Optoelectronică

Curs 11

2025/2026

Disciplina 2025/2026

- 2C/1L Optoelectronică OPTO
- **Minim 7 prezente curs + laborator**
- Curs – conf. Radu Damian
  - an IV μE
  - Marti 14:00-16:00, P7 -> **P6**
  - E – 70% din nota (50%+20%)
    - **20% test (VP) la curs**, saptamana **5-7**?
  - probleme + (2p prez. curs)
  - **toate materialele permise**
- Laborator – sl. Catalin Iov
  - an IV μE
    - Marti 16-18, I.08
    - Max. 7 prezente
  - L – 30% din nota (+Caiet de laborator +Probleme)

Cuprins

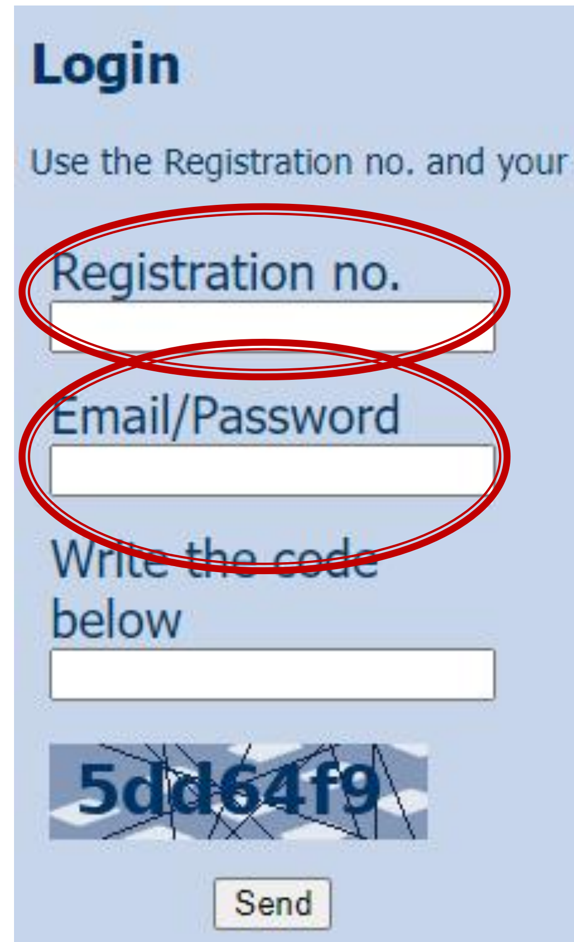
- Lumina ca undă electromagnetică* (ecuaţiile lui Maxwell, ecuaţia undelor, parametrii de propagare)
- Elemente de fotometrie şi radiometrie* (mărimi energetice/luminoase)
- **Fibra optică** (realizare, principiu de funcţionare, atenuare, dispersie, banda de frecvenţă)
- **Cabluri optice** (tehnologie, conectori, lipire – splice)
- **Proiectare sistemică a legăturii pe fibra optică** (bandă de frecvenţă, balanţa puterilor)
- **Emiţătoare optice** (LED şi dioda laser – realizare fizică şi functionare)
- **Receptoare optice** (dioda PIN, dioda cu avalanşă – realizare fizică şi functionare)
- Amplificatoare transimpedanţă (parametri, scheme tipice, TIA în buclă deschisă, cu reacţie, diferenţiale, control automat al câştigului)
- Realizarea circuitelor pentru controlul emiţătoarelor optice **(**parametri, scheme tipice, controlul puterii, multiplexoare**)**
- **Dispozitive de captare a energiei solare** (principiu de functionare, utilizare, proiectare)

*** – VP**

Acces

- Personalizat (parola), Generic (email)

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	-	



LED

Dioda electroluminescenta
Capitolul 7

LED – Principiul de operare

- Lumina este generata de o recombinare **radiativa** dintre un electron si un gol
- Recombinarea **neradiativa** transforma energia in **caldura**
- Eficienta cuantica $\eta = \frac{R_r}{R_r + R_{nr}}$
- La recombinarea radiativa $E_g = h\nu; \quad \lambda = \frac{hc}{E_g}$
- Recombinare eficienta:
  - alegerea judicioasa a materialului
  - concentrarea purtatorilor in zona jonctiunii
- Lungimea de unda depinde de temperatura de functionare a dispozitivului: 0.6nm/°C

Lăţimea benzii interzise/lungime de undă pentru materialele uzuale

Material	Formula	Wavelength Range λ (μm)	Bandgap Energy W_g (eV)
Indium Phosphide	InP	0.92	1.35
Indium Arsenide	InAs	3.6	0.34
Gallium Phosphide	GaP	0.55	2.24
Gallium Arsenide	GaAs	0.87	1.42
Aluminium Arsenide	AlAs	0.59	2.09
Gallium Indium Phosphide	GaInP	0.64-0.68	1.82-1.94
Aluminium Gallium Arsenide	AlGaAs	0.8-0.9	1.4-1.55
Indium Gallium Arsenide	InGaAs	1.0-1.3	0.95-1.24
Indium Gallium Arsenide Phosphide	InGaAsP	0.9-1.7	0.73-1.35

$$E_g = h\nu; \quad \lambda = \frac{hc}{E_g}; \quad \lambda[\mu\text{m}] = \frac{1.240}{E_g[\text{eV}]}$$

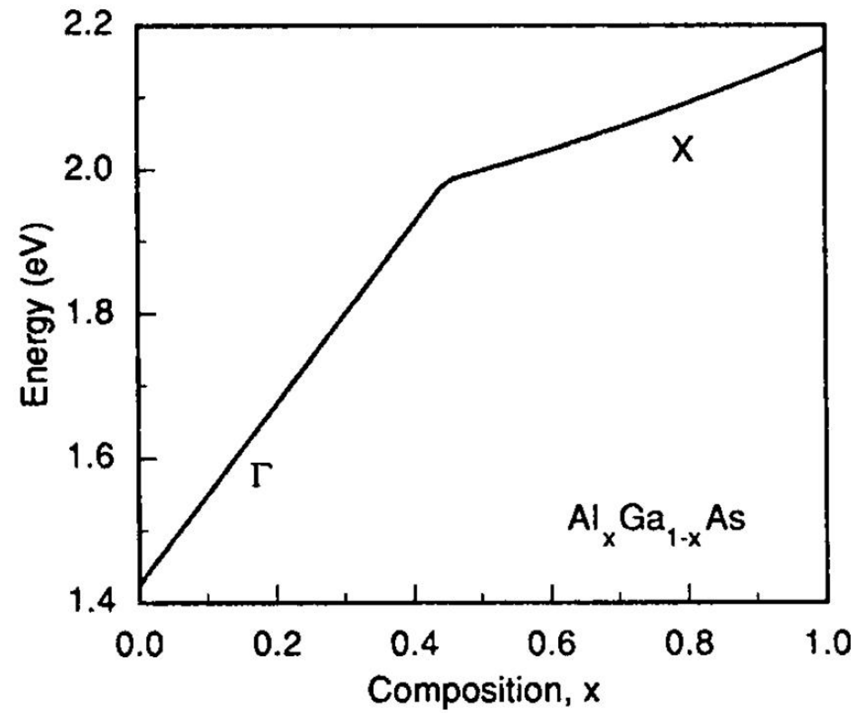
- h constanta lui Plank $6.6261 \cdot 10^{-34}$ Ws^2
- c viteza luminii **in vid** $2.998 \cdot 10^{8}$ m/s
- e sarcina electronului $1.6 \cdot 10^{-19}$ C
- benzi energetice: λ_0, **$\Delta\lambda$**

Materiale

- Lungimi de unda mici (spectru vizibil – 1000nm)
  - GaP (665nm), $GaAs_yP_{1-y}$
  - **GaAs** (900nm), $Ga_{1-x}Al_xAs$ (AlAs – 550nm)
- Lungimi de unda mari (1000÷1700nm)
  - **InP** (920nm), $In_xGa_{1-x}As_yP_{1-y}$
  - x,y concentratii relative in aliaj a materialelor corespunzatoare
  - x,y alese din considerente privind
    - lungimea de unda
    - spatierea atomilor
- Ultraviolet – Albastru: **GaN**, GaInN

