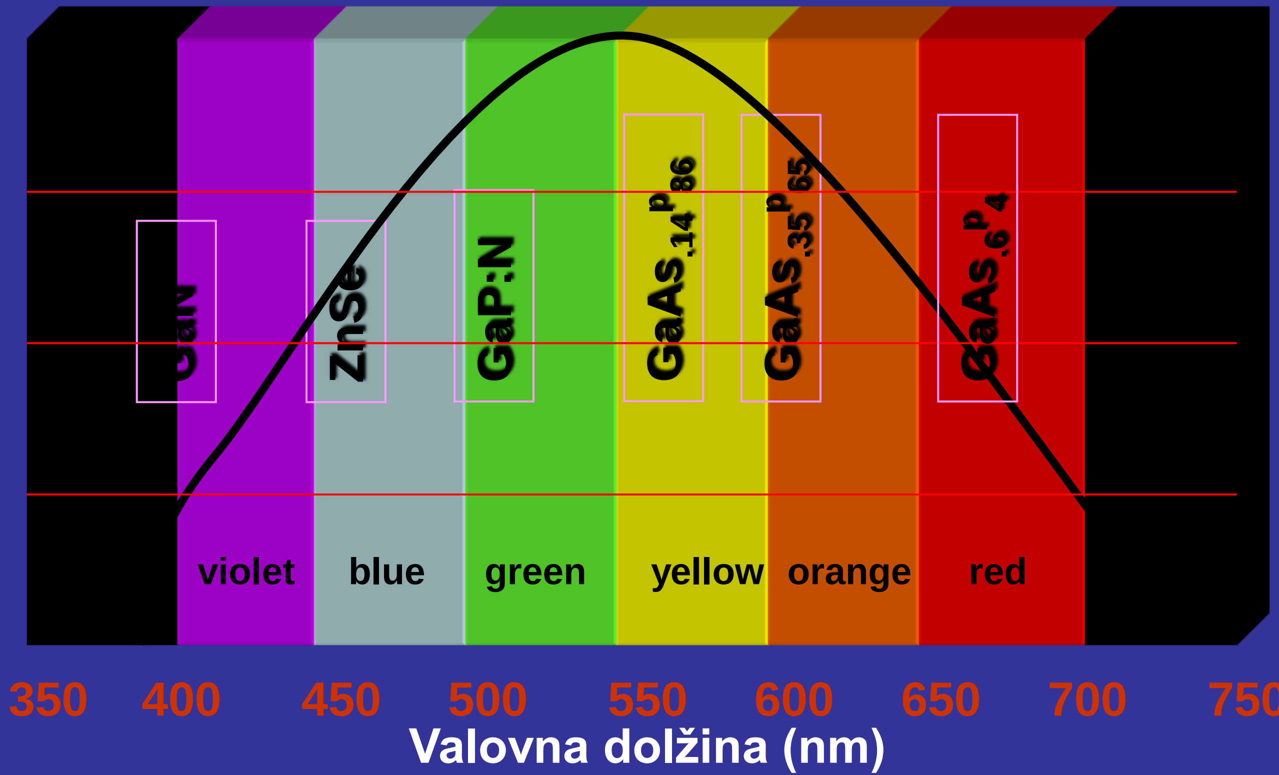
Moderni polprevodniški izvori svetlobe



Marko Zgonik, Oddelek za fiziko FMF,

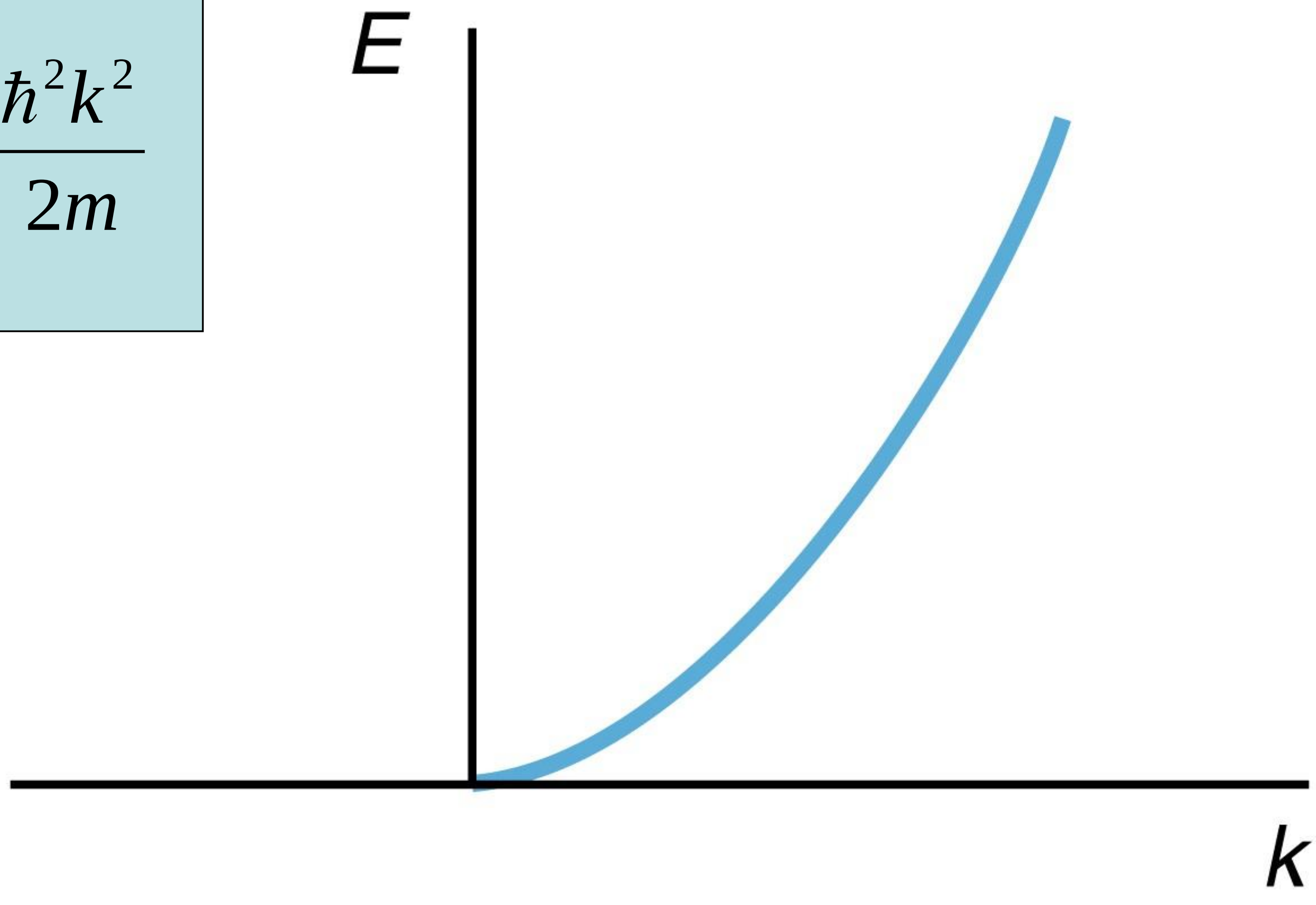
22.10. 2010

Moderni polprevodniški izvori svetlobe

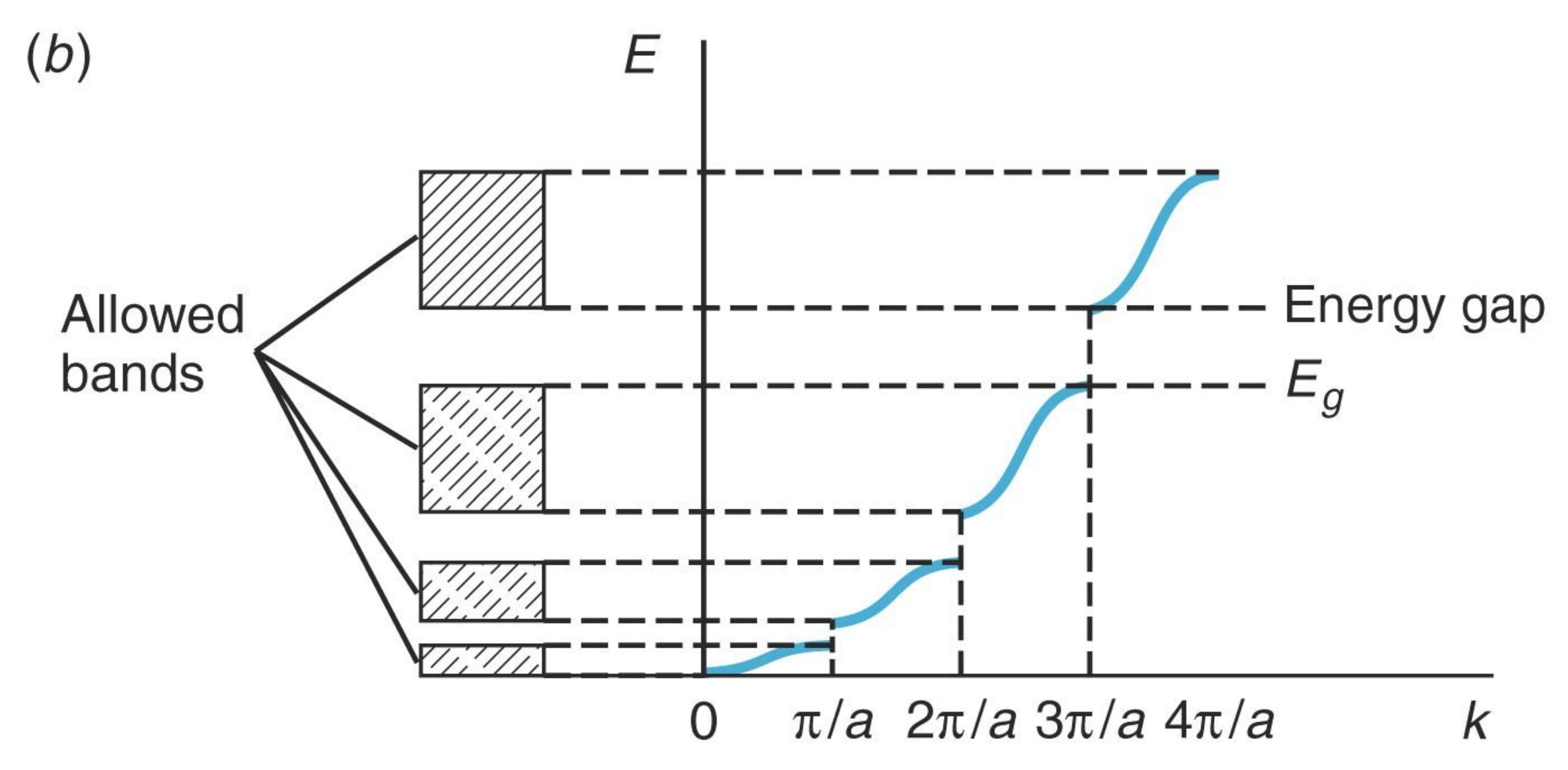
- Osnovna fizika elektronskih stanj
- Interakcija svetlobe in elektronov
- Nehomogeni polprevodniki - heterostrukture
- Delovanje svetlečih diod in laserjev
- Tehnologija izdelave
- Nekaj fotometrije
- Primeri naprav in njihovih karakteristik

Energija prostega elektrona

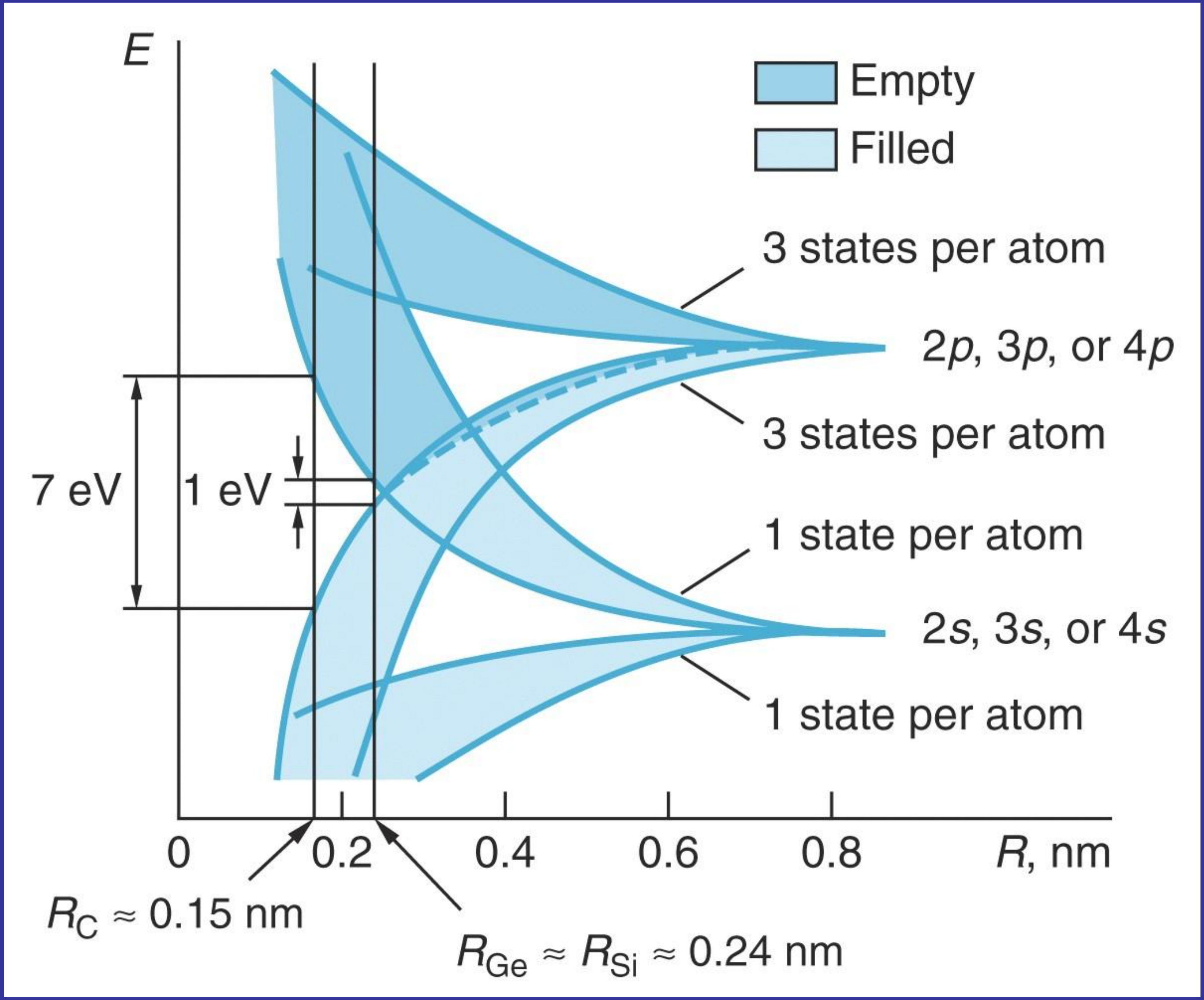
$$E = \frac{\hbar^2 k^2}{2m}$$



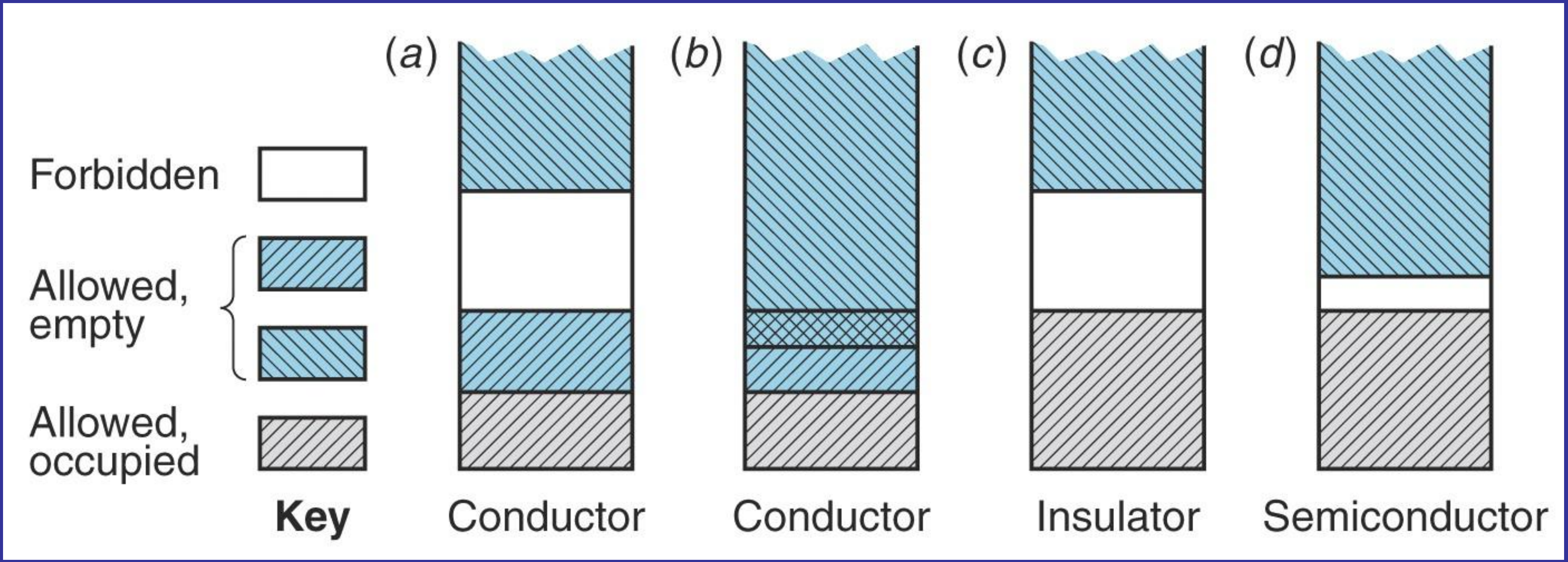
Energija elektrona v periodičnem potencialu



