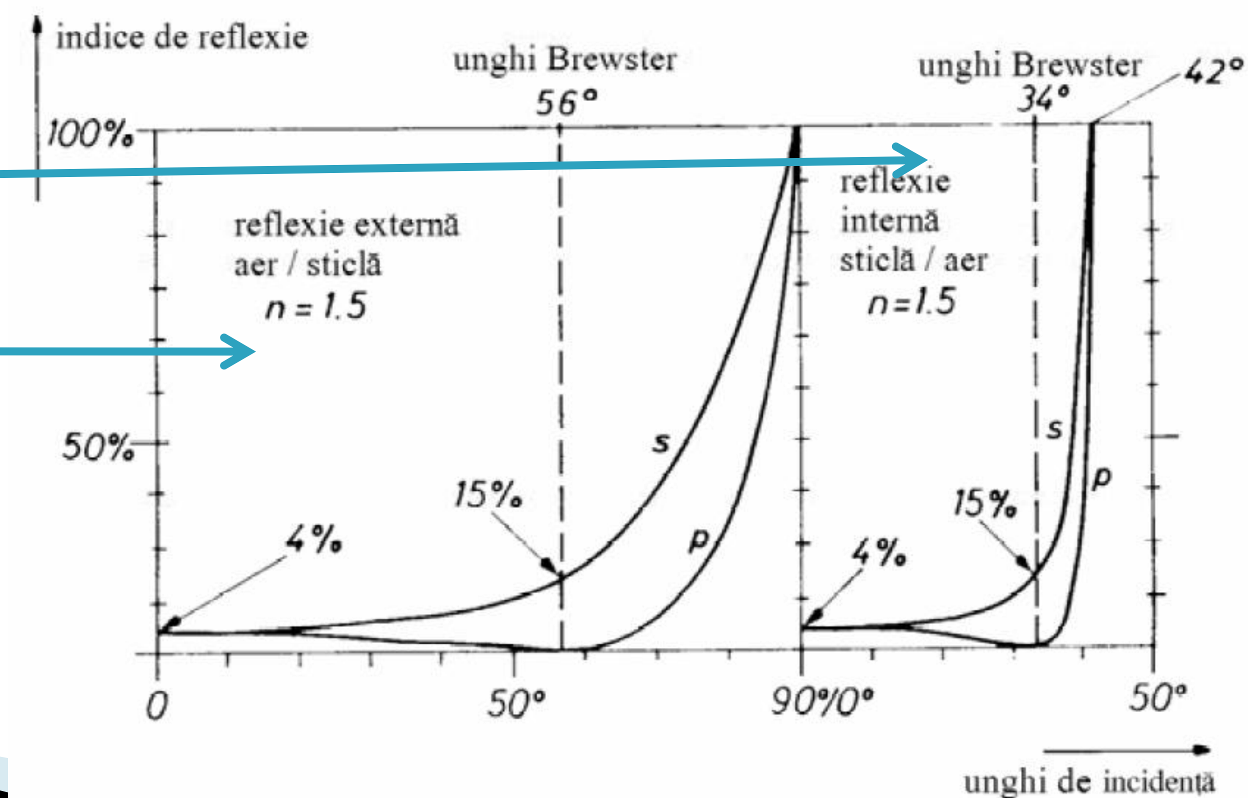
Unghi Brewster

- transmisia totala a polarizarii p
- lumina reflectata este total polarizata (s)

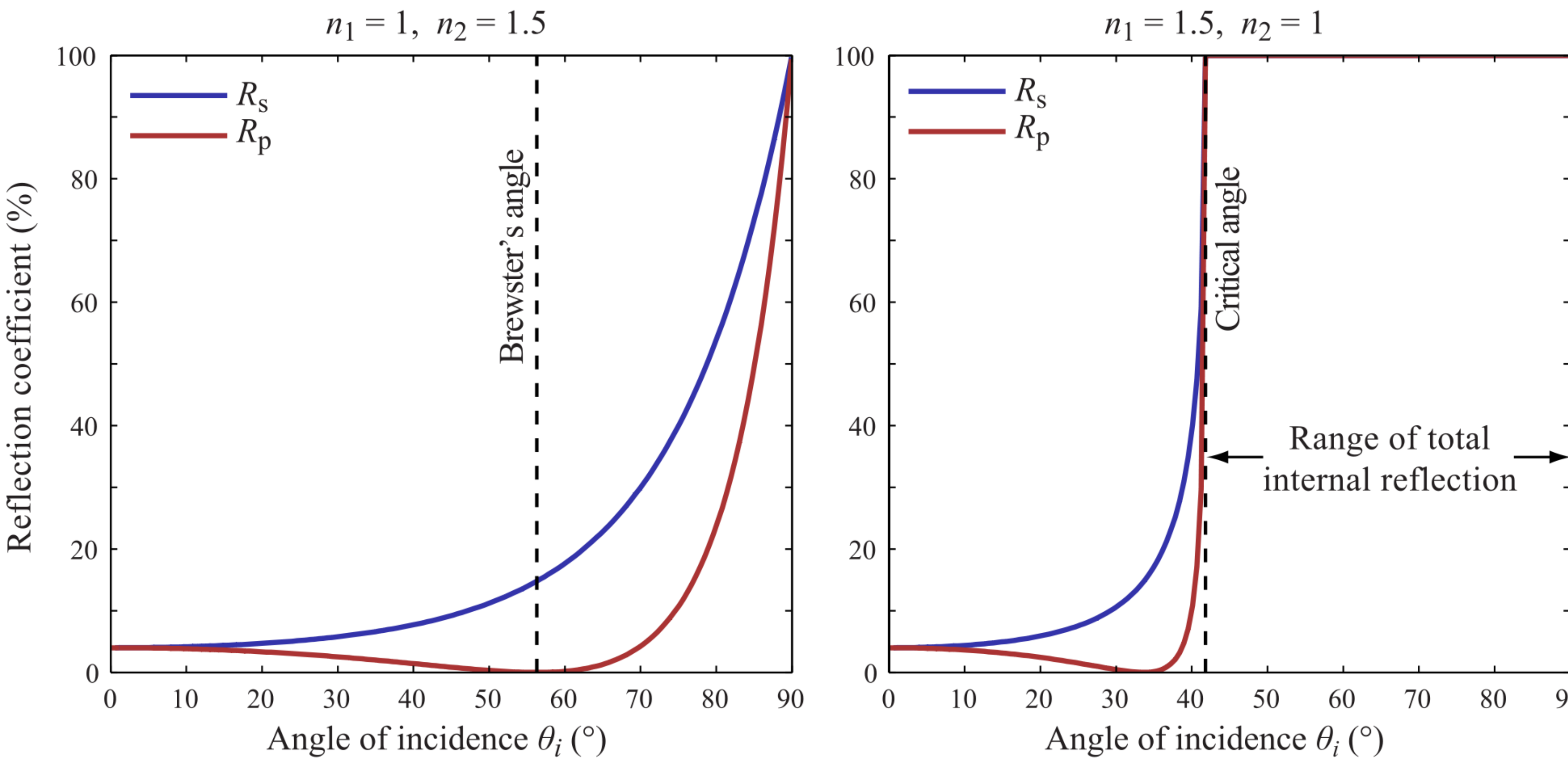
$$\phi_B = \arctan\left(\frac{n_2}{n_1}\right)$$