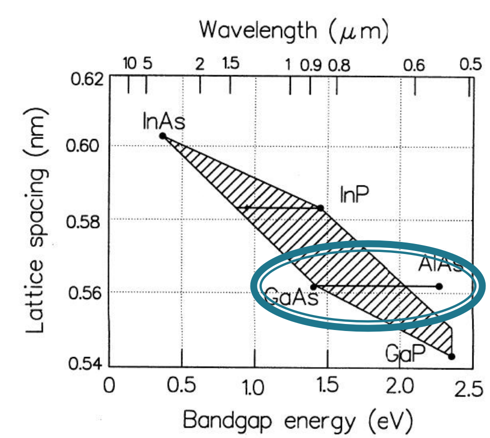
Materiale

- Lungimi de unda mici
  - $Ga_{1-x}Al_xAs$
  - substrat GaAs
  - limitare pentru tranzitie directa, x<0.45
  - E_g (in **eV**)



$$E_g = 1.424 + 1.247 \cdot x, \quad x < 0.45$$

$$E_g = 1.9 + 0.125 \cdot x + 0.143 \cdot x^2, \quad x > 0.45$$



Materiale

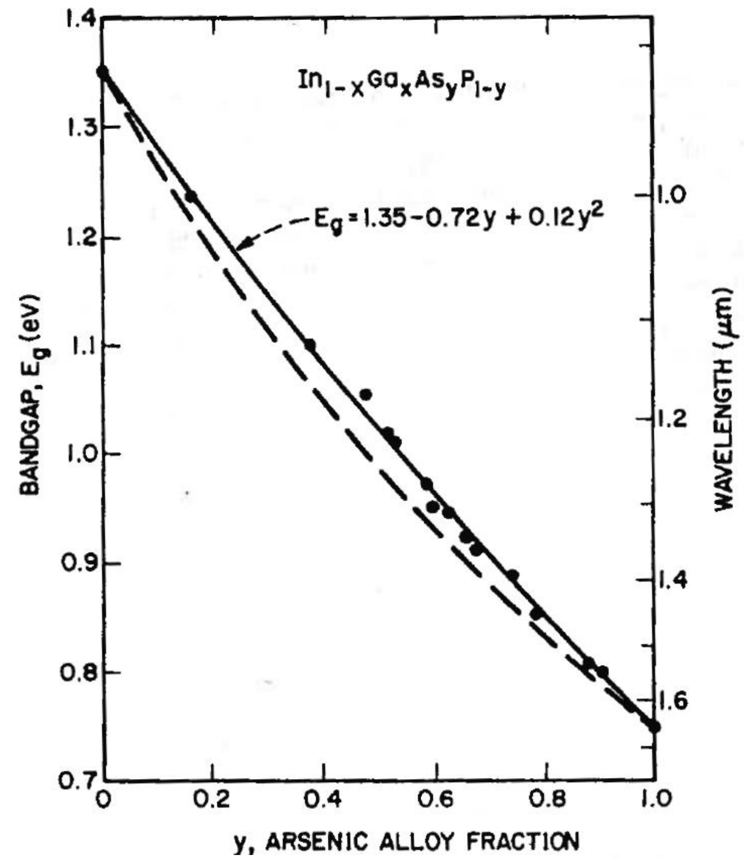
- Lungimi de unda mari
  - $In_xGa_{1-x}As_yP_{1-y}$
  - Tipic substratul este InP
    - Spatierea atomilor (lattice spacing) corespunzatoare InP

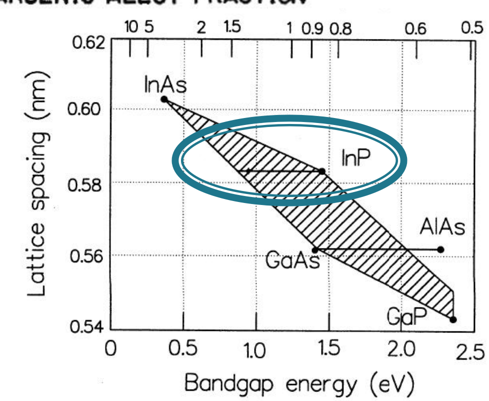
$$x = \frac{0.4526 \cdot y}{1 - 0.031 \cdot y}$$

  - E_g (in **eV**)

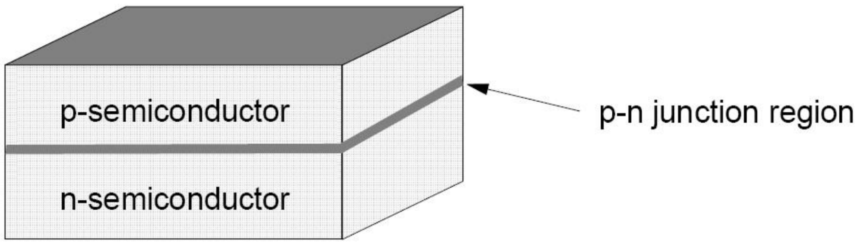
$$E_g = 1.35 - 0.72 \cdot y + 0.12 \cdot y^2$$

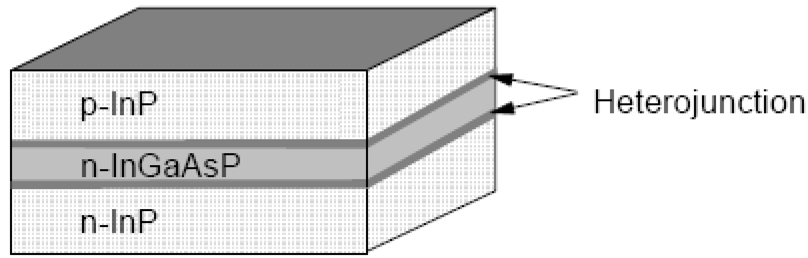
  - Exemplu: 1300nm se obtine cu y=0.611 si x=0.282,
    - $In_{0.282}Ga_{0.718}As_{0.611}P_{0.389}$



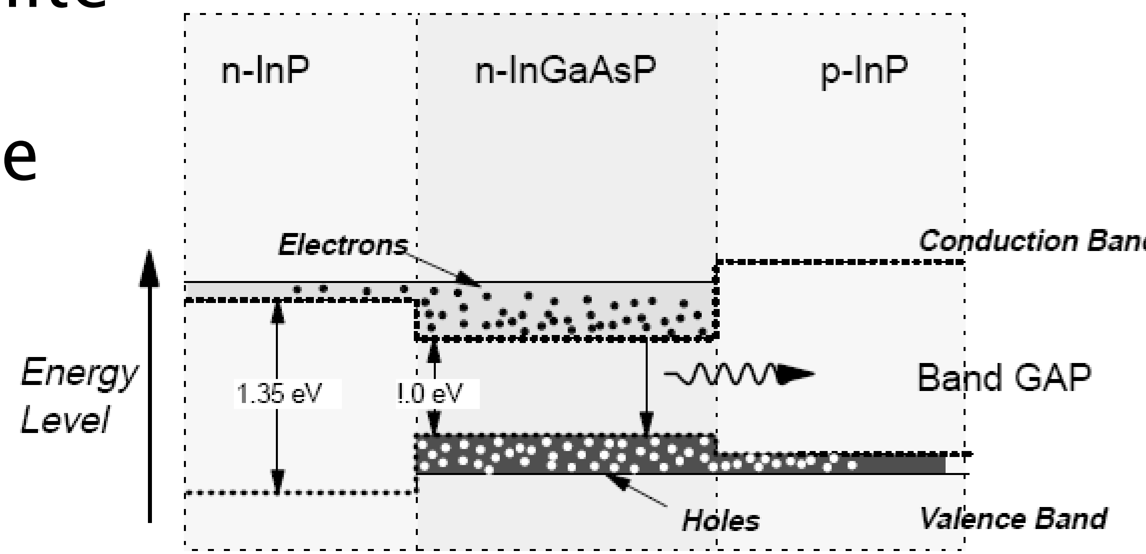


LED cu heterojuncţiuni – principiu





- Structura de nivele energetice permite capturarea purtatorilor intre cele doua heterojonctiuni

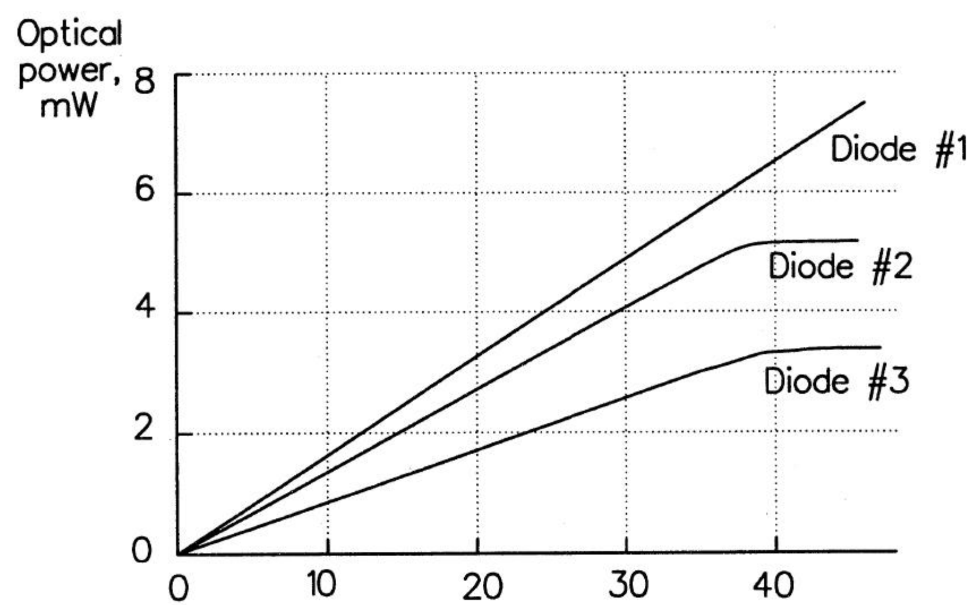


Caracteristica de raspuns a LED-urilor

- Caracteristica putere optica emisa functie de curentul direct prin LED este liniara la nivele mici ale curentului.
- Nu exista curent de prag
- La nivele foarte mari puterea optica se satureaza
- Responzivitatea