Elektronska stanja v Si, Ge in C



Shema elektronskih stanj v različnih materialih



ELEKTRONSKA STANJA
(a) izolator ali polprevodnik
(b) kovina

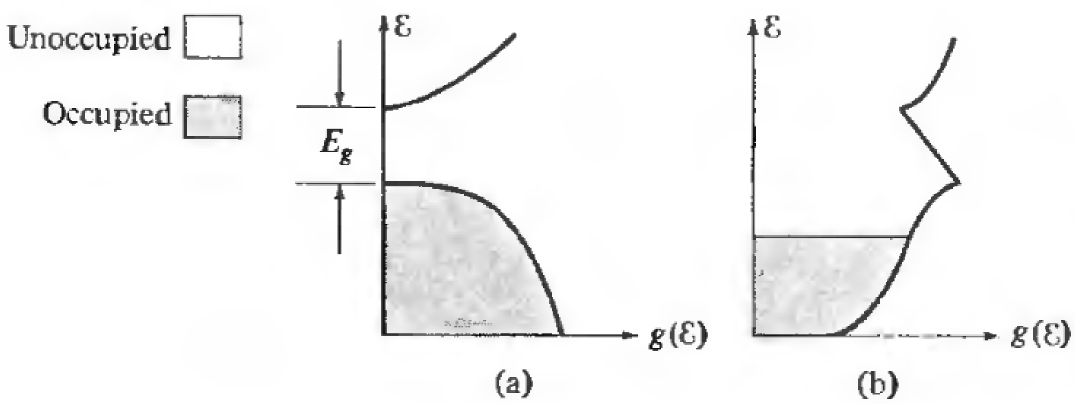
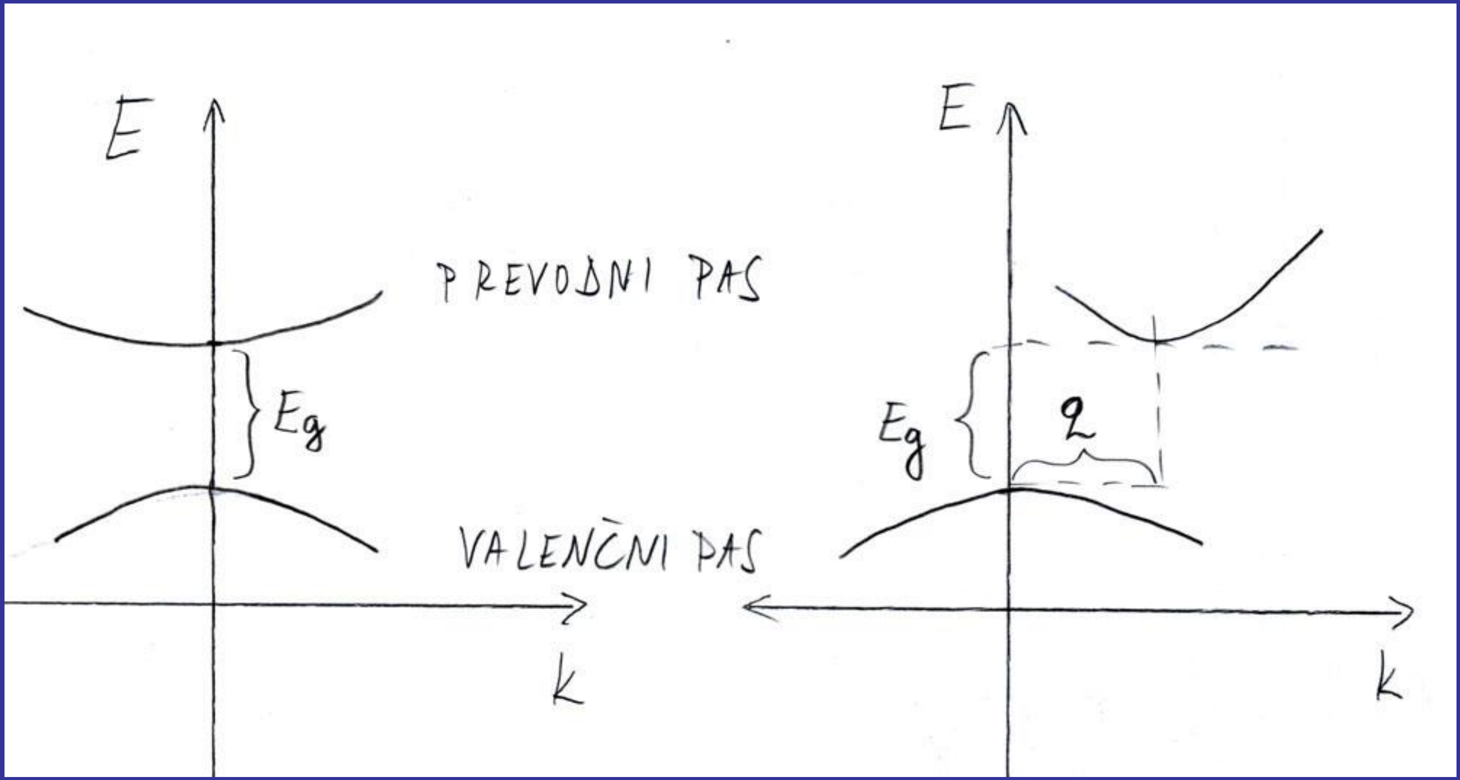
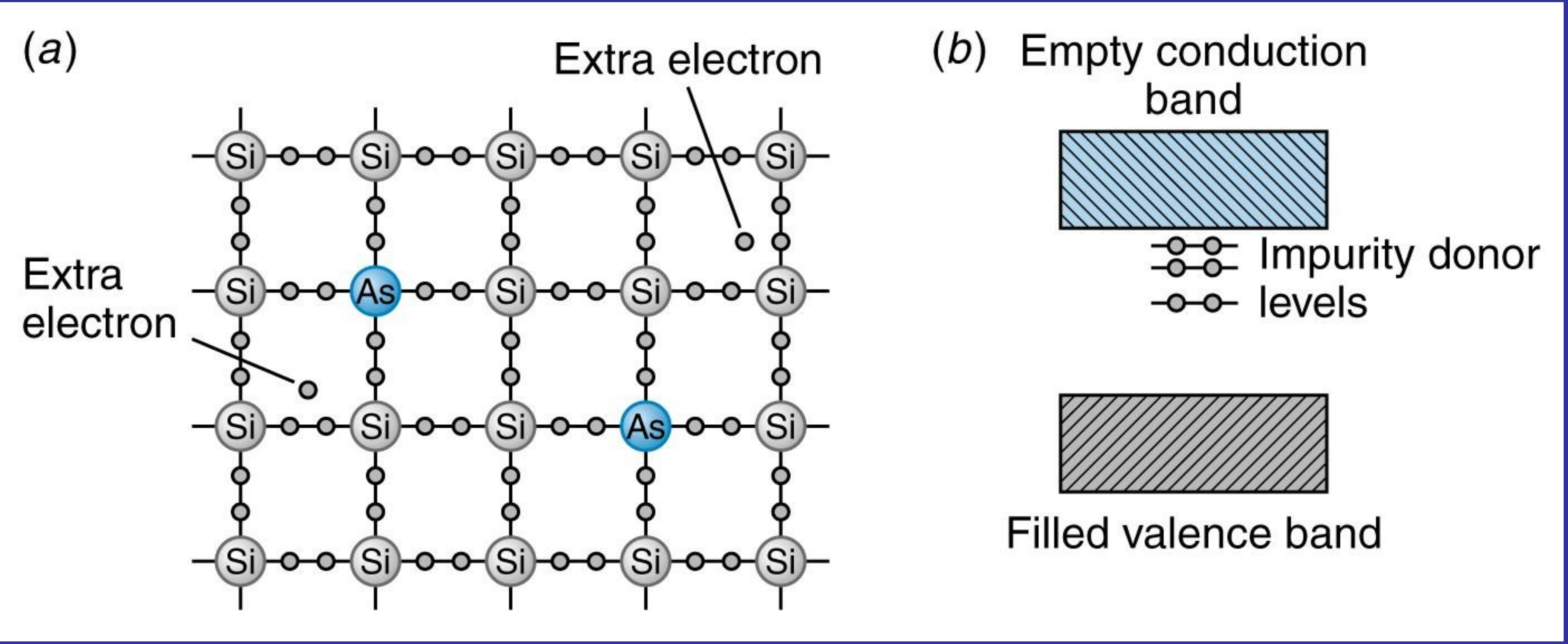


Figure 28.1
(a) In an insulator there is a region of forbidden energies separating the highest occupied and lowest unoccupied levels. (b) In a metal the boundary occurs in a region of allowed levels. This is indicated schematically by plotting the density of levels (horizontally) vs. energy (vertically).

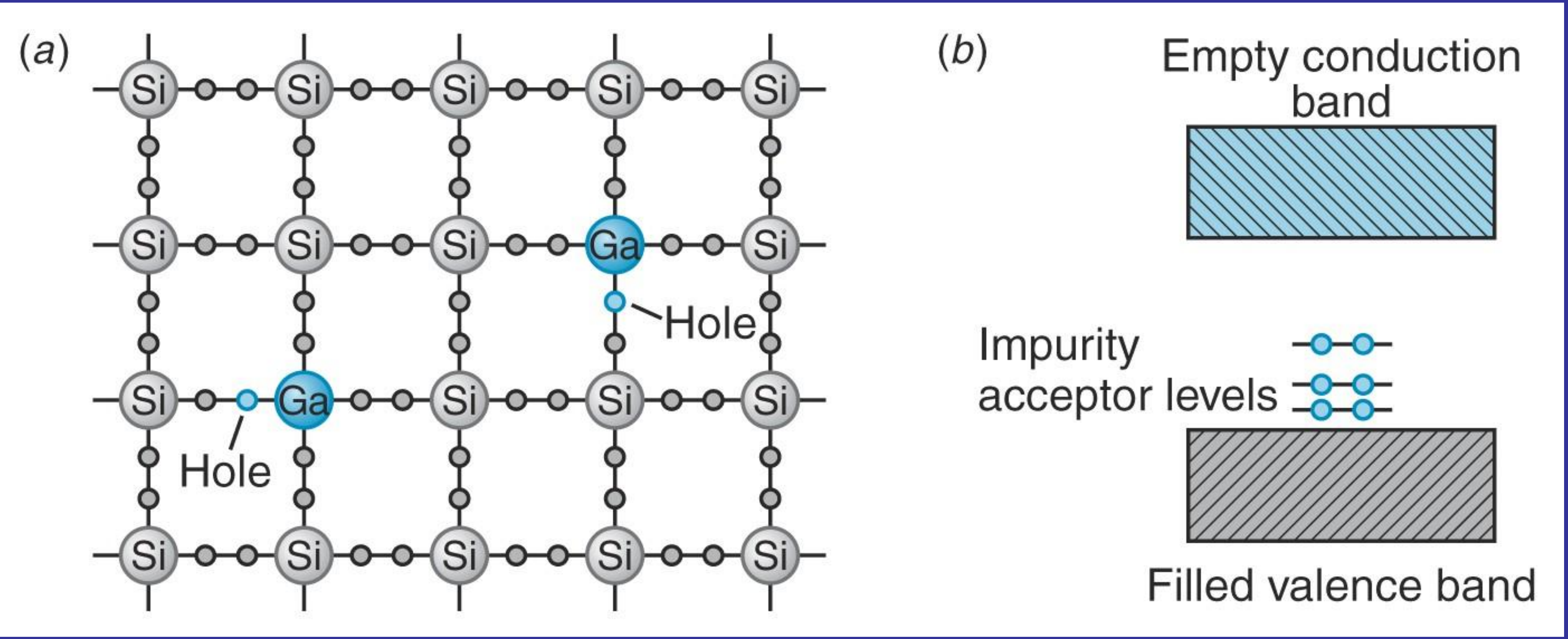
Energija elektronov v direktnem in indirektnem polprevodniku



