Optoelectronică, structuri şi tehnologii

Curs 3
2015/2016

Disciplina 2015/2016

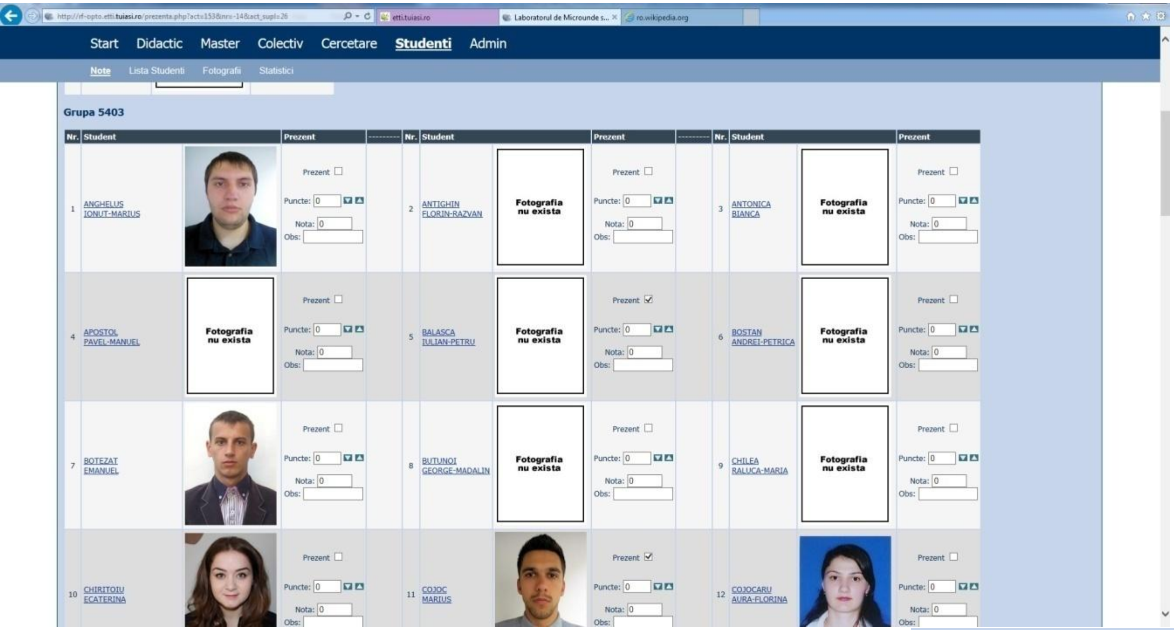
- 2C/1L Optoelectronică, structuri şi tehnologii, OSTC
- **Minim 7 prezente (C+L)**
- Curs – sl. Radu Damian
  - an IV µE
  - Luni 18-20, P5
  - E – 66% din nota
  - probleme + (**? 1 subiect teorie**) + (2p prez. curs)
  - toate materialele permise
- Laborator – sl. Daniel Matasaru
  - an IV µE, an IV Tc
    - Luni 16-18 impar
    - Marti 18-20
    - Joi 8-12 impar
  - L – 17% din nota
  - T – 17% din nota

Fotografii

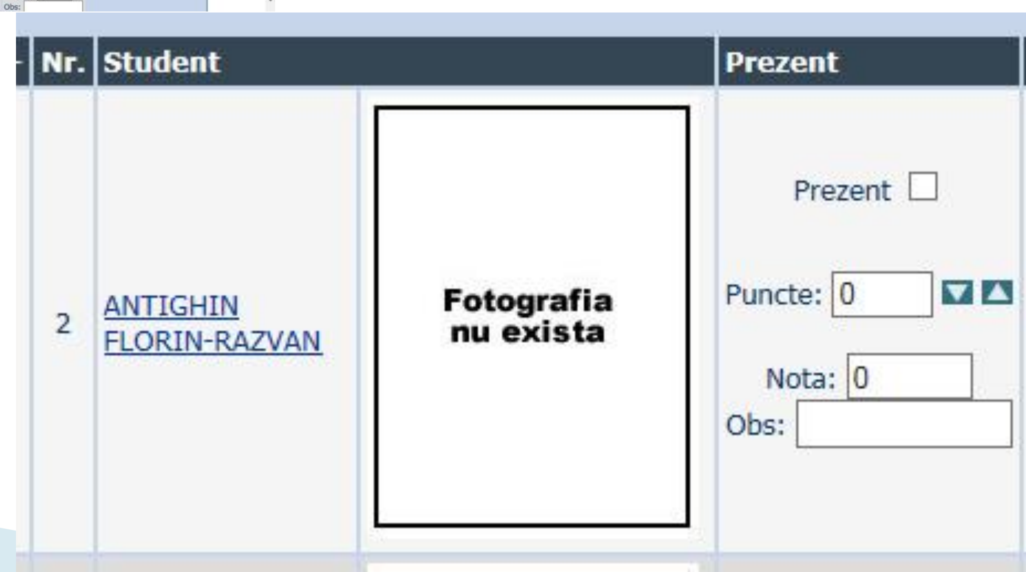

Studentii care au trimis fotografiile
Grupa: 5402
Grupa: 5403
Grupa: 5404
Grupa: 5405
Nr. Nume
1 APETRII MARIA
1 ALEXANDRESCU SEBASTIAN
1 APERGHIS MIHAI-ALIN
1 ANGHELUS MARIU


Studentii care inca nu au trimis fotografiile
Grupa: 5304
Grupa: 5402
Grupa: 5403
Grupa: 5404
Nr. Nume

Fotografii



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

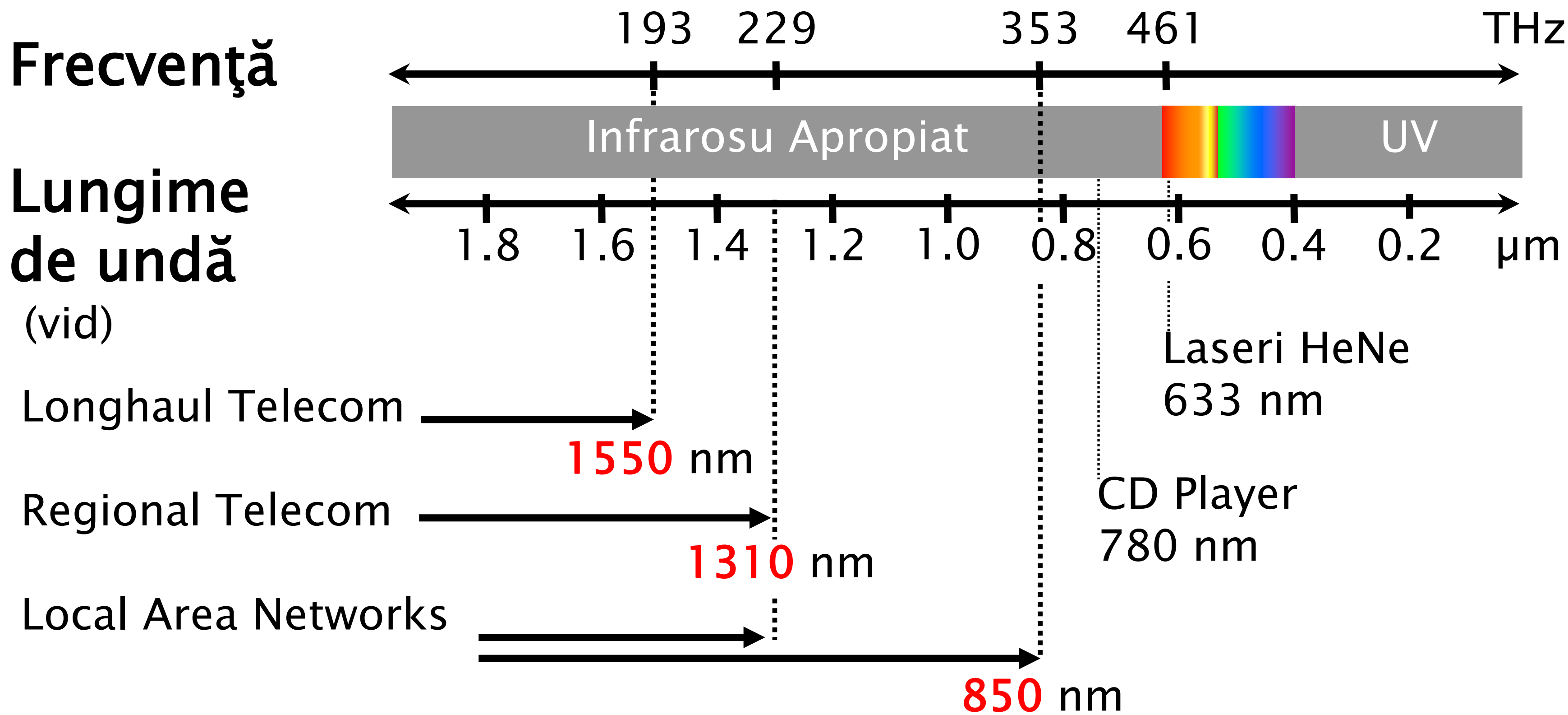


Nr.
Student
Prezent
2
ANTIGHIN FLORIN-RAZVAN
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:

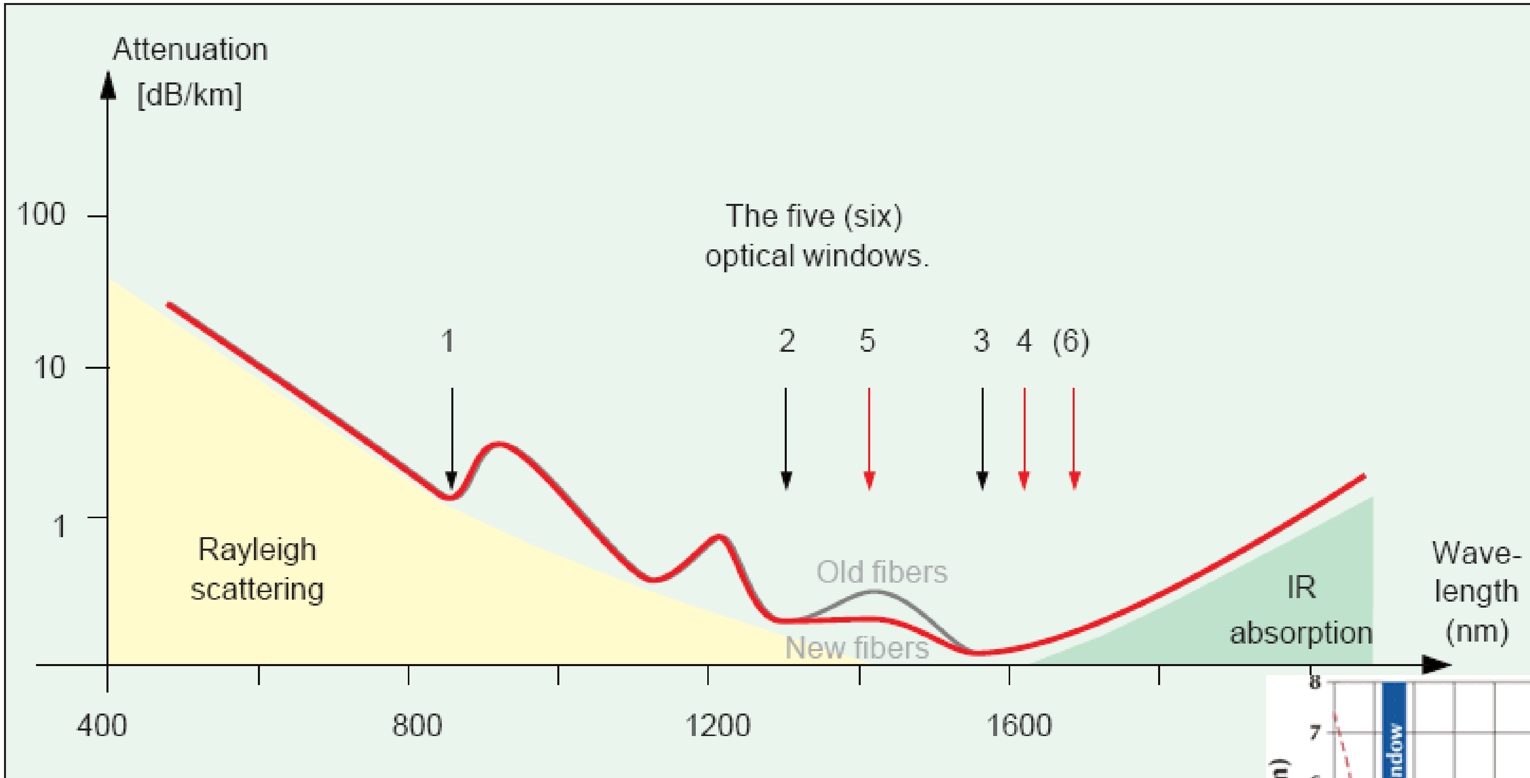
Recapitulare

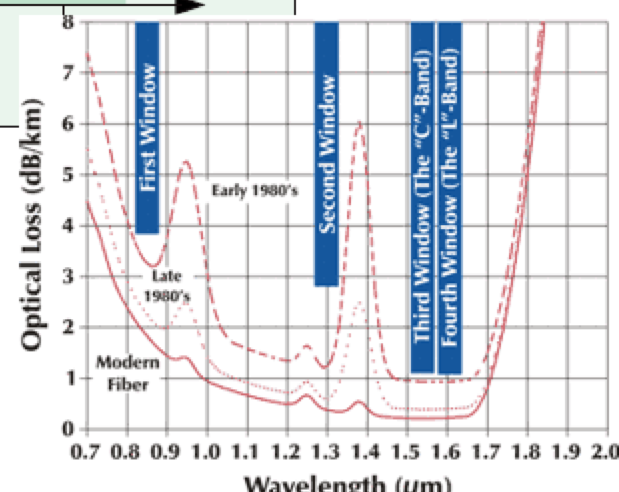
Curs 2

Benzi de lucru in comunicaţiile optice



Atenuarea în fibra optică (SiO_2)





850nm, 1310nm, 1550nm

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]

Lumina ca undă electromagnetică

Capitolul 2

Parametri, dependenta de mediu

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

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

$n = 1$

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

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

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

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

$n = \sqrt{\varepsilon_r}$

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

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

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

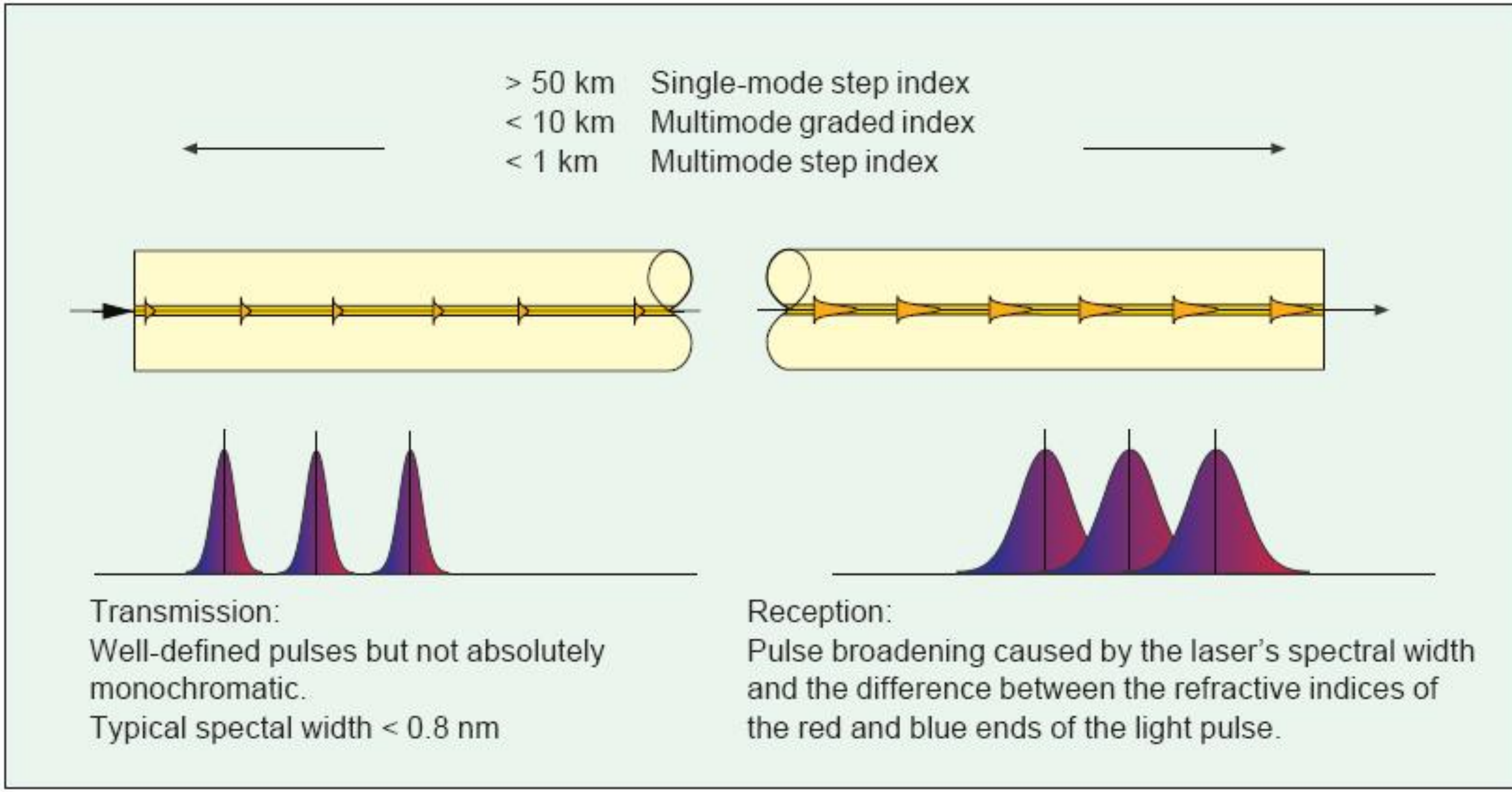
ITU G.692

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

SI

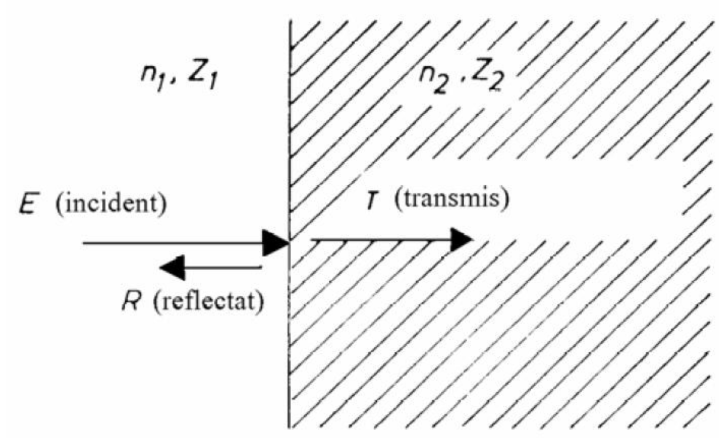
"a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz"

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.