$$r = \frac{P_o}{I} \quad \left[\frac{W}{A}\right]$$

- Tipic r=50μW/mA



Dioda Laser

Capitolul 8

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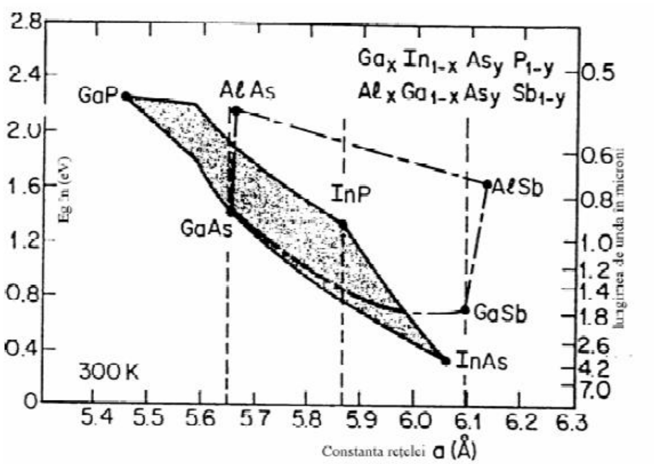
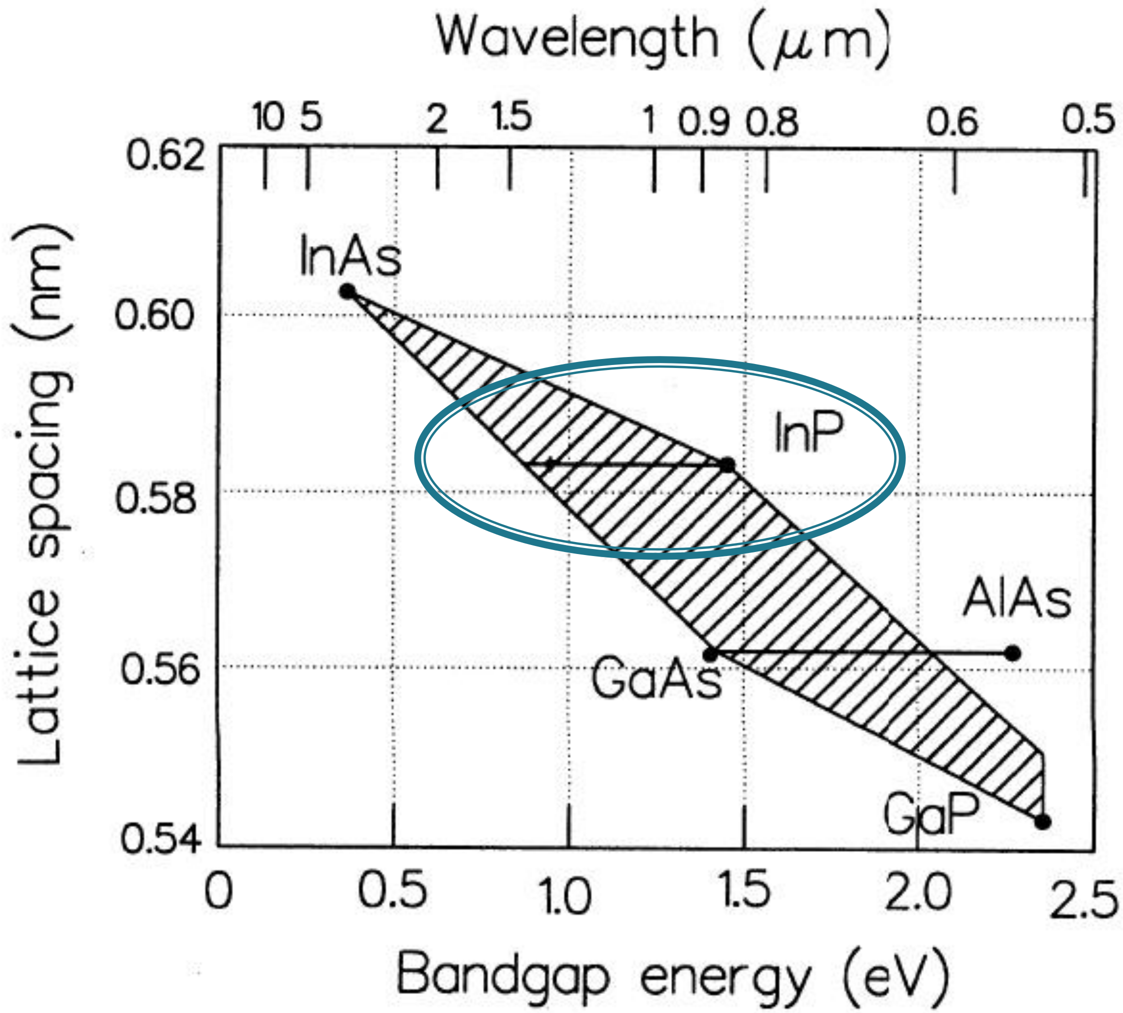
Dependenţa benzii interzise de constanta reţelei





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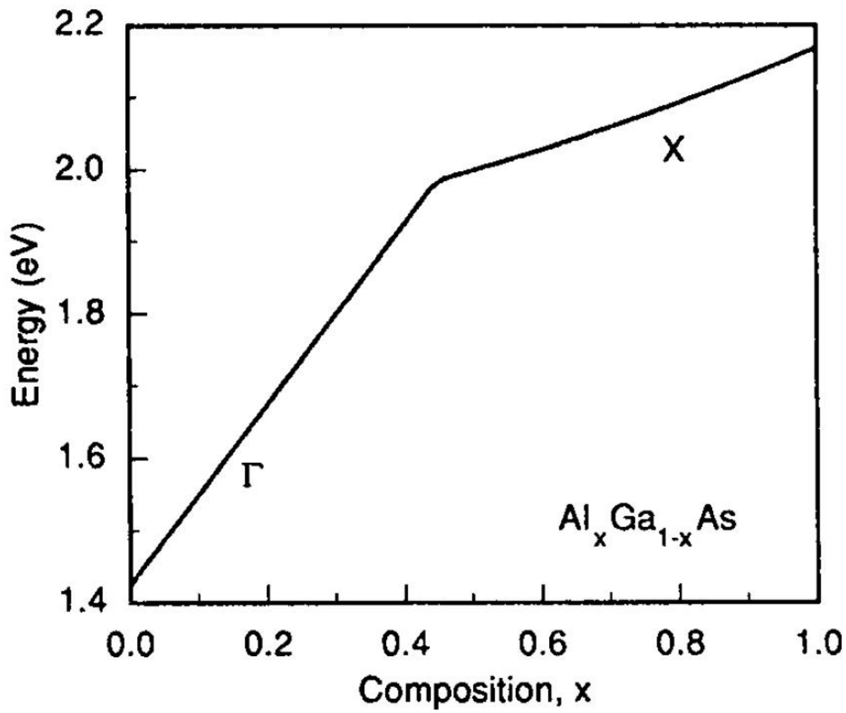

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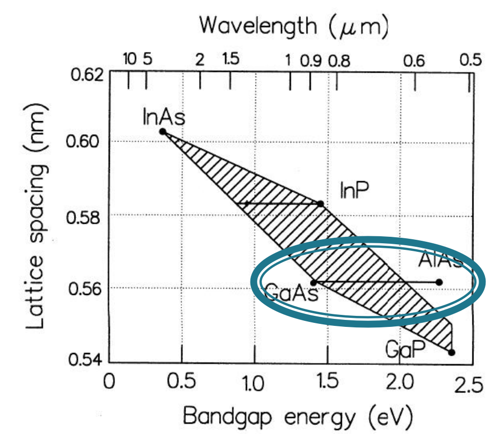

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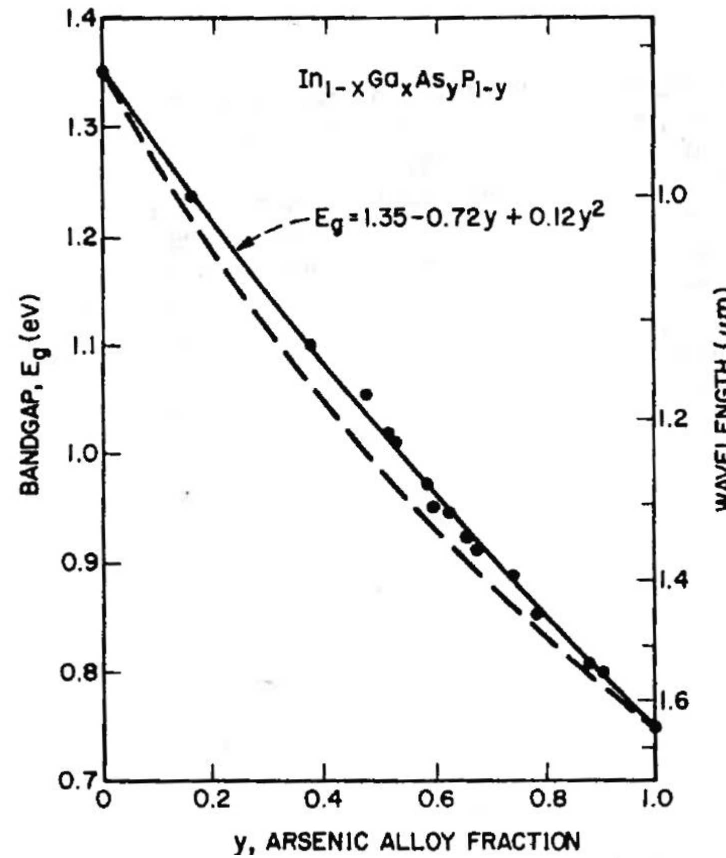