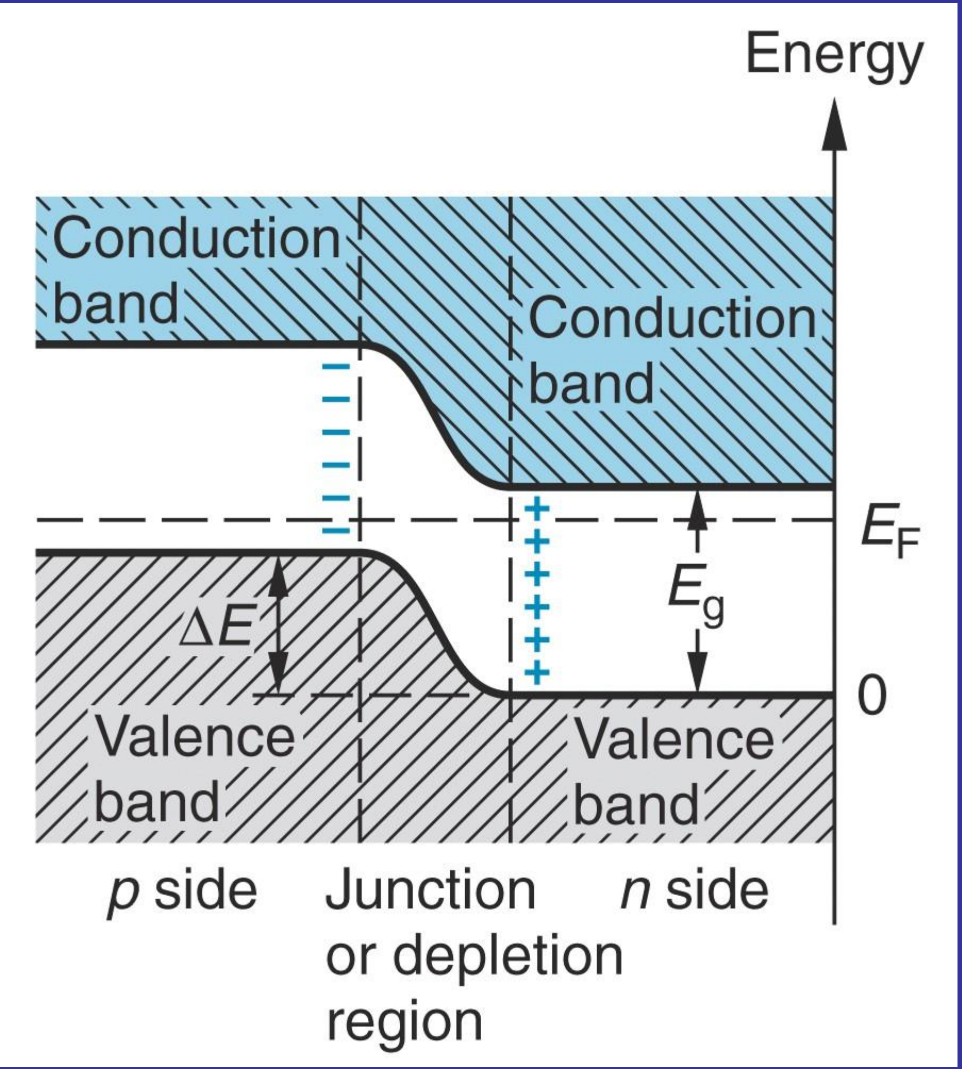
Dopiranje Si z As
n - dopiranje



Dopiranje Si z Ga
p - dopiranje

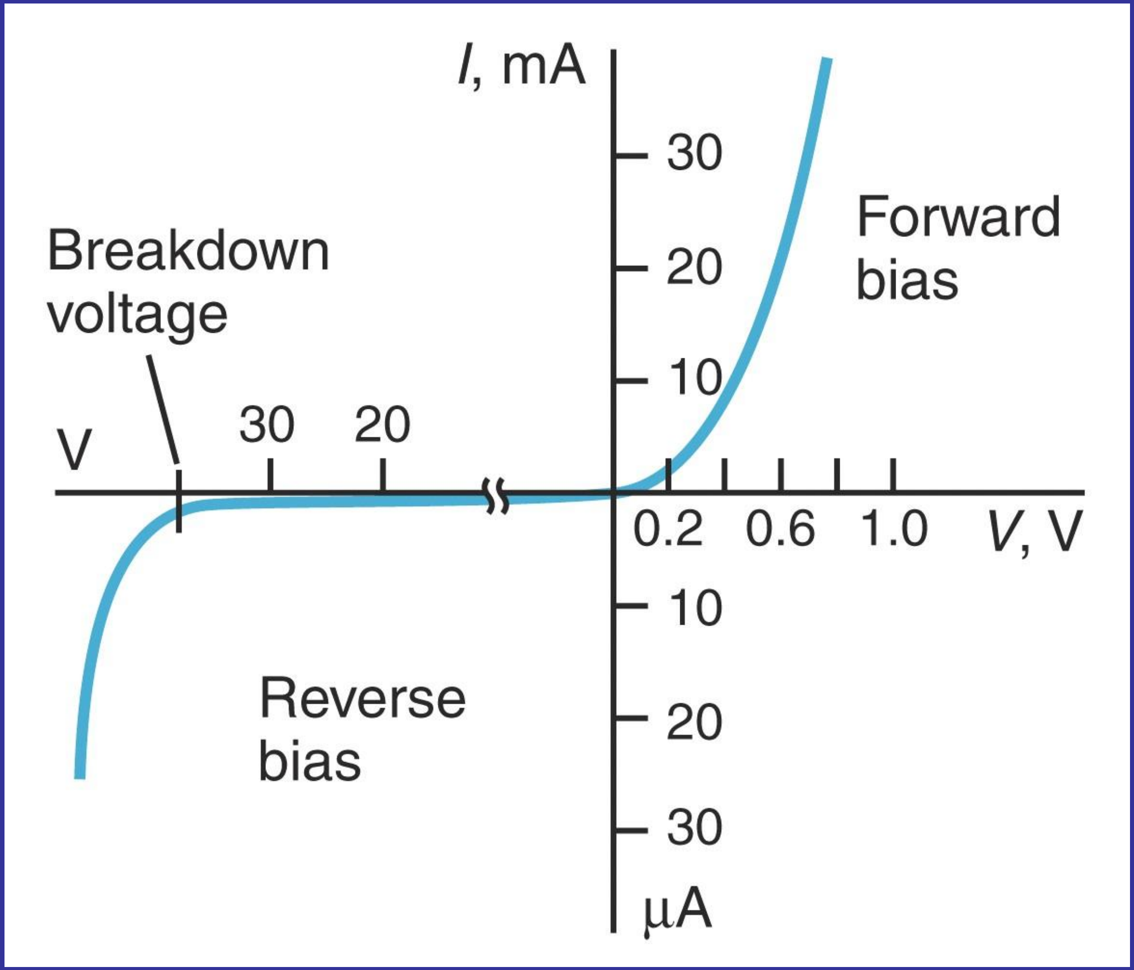


Spoj *pn*

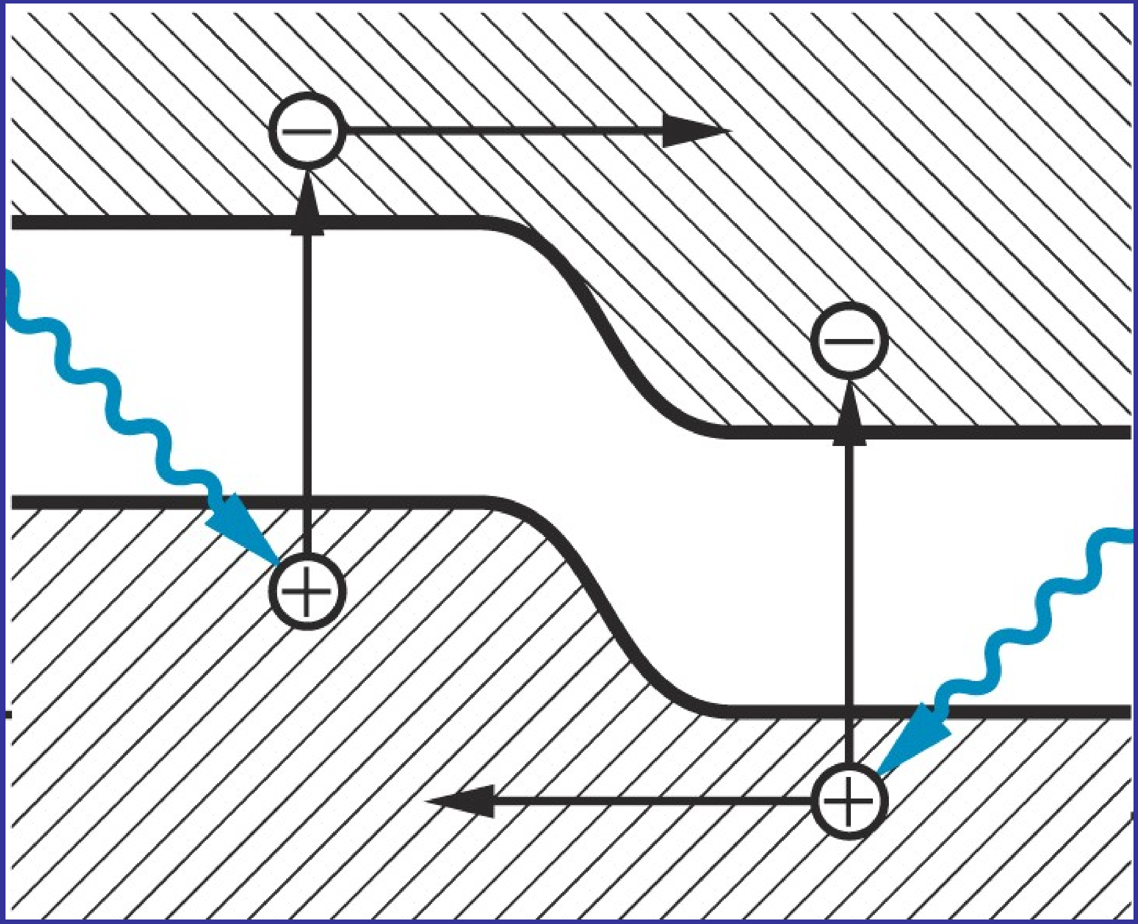


Energy
Conduction
band
Conduction
band
E_F
E_g
ΔE
0
Valence
band
Valence
band
p side
Junction
or depletion
region
n side

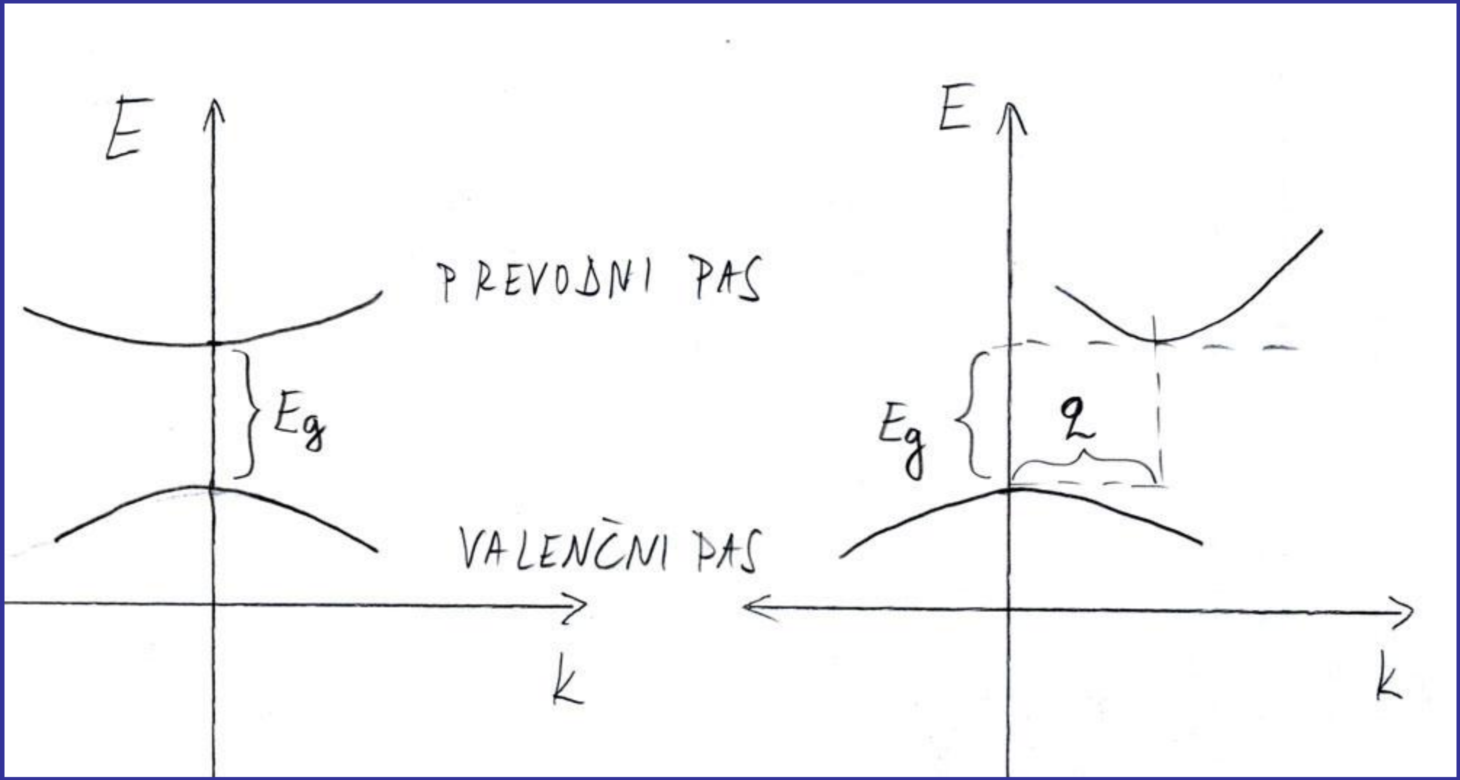
Karakteristika *pn* spoja, polprevodniška dioda



Notranji fotoefekt v *pn* spoju



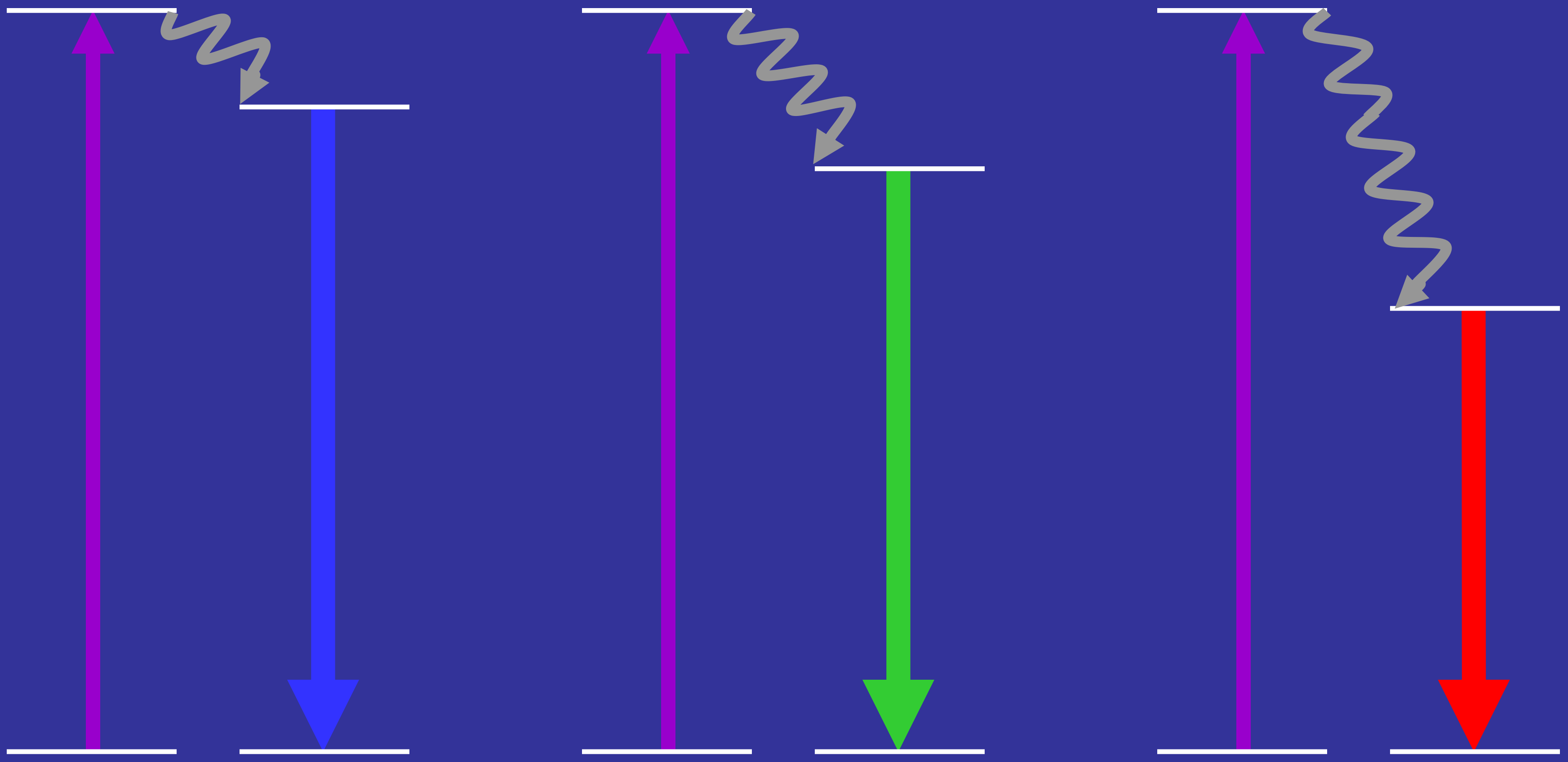
Energija elektronov v direktnem in indirektnem polprevodniku