Transmisia puterii intre medii

- incidenta normala
- reflexia in amplitudine



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

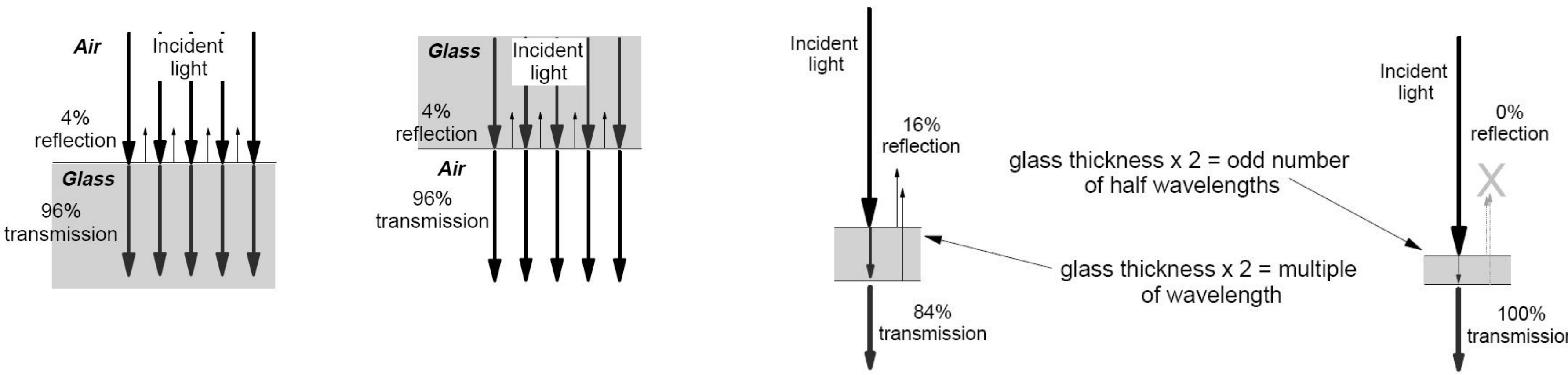
- densitatea de putere proportionala cu patratul amplitudinii câmpului

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

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

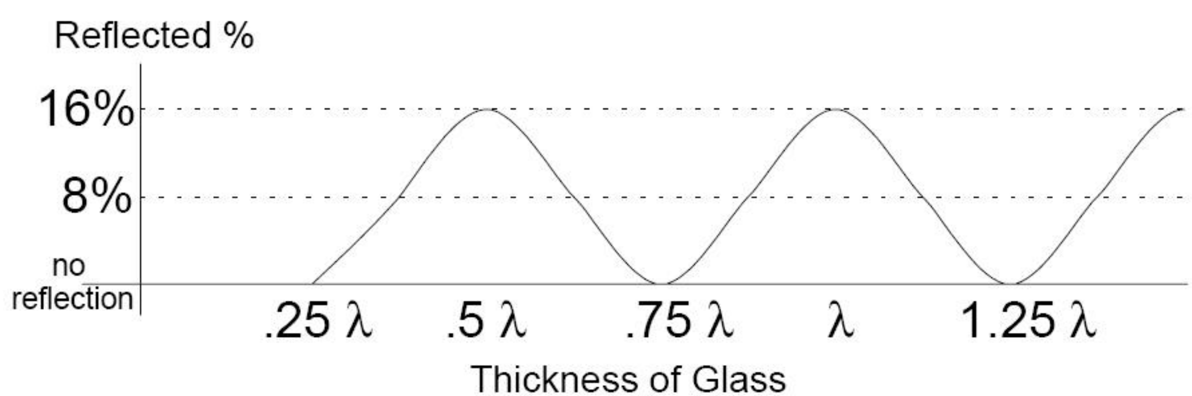
$$r = 0.04 = 4\%$$

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



Continuare

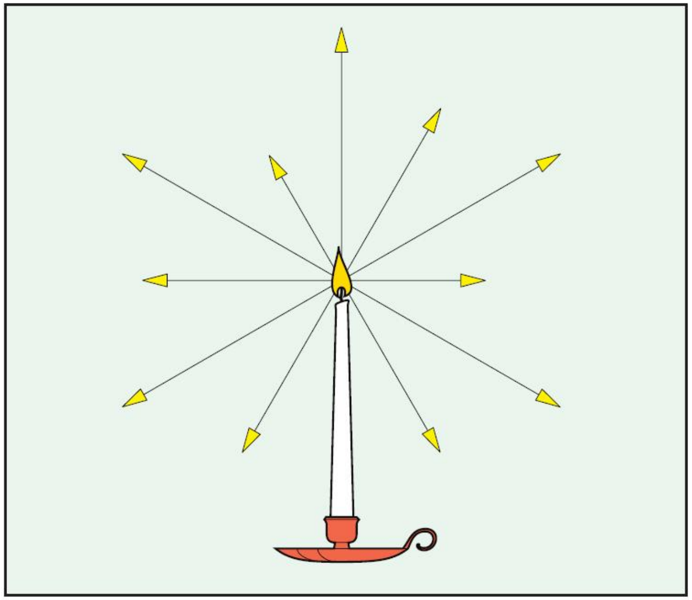
Curs 3

Optică geometrică

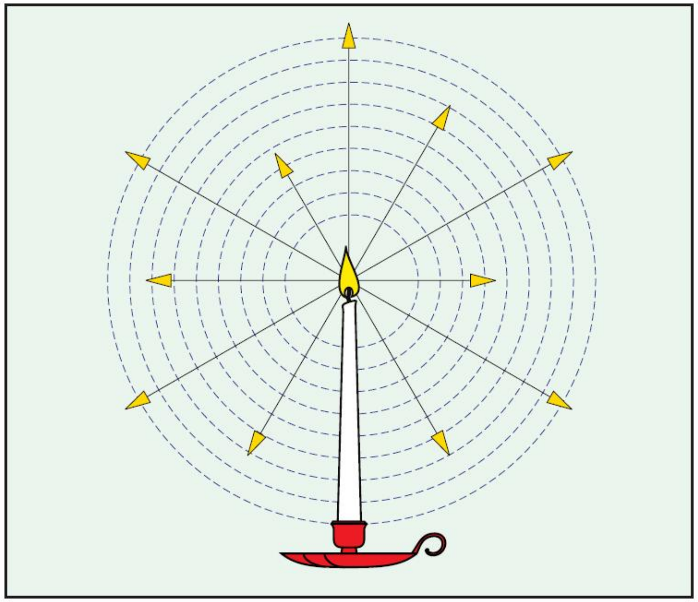
Capitolul 3

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)



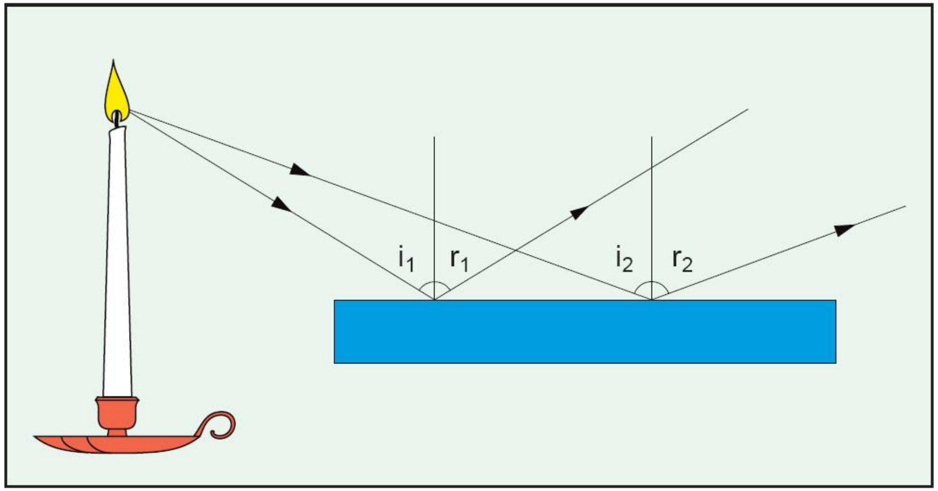
$$P = \frac{P_0}{r^2}$$

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

$$\phi_i = \phi_r$$



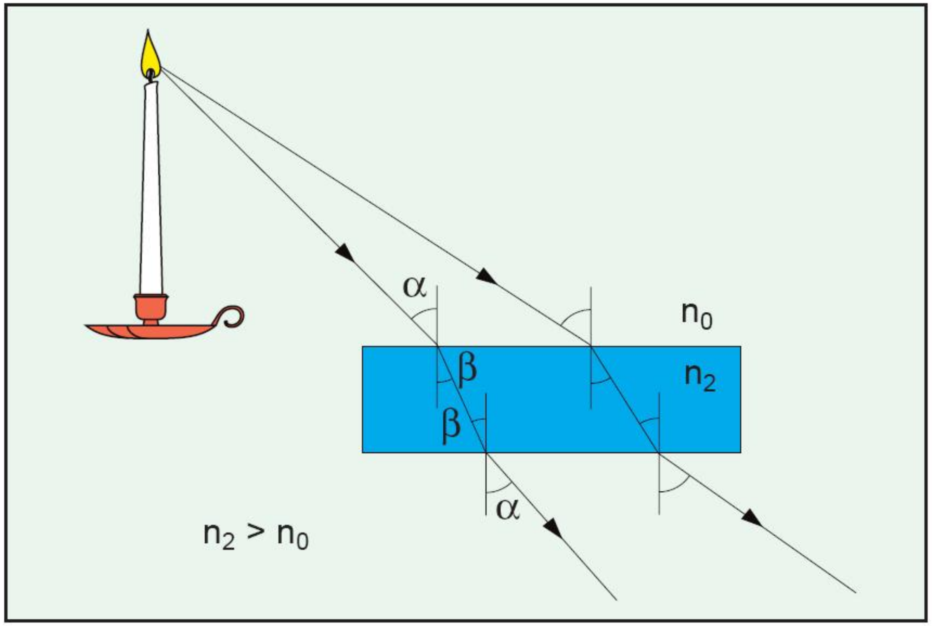
Refractia luminii

- 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)