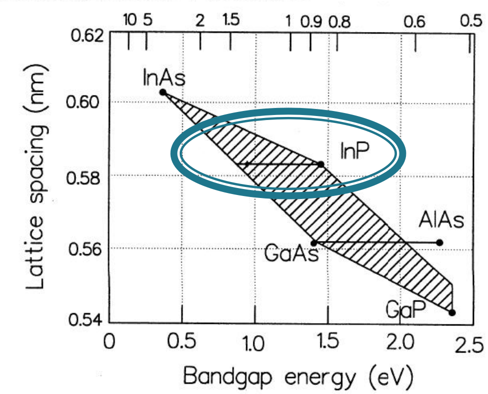

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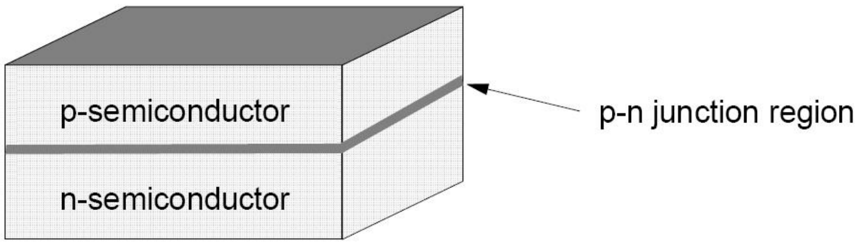

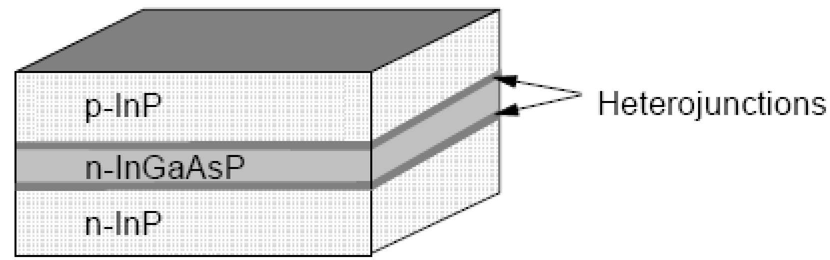

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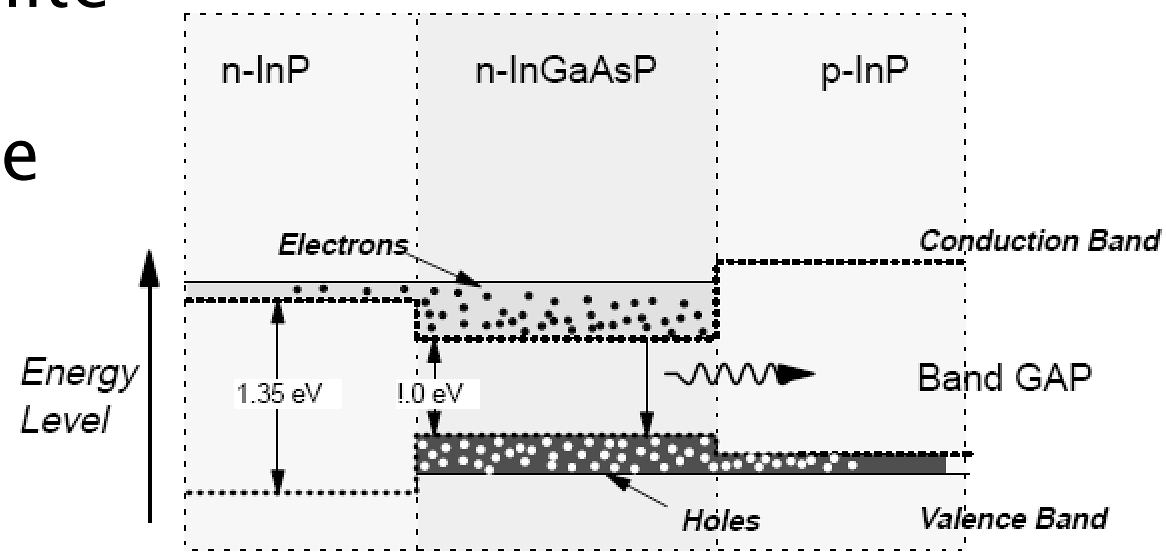
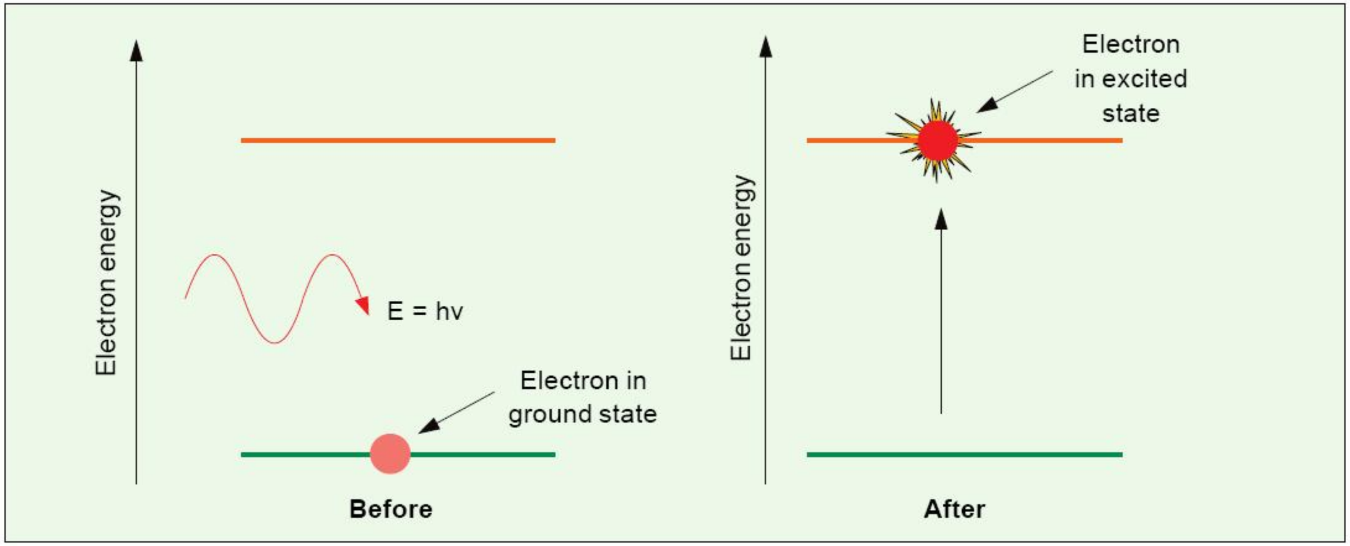


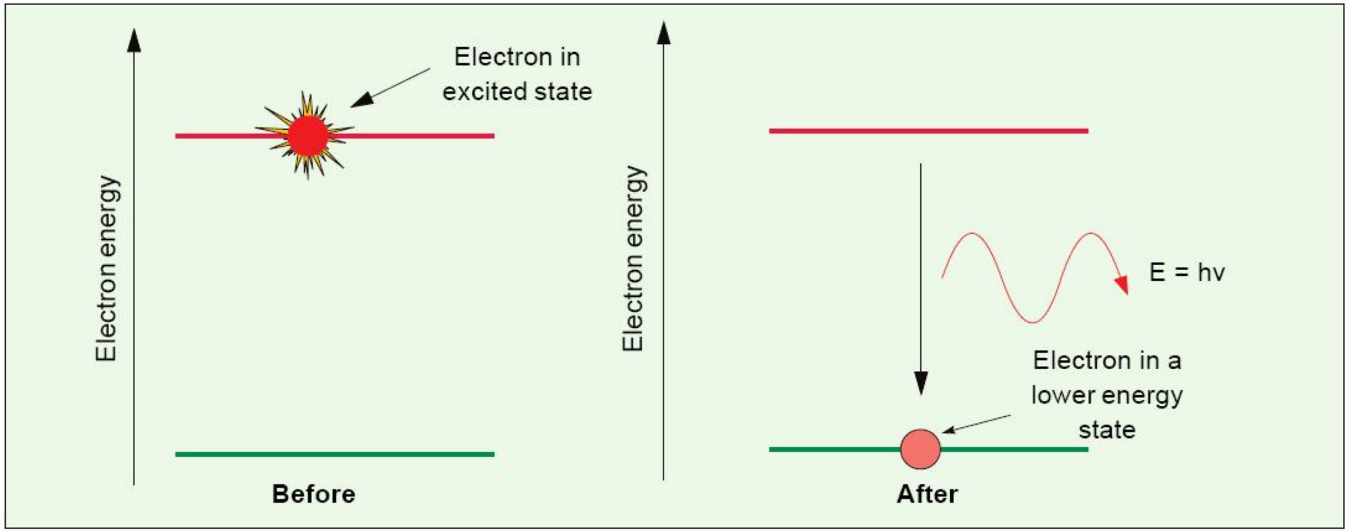
Dioda LASER – Principiu de operare

- LASER = Light Amplification by the Stimulated Emission of Radiation = Amplificarea Luminii prin Emisie Stimulata
- Un foton incident poate cauza prin absorbtie tranzitia unui electron pe un nivel energetic superior