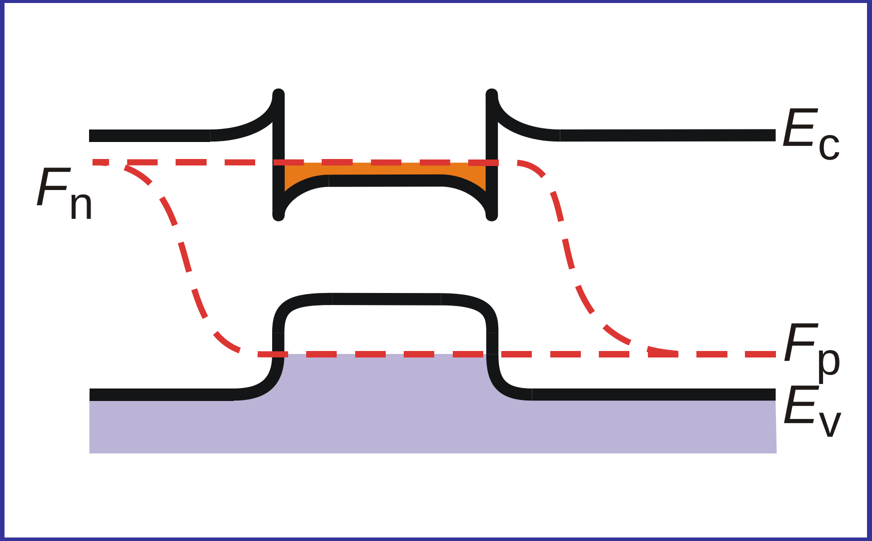
Nekaj, kar je dobro vedeti

$$\lambda = \frac{1248\,\mathrm{nm\,eV}}{E}$$

Photoluminiscenca

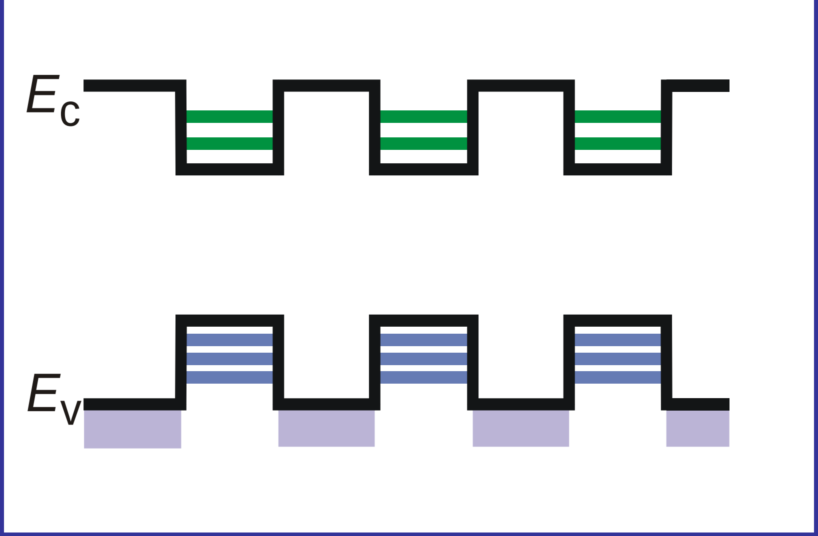


Elektronska stanja v heterostrukturah

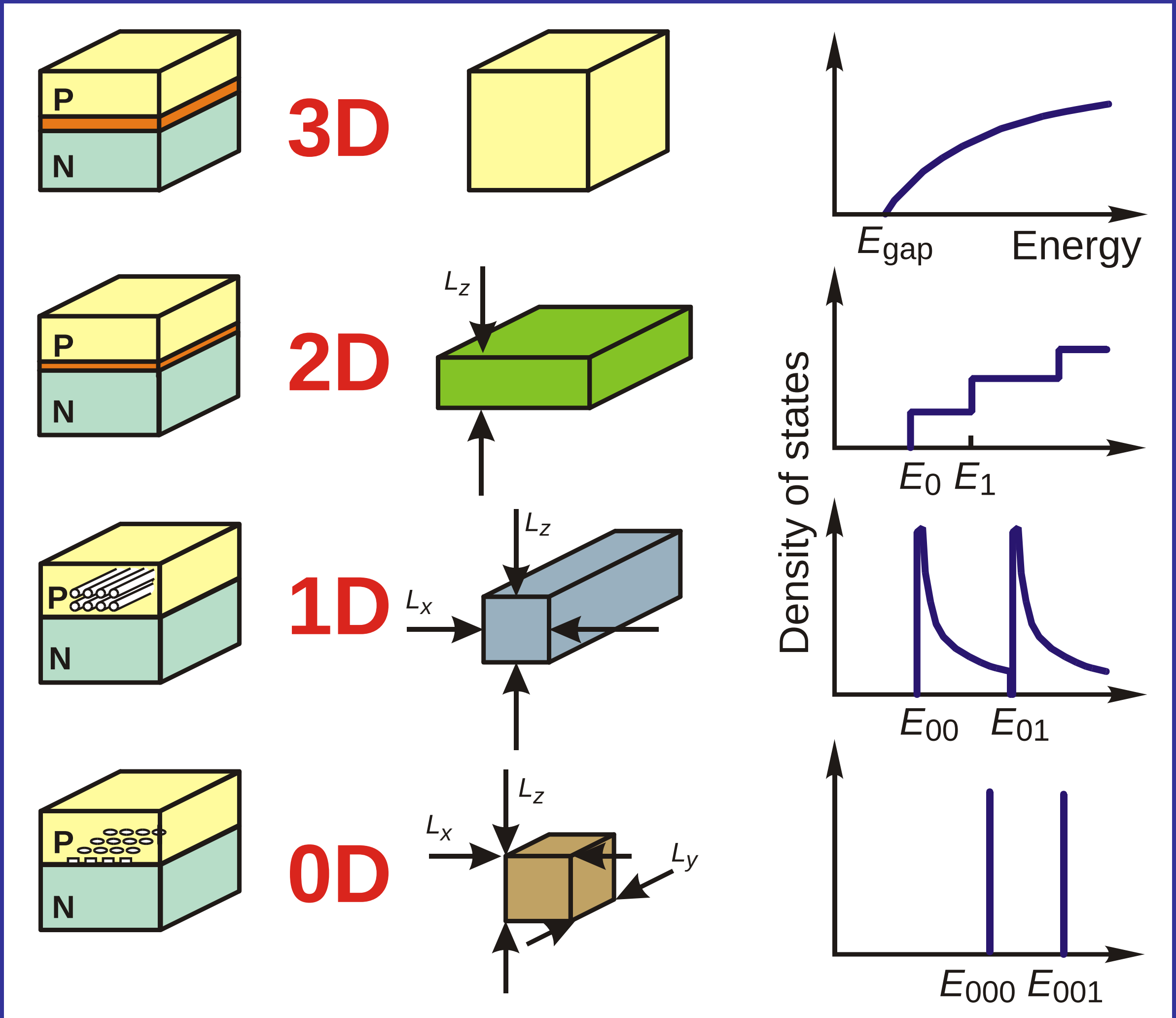


Koncentracija (omejevanje) elektronov in svetlobe v tanki plasti

Kvantne jame, enojne in večkratne



Kako lahko omejujemo elektrone



Elektroni v *pn* spoju in v hetero-strukturi

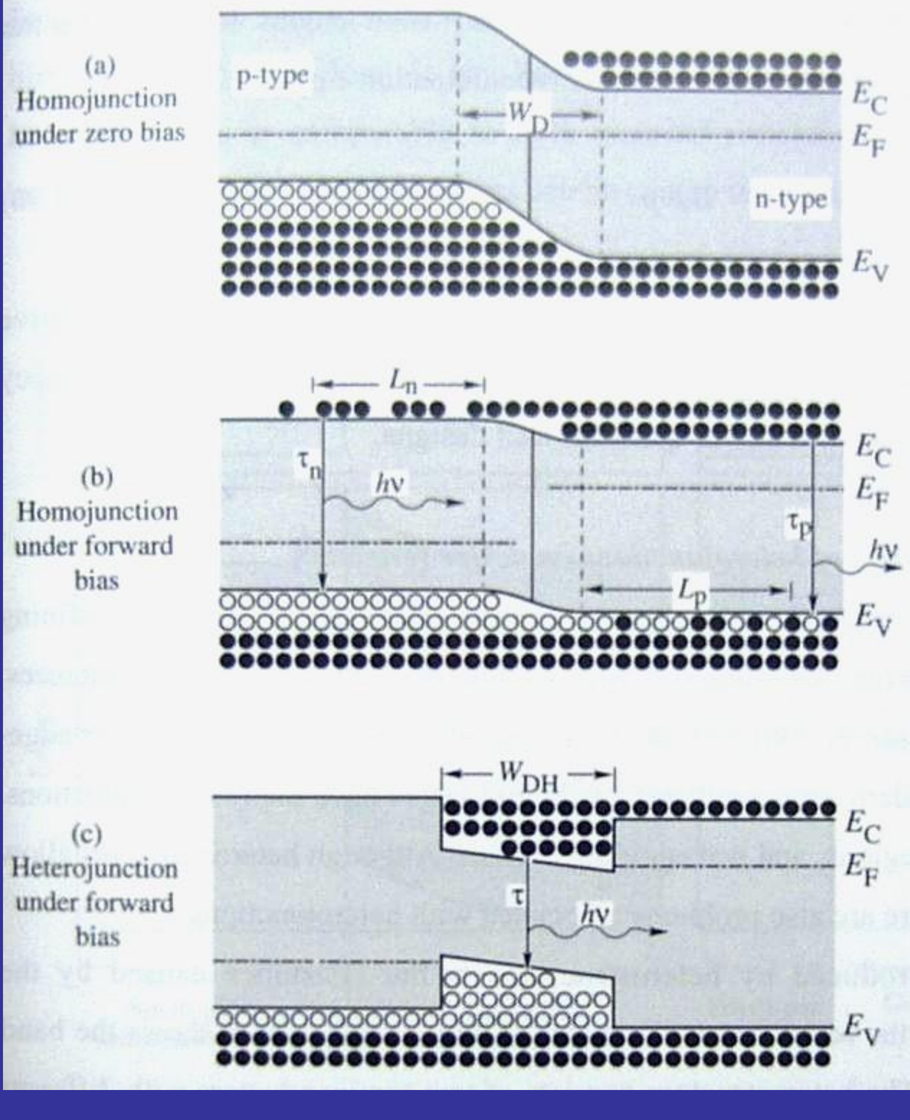
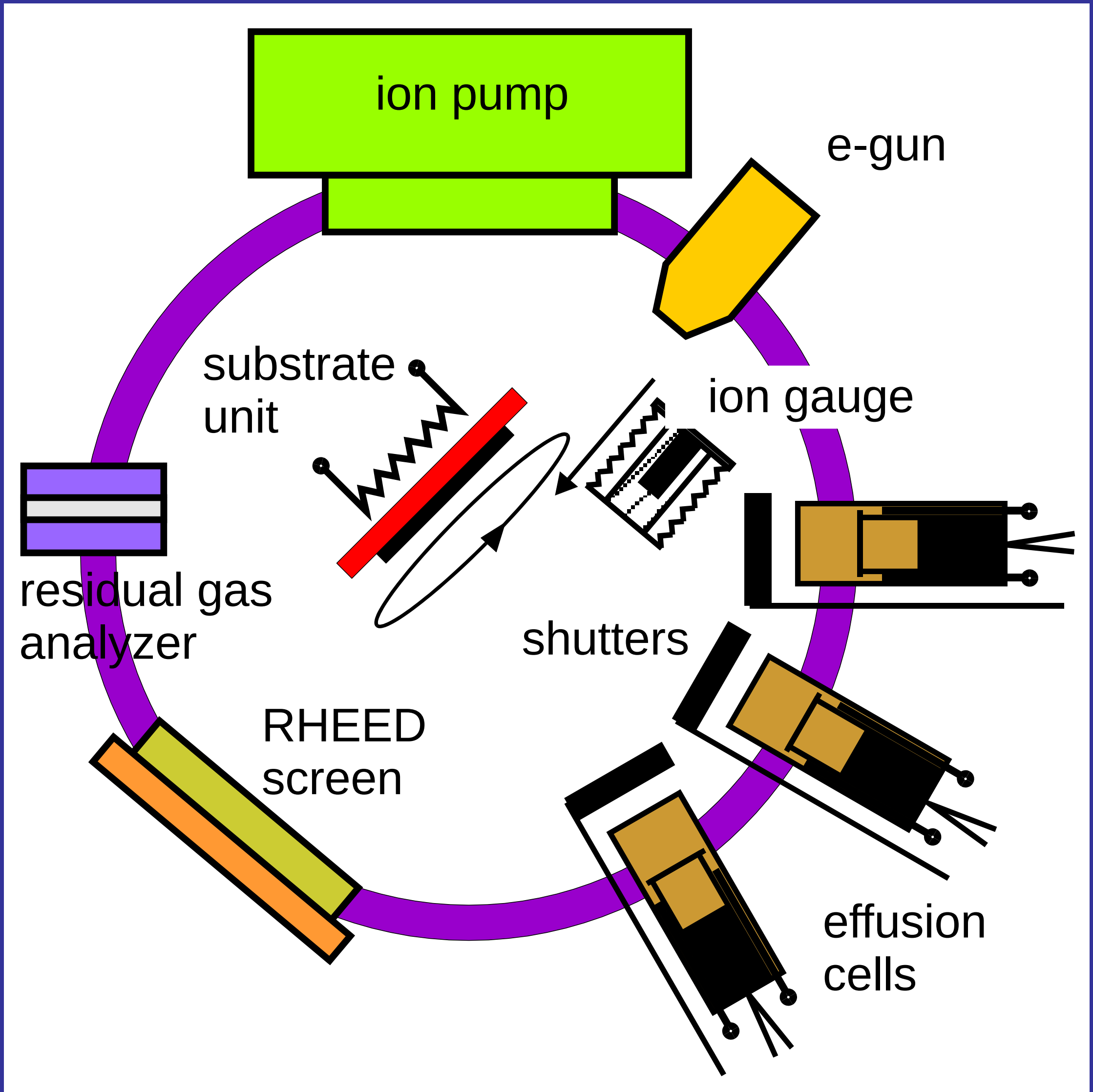


Fig. 4.6. P-n homojunction under (a) zero and (b) forward bias. P-n heterojunction (c) under forward bias. In homojunctions, carriers diffuse, on average, over the diffusion lengths L_n and L_p before recombining. In heterojunctions, carriers are confined by the heterojunction barriers.

Molecular Beam Epitaxy (MBE)
III–V compounds



Molekularna žarkovna epitaksija

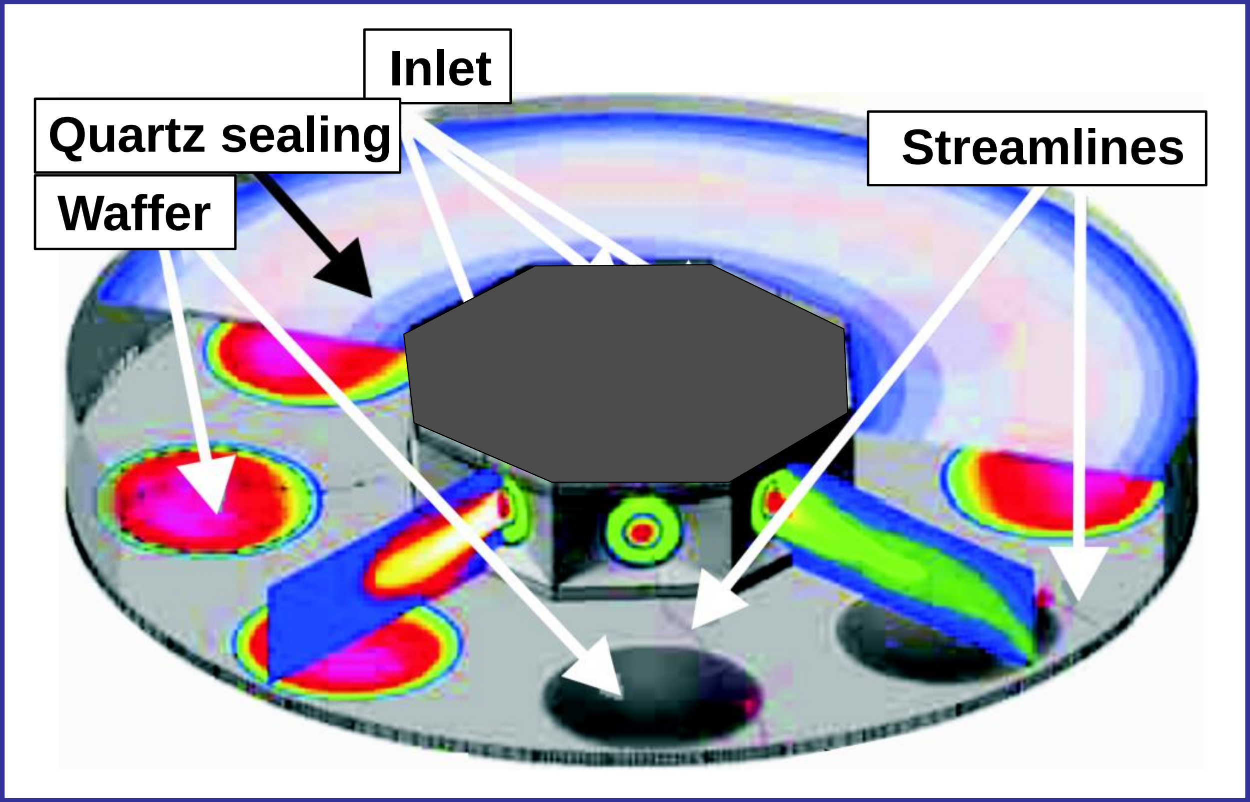
Zelo dobra kontrola čistosti in sestave, dobra kontrola strukture v času rasti, natančnost debeline skoraj na atomsko plast.

Shema MBE

Molecular Beam Epitaxy (MBE)
III–V compounds

MOCVD growth of III–V compounds

Schematic view of MOCVD chamber



MOCVD — high purity of materials, large-scale device-oriented technology

MOCVD growth of III–V compounds

Aixtron AIX2000 HT
(up to 6 x 2" wafers)
Production oriented growth machine for the fabrication of device structures

LED: kako do svetlobe iz polprevodnika?

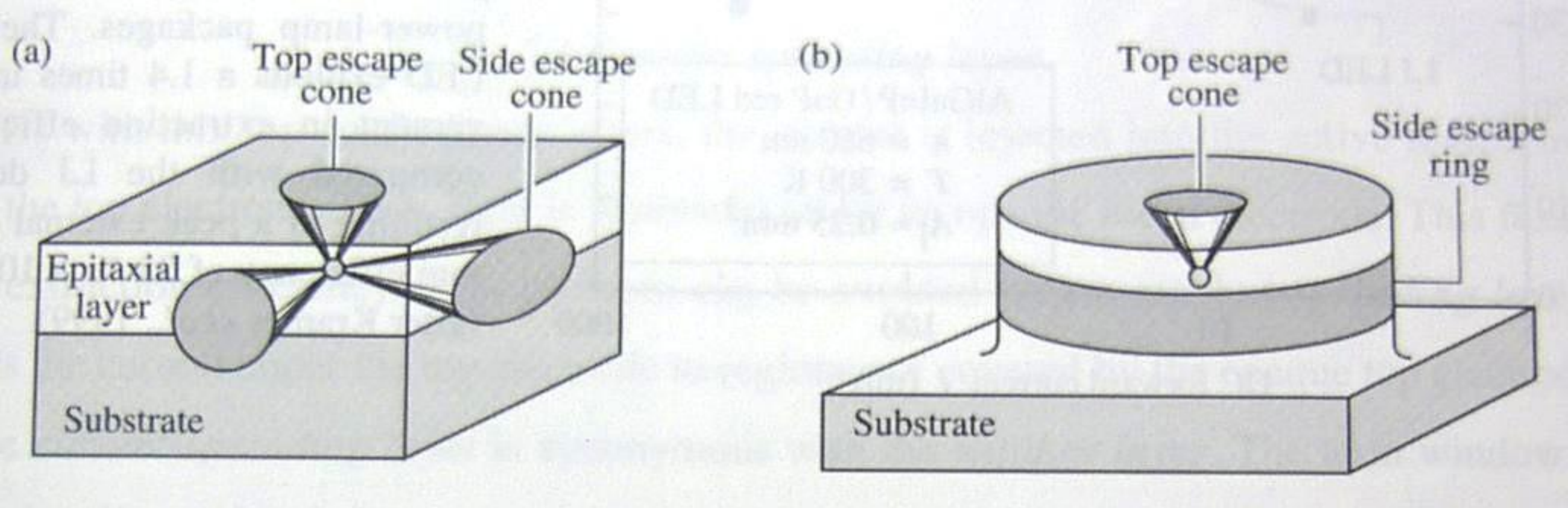
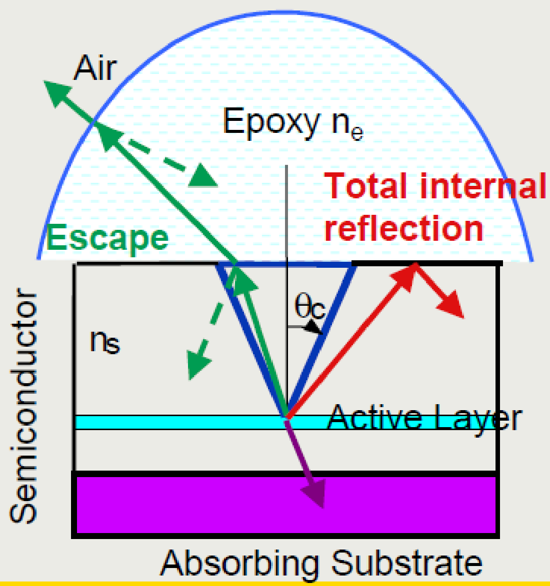


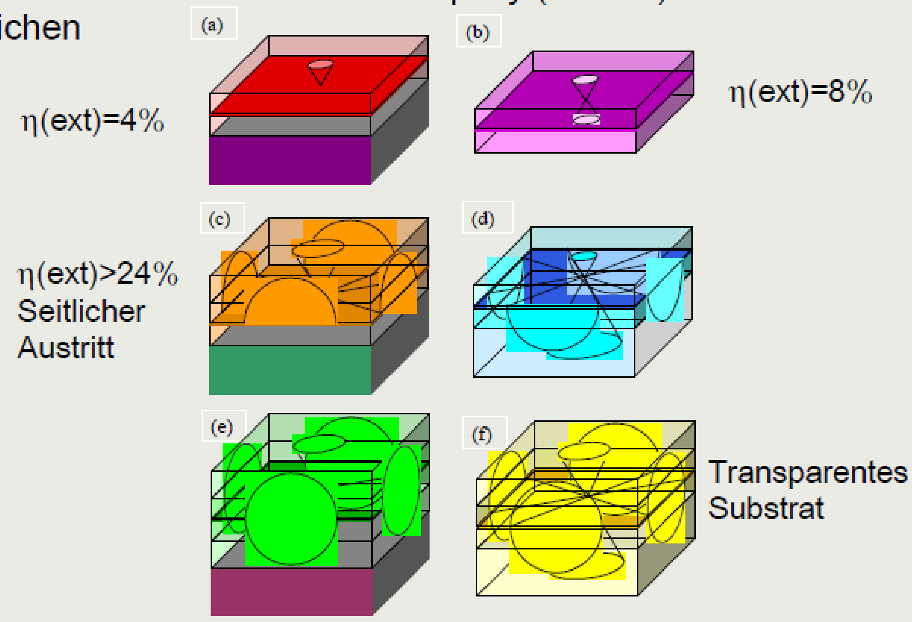
Fig. 7.5. Illustration of different geometric shapes of LEDs. (a) Rectangular parallelepipedal LED die with a total of six escape cones. (b) Cylindrical LED die with a top escape cone and a side escape ring.