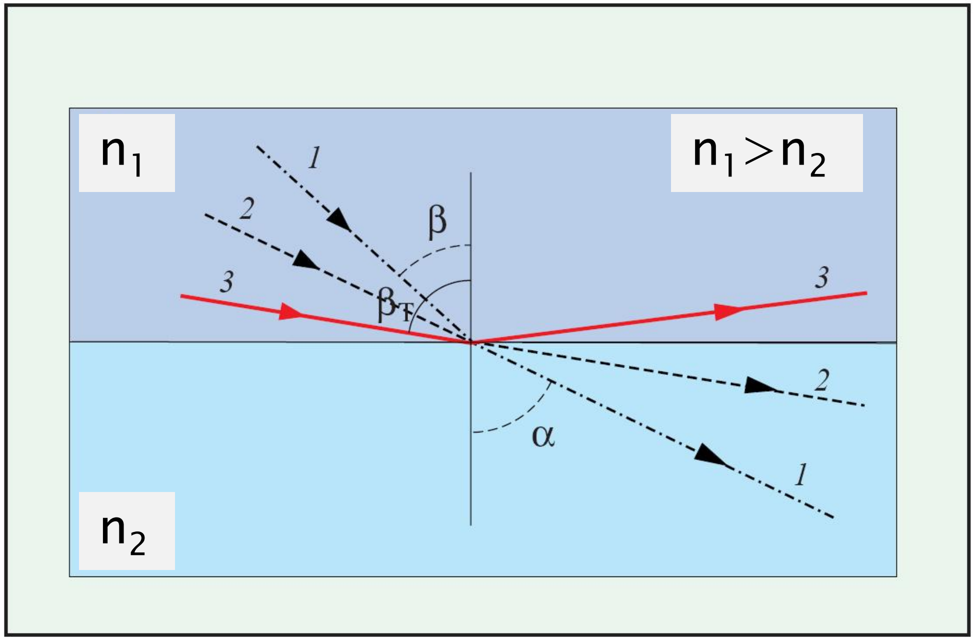
Reflexia totala

- 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

$$n_1 > n_2; \quad \phi_R = 90^\circ$$

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

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

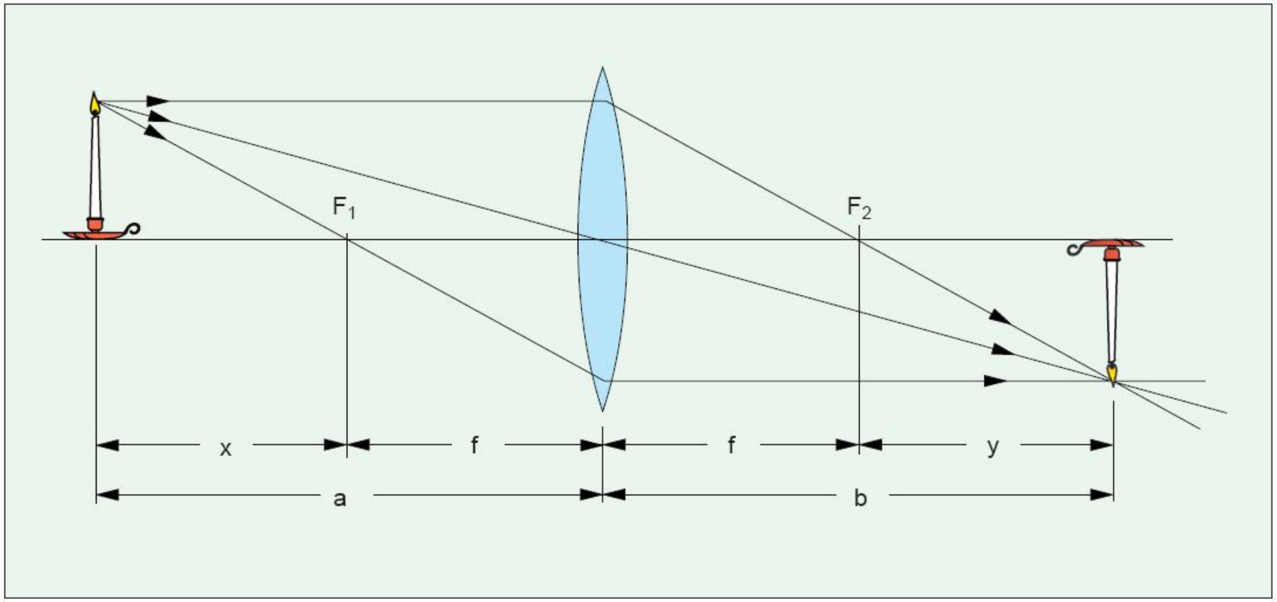


Lentile

- 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

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

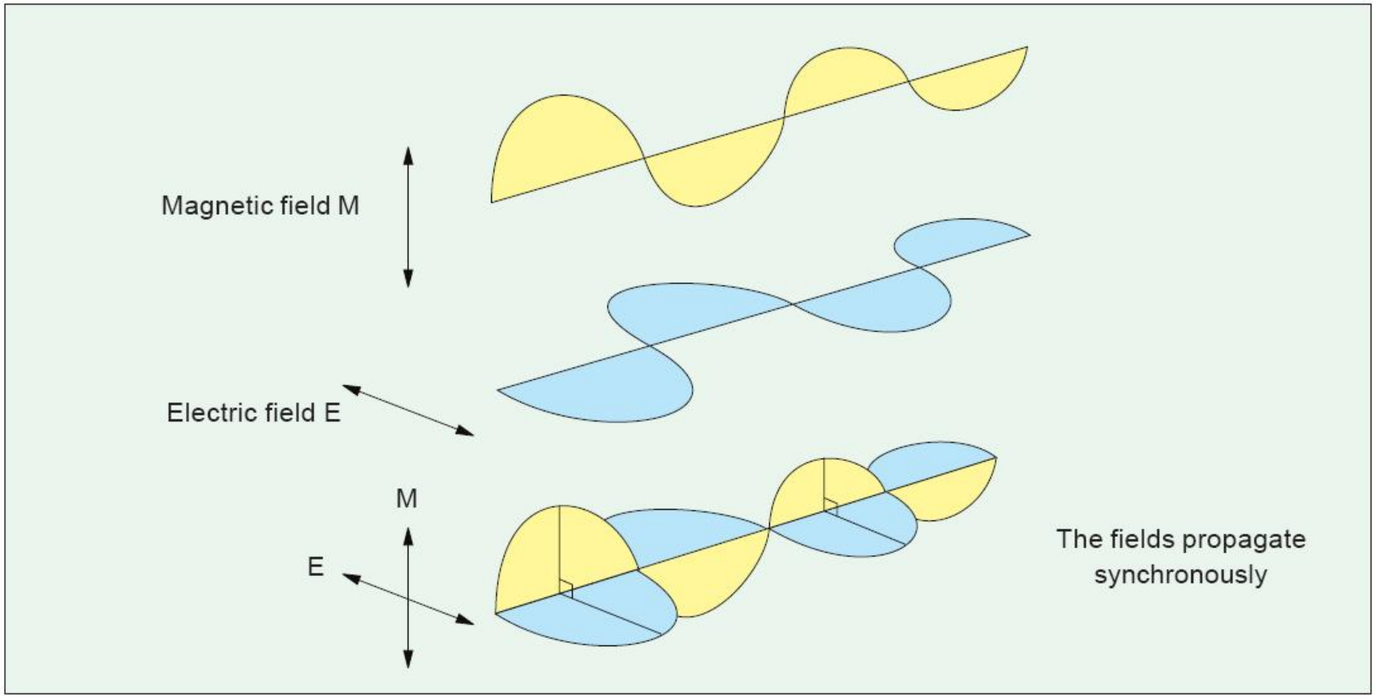
$$x \cdot y = f^2$$

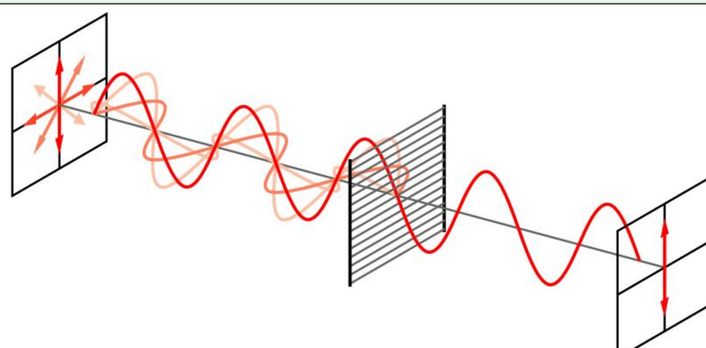


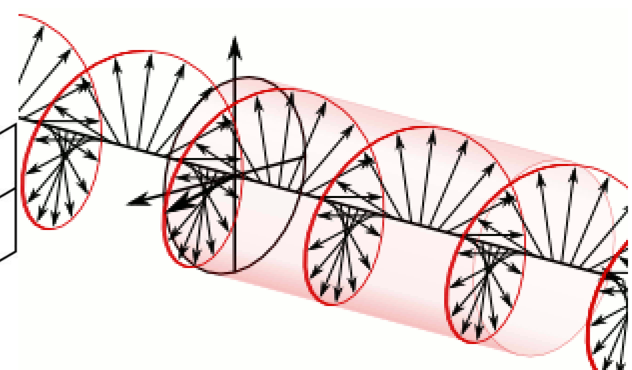
Lumina ca undă electromagnetică

(tot) Capitolul 2

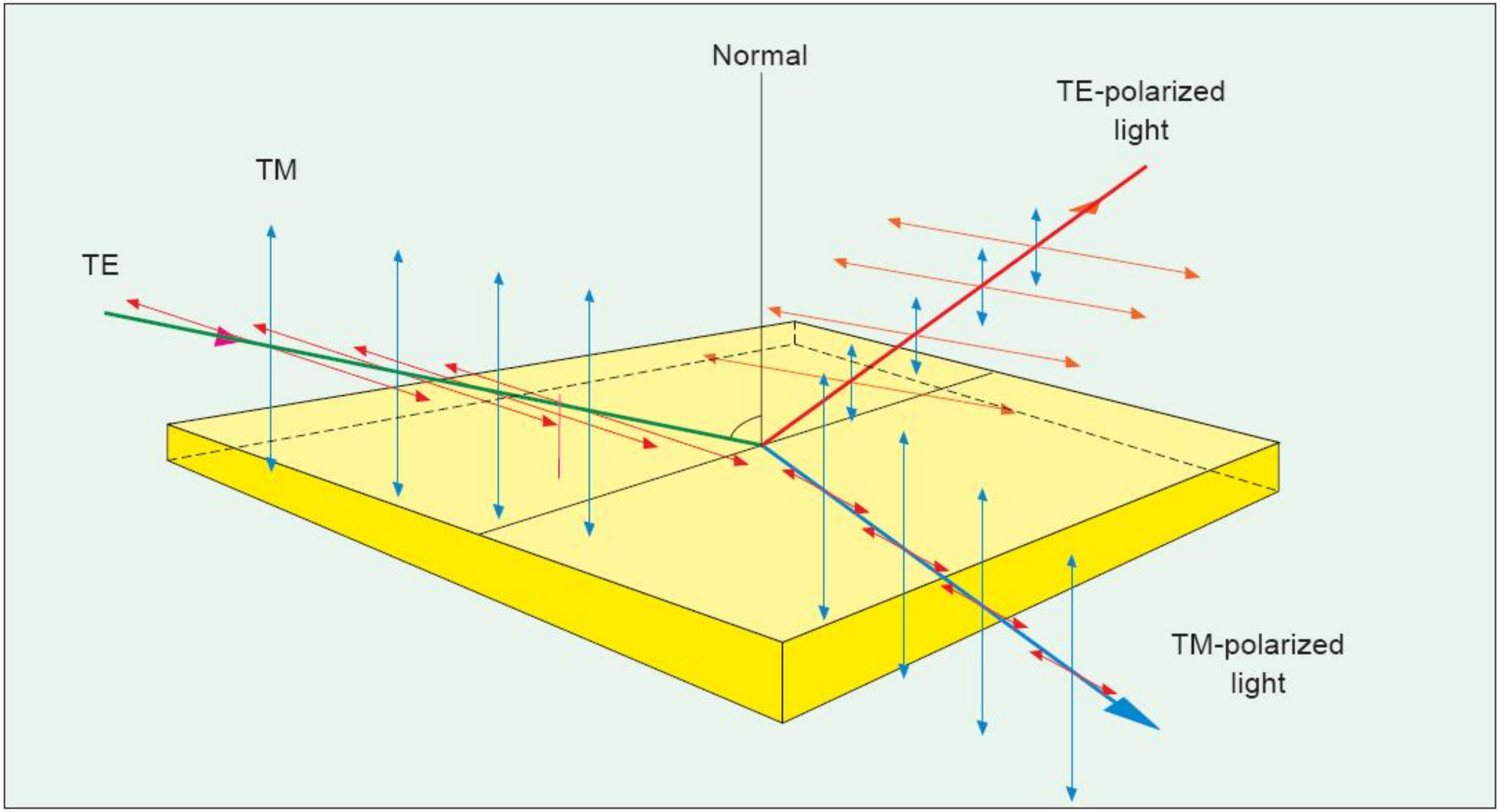
Polarizarea luminii



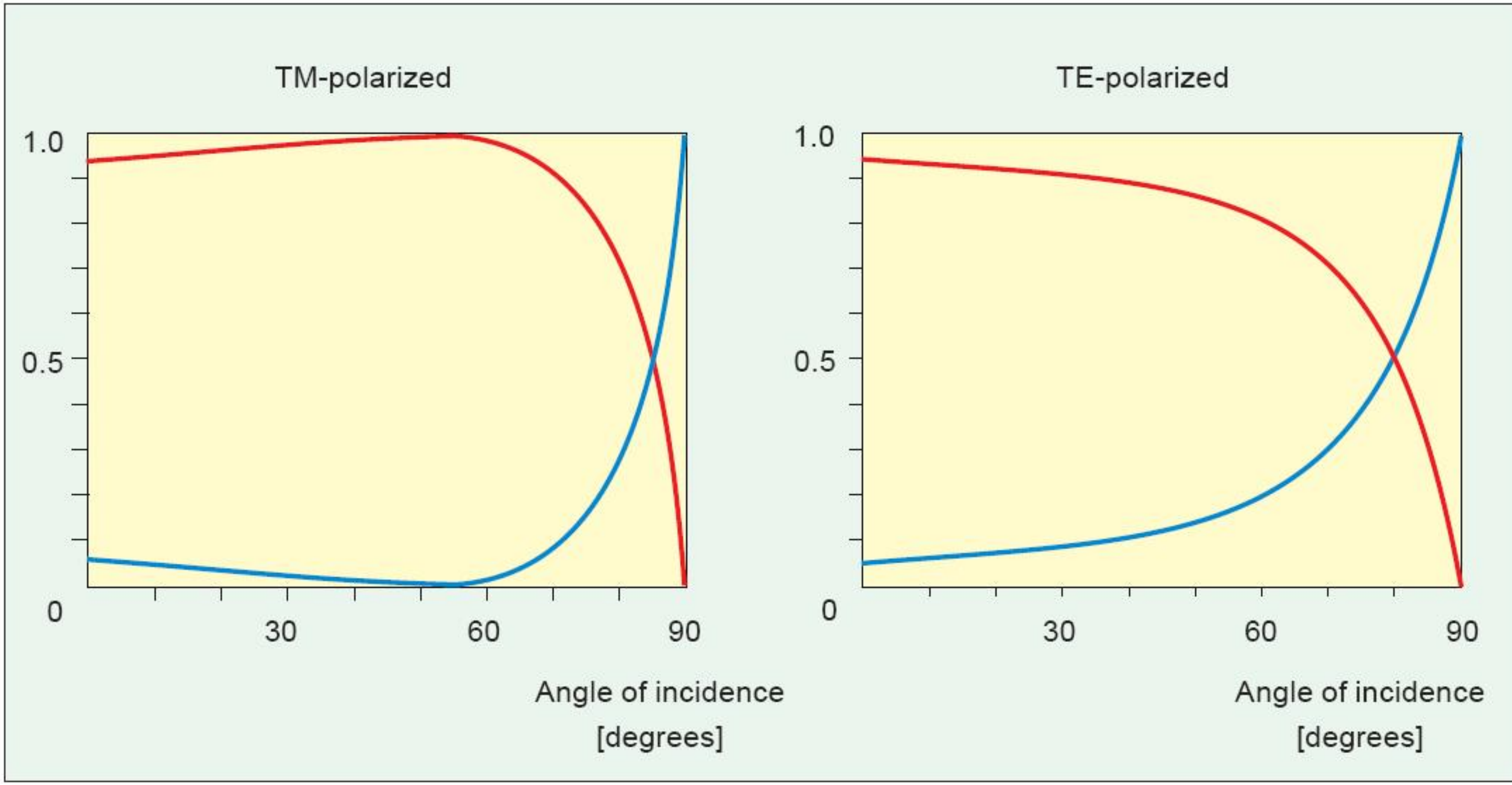




Polarizarea luminii



Polarizarea luminii



(revenire) Polarizarea luminii

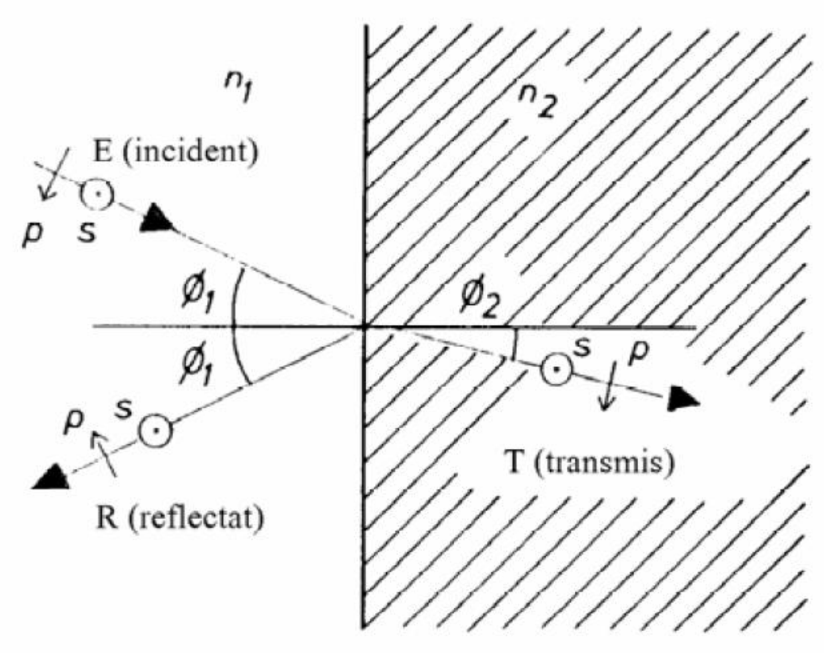
- incidenta oblica
- reflexiile in amplitudine a campului:

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

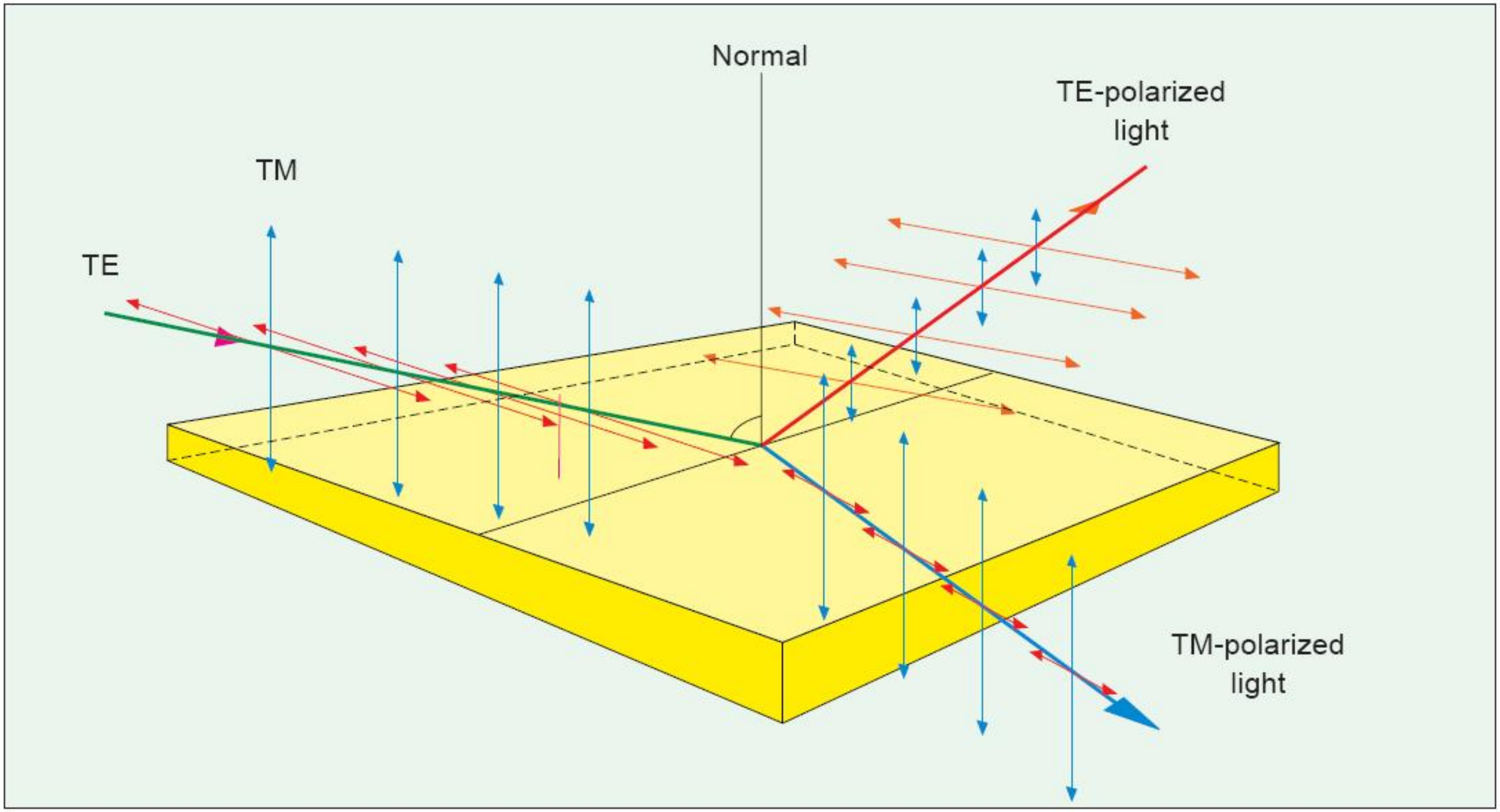
$$r_p = \frac{\tan(\phi_1 - \phi_2)}{\tan(\phi_1 + \phi_2)}$$

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

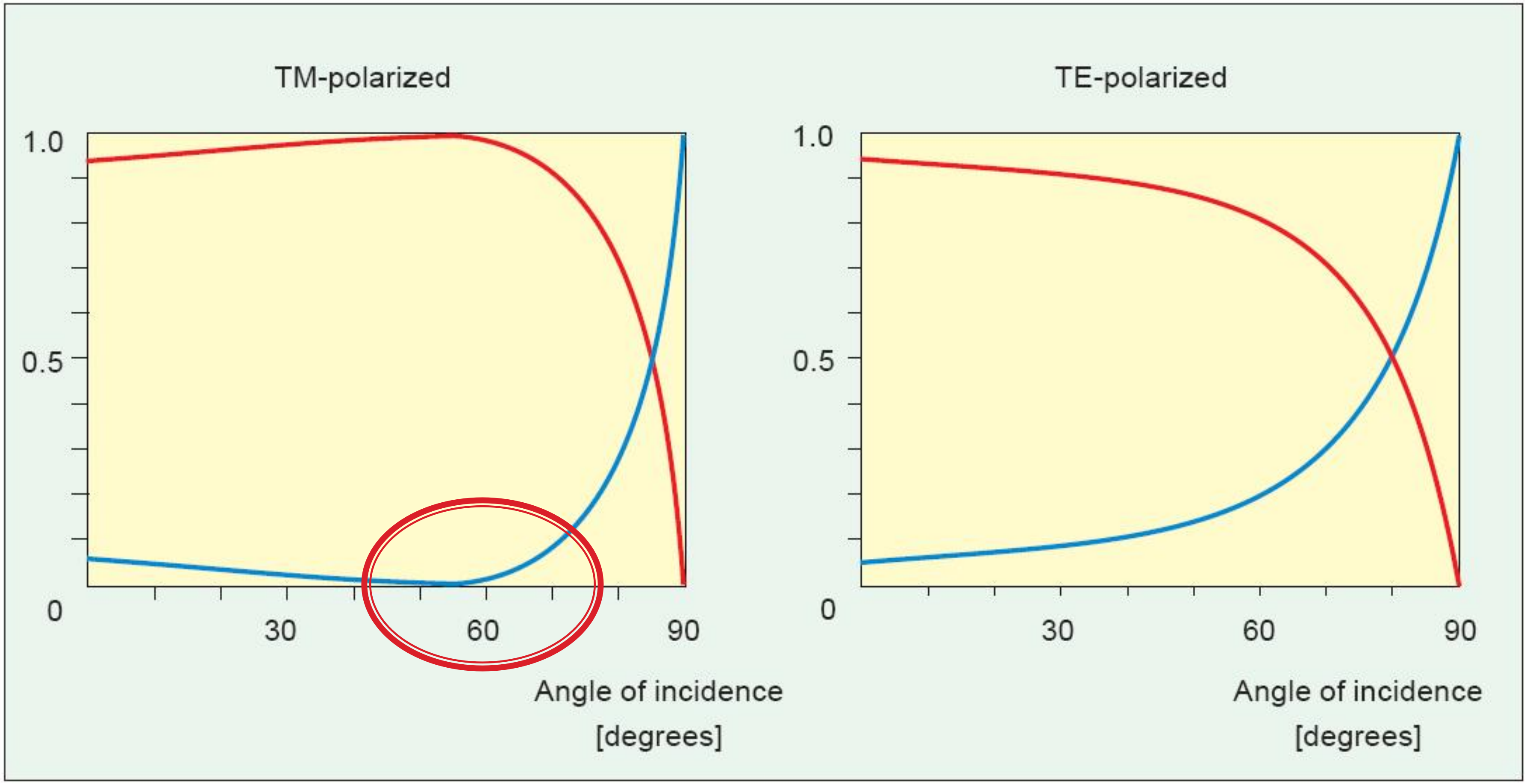
$$t_p = \frac{2\sin\phi_2\cos\phi_1}{\sin(\phi_1 + \phi_2)\cos(\phi_1 - \phi_2)}$$



Polarizarea luminii



Polarizarea luminii



Unghi Brewster

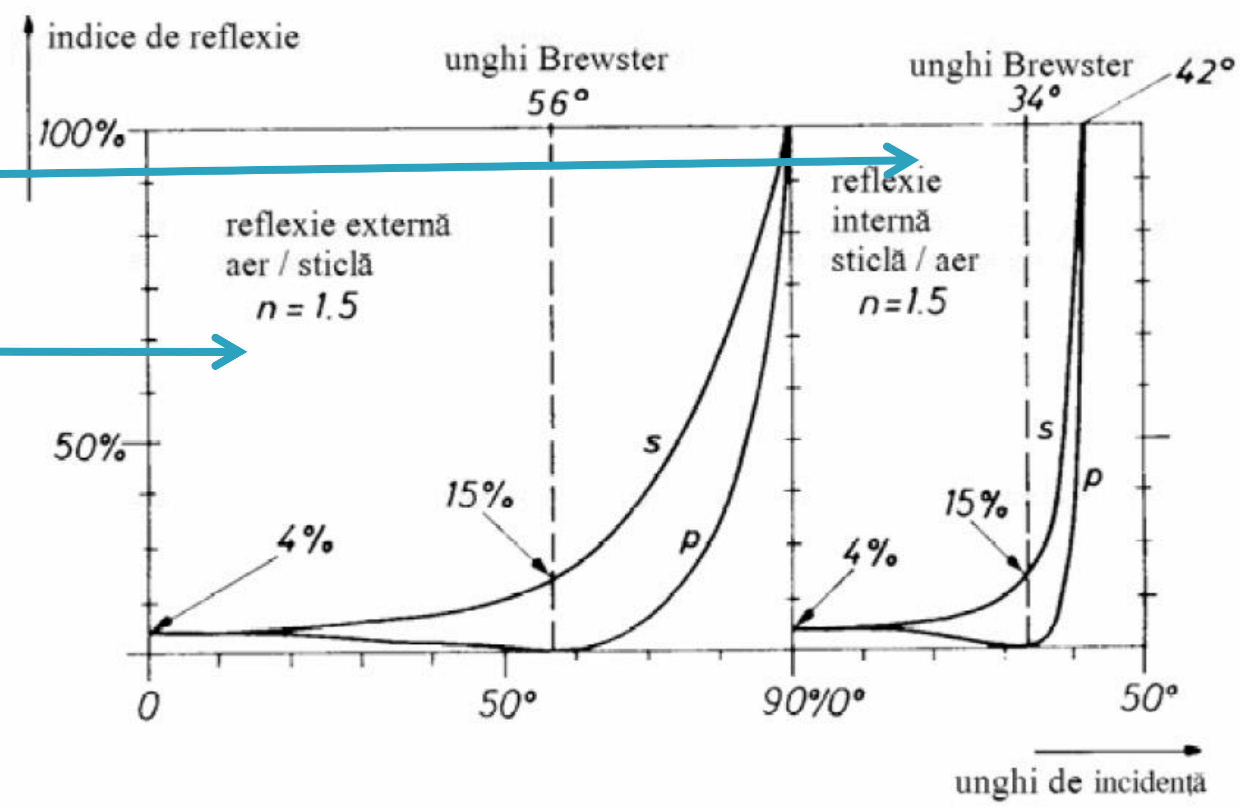
$$r_p = 0 \quad \Rightarrow \quad \tan(\phi_1 + \phi_2) \to \infty \quad \Rightarrow \quad \phi_1 + \phi_2 = \frac{\pi}{2}$$

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

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

$$\phi_B = 34°$$

$$\phi_B = 56°$$



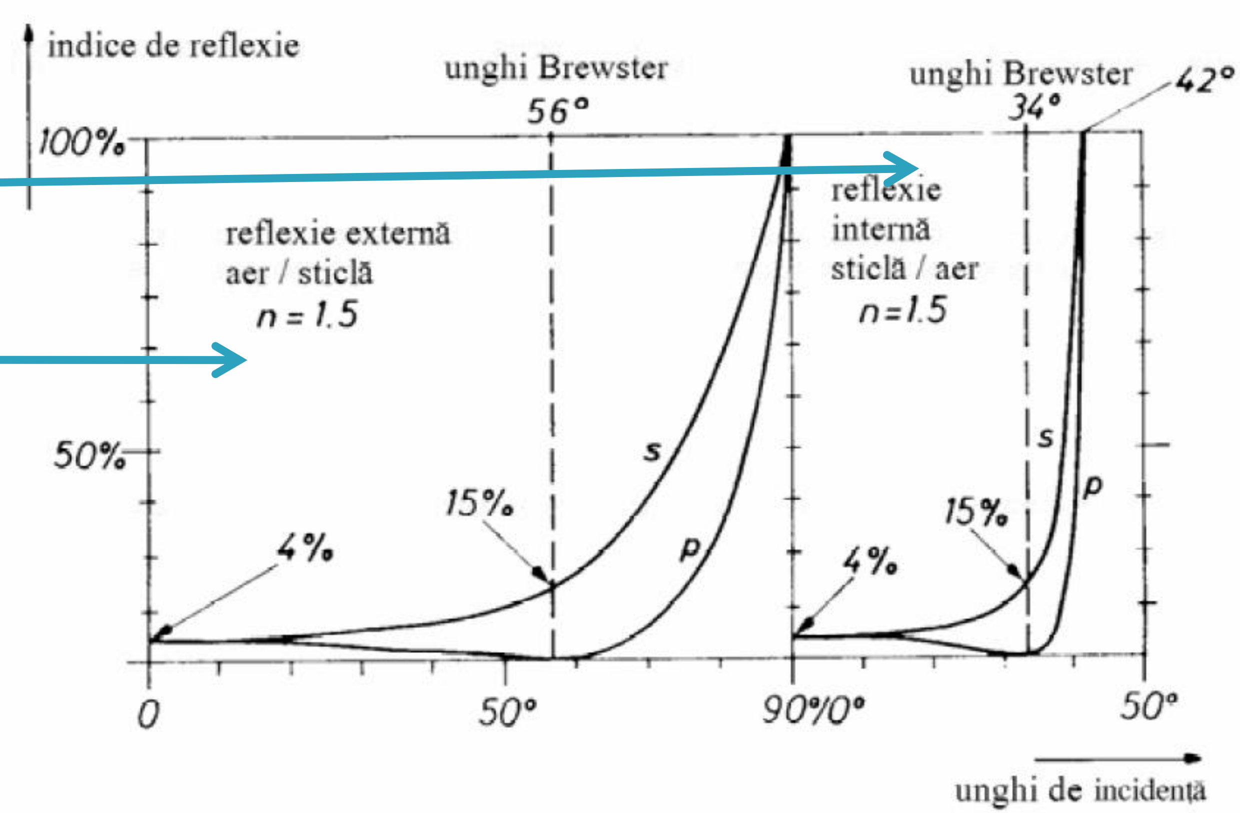
Unghi Brewster

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

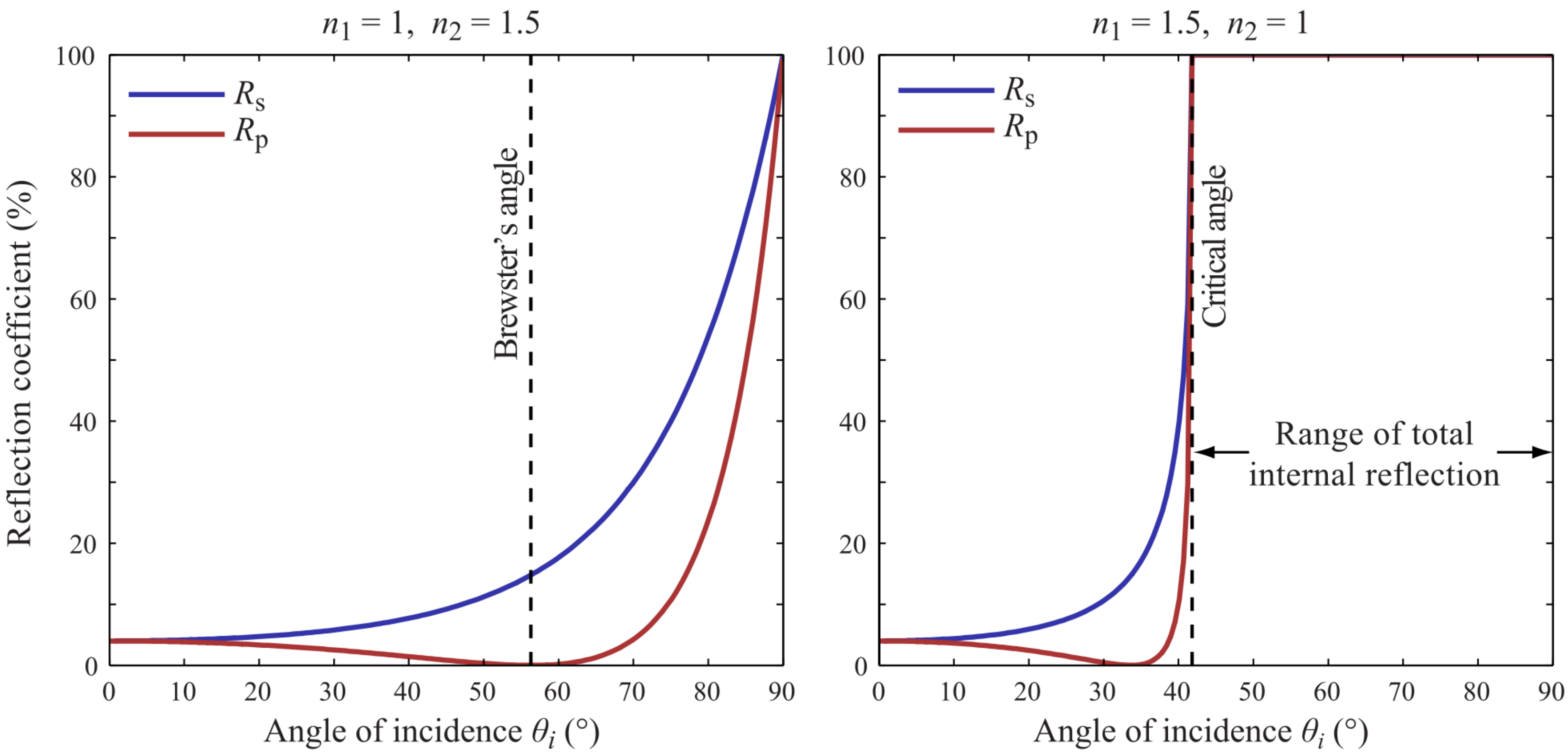
$$\phi_B = \arctan\left(\frac{n_2}{n_1}\right)$$