$$\phi_B = 34^\circ$$

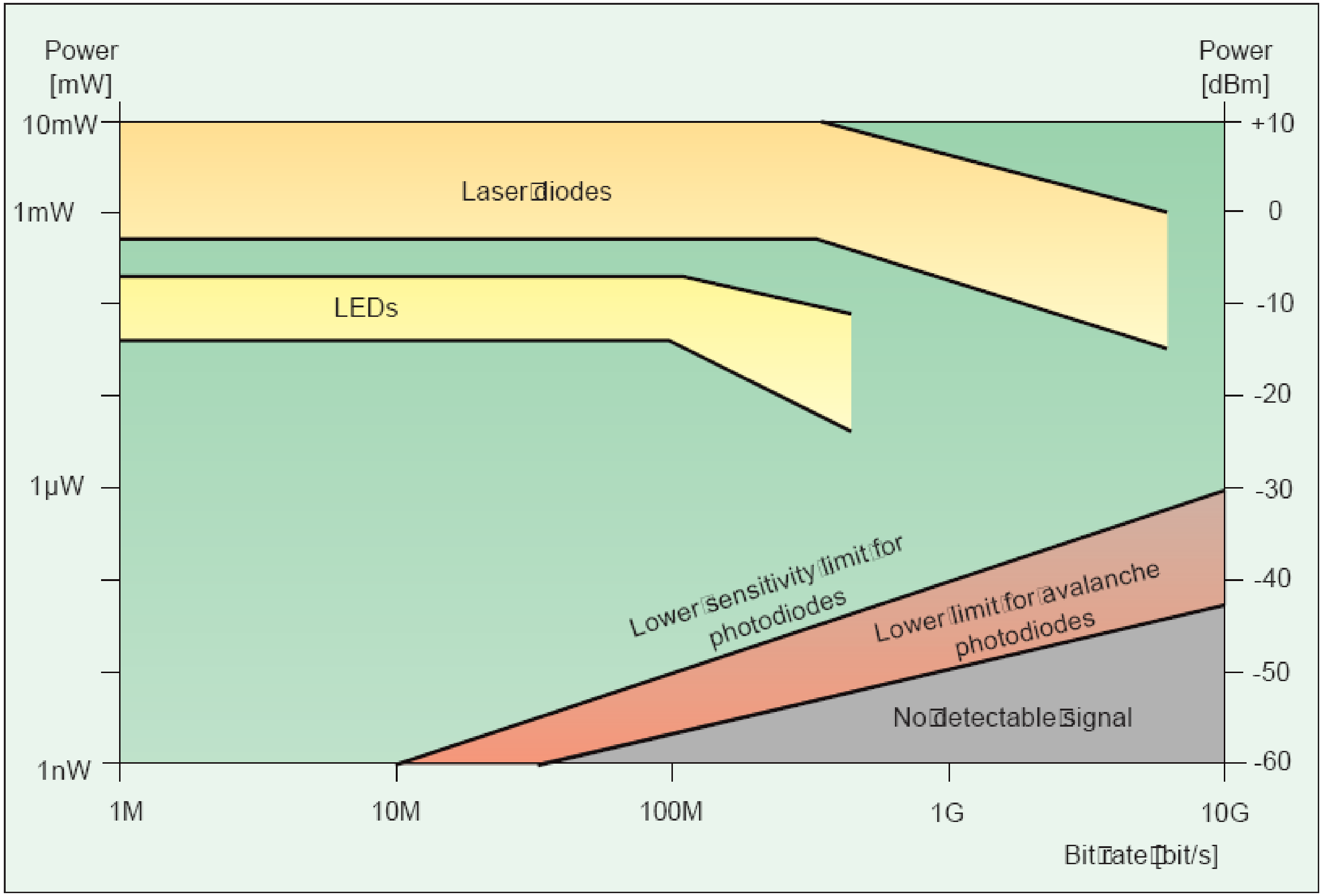
$$\phi_B = 56^\circ$$



Unghi Brewster



Limite putere/bandă a dispozitivelor optoelectronice



Contact

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