Geometrija je pomembna zaradi loma na meji polprevodnika

Kaj omejuje izkostistek LED

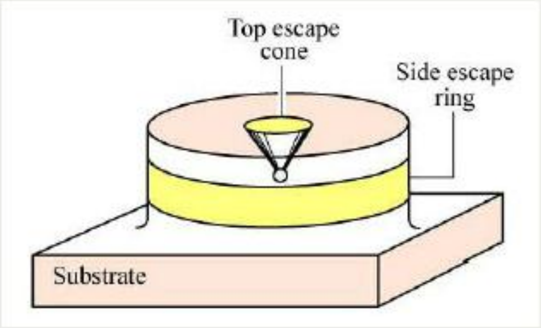
- Grenzwinkel α_g: $\sin \alpha_g = n_2/n_1$ (← Brechungsgesetz)
  - n_2 (Luft) =1
  - $n_1 = 1{,}5 : \alpha_g \approx 42°$
  - $n_1 = 2{,}5 : \alpha_g \approx 24°$
  - $n_1 = 3{,}5 : \alpha_g \approx 17°$
- Vergrößerung des Austrittskegels durch Überschichten mit z.B. Epoxy ($n \approx 1.5$)
- möglichst viele Austrittskegel ermöglichen

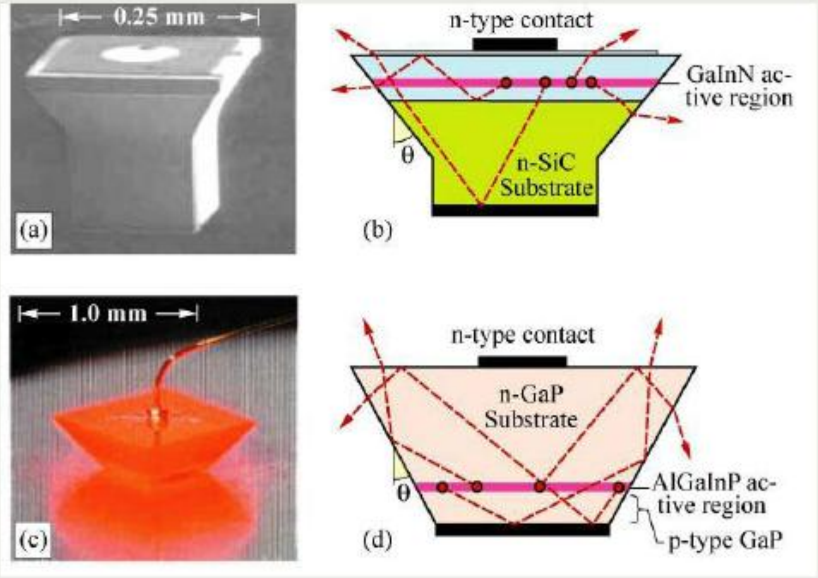




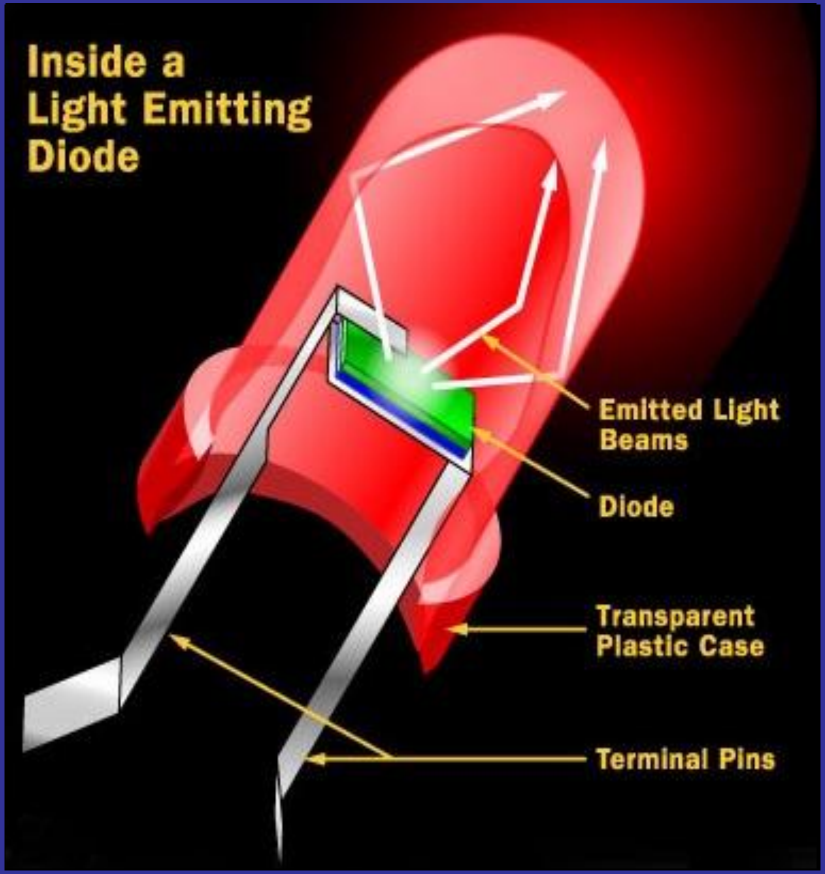
nach Zuskaukas et al.

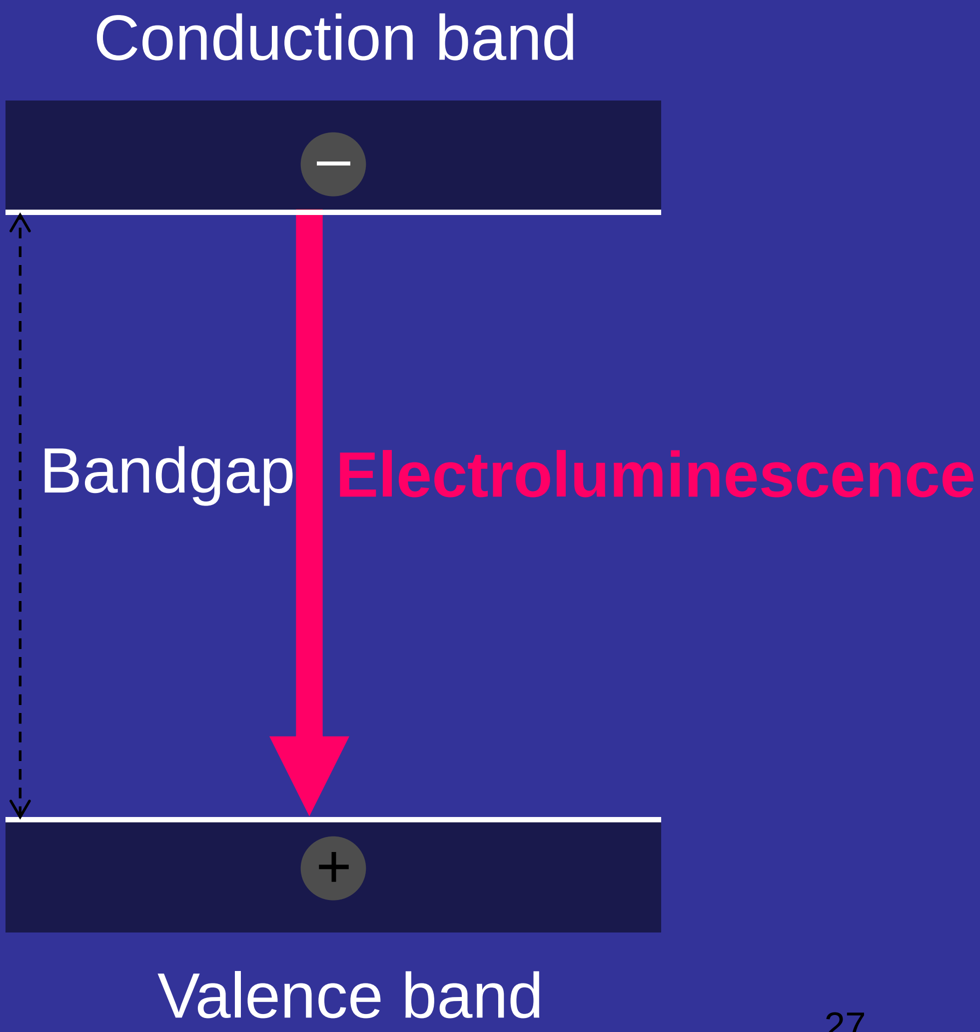
Kako izboljšati izkoristek LED





Običajna svetleča dioda (LED)





LED Materials

Inorganic

III – V Semiconductors

Al, Ga, In N, P, As, Sb

AlGaAs

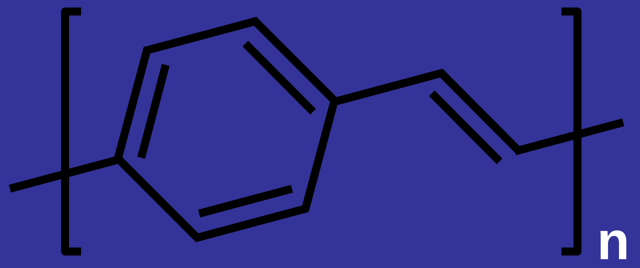
AlGaInP

AlGaP

GaN

Organic (OLED)

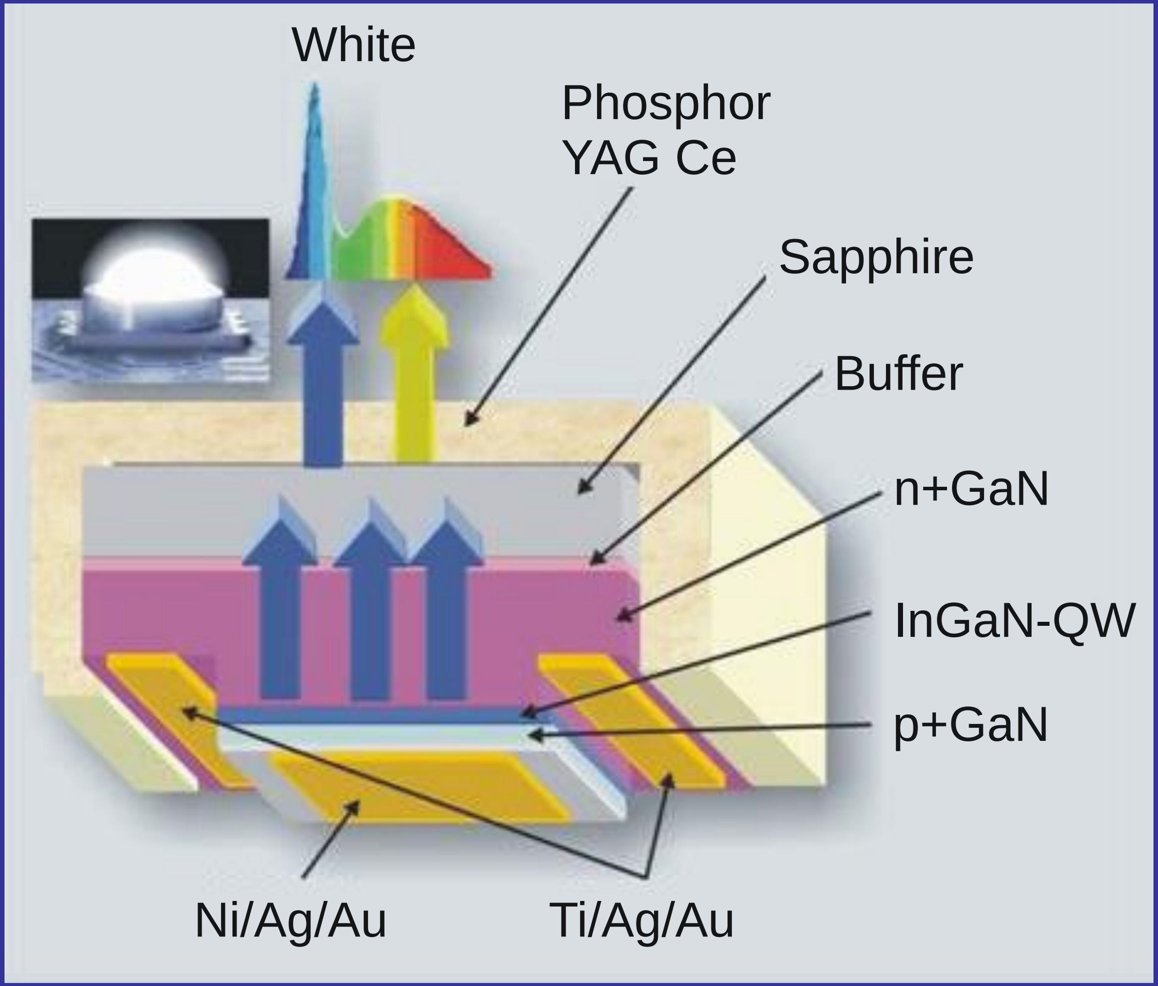
Polymeric luminescent molecules with conjugated electron systems



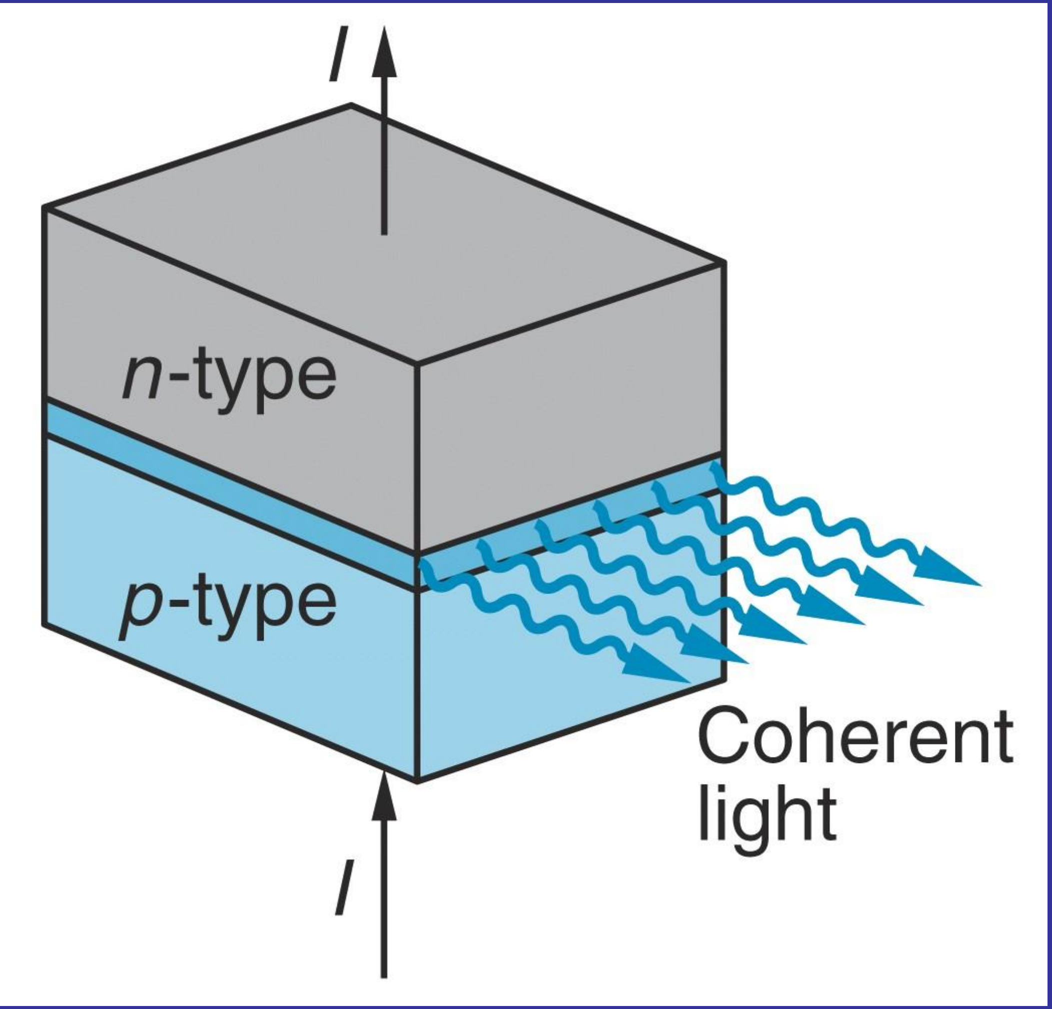
Polyphenylenvinylene

LED: kako do bele barve?