$$\phi_B = 34°$$

$$\phi_B = 56°$$



Unghi Brewster



Fotometrie şi radiometrie

Capitolul 4

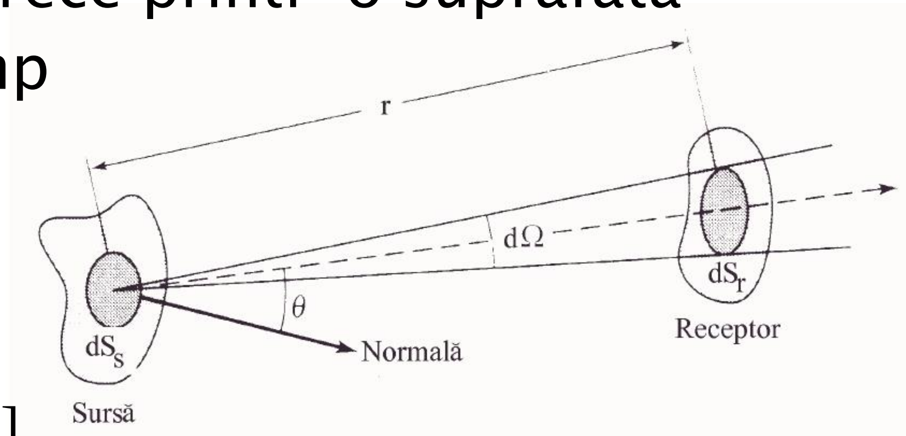
O alta dualitate

- In optoelectronica lumina poate fi privita din doua puncte de vedere
  - energetic (efect asupra dispozitivului)
  - uman (efect asupra ochiului uman)
- Dualitatea mărimilor implicate
  - energetice
  - luminoase
- Candela (cd) este una din cele 7 mărimi fundamentale ale SI
  - Cd = intensitatea luminoasa a unei surse ce emite o radiație monocromatica cu frecventa $540 \cdot 10^{12}$ Hz (λ = 555nm in vid) si are o intensitate radianta de 1/683 W/sr

Flux energetic

- Flux energetic al luminii
  - viteza cu care energia trece printr-o suprafata
  - energie/unitatea de timp
  - unitatea SI – W

$$\Phi_e = \frac{dE}{dt} \quad [W]$$

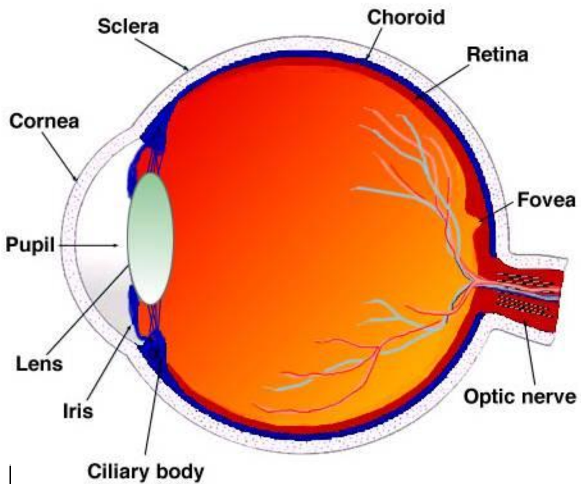


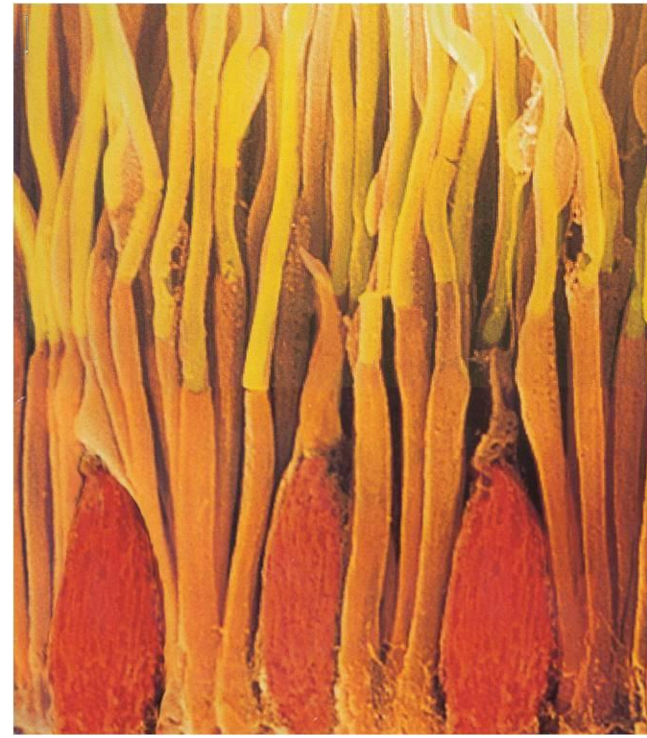
- Unghi solid
  - definitie $\Omega = \frac{A}{r^2} \quad [sr]$
  - valoarea maxima, sfera: Ω = 4π sr
  - pentru con cu deschiderea la varf 2ϕ: $\Omega = 2\pi \cdot (1 - \cos\varphi)$
  - pentru unghiuri mici: $\Omega = \pi \cdot \varphi^2$

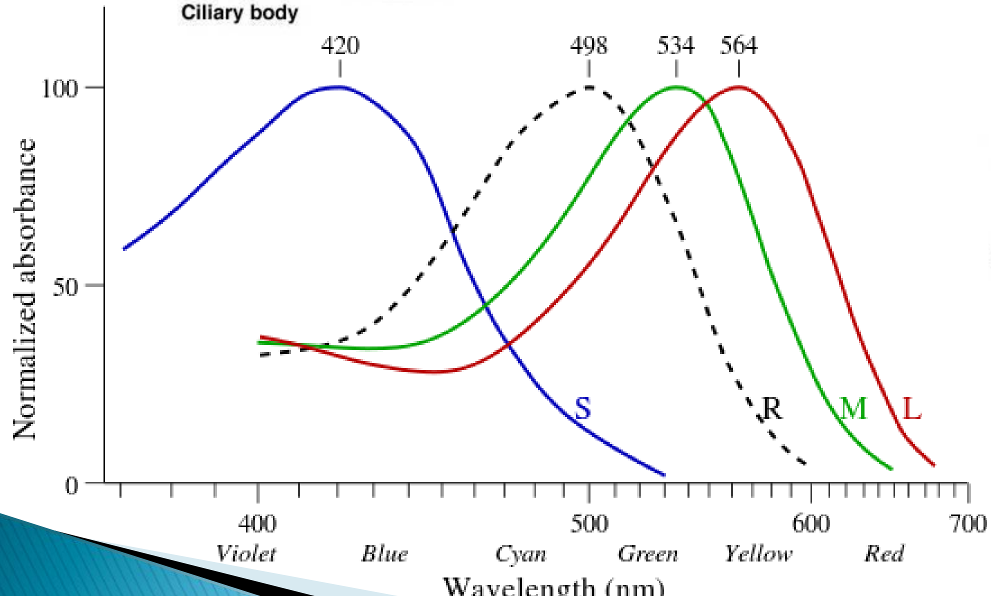
Flux luminos

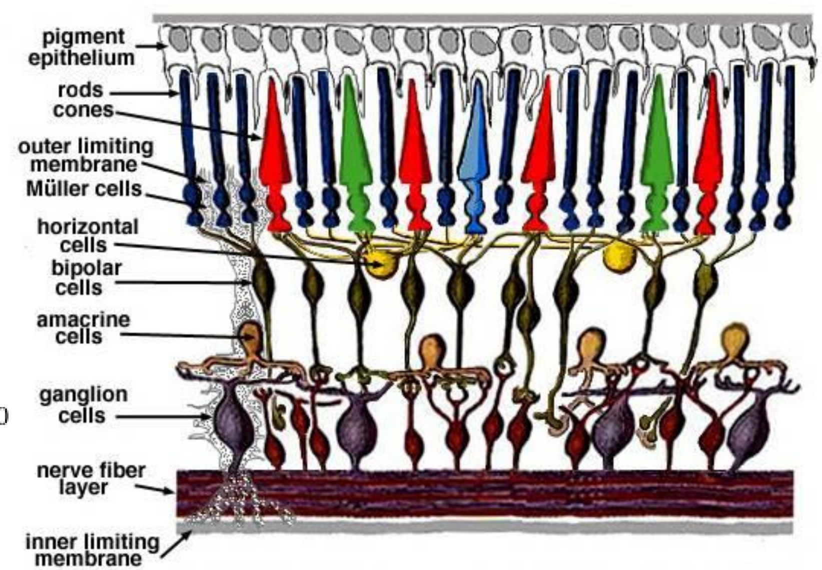
- Flux luminos, definitie
  - o masura a puterii luminoase percepute de om
- Unitate de masura – lm = lumen
  - In SI de unitati **lumenul** este definit ca fluxul luminos al unei surse luminoase punctiforme cu intensitatea luminoasa de o candela intr-un unghi solid egal cu 1 sr.
  - la λ = 555nm $\Phi_e = 1W \Leftrightarrow \Phi_v = 683\,lm$
- Dualitate pentru toate marimile implicate
  - radiometrie – indice “e”
  - fotometri – indice “v”
- La alte lungimi de unda se tine cont de sensibilitatea relativa medie a ochiului uman

Ochiul uman


Sclera
Choroid
Retina
Cornea
Fovea
Pupil
Lens
Iris
Optic nerve
Ciliary body



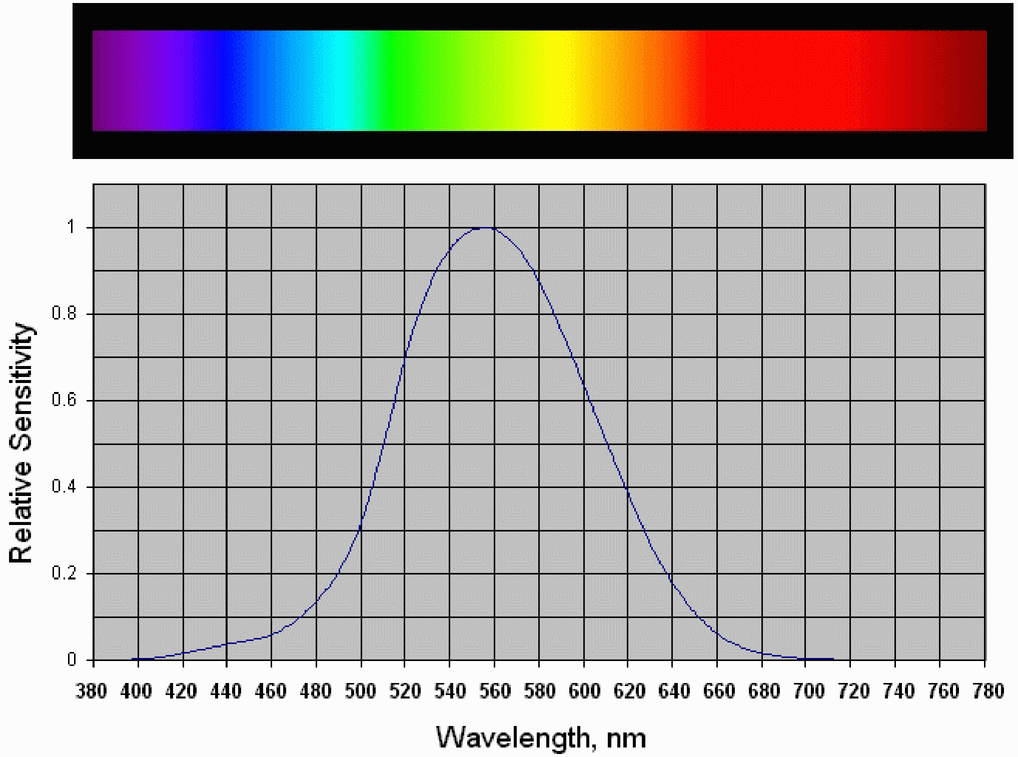

420
498
534
564
100
50
0
Normalized absorbance
S
R
M
L
400
500
600
700
Violet
Blue
Cyan
Green
Yellow
Red
Wavelength (nm)


pigment epithelium
rods
cones
outer limiting membrane
Müller cells
horizontal cells
bipolar cells
amacrine cells
ganglion cells
nerve fiber layer
inner limiting membrane

Standarde

- Se incearca definirea omului "standard"
- CIE – Commission Internationale de l'Éclairage
  - 1931 – luminozitatea relativa standard $V(\lambda)$ – fotopic
  - 1951 – luminozitatea relativa standard $V(\lambda)$ – scotopic
  - 1978 – Vos
  - 2005 – Sharpe, Stockman, Jagla, Jägle
  - 2008 – CIE $V(\lambda)$ – fotopic (~Sharpe)
- Sensibilitatea maxima a ochiului uman
  - vedere diurna (fotopic), λ=555 nm, η_v = 683 lm/W
  - vedere nocturna (scotopic), λ=507 nm , η_v = 1700 lm/W

CIE V(λ)



Response of Human Eye Versus Wavelength

(Data from the 1988 C.I.E. Photopic Luminous Efficiency Function)

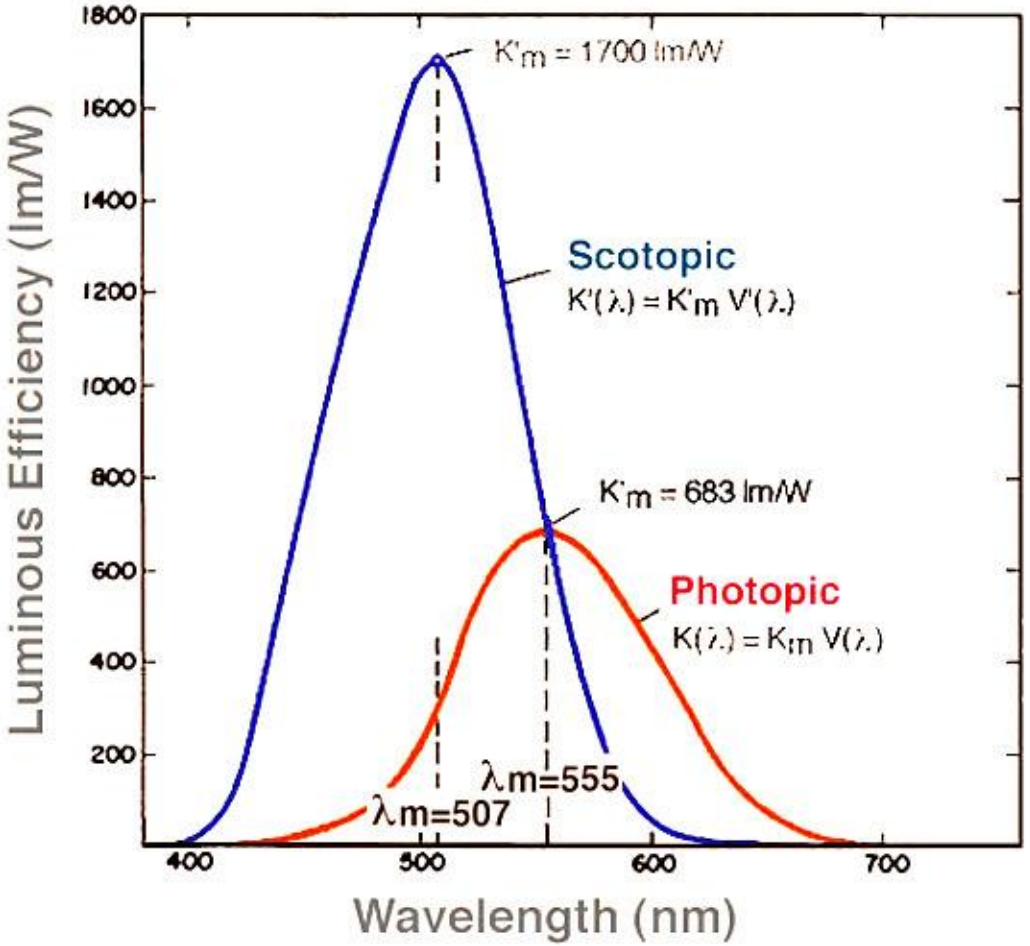


Figure 9. The scotopic and the photopic curves of spectral luminous efficacy (non-normalised values).

efect Purkinje

Curbe normalizate CIE

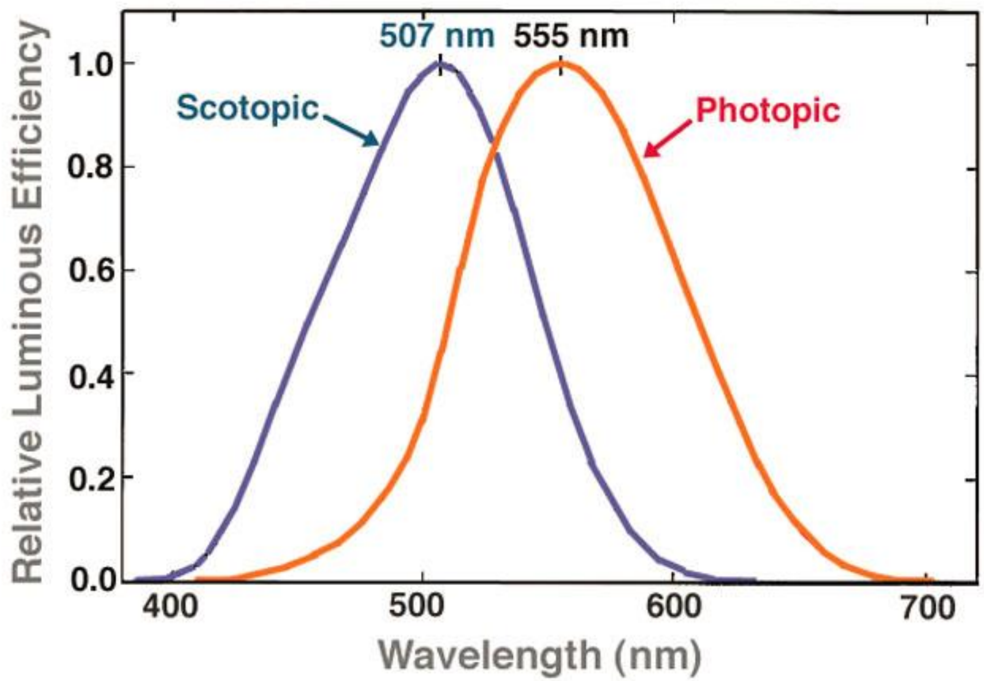
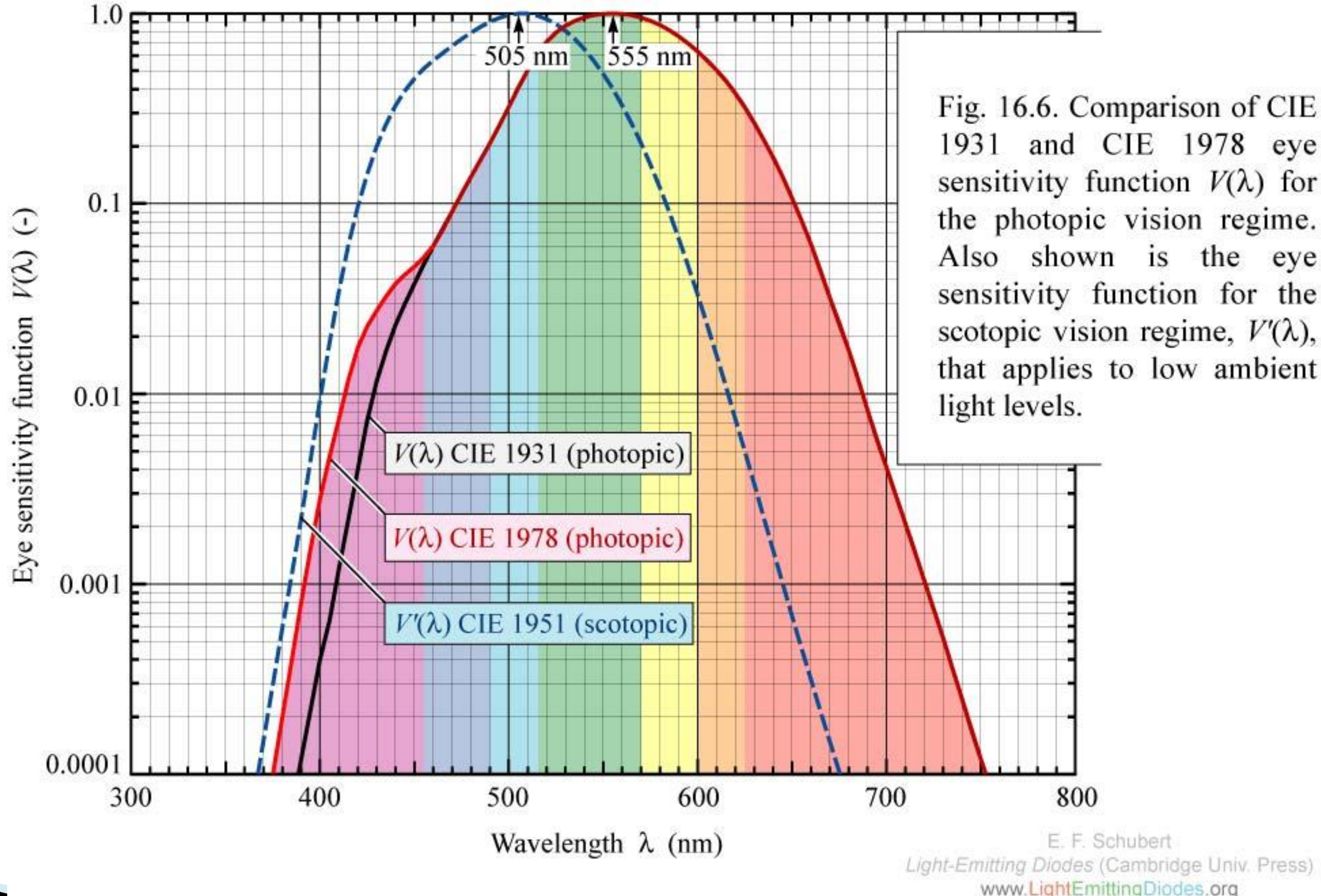