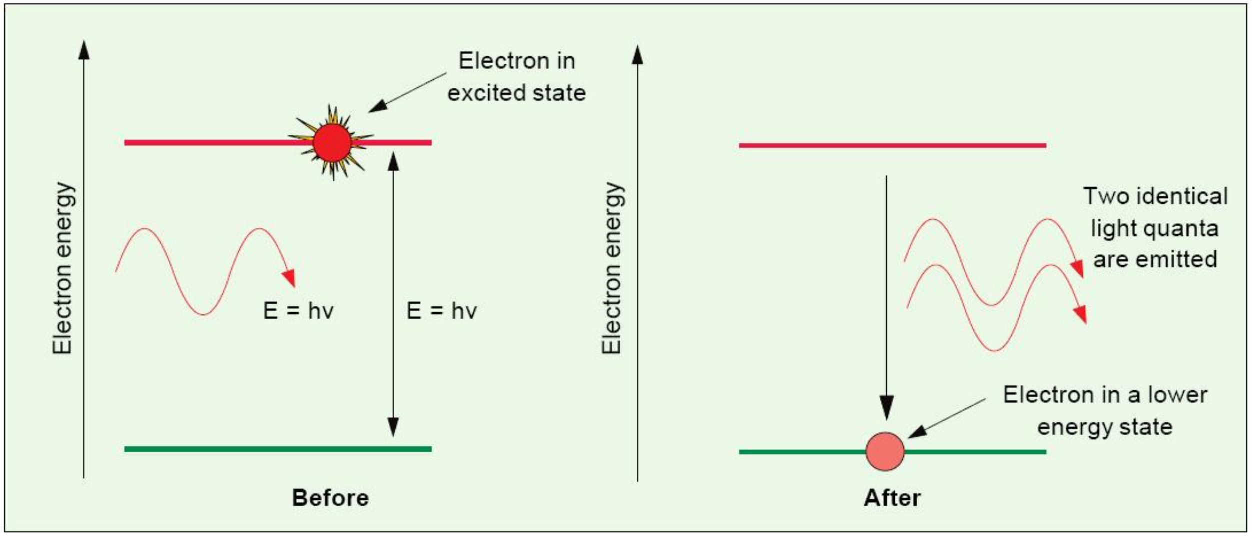
Dioda LASER – Principiu de operare

- Emisia spontana – electronul trece in starea energetica de echilibru emitand un foton
- Trecerea se realizeaza prin recombinarea unei perechi electron-gol
- Directia si faza radiatiei emise sunt aleatoare



Dioda LASER – Principiu de operare

- Emisia stimulata – un foton incident cu energie corespunzatoare poate stimula emisia unui al doilea foton **fara a fi absorbit**
- Noul foton are aceeasi directie si faza cu fotonul incident, Lumina rezultata e **coerenta**



Principii LASER

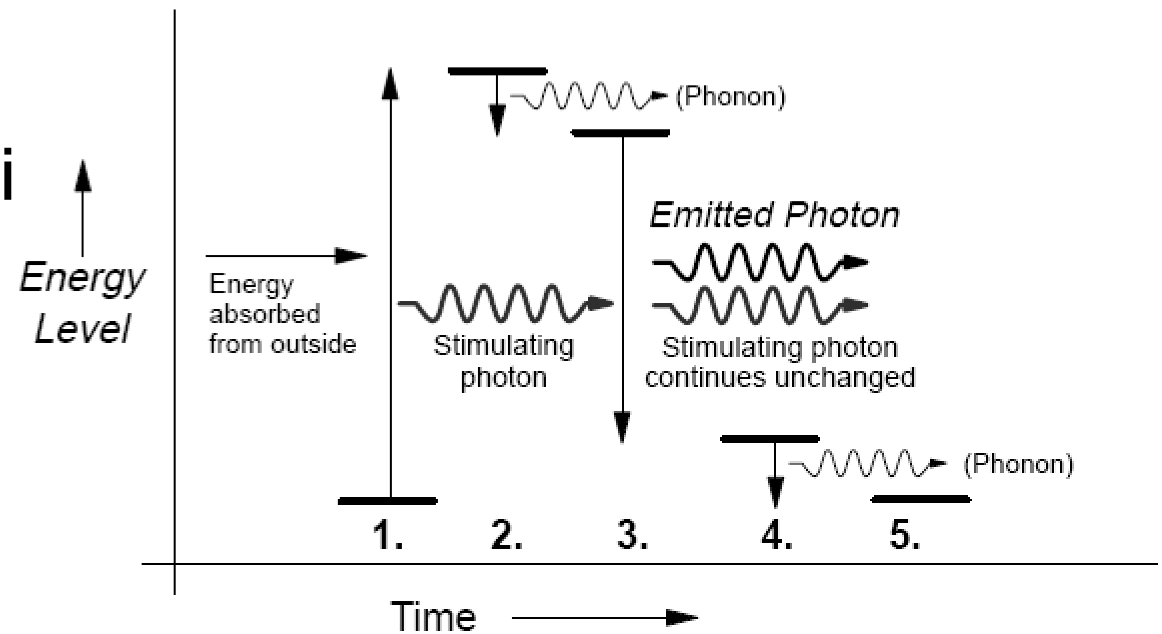
- Inversiune de populatie
  - necesara deoarece electronii au capabilitatea de a absorbi energie **la aceeasi frecventa** la care are loc emisia stimulata
  - se defineste probabilistic: probabilitatea de emisie stimulata sa fie mai mare decat probabilitatea de absorbtie

$$n_c \cdot p_e > n_v \cdot p_a$$

- Materialele capabile sa genereze inversiune de populatie au starea excitata metastabila

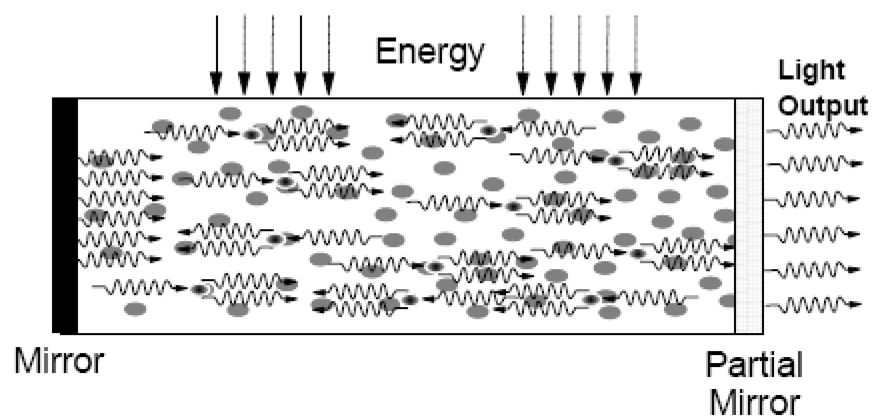
Materiale cu 4 nivele energetice

- La un material cu 4 nivele energetice tranzitia radianta a electronului (3) se termina intr-o stare instabila, starea de echilibru obtinandu-se prin emisia unui fonon
- Inversiunea de populatie se obtine mult mai usor datorita electronilor din starea intermediara