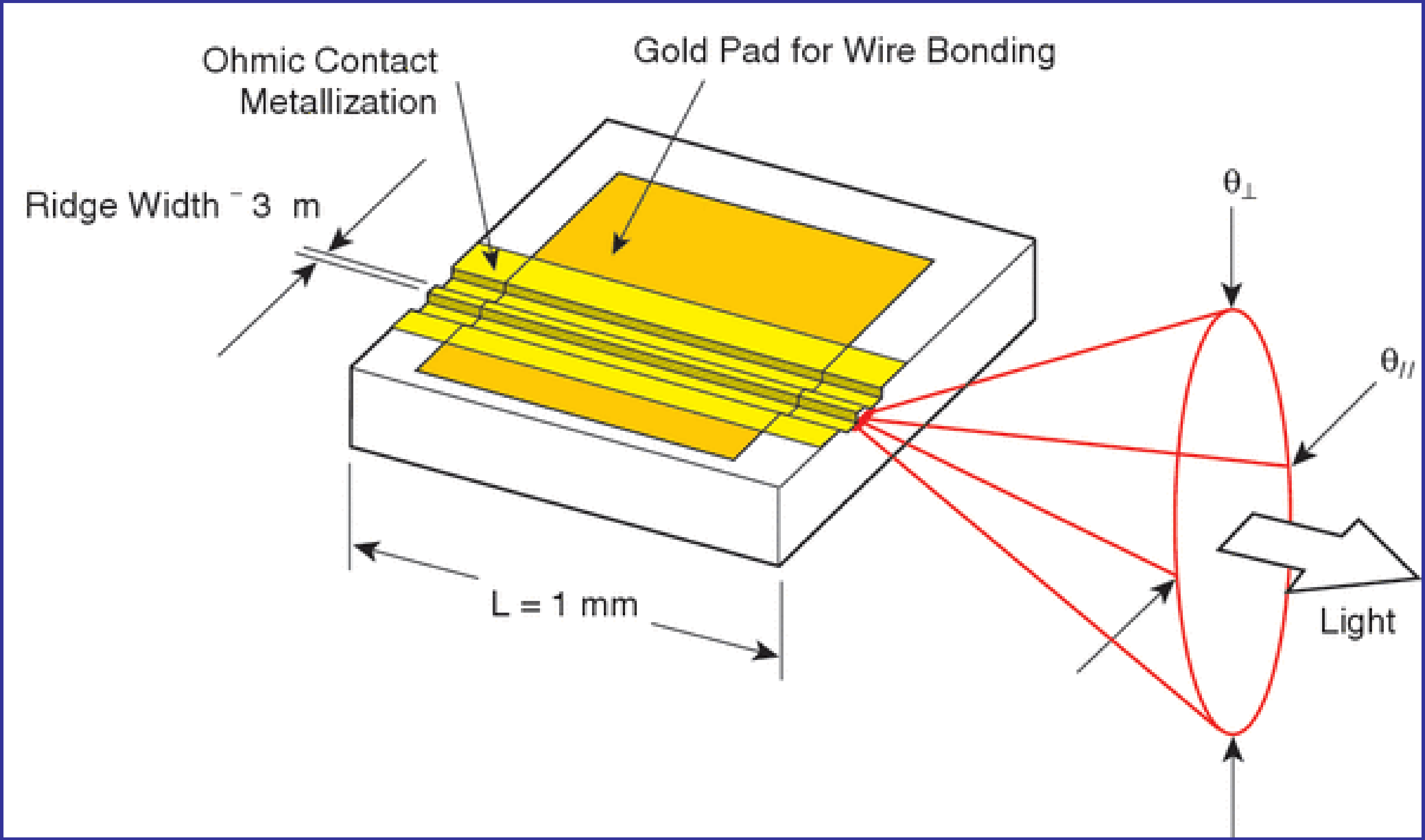
InGaN-QW/GaN/sapphire
light-emitting chip + YAG Ce phosphor



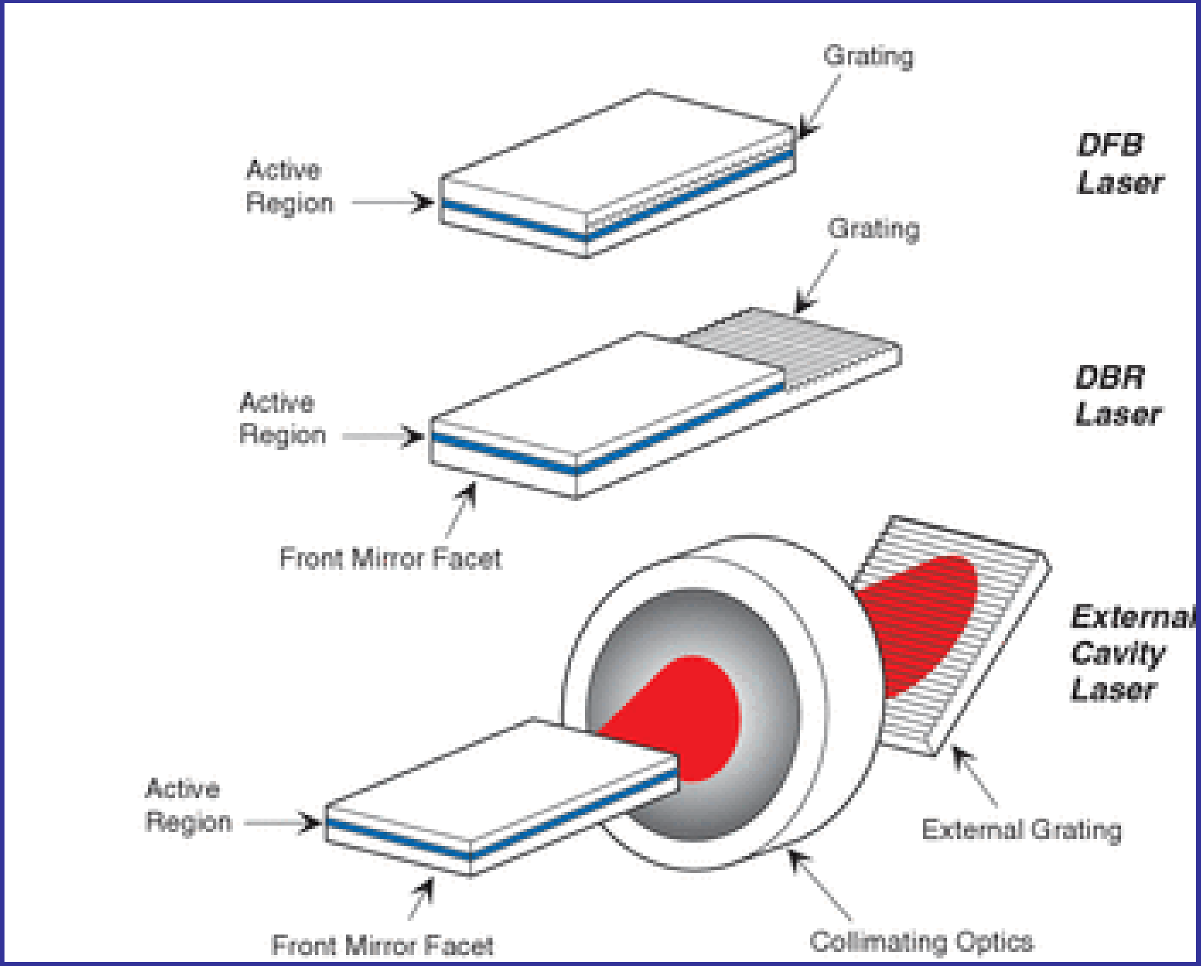
Kako do svetlobe iz laserske diode?



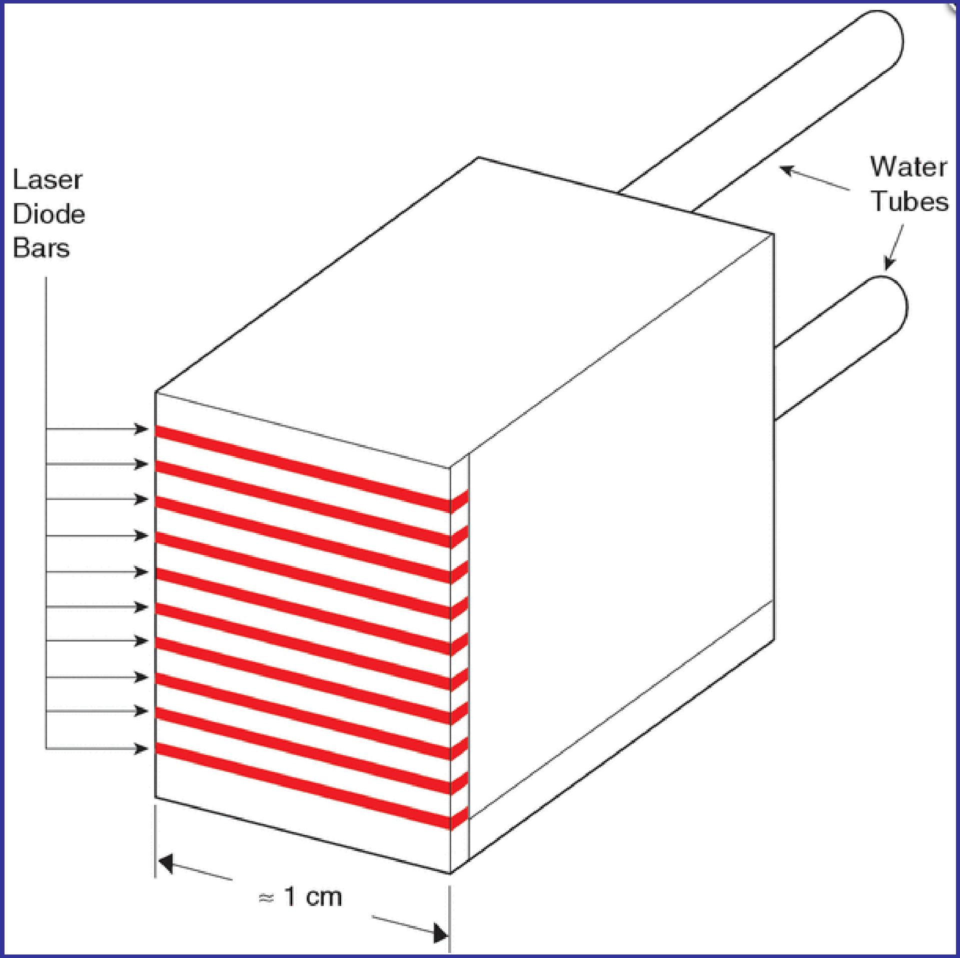
Tipična laserska dioda manjše moči



Laserski resonatorji



Sestavljen laser za velike moči



OSVETLJEVANJE
S
SVETLEČIMI
DIODAMI

Fotometrija

Fizikalne enote | Fiziološke enote

Svetlobni tok

W | **Lumen**

Svetilnost

Svetlobni tok / prostorskim kotom

Svetlost

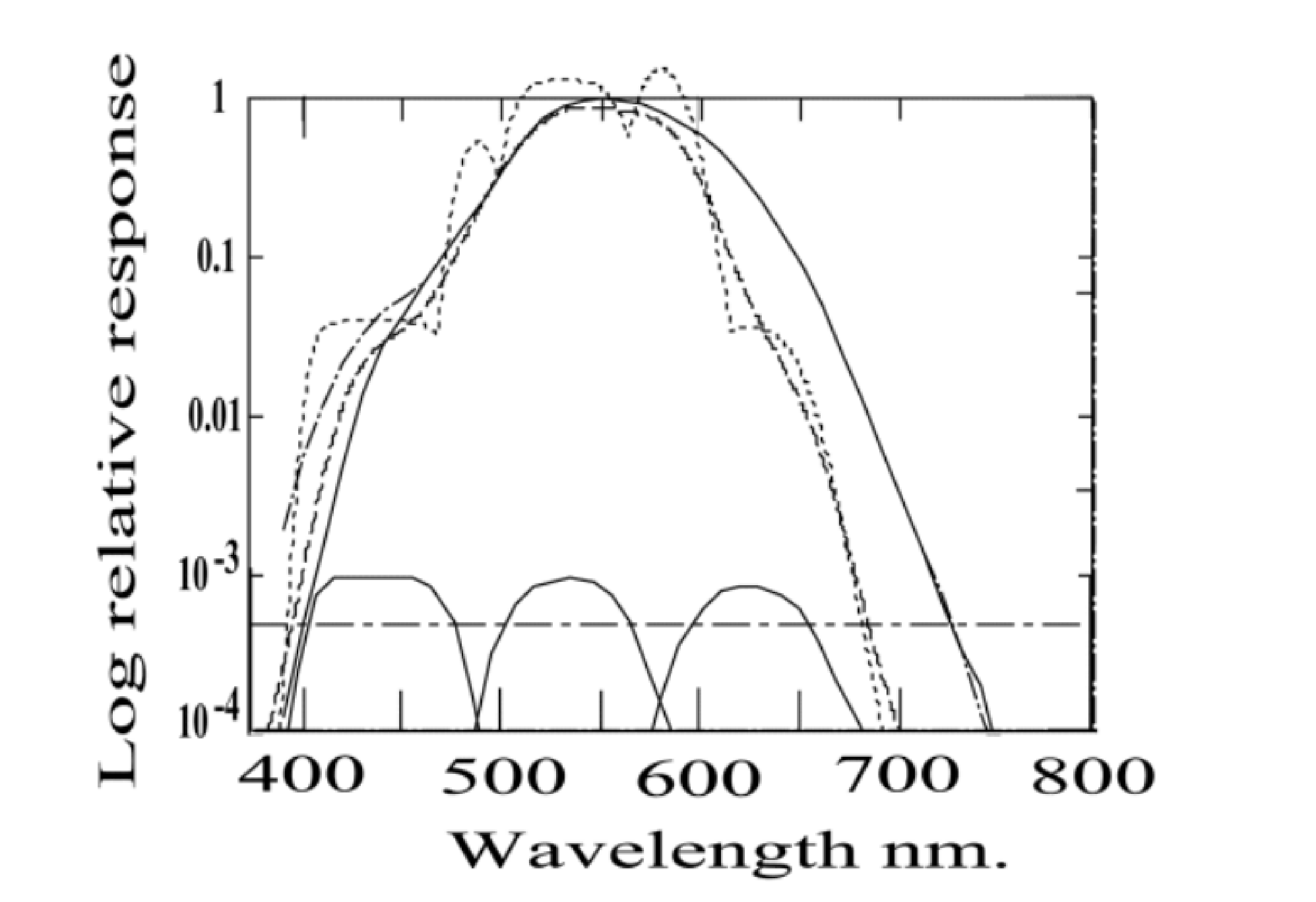
Svetilnost / površino

Relativna občutljivost oči

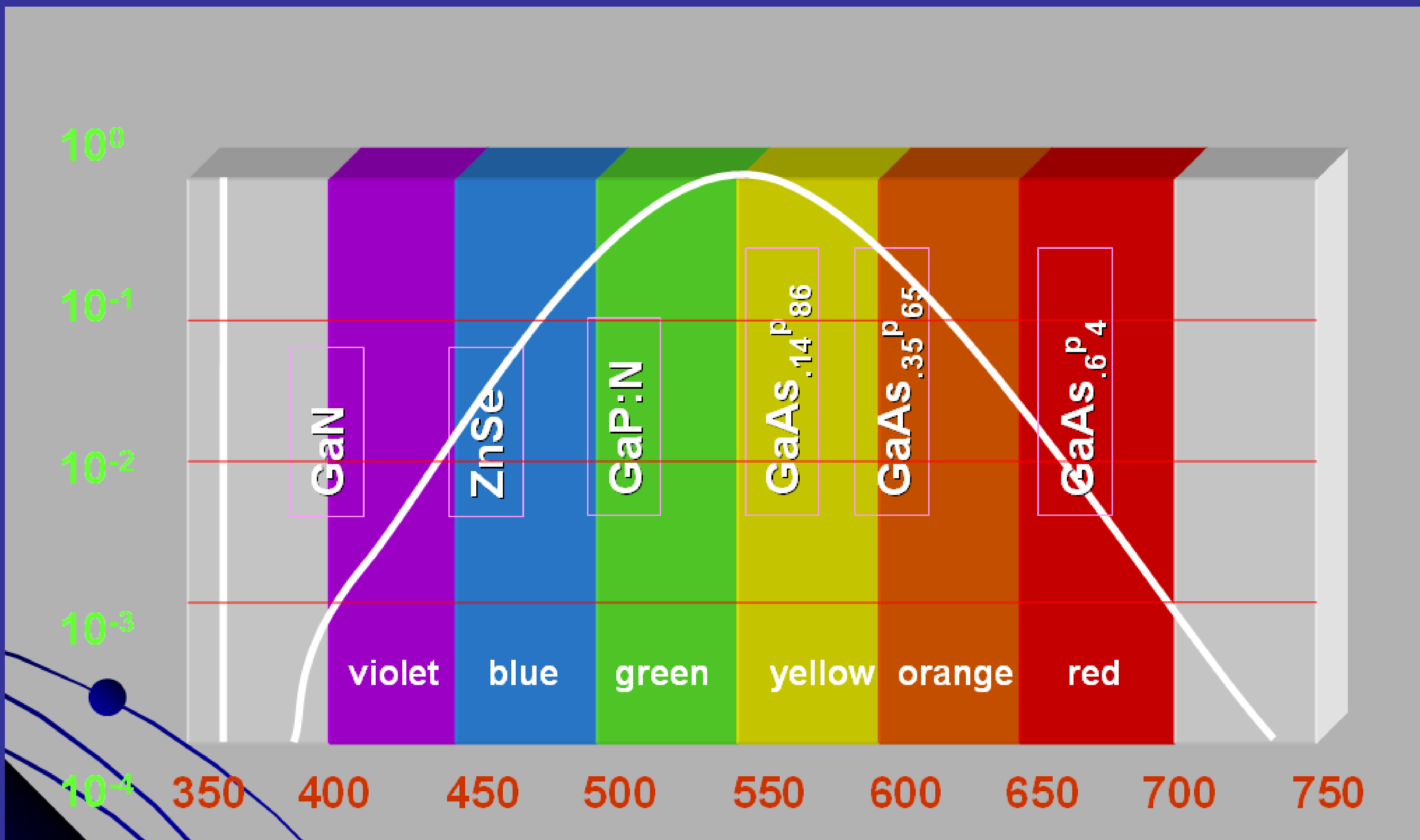
- Pri 555 nm velja 1 W = 680 lm ... definicija