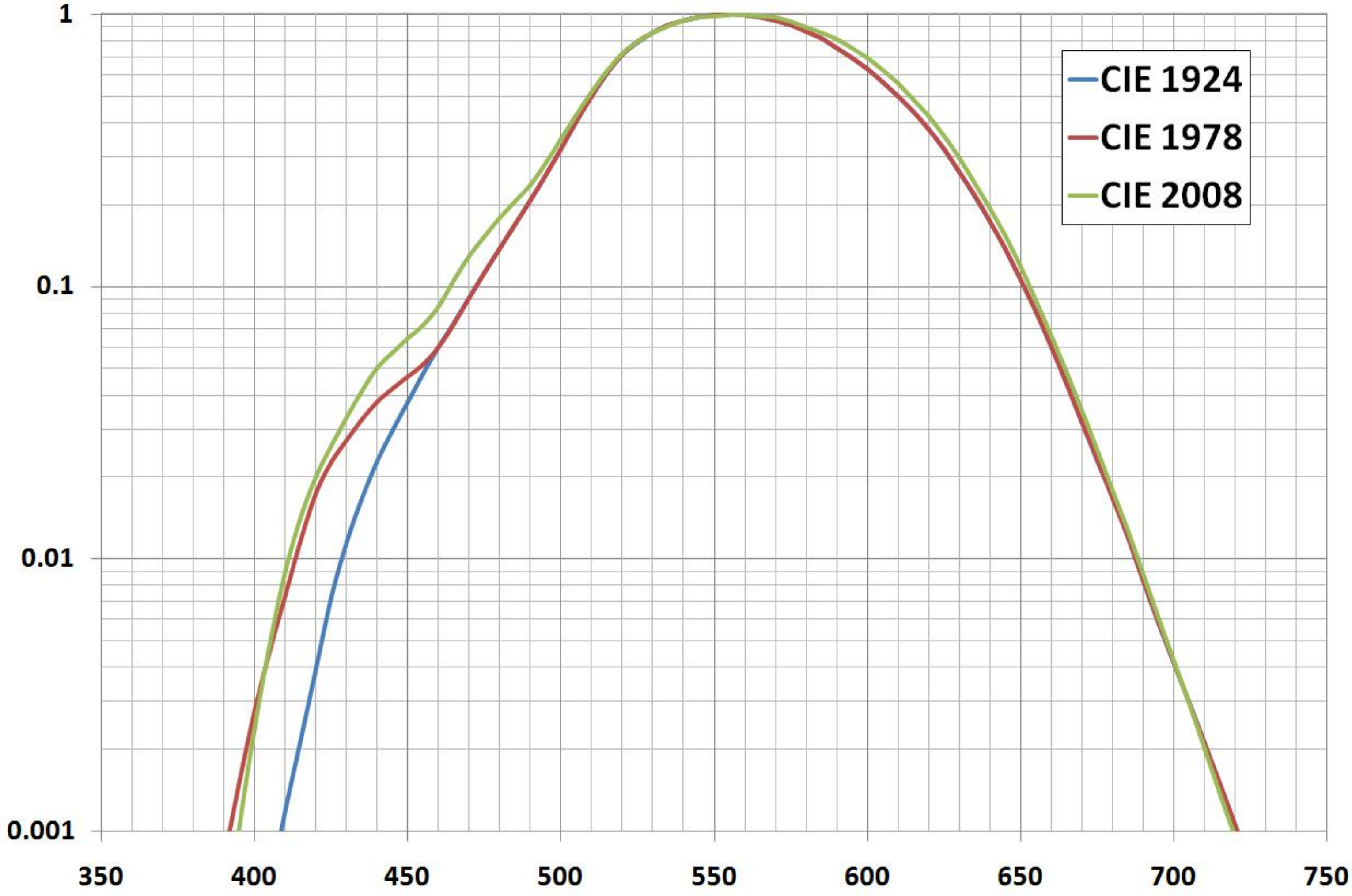
Figure 10. The scotopic and the photopic curves of relative spectral luminous efficiency as specified by the CIE (normalised values).

CIE V(λ)

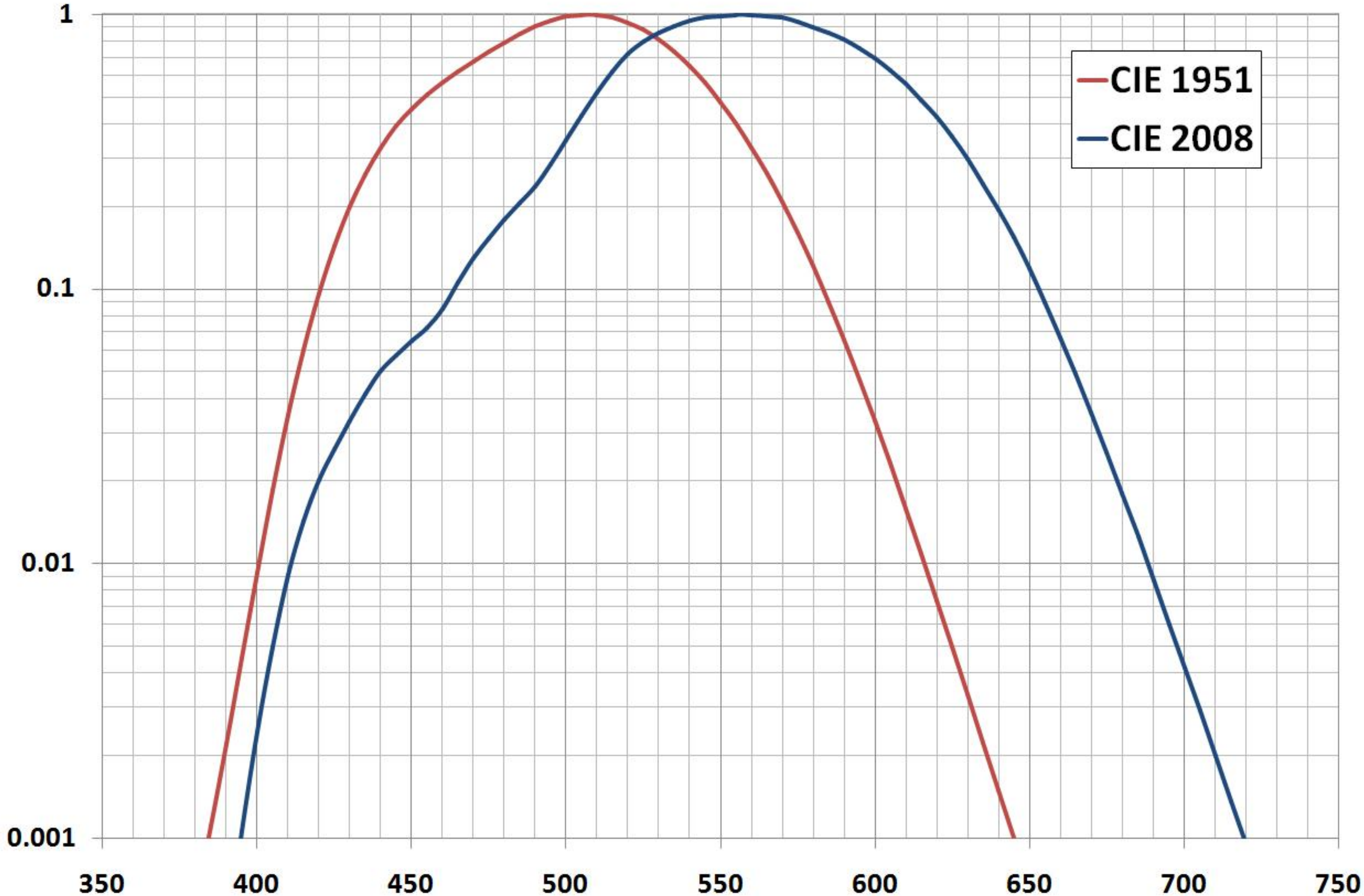


1.0
0.1
0.01
0.001
0.0001
505 nm
555 nm
300
400
500
600
700
800
Eye sensitivity function V(λ) (-)
Wavelength λ (nm)
V(λ) CIE 1931 (photopic)
V(λ) CIE 1978 (photopic)
V'(λ) CIE 1951 (scotopic)
Fig. 16.6. Comparison of CIE 1931 and CIE 1978 eye sensitivity function V(λ) for the photopic vision regime. Also shown is the eye sensitivity function for the scotopic vision regime, V'(λ), that applies to low ambient light levels.
E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

CIE V(λ) fotopic



CIE V(λ) fotopic / scotopic



Eficienta luminoasa relativa V(λ)

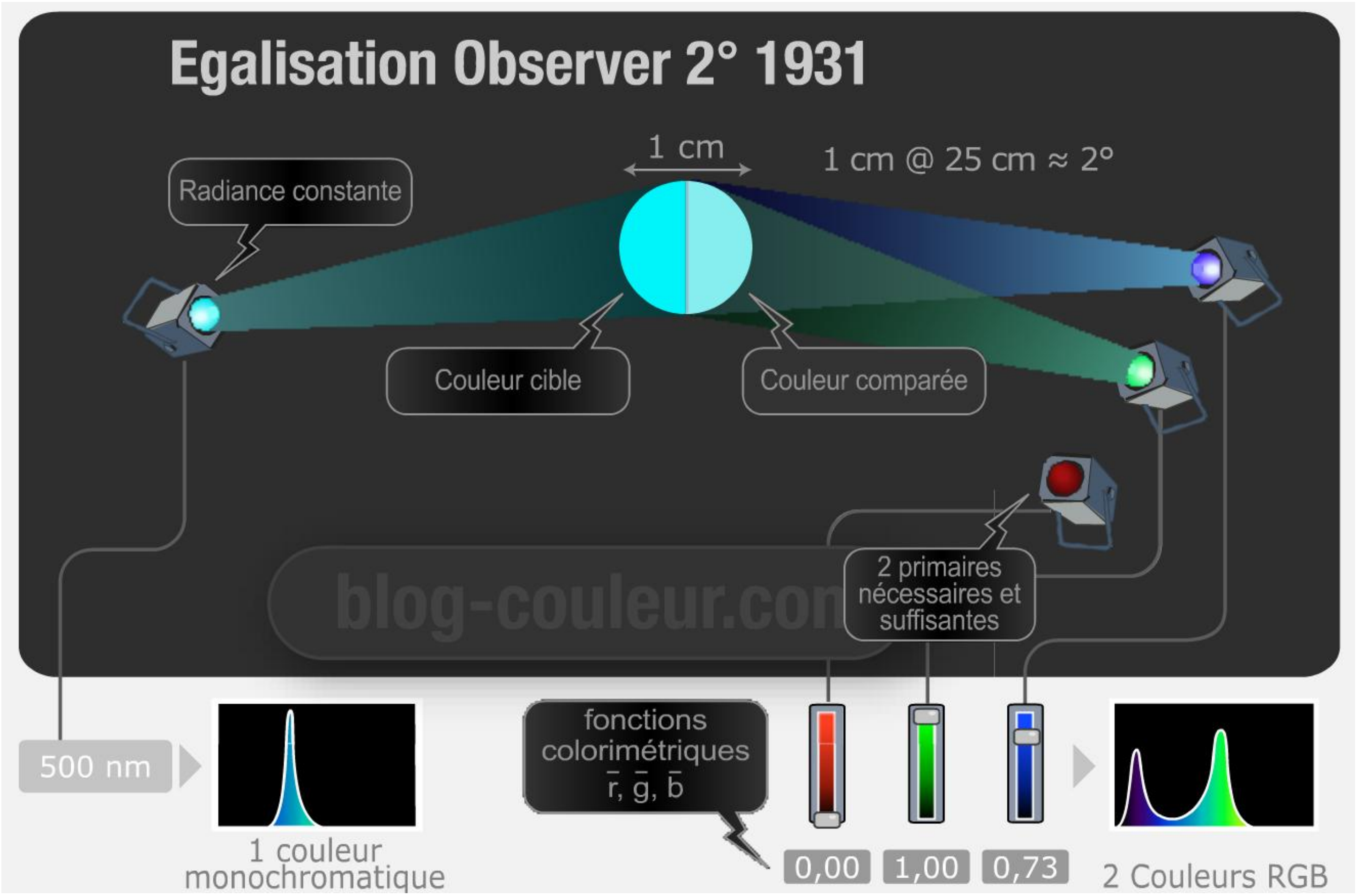
	λ	fotopic CIE 1924	fotopic CIE 2008	scotopic CIE 1951
Violet	400	0.000396	0.00245219	0.00929
Indigo	445	0.0298	0.0574339	0.3931
Albastru	475	0.1126	0.153507	0.734
Verde	510	0.503	0.520497	0.997
Galben	570	0.952	0.973261	0.2076
Portocaliu	590	0.757	0.811587	0.0655
Rosu	650	0.107	0.119312	0.000677

CIE V(λ) 1931

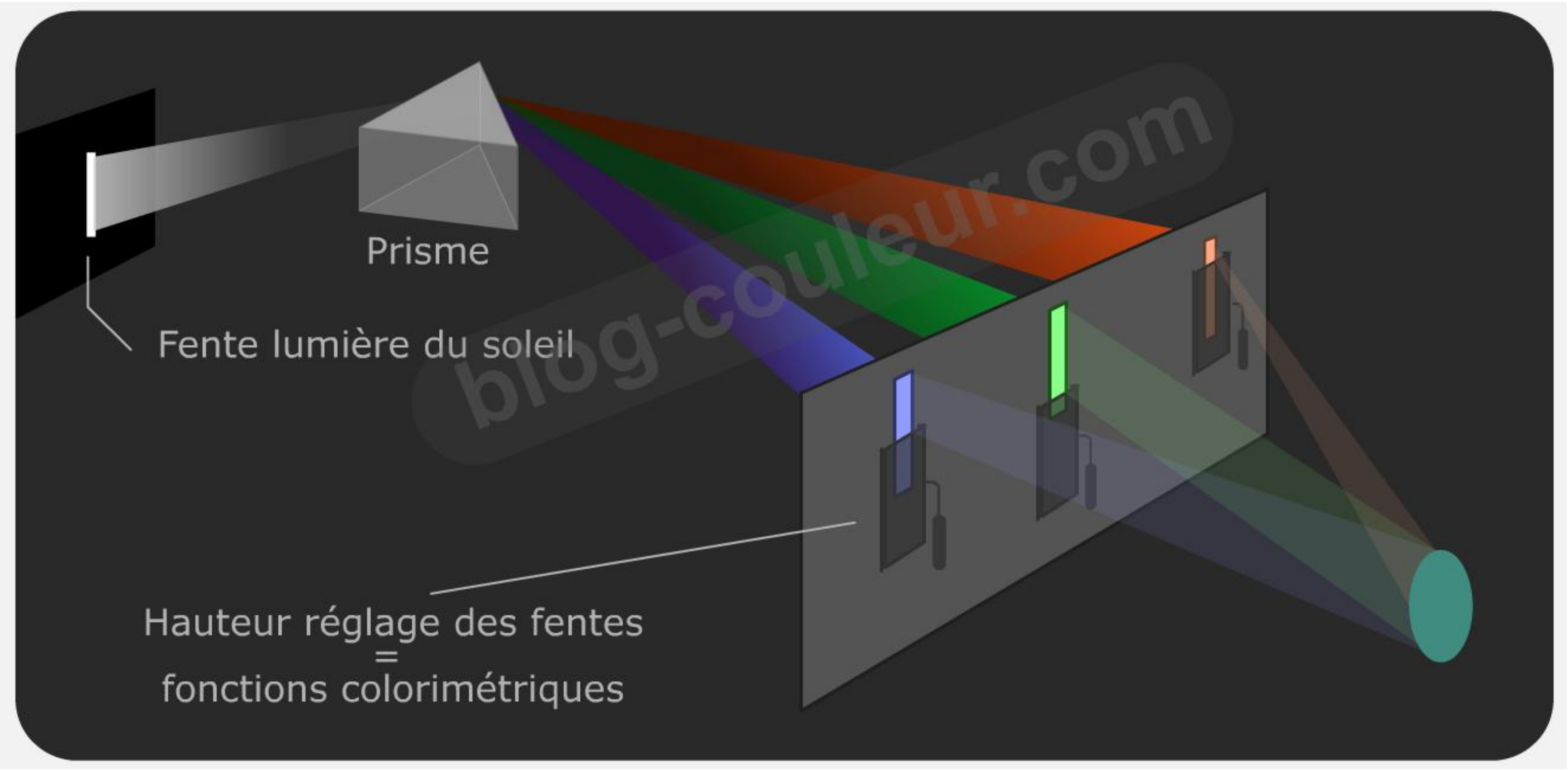
La Commission internationale de l'Éclairage recommande, pour l'usage général, les valeurs suivantes, comme valeurs provisoires pour le facteur de visibilité.