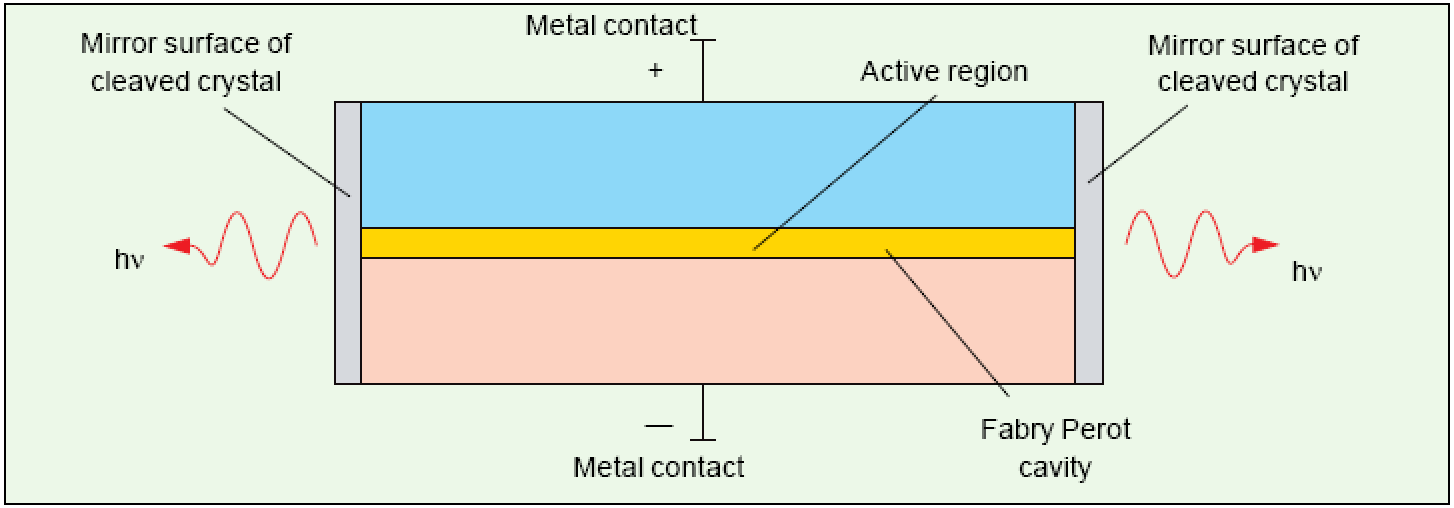


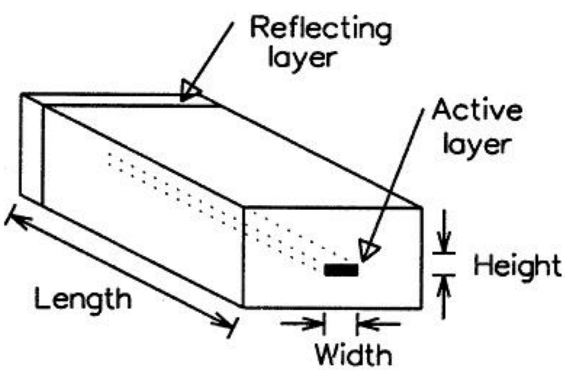
Dioda LASER – Principiu de realizare

- Pentru ca emisia stimulata sa apara, fotonii emisi trebuie sa ramana in contact cu materialul o perioada mai mare de timp – 2 oglinzi necesare
- Pentru a permite extragerea radiatiei e necesar ca una din oglinzi sa fie partial reflectanta



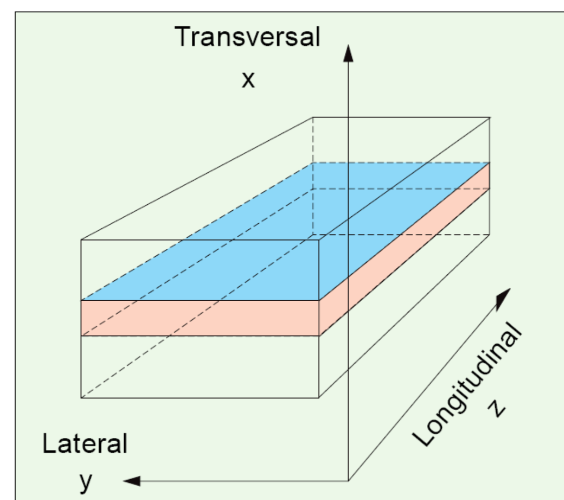
Dioda LASER Fabry Perot





Height: 0.1 – 0.2 μm
Length: 250 – 500 μm
Width: 5 – 15 μm
Sides: rough–cut
Front: cleaved
Back: 100% reflector

Definirea directiilor in dioda LASER



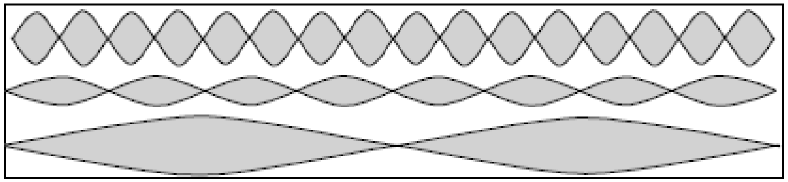
Dioda LASER – Principiu de realizare

- Pentru a realiza
  - coerenta radiatiei
  - interferenta constructiva intre radiatiile incidente si reflectate de oglinzi,
- distanta intre oglinzi trebuie sa fie un multiplu a jumatate din lungimea de unda

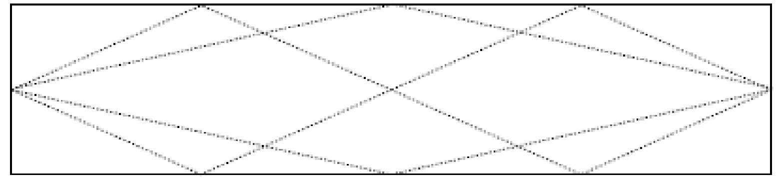
$$L = k \cdot \frac{1}{2} \cdot \frac{\lambda_0}{n} \qquad L = k \cdot \frac{c_0}{2 \cdot n \cdot f} \qquad f = k \cdot \frac{c_0}{2 \cdot n \cdot L}$$

- Pentru eficientizarea pomparii de energie din exterior L=100÷200µm, k ≅ 400

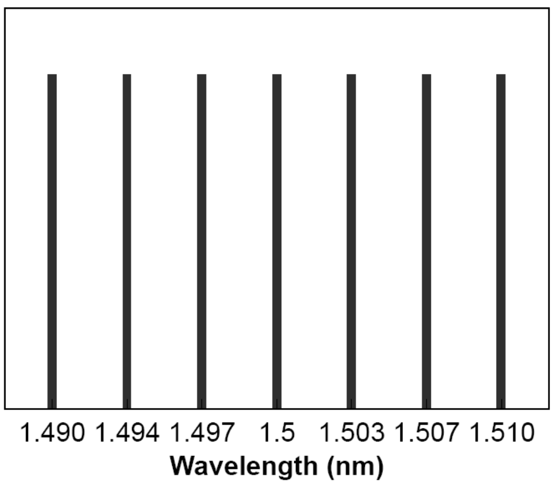
Spectrul diodei LASER



Longitudinal Modes



Lateral Modes



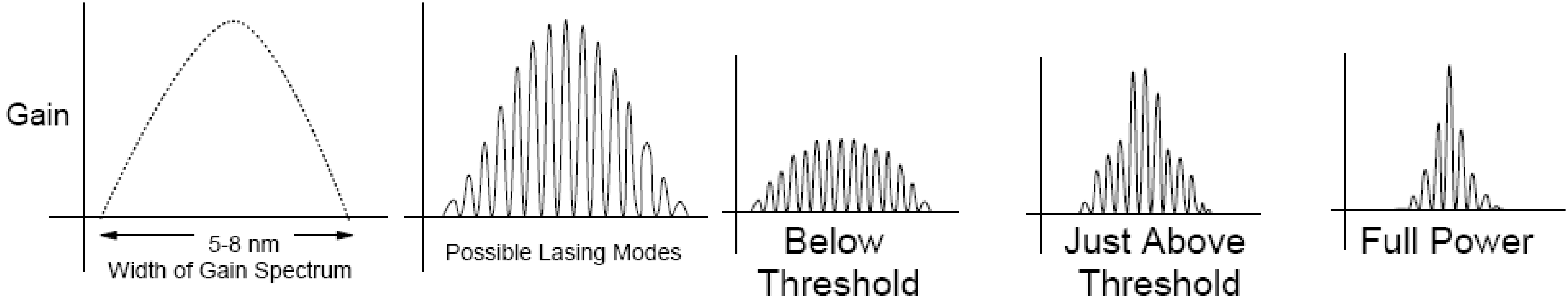
$$f_k = k \cdot \frac{c_0}{2 \cdot n \cdot L} \qquad \Delta f = \frac{c_0}{2 \cdot n \cdot L}$$

$$\Delta\lambda \cong \frac{\lambda_0^2}{2 \cdot n \cdot L}$$

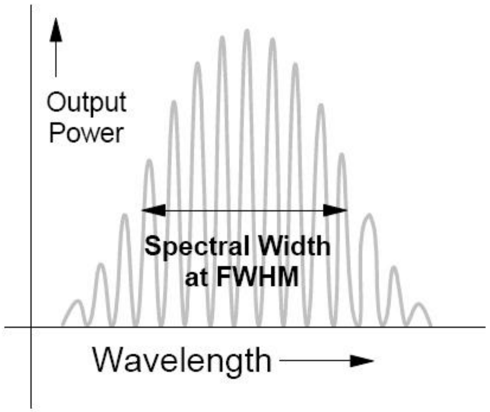
Continuare

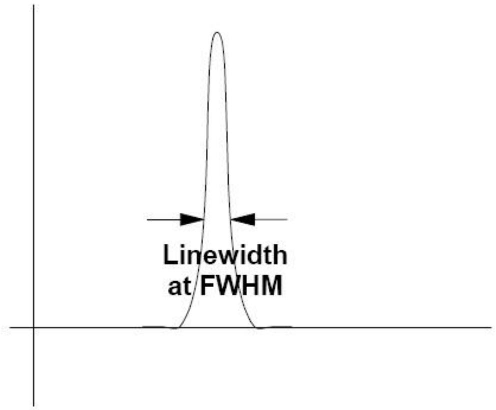
Spectrul diodei LASER

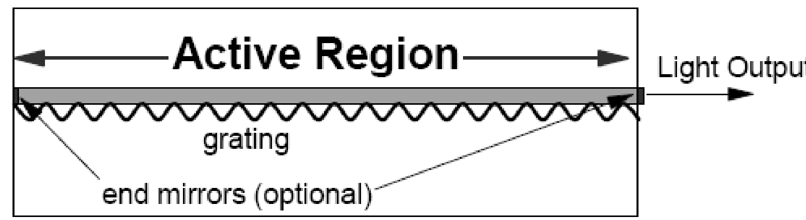
- Castigul diodei laser (eficacitatea aparitiei emisiei stimulate) depinde
  - de caracteristicile energetice ale materialului din care e realizata dioda
  - de energia pompata din exterior (curentul prin dioda)