- 700 nm 1 W = 2.7 lm
- 600 nm 1 W = 430 lm
- 500 nm 1 W = 220 lm
- 400 nm 1 W = 0.27 lm

Relativna občutljivost oči pri barvnem gledanju

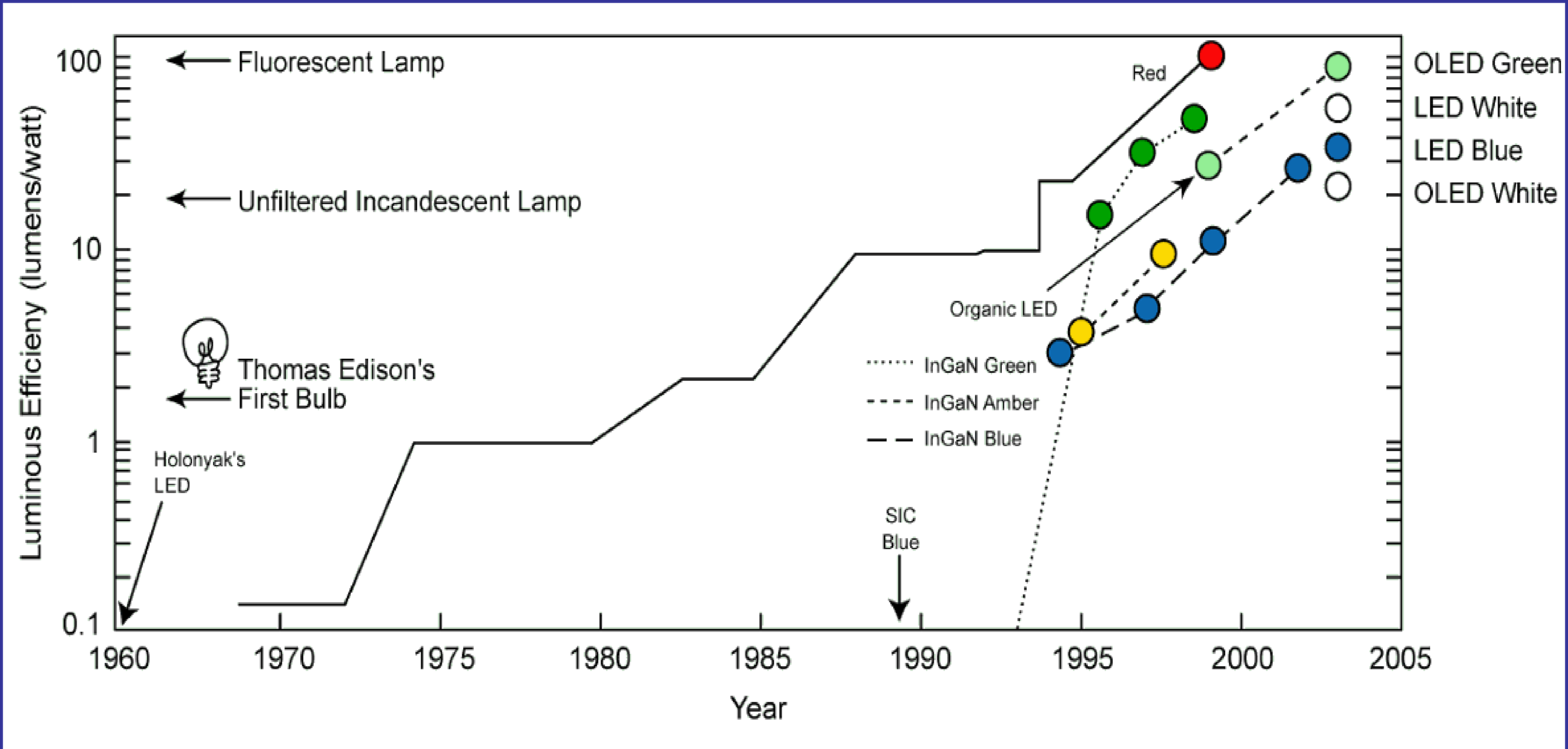


Barve različnih LED in občutljivost oči



Valovna dolžina (nm)

Učinkovitost svetlobnih izvorov za osvetljevanje



OSRAM LED za osvetljevanje

Karakteristike OSRAM LED za osvetljevanje 1

Type	color temperature	Luminous Flux[1)] page 23 I_F = 350 mA Φ_V (mlm)	Luminous Intensity[2)] page 23 I_F = 350 mA I_V (mcd)
LCW W5AM-JYKX-4U9X	2700 K	52.000 ... 82.000	16.750 (typ.)
LCW W5AM-JYJZ-4R9T LCW W5AM-JZKY-4R9T LCW W5AM-KXKY-4R9T	3000 K	52.000 ... 71.000 61.000 ... 97.000 71.000 ... 97.000	15.400 (typ.) 19.800 (typ.) 21.000 (typ.)
LCW W5AM-JYKZ-4O9Q	3500 K	52.000 ... 112.000	20.500 (typ.)
LCW W5AM-JZKX-4L8N LCW W5AM-KXKY-4L8N LCW W5AM-KYKZ-4L8N	4000 K	61.000 ... 82.000 71.000 ... 97.000 82.000 ... 112.000	17.900 (typ.) 21.000 (typ.) 26.150 (typ.)
LCW W5AM-JZKZ-4J8K	4500 K	61.000 ... 112.000	21.650 (typ.)

Karakteristike OSRAM LED za osvetljevanje 2

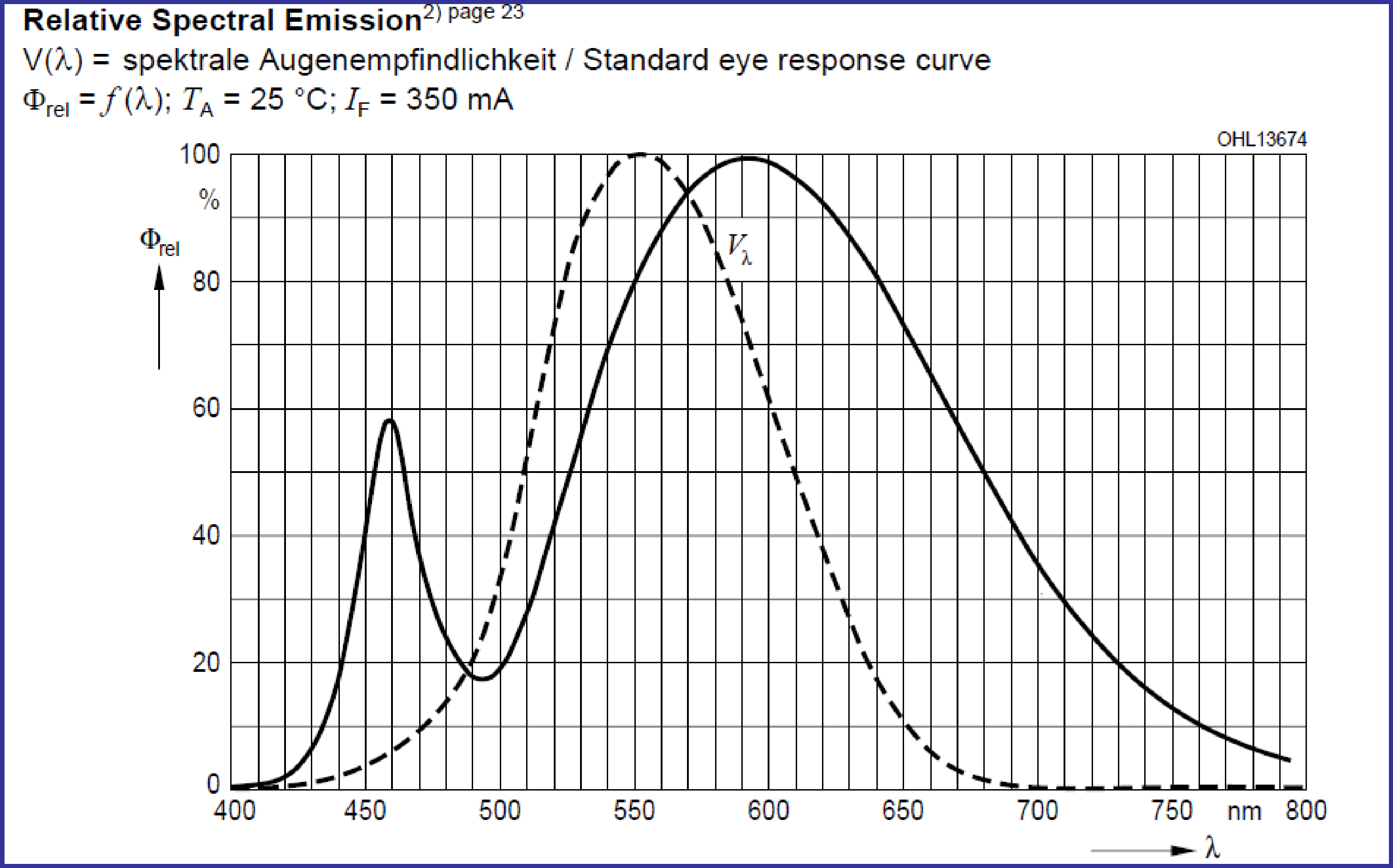
Maximum Ratings

Bezeichnung **Parameter**		**Symbol** **Symbol**	**Wert** **Value**	**Einheit** **Unit**
Betriebstemperatur Operating temperature range		T_{op}	– 40 … + 110	°C
Lagertemperatur Storage temperature range		T_{stg}	– 40 … + 110	°C
Sperrschichttemperatur Junction temperature		T_j	125	°C
Durchlassstrom Forward current (T_A=25°C)	(min.) (max.)	I_F I_F	100 1000	mA mA
Stoßstrom Surge current $t \leq 10$ µs, D = 0.005, T_A=25°C		I_{FM}	2000	mA
Sperrspannung Reverse voltage (T_A=25°C)		V_R	not designed for reverse operation	V
Leistungsaufnahme Power consumption (T_A=25°C)		P_{tot}	4.0	W
Wärmewiderstand Thermal resistance Sperrschicht/Lötpad Junction/solder point	(max.)	$R_{th\ JS}$	11	K/W

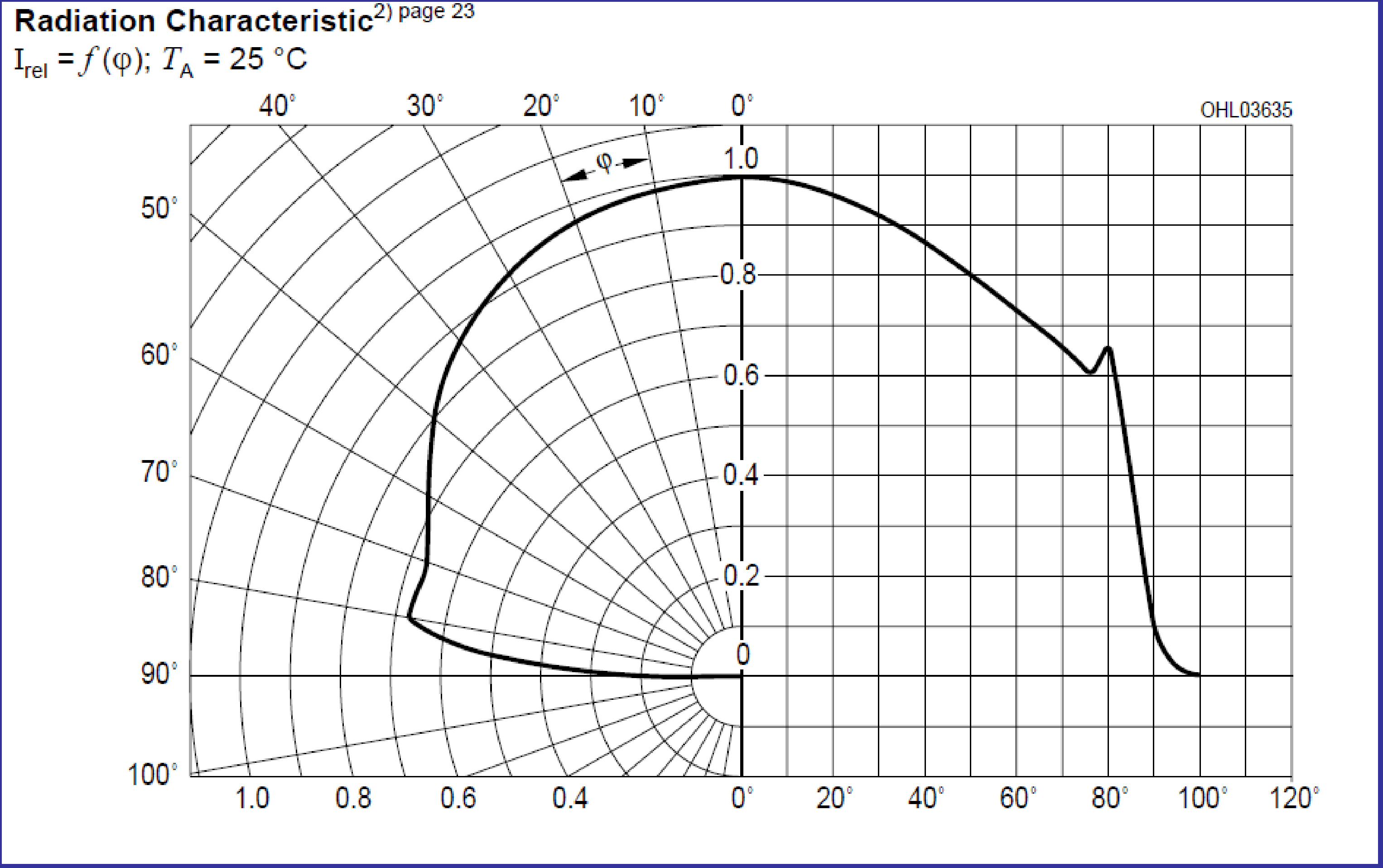
Karakteristike OSRAM LED za osvetljevanje 3

Farbtemperatur [2) Seite 23)] Color temperature [2) page 23] I_F = 350 mA	(min.) (max.)	T T T	2500 4800	K K K
Abstrahlwinkel bei 50 % I_V (Vollwinkel) Viewing angle at 50 % I_V	(typ.)	2φ	170	Grad deg.
Durchlassspannung [4) Seite 23)] Forward voltage[4) page 23] I_F = 350 mA	(min.) (typ.) (max.)	V_F V_F V_F	2.7 3.2 3.8	V V V
Sperrstrom Reverse current	(max.)	I_R	not designed for reverse operation	µA
Optischer Wirkungsgrad Optical efficiency I_F = 350 mA, T_C = 3500 K	(typ.)	η_{opt}	62	lm/W

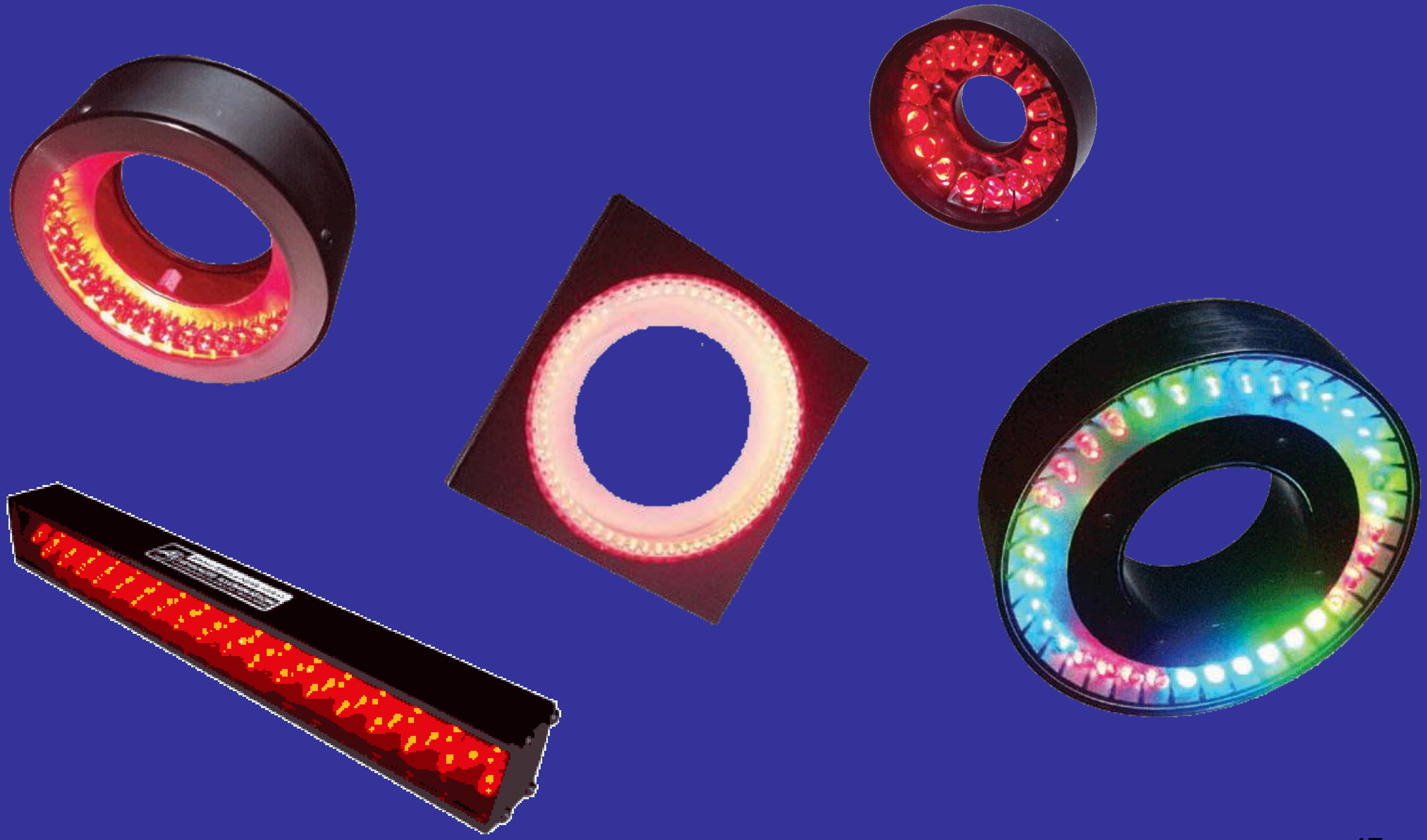
Karakteristike OSRAM LED za osvetljevanje 4