Longueur d'onde (mμ)	Facteur de Visibilité relative(mμ)	Longueur d'onde	Facteur de Visibilité relative	Longueur d'onde (mμ)	Facteur de Visibilité relative
400	0.0004	530	0.862	650	0.107
10	0012	40	954	60	061
20	0040	550	995	70	032
30	0116	60	995	80	017
40	023	70	952	90	0082
450	038	80	870	700	0041
60	060	90	757	10	0021
70	091	600	631	20	00105
80	139	10	503	30	00052
90	208	20	381	40	00025
500	323	30	265	750	00012
10	503	40	175	60	00006
20	710				

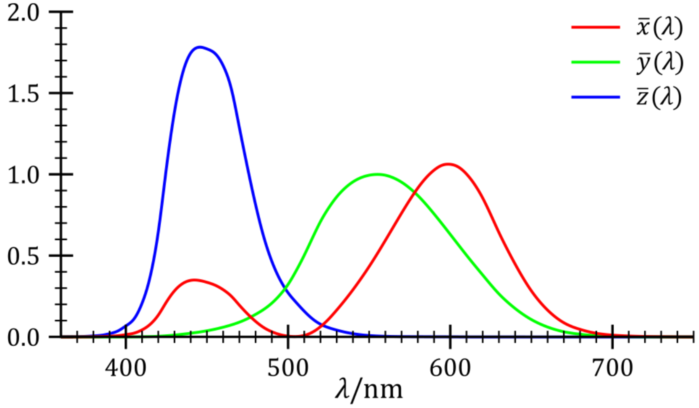
CIE xy 1931


Egalisation Observer 2° 1931
1 cm
1 cm @ 25 cm ≈ 2°
Radiance constante
Couleur cible
Couleur comparée
blog-couleur.com
2 primaires nécessaires et suffisantes
500 nm
1 couleur monochromatique
fonctions colorimétriques
r̄, ḡ, b̄
0,00
1,00
0,73
2 Couleurs RGB

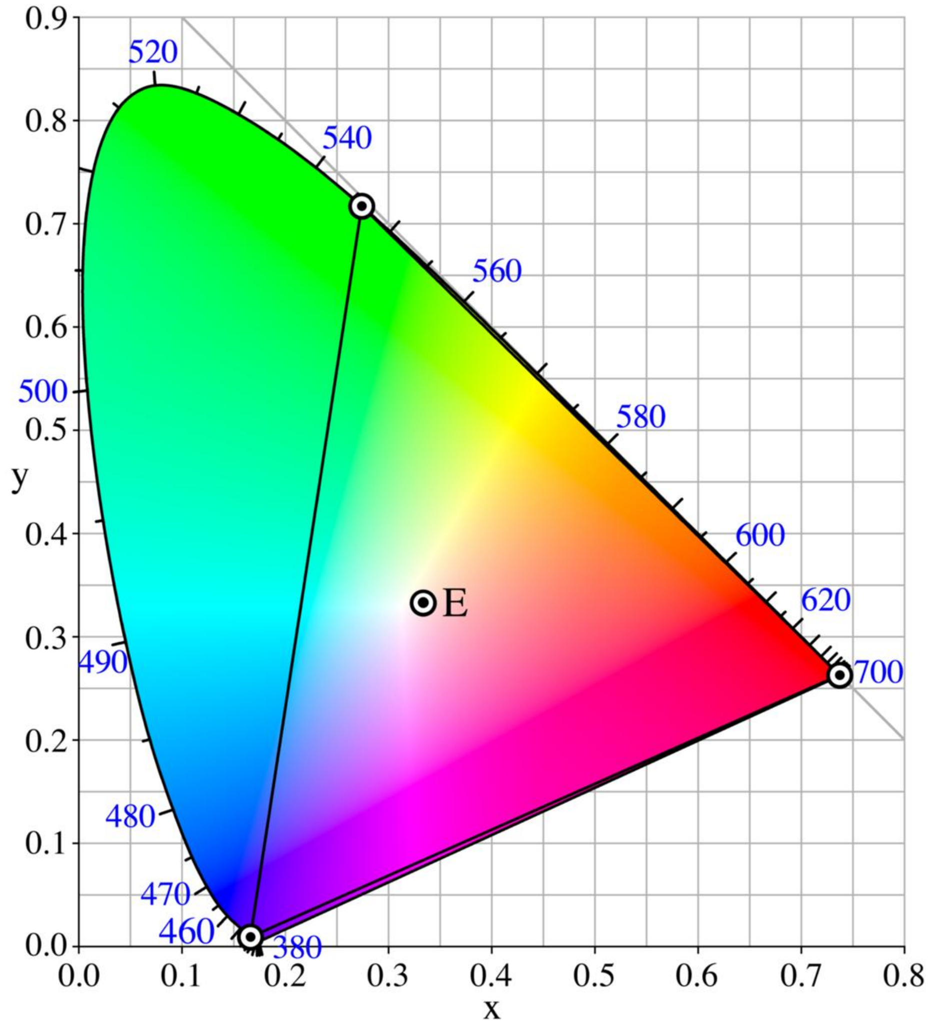
CIE xy 1931


Prisme
Fente lumière du soleil
Hauteur réglage des fentes
=
fonctions colorimétriques
blog-couleur.com

CIE xy 1931

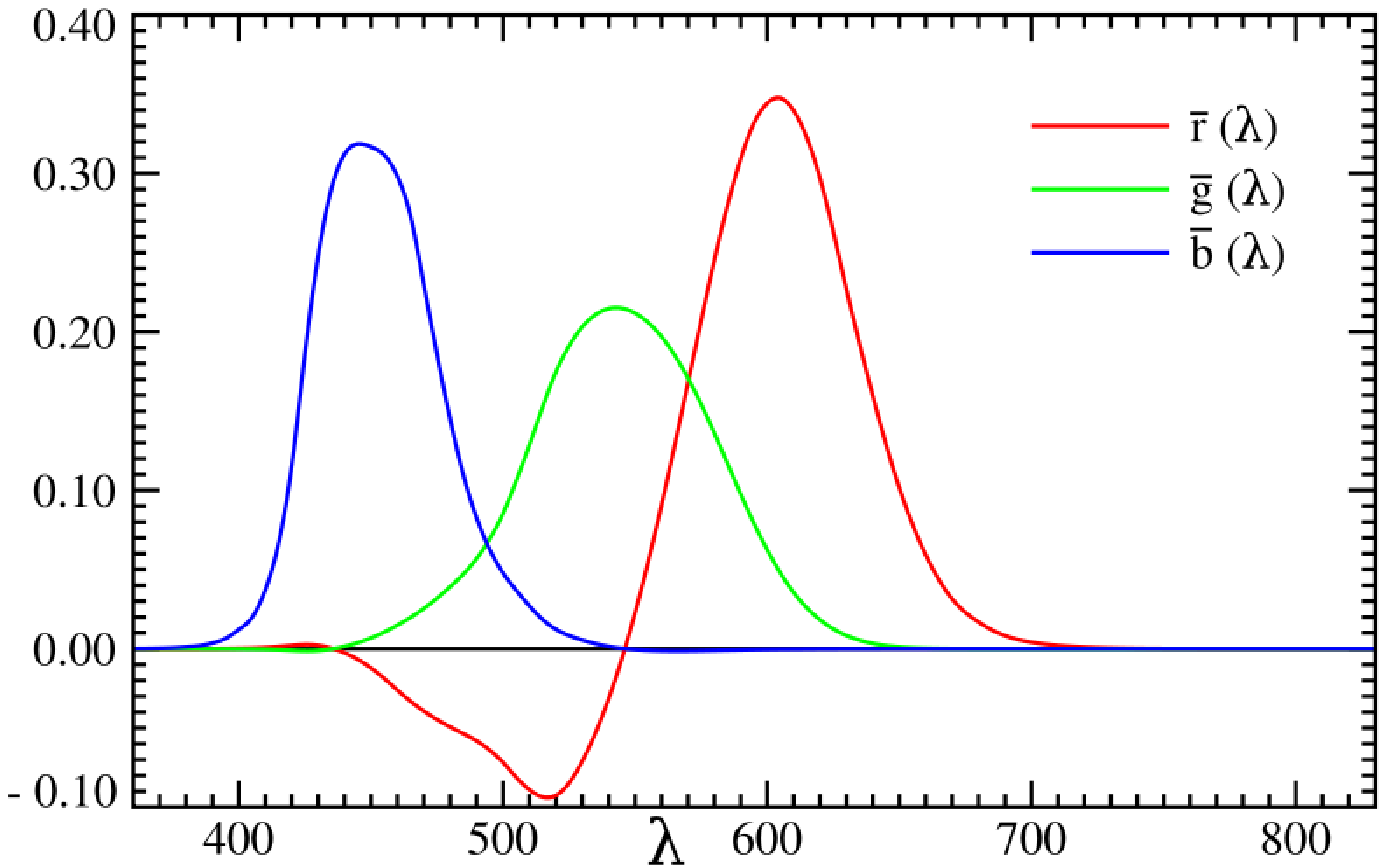


2.0
1.5
1.0
0.5
0.0
400
500
600
700
λ/nm
$\bar{x}(\lambda)$
$\bar{y}(\lambda)$
$\bar{z}(\lambda)$



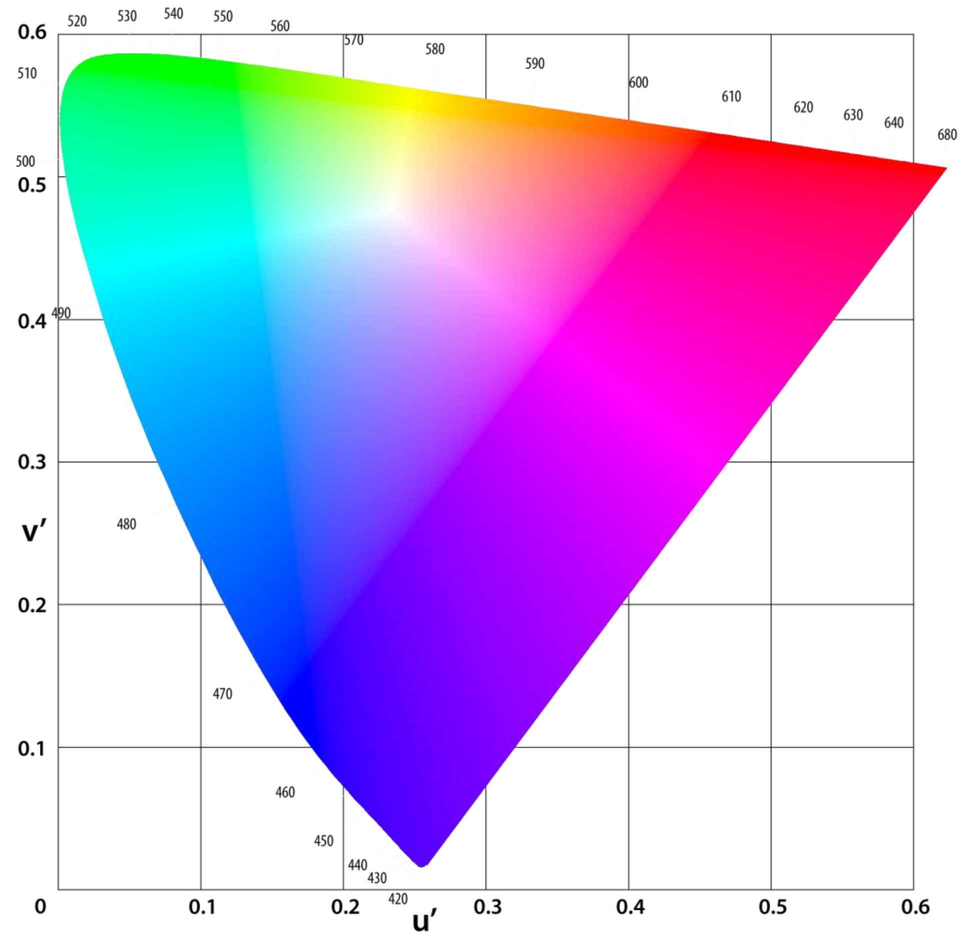
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
520
540
560
580
600
620
700
500
490
480
470
460
380
E

Cantitatea din culorile primare pentru aceeasi senzatie de culoare



CIELUV 1976

- uniformitatea perceptiei, a "diferentei de culoare"

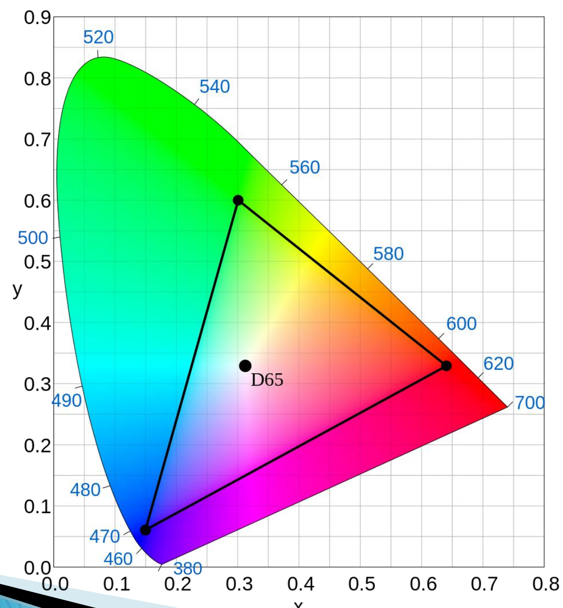


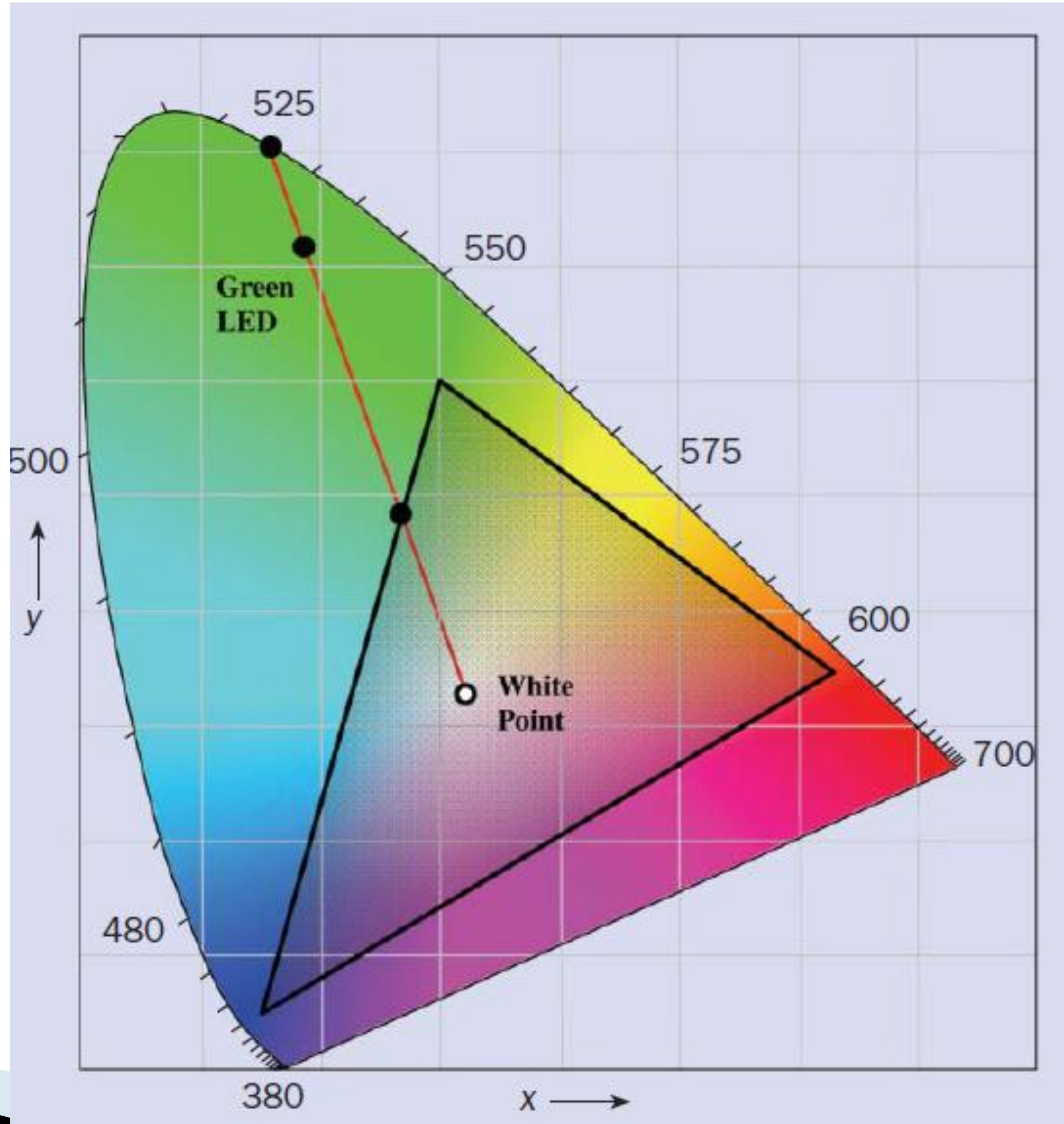
ITU-R BT.709

ITU-R BT.709 phosphor properties

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

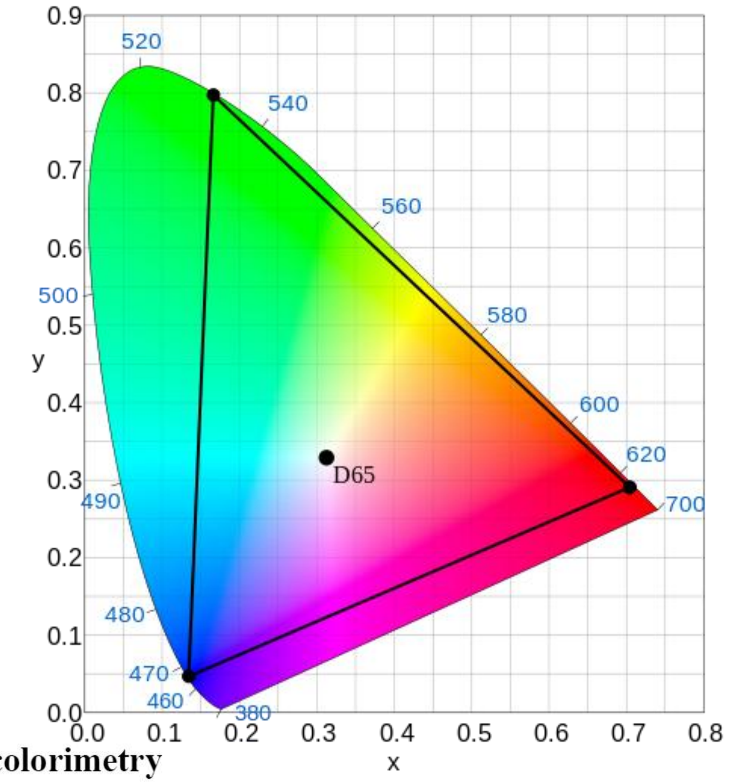
Data refers to xy chromaticity co-ordinates of ITU-R BT.709 phosphors which are used in most CRT displays [1].





ITU-R BT.2020

- **Parameter values for ultra-high definition television systems**
- UHDTV

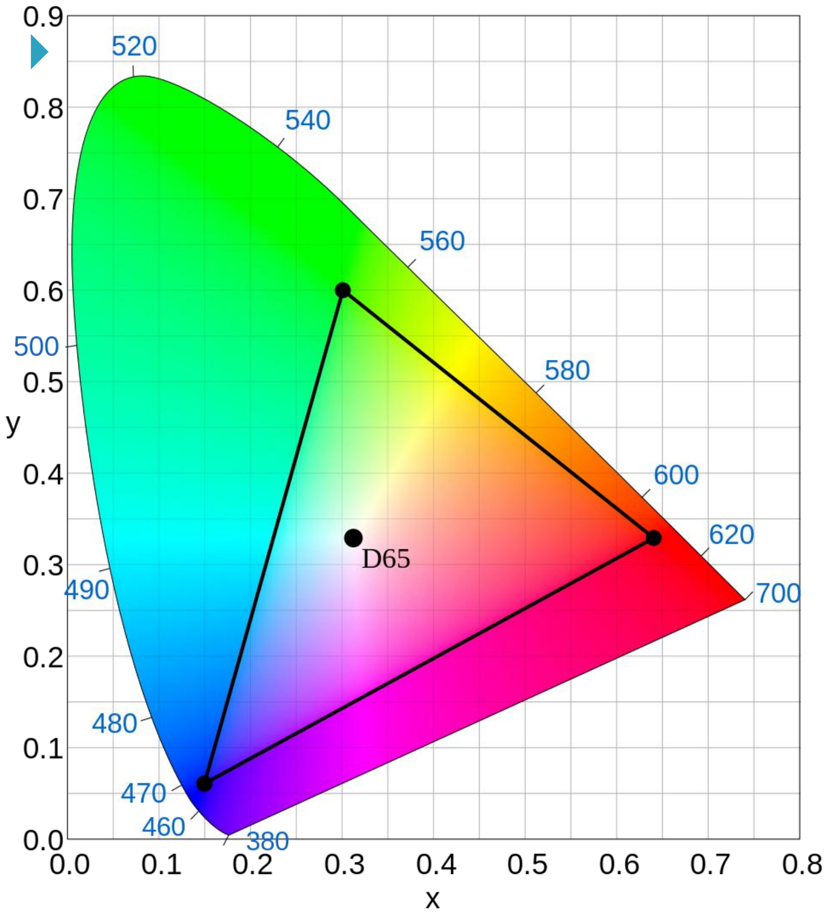


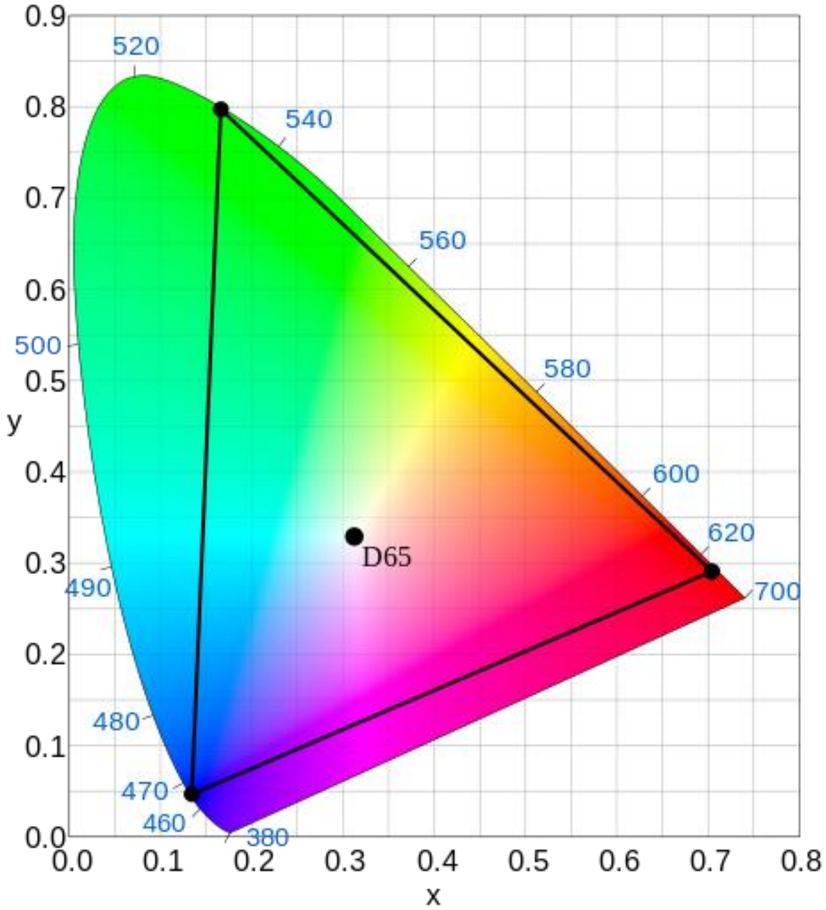
System colorimetry

Parameter	Values		
Opto-electronic transfer characteristics before non-linear pre-correction	Assumed linear(1)		
Primary colours and reference white(2)	Chromaticity coordinates (CIE, 1931)	x	y
	Red primary (R)	0.708	0.292
	Green primary (G)	0.170	0.797
	Blue primary (B)	0.131	0.046
	Reference white (D65)	0.3127	0.3290