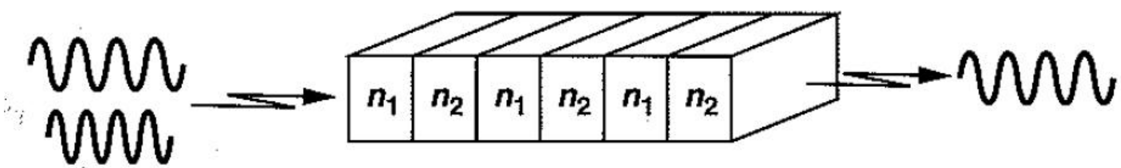


Distributed Feedback (DFB) Lasers

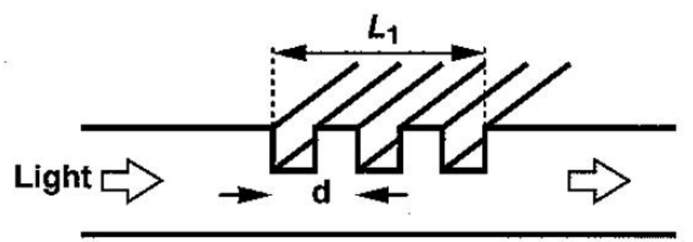








(a)

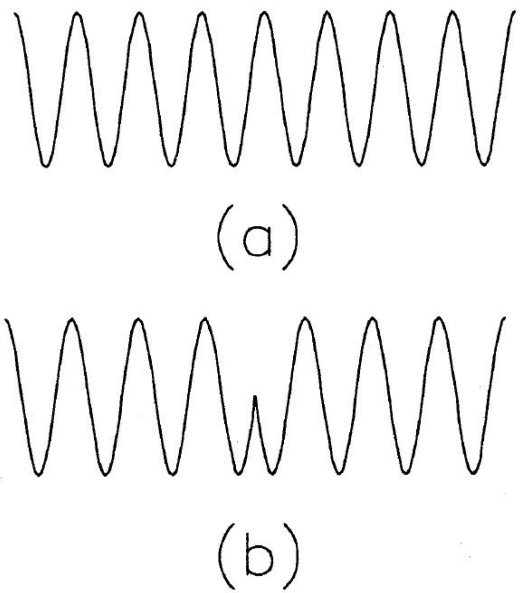


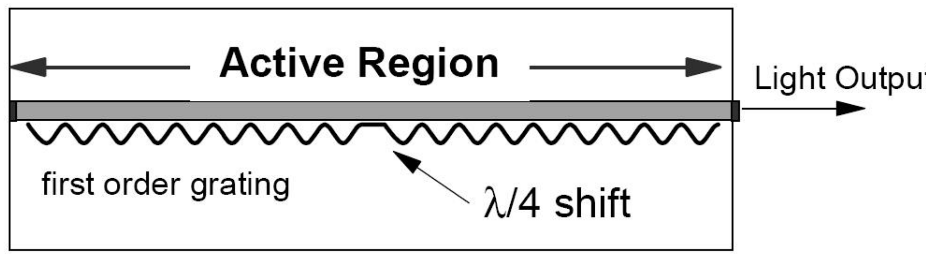
(b)

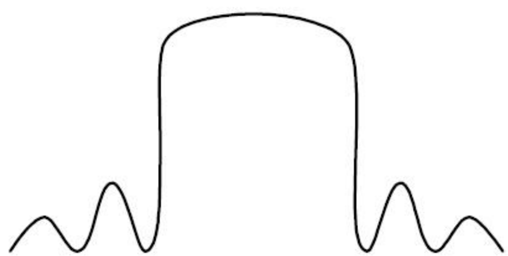
Filtre spatiale in regiunea activa

Distributed Feedback (DFB) Lasers

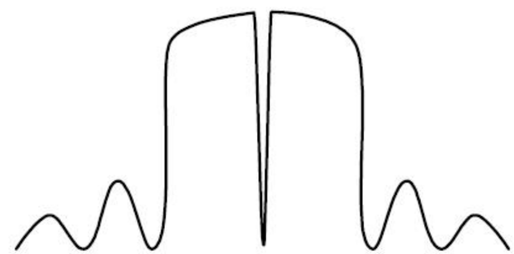
- Pentru operarea in impulsuri, un salt de λ/4 ingusteaza suplimentar spectrul diodei laser







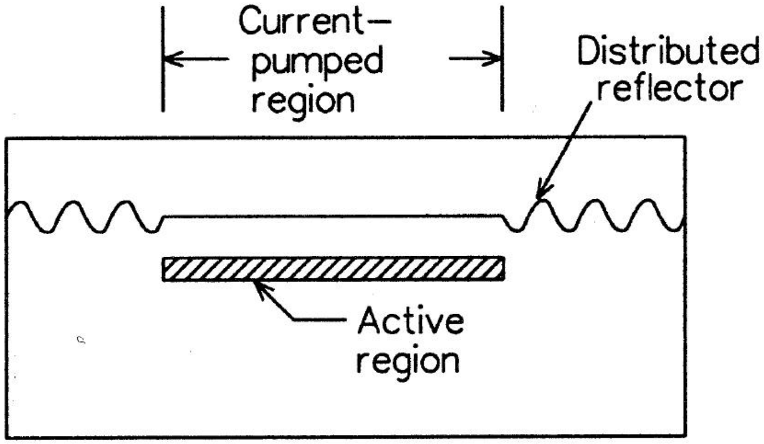
Reflection Characteristic
without Phase Shift

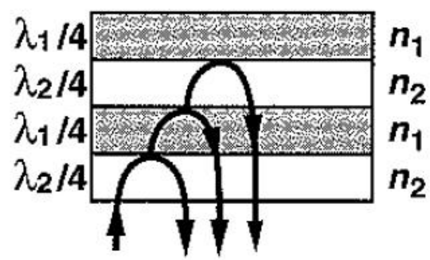


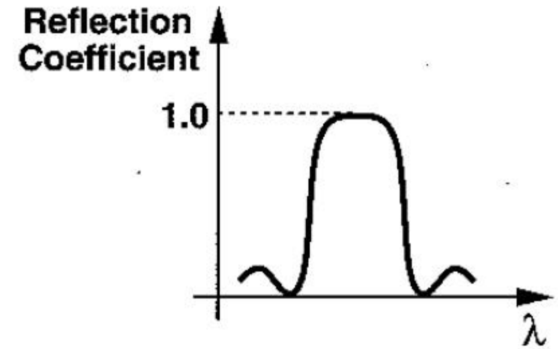
Reflection Characteristic
Phase Shifted grating

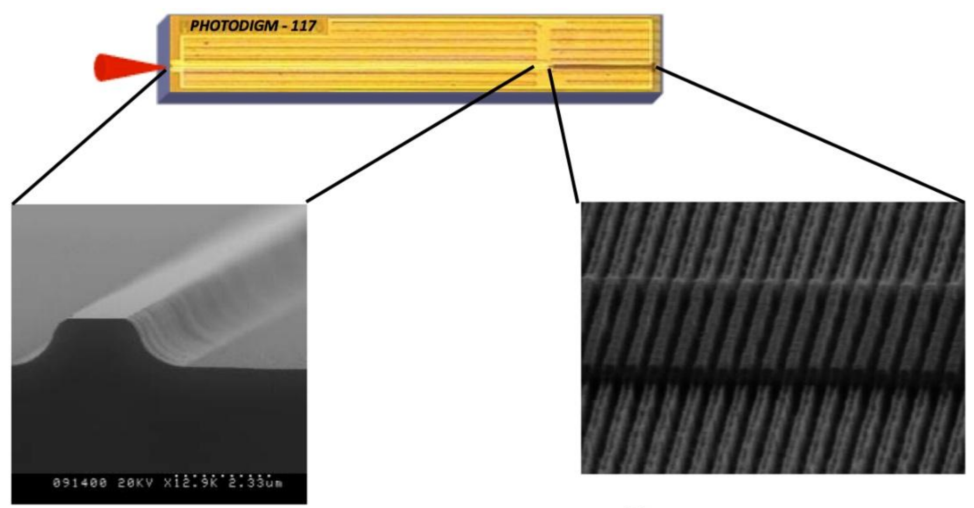
Distributed Bragg Reflector (DBR) Lasers

- Se utilizeaza suprafete reflective selective pentru filtrare optica









Gain region

Grating region

Caracteristica de raspuns LD

- Amorsarea **emisiei stimulate** necesita pomparea unei anumite cantitati de energie – curent de prag