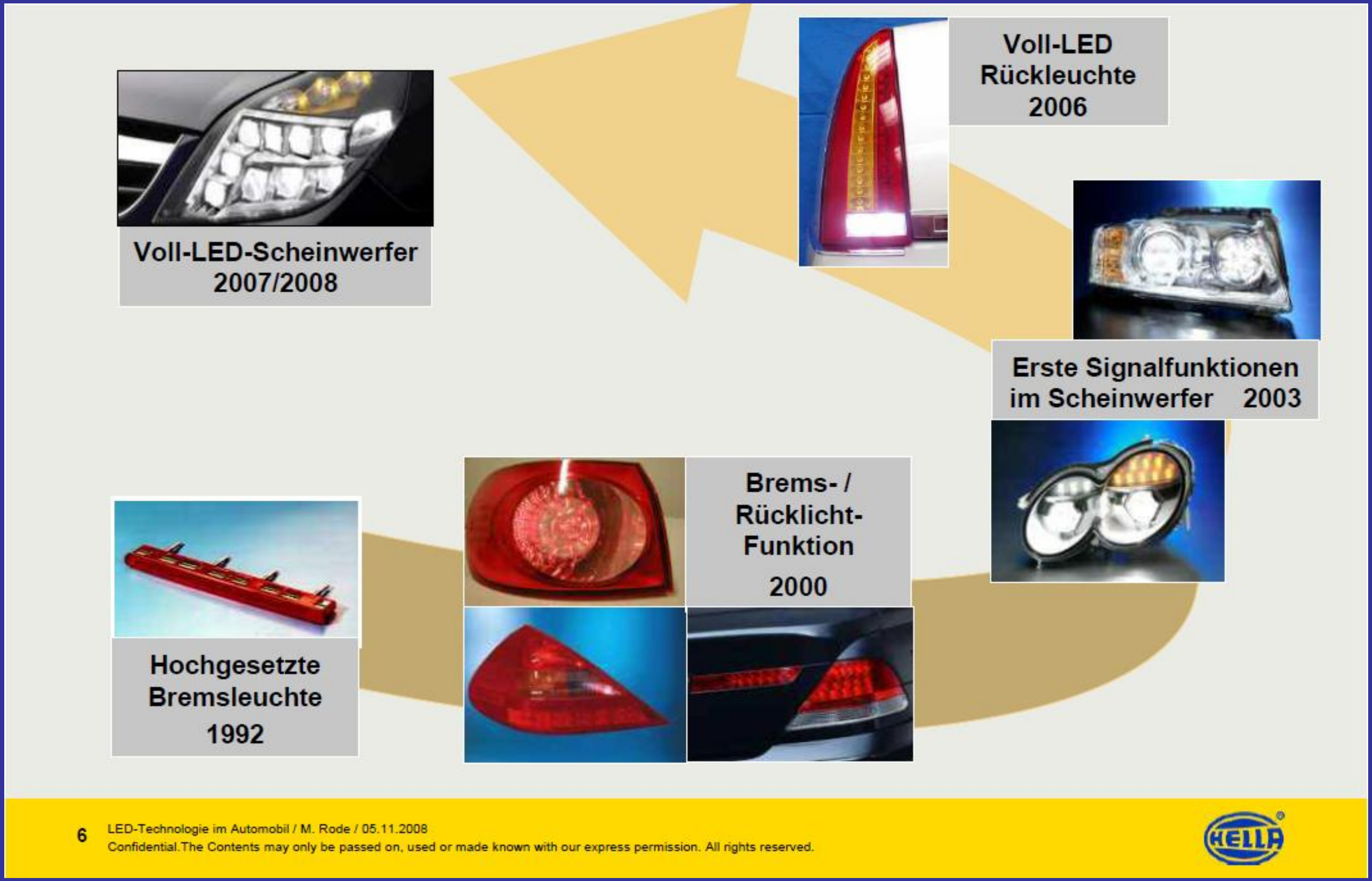
Karakteristike OSRAM LED za osvetljevanje 5



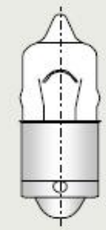
Osvetljevalniki za mikroskopijo



Tehnologija LED v avtomobilih



Primerjava avtomobilskih žarnic


	Glüh-lampe P21 W	Halogen-lampe H21 W	Halogen-lampe H7	Xenon-lampe D2 S	LED
Effizienz lm/W	**18**	**25**	**25**	**90**	**50 – 90*** (* Labor)
Lebens-dauer h	**400 (Tc)**	**440 (Tc)**	**550 (Tc)**	**2000 (B50)**	**10000 - 50000 (B50)**

Tc: 63 % Ausfälle, B50: 50 % Ausfälle

Laserska dioda 10 W

Data Sheet

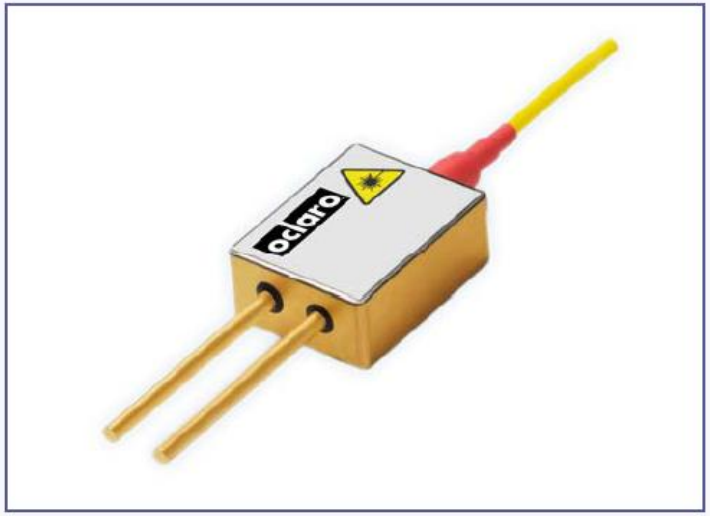
oclaro

10W 9xxnm Uncooled Multimode Laser Diode Module

BMU10A-9xx-01/02-R

Features:

- High output powers of 10W
- 0.15NA or 0.22NA 105µm core multimode optical fiber
- Hermetically sealed 2-pin package
- Floating anode/cathode
- High reliability
- Excellent solderability
- Standard wavelengths at 915, 940, 960, and 975nm (others available on request)



OCLARO 10 W laserska dioda z optičnim vlaknom

Features:

- High output powers of 10W
- 0.15NA or 0.22NA 105µm core multimode optical fiber
- Hermetically sealed 2-pin package
- Floating anode/cathode
- High reliability
- Excellent solderability
- Standard wavelengths at 915, 940, 960, and 975nm (others available on request)
- RoHS compliant

OCLARO 10 W laserska dioda z optičnim vlaknom - karakteristike

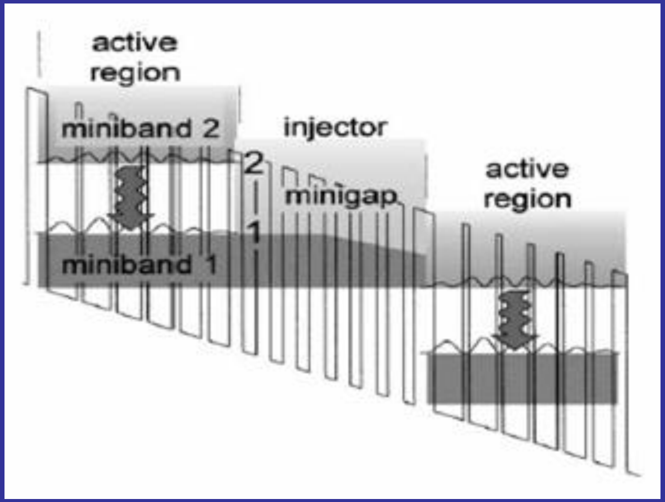
Parameter	Symbol	Typical	Unit
Fiber Coupled CW Output Power	P_{op}	10	W
Center Wavelength [1] BMU10A-915-01/02-R BMU10A-940-01/02-R BMU10A-960-01/02-R BMU10A-975-01/02-R BMU10A-975B-01/02-R	 λ_{c915} λ_{c940} λ_{c960} λ_{c975} λ_{c975B}	 915 ± 10 940 ± 10 960 ± 10 975 ± 10 976 ± 3	nm
Spectral Width (95% of Power)	$\Delta\lambda$	6	nm
Threshold Current	I_{th}	600	mA
Slope Efficiency	$\eta_D = P_{op}/(I_{op} - I_{th})$	0.95	W/A
Conversion Efficiency	$H = P_{op}/(V_{op} \mathbf{x} I_{op})$	48	%
Operating Current	I_{op}	11.5	A
Operating Voltage	V_{op}	1.9	V
Operating Temperature	T_{op}	25 ±5	°C

Uporaba močnostnih laserskih diod

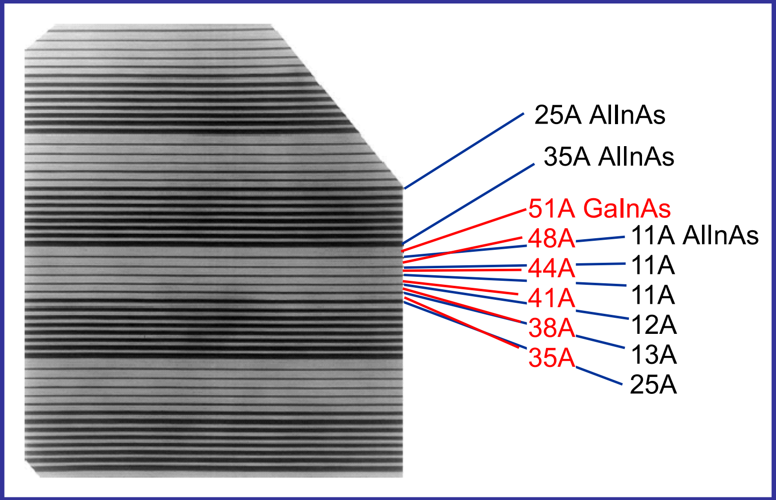
- Črpanje (vlakenskih) laserjev
- Direktna uporaba snopa
- Obdelava materialov
- Tiskanje
- Medicinske aplikacije

Quantum cascade lasers

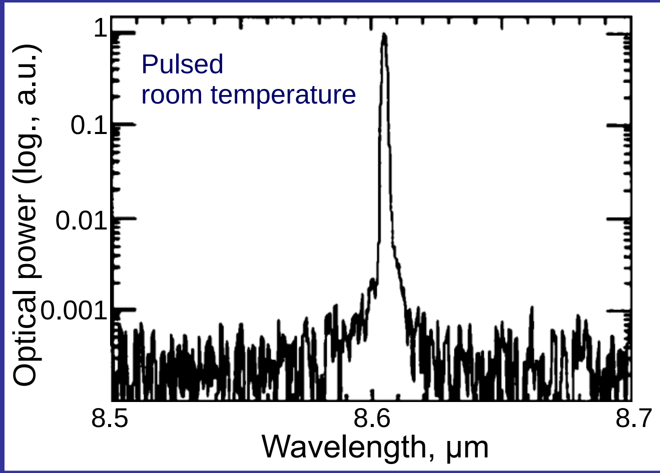
Band diagram



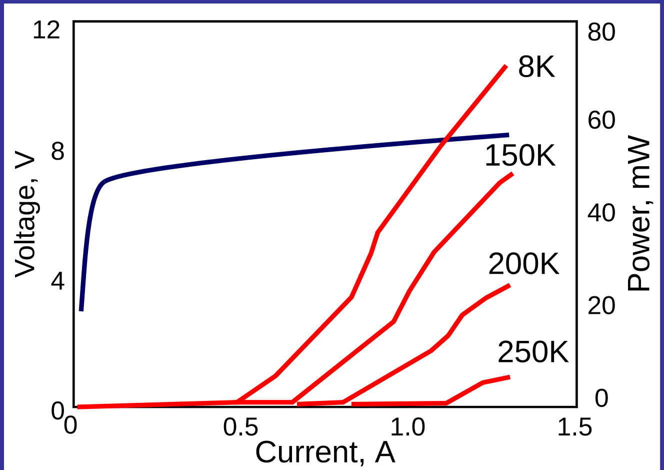
Layer sequence



Emission spectrum at room temperature

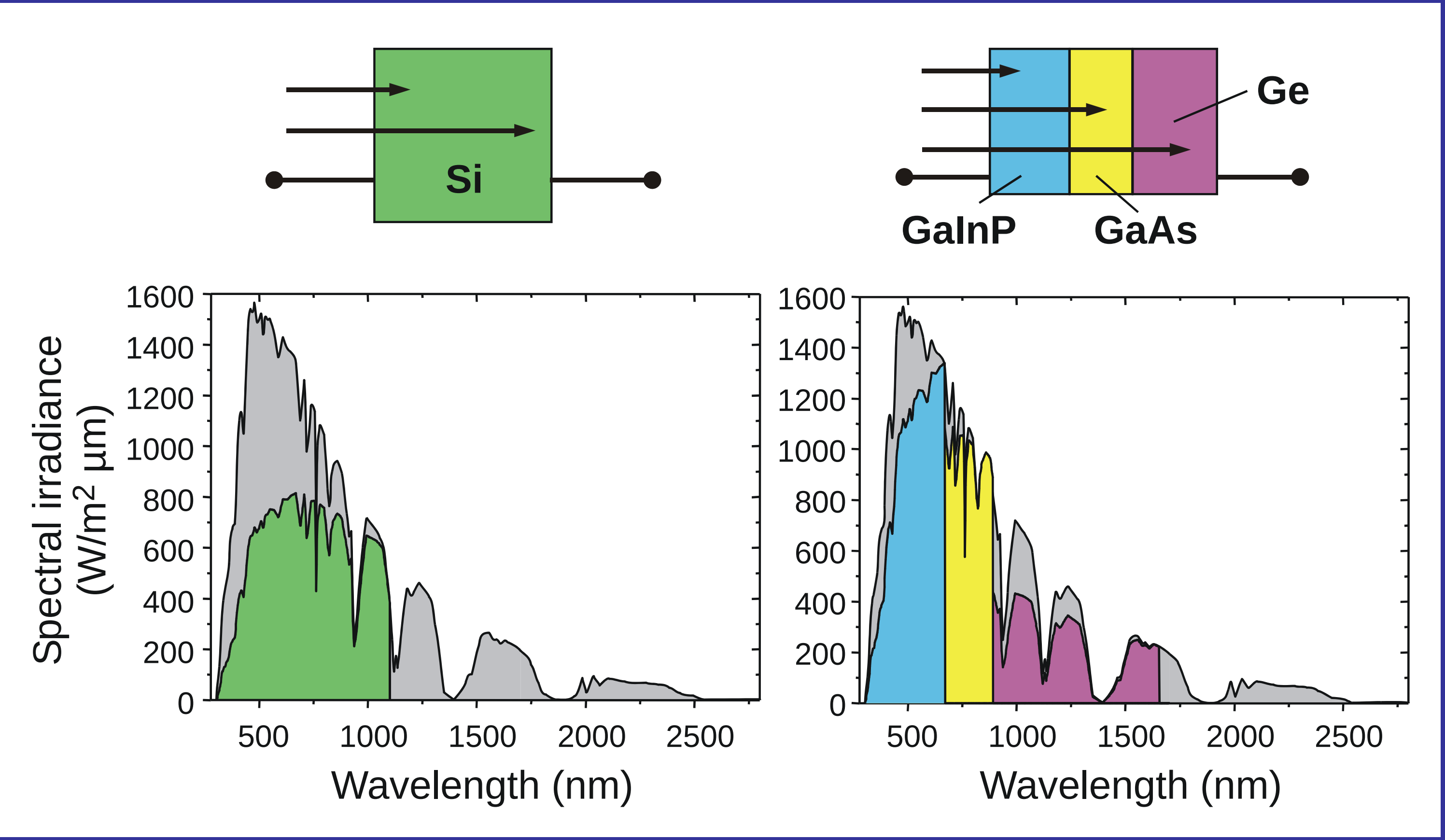


Light- and Volt-current characteristics



Multijunction solar cells provide conversion of the solar spectrum with higher efficiency.

Achievable efficiency of multijunction cells is > 50%



Hvala za vašo pozornost!