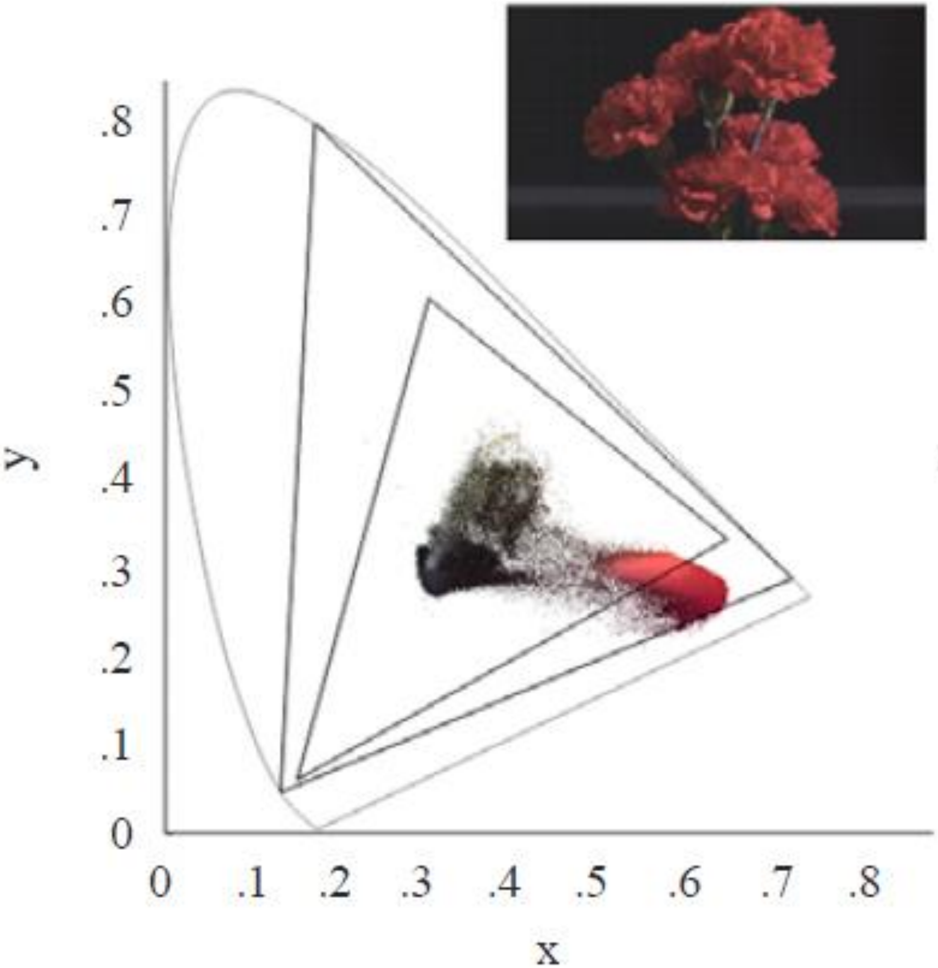
(1) Picture information can be linearly indicated by the tristimulus values of RGB in the range of 0-1.

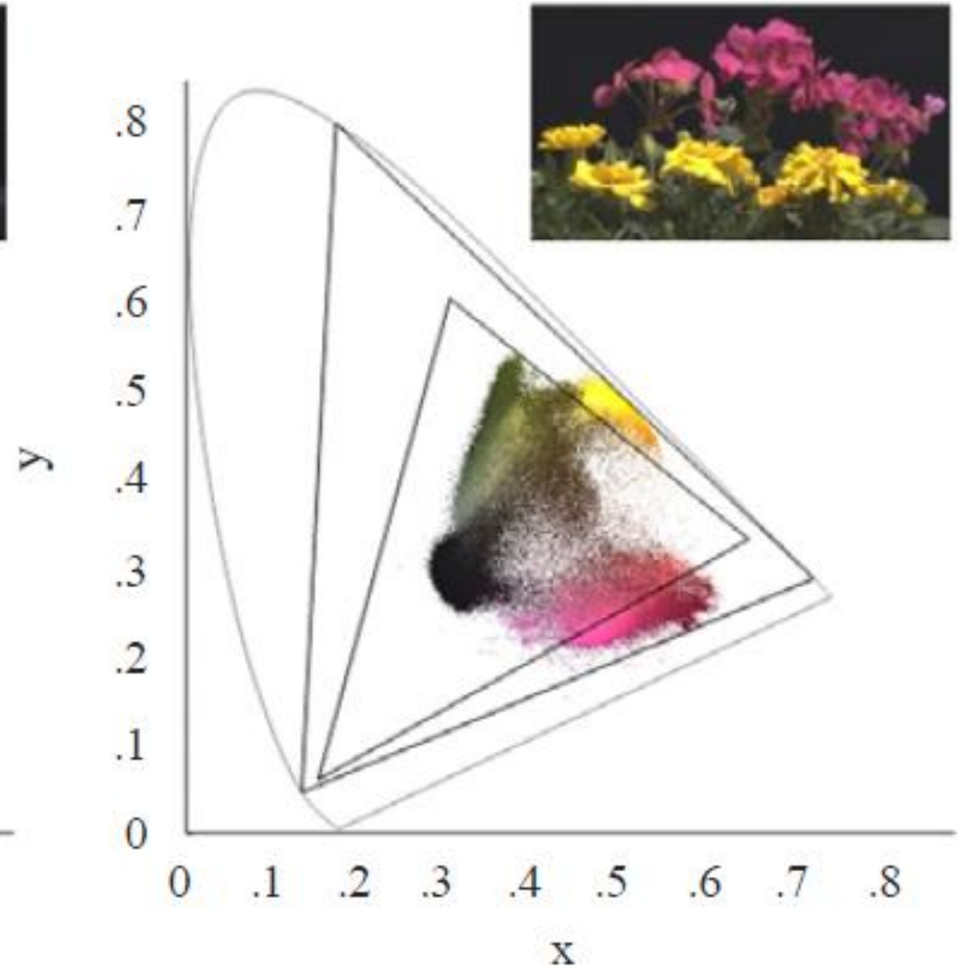
ITU-R BT.709/.2020



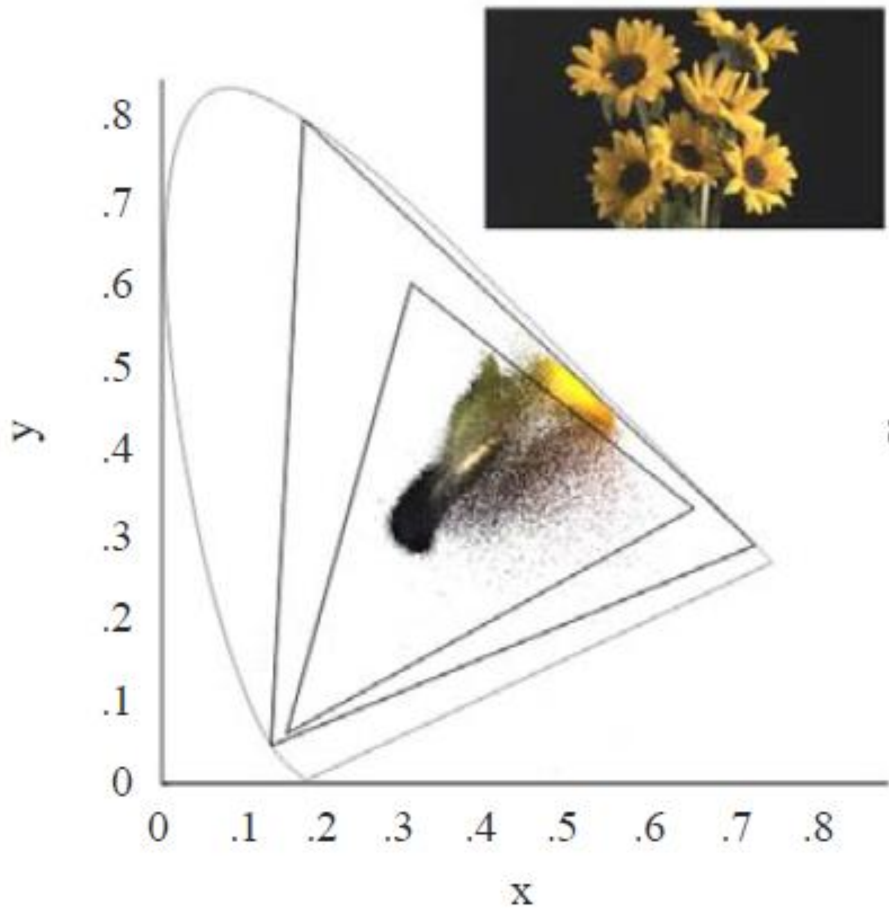


ITU-R BT.709/.2020

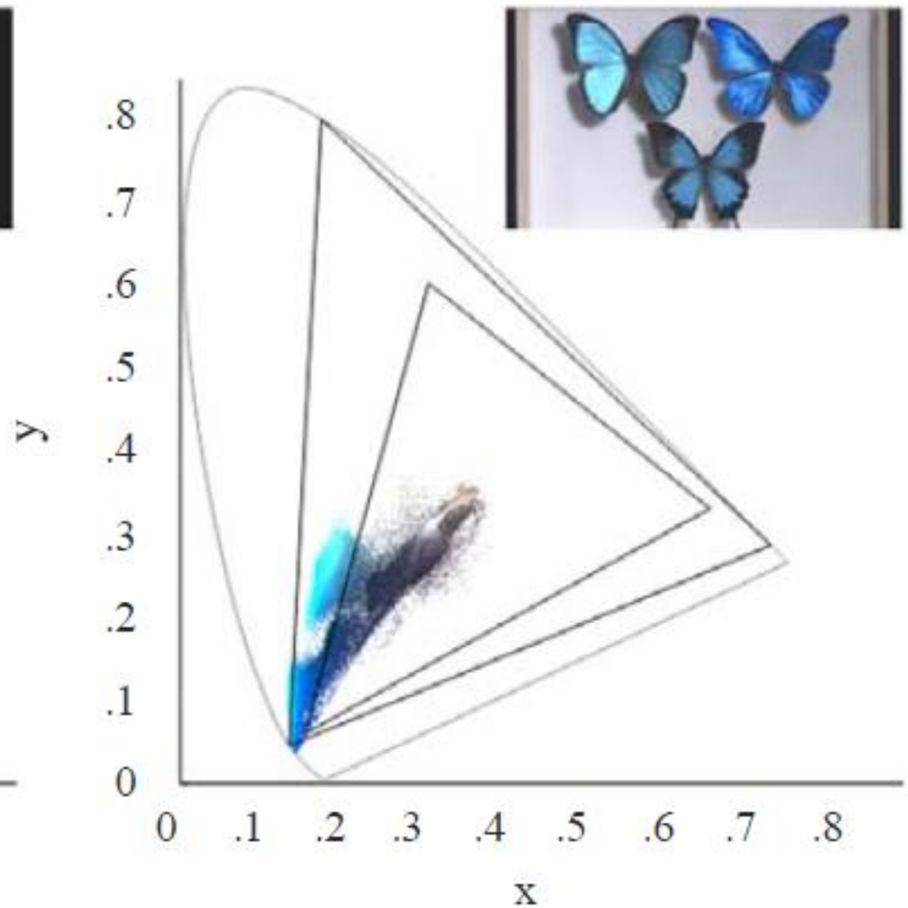




ITU-R BT.709/.2020



c) Sunflower



(d) Butterfly

Determinarea lungimii de unda dominante

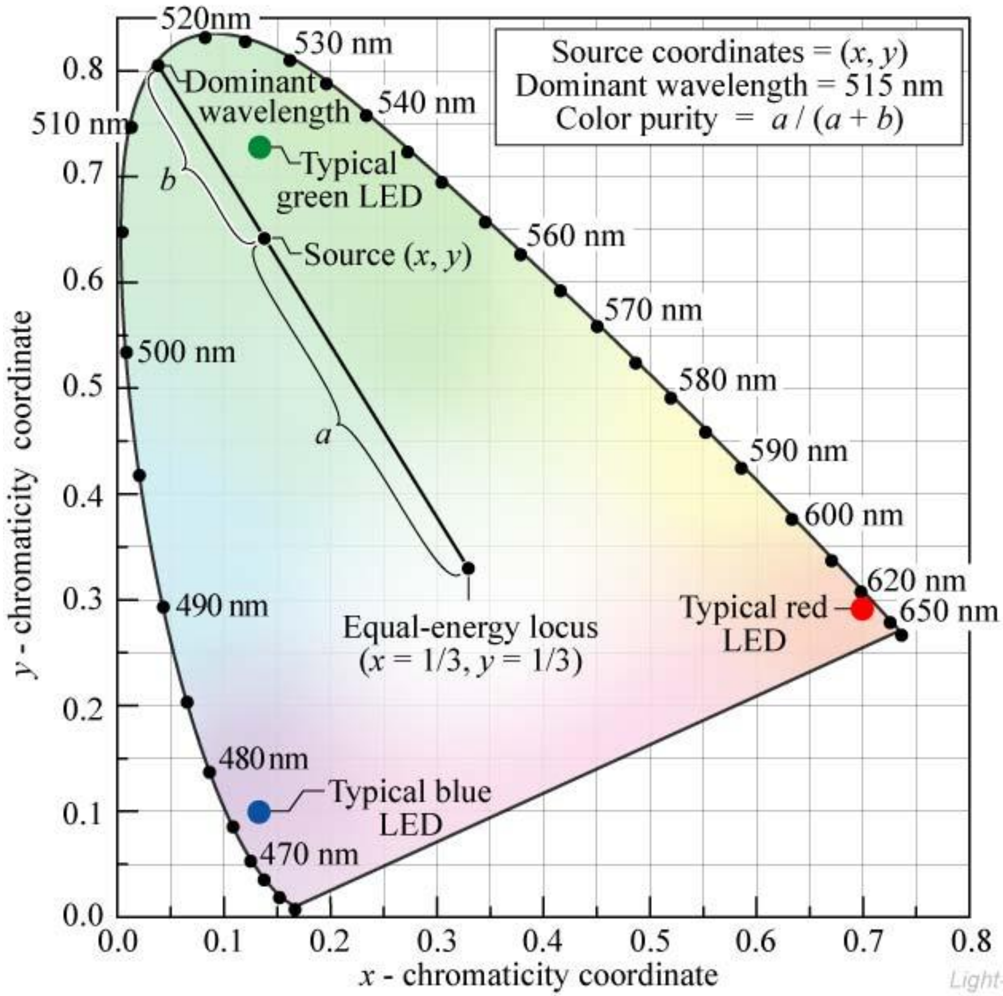
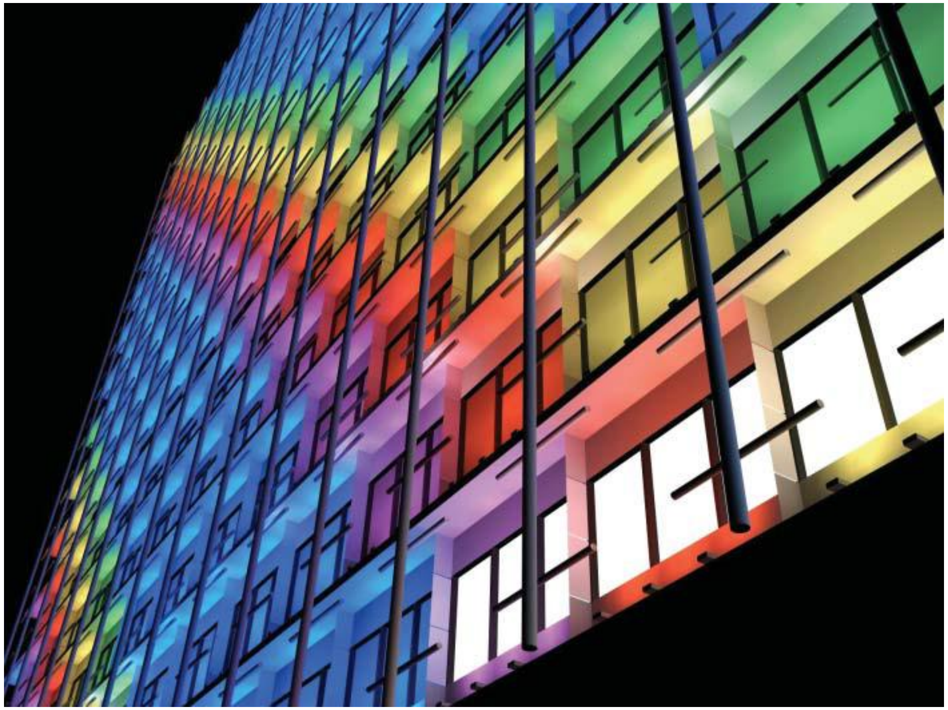


Fig. 17.8. Chromaticity diagram showing the determination of the *dominant color* and *color purity* of a light source with chromaticity coordinates (x, y) using the equal-energy locus (x = 1/3, y = 1/3) as the white-light reference. Also shown are typical locations of blue, green, and red LEDs.

ITU-R BT.709

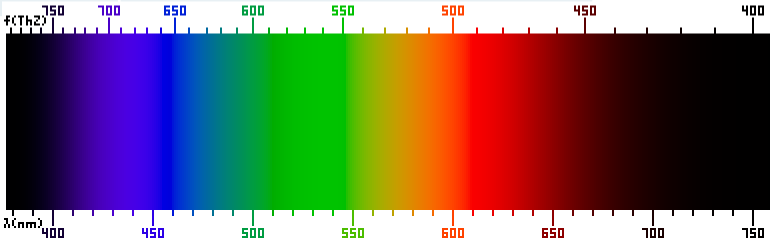


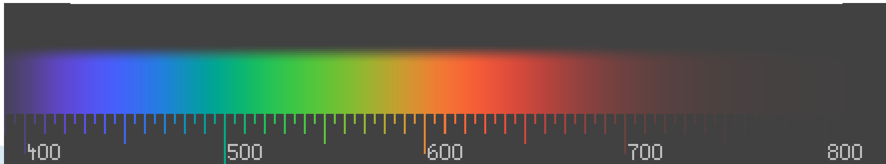
RGB values for Luxeon LEDs

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

Culori – lungime de unda

Culoare	Lungime de unda	Frecventa
Rosu	~ 700–630 nm	~ 430–480 THz
Portocaliu	~ 630–590 nm	~ 480–510 THz
Galben	~ 590–560 nm	~ 510–540 THz
Verde	~ 560–490 nm	~ 540–610 THz
Albastru	~ 490–450 nm	~ 610–670 THz
Violet	~ 450–400 nm	~ 670–750 THz





Interpretarea standard a culorilor

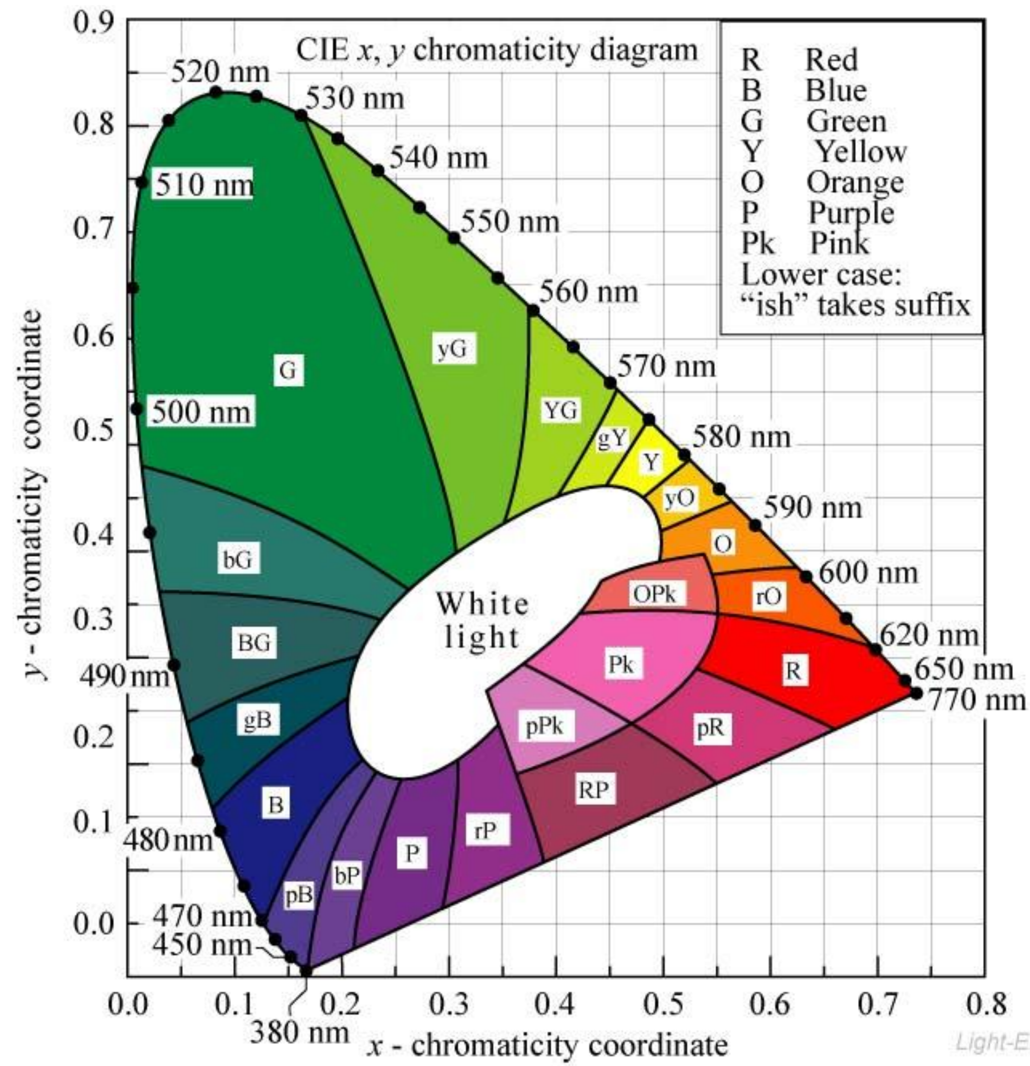


Fig. 17.3. 1931 CIE chromaticity diagram with areas attributed to distinct colors (adopted from Gage *et al.*, 1977).

E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

Interpretarea standard a culorilor

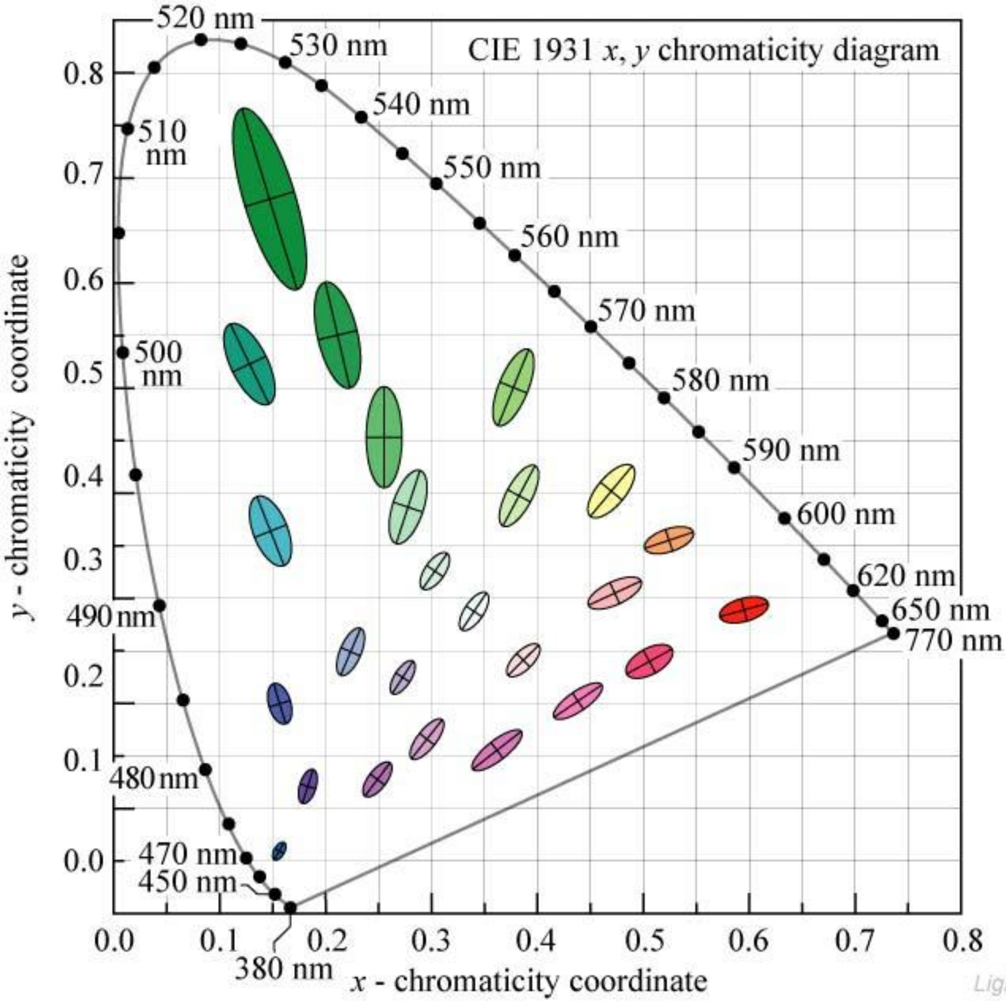


Fig. 17.5. MacAdam ellipses plotted in the CIE 1931 (*x*, *y*) chromaticity diagram. The axes of the ellipses are ten times their actual lengths (after MacAdam, 1943; Wright, 1943; MacAdam, 1993).

E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

Temperatura de culoare

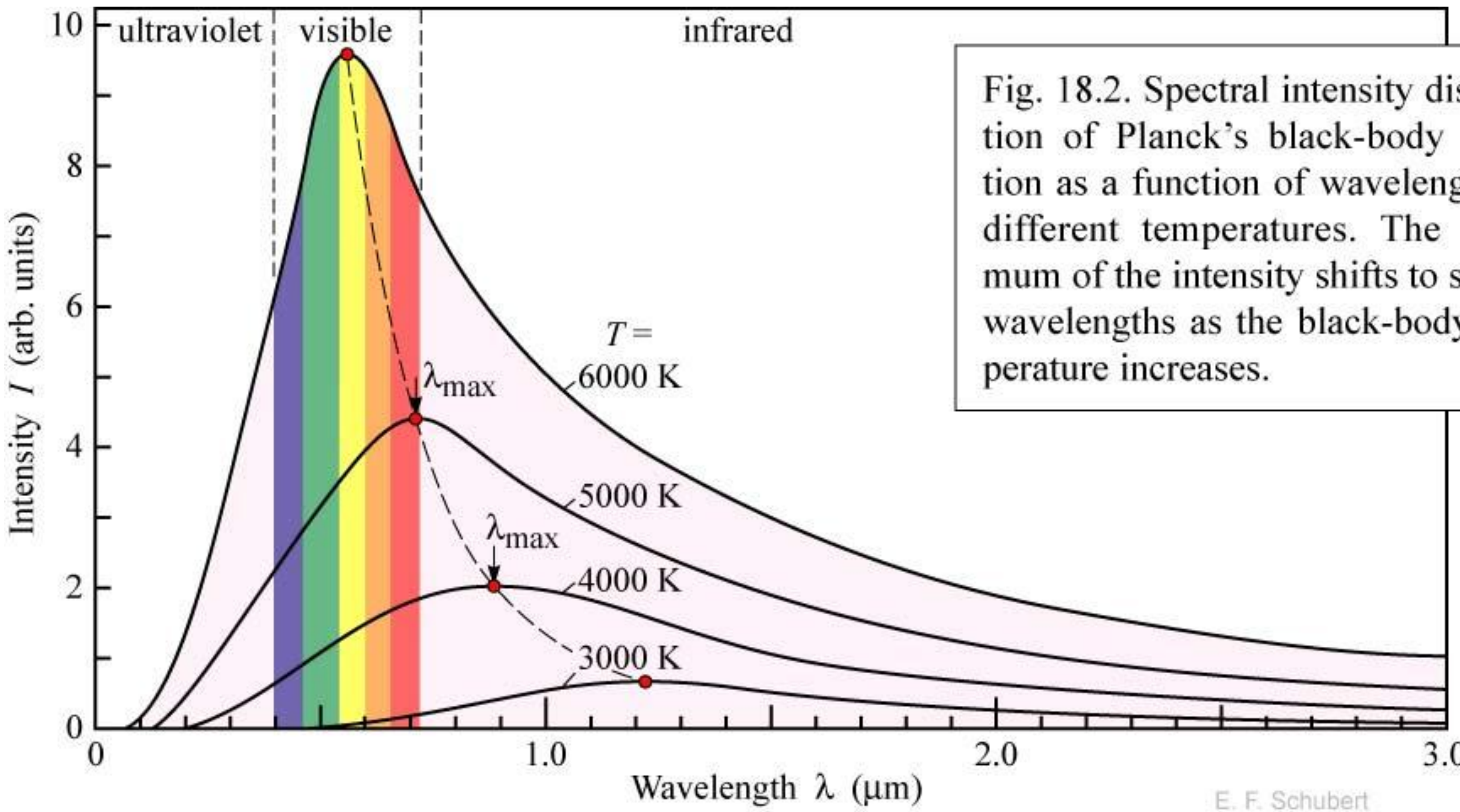
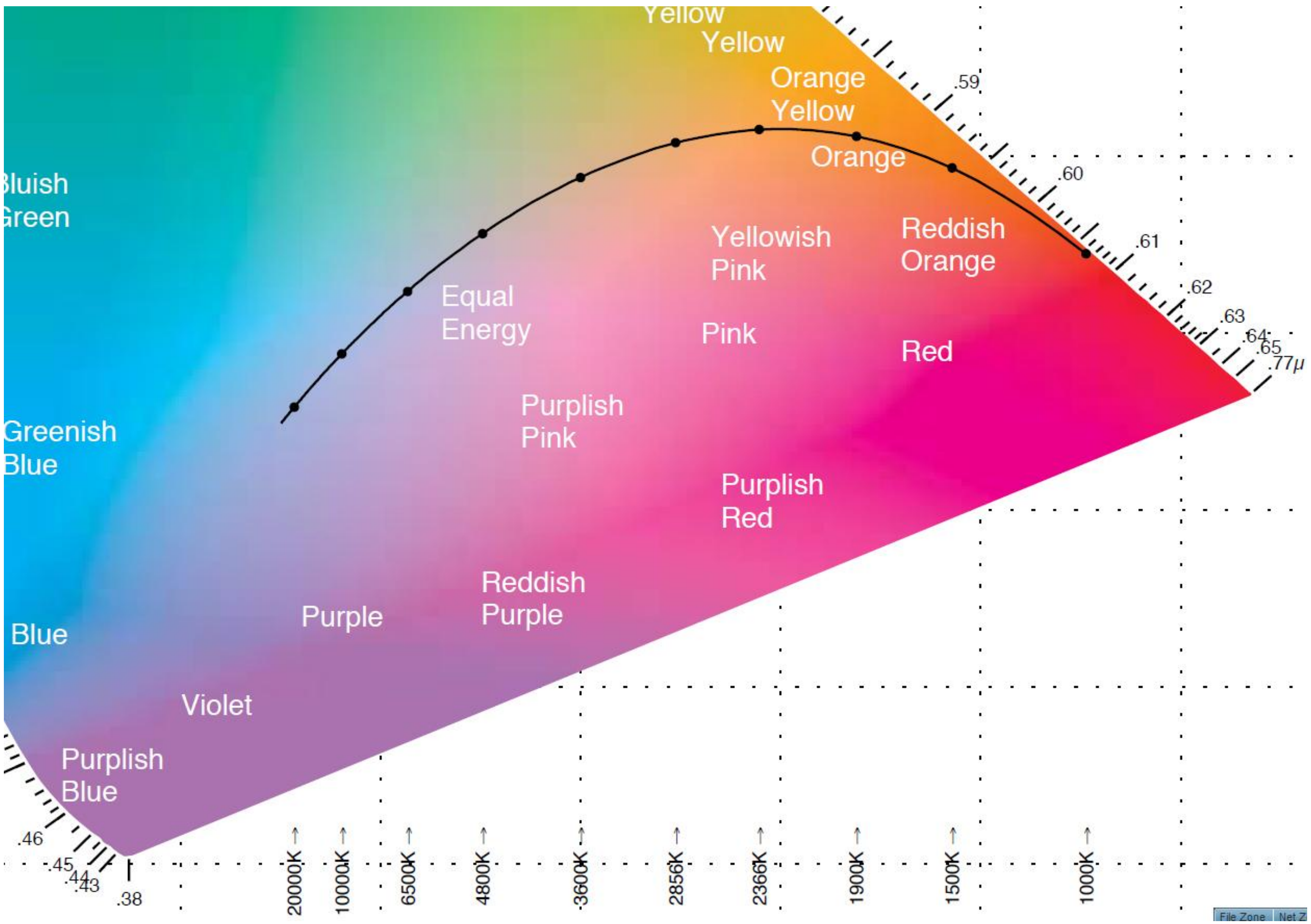


Fig. 18.2. Spectral intensity distribution of Planck's black-body radiation as a function of wavelength for different temperatures. The maximum of the intensity shifts to shorter wavelengths as the black-body temperature increases.

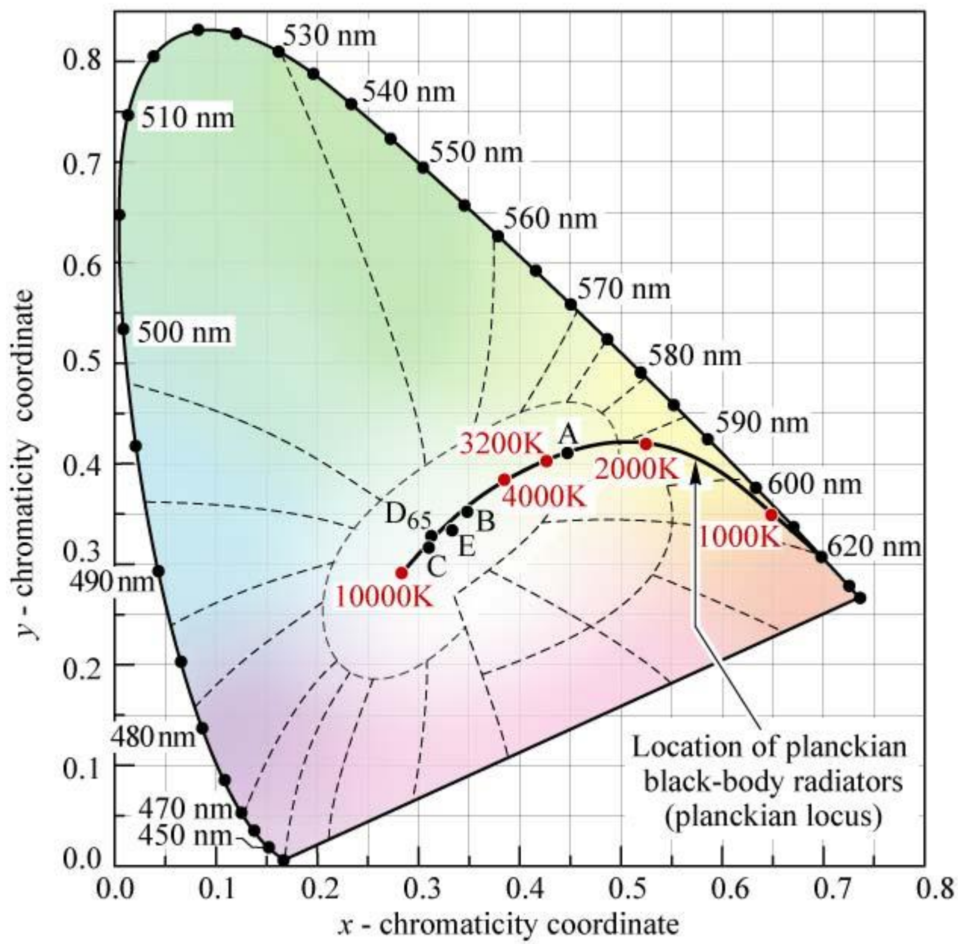
E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

CIE xy 1931



Yellow
Yellow
Orange Yellow
Orange
Bluish Green
Yellowish Pink
Reddish Orange
Equal Energy
Pink
Red
Purplish Pink
Greenish Blue
Purplish Red
Reddish Purple
Purple
Blue
Violet
Purplish Blue
.59
.60
.61
.62
.63
.64
.65
.77μ
.46
.45
.44
.43
.38
20000K
10000K
6500K
4800K
3600K
2856K
2366K
1900K
1500K
1000K

Temperatura de culoare



Illuminant A
$(x, y) = (0.4476, 0.4074)$
(Incandescent source, $T = 2856$ K)

Illuminant B
$(x, y) = (0.3484, 0.3516)$
(Direct sunlight, $T = 4870$ K)

Illuminant C
$(x, y) = (0.3101, 0.3162)$
(Overcast source, $T = 6770$ K)

Illuminant D_{65}
$(x, y) = (0.3128, 0.3292)$
(Daylight, $T = 6500$ K)

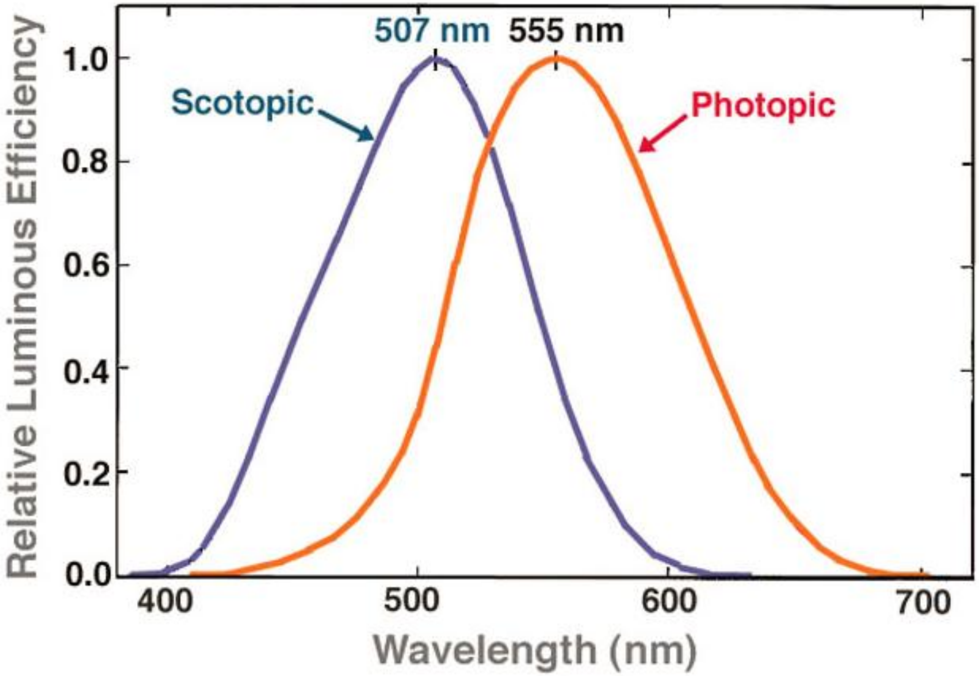
Illuminant E (equal-energy point)
$(x, y) = (0.3333, 0.3333)$

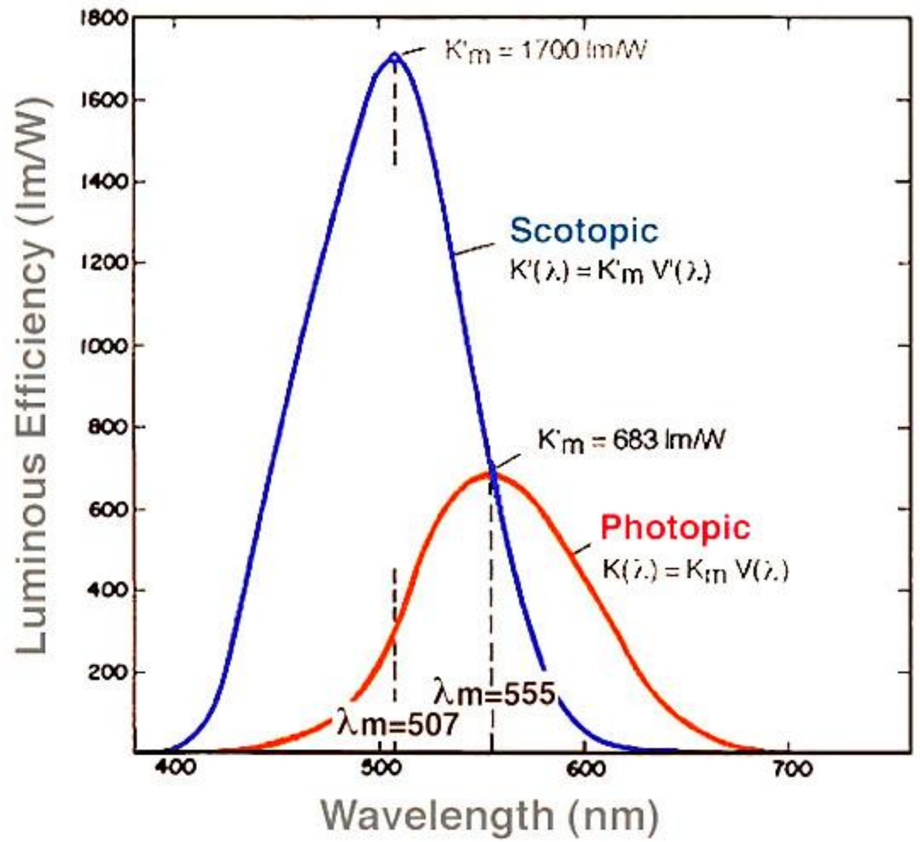
Fig. 18.3. Chromaticity diagram showing planckian locus, the standardized white Illuminants A, B, C, D_{65}, and E, and their color temperature (after CIE, 1978).

Lungimi de unda tipice – LED

Wavelength (nm)	Color Name
940	Infrared
880	Infrared
850	Infrared
660	Ultra Red
635	High Eff. Red
633	Super Red
620	Super Orange
612	Super Orange
605	Orange
595	Super Yellow
592	Super Pure Yellow
585	Yellow
4500K	"Incandescent" White
6500K	Pale White
8000K	Cool White
574	Super Lime Yellow
570	Super Lime Green
565	High Efficiency Green
560	Super Pure Green
555	Pure Green
525	Aqua Green
505	Blue Green
470	Super Blue
430	Ultra Blue

Relatie radiometrie/fotometrie





Contact

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- rdamian@etti.tuiasi.ro