$I < I_{th}$ regim LED

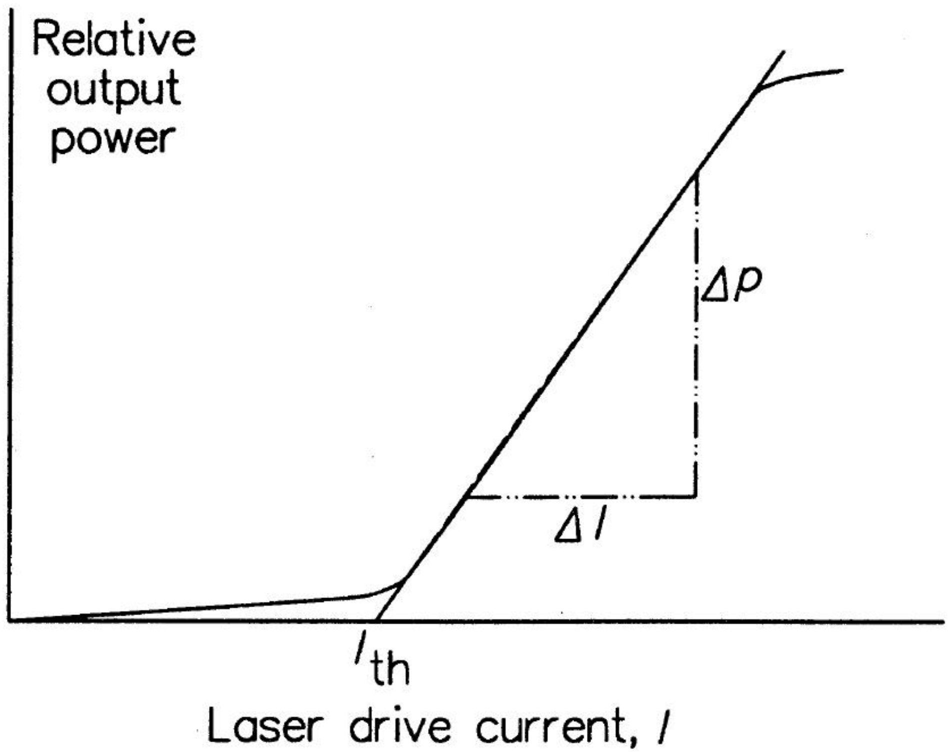
ineficient!, $P_o \cong 0$

$I > I_{th}$ regim LASER

$$r = \frac{\Delta P_o}{\Delta I} \quad \left[\frac{W}{A}\right]$$

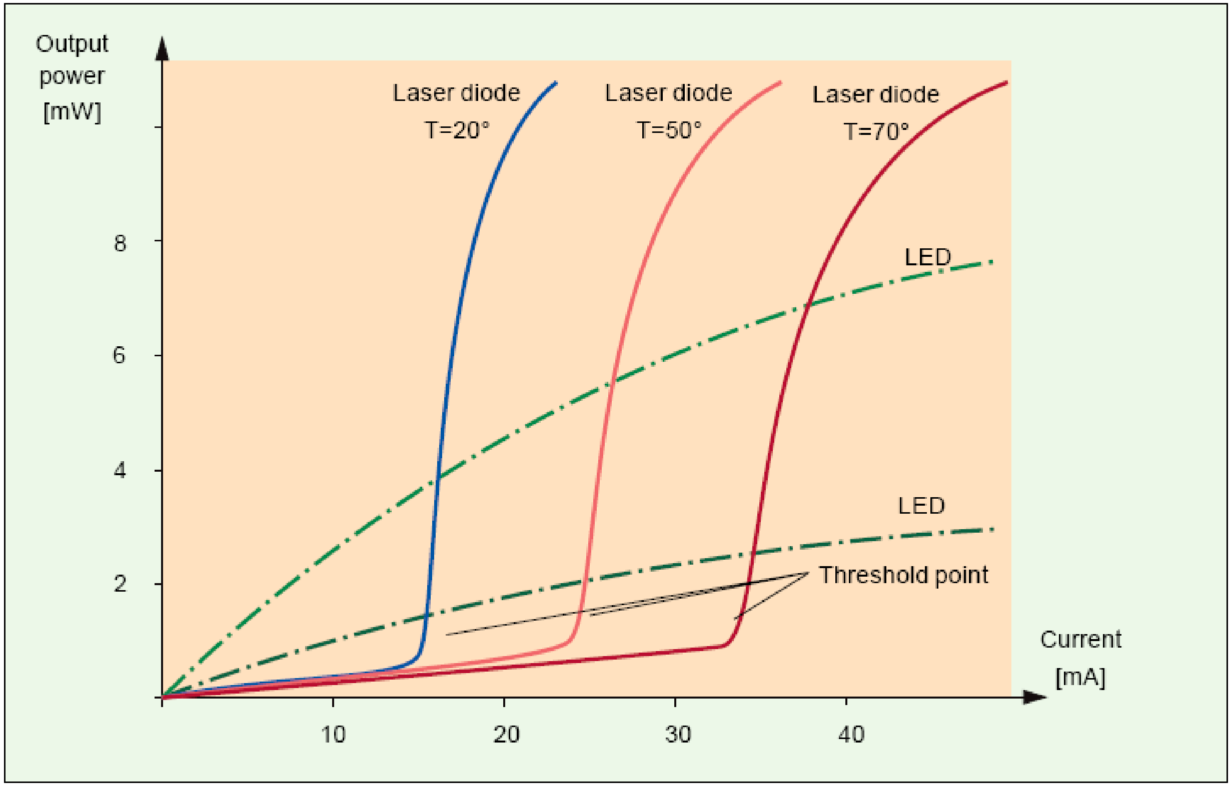
$$P_o = r \cdot (I - I_{th})$$

Apare **saturare** la nivele mari de curent

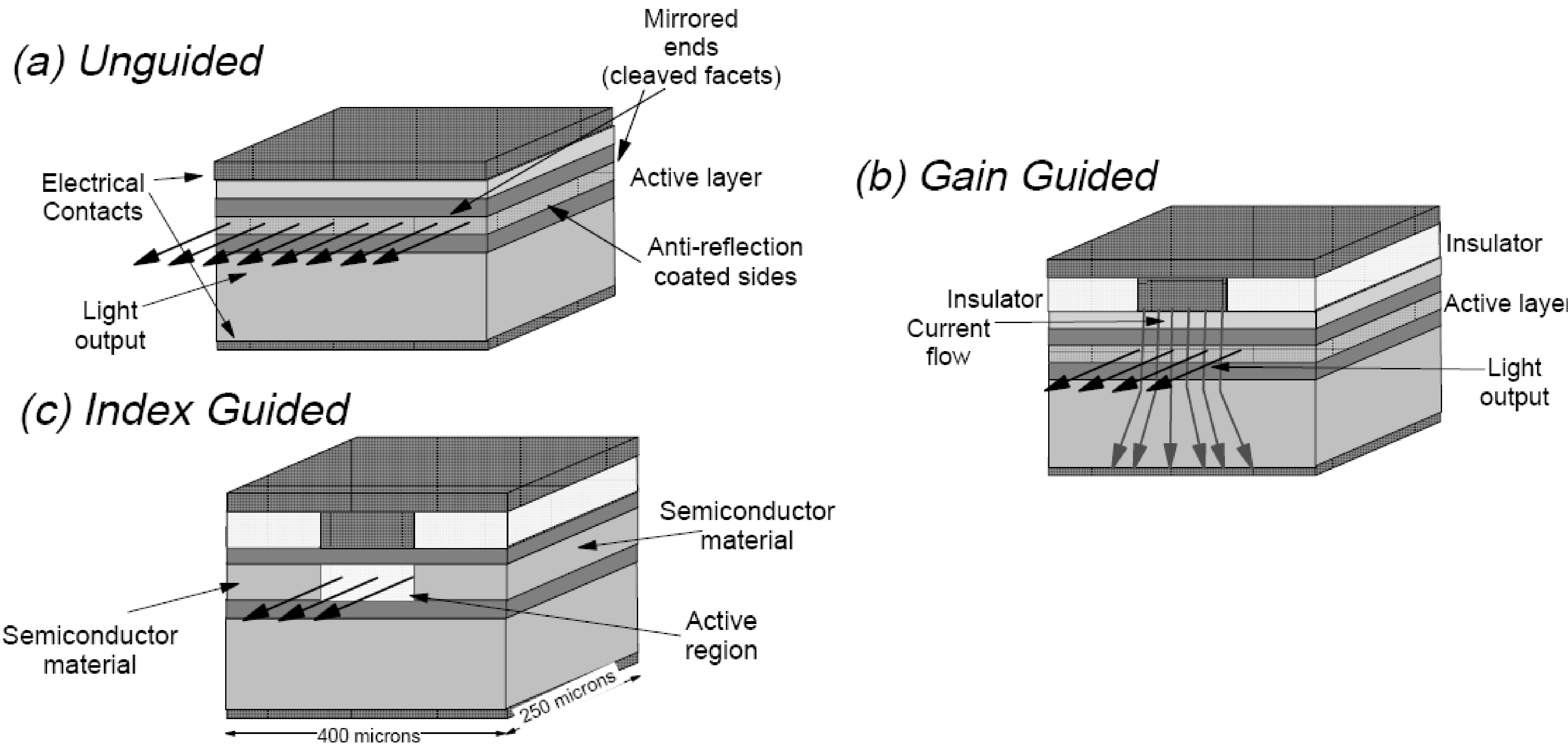


Temperatura si îmbatrânire

- Curentul de prag variaza cu temperatura si cu timpul
- Variatia tipica 1-2%/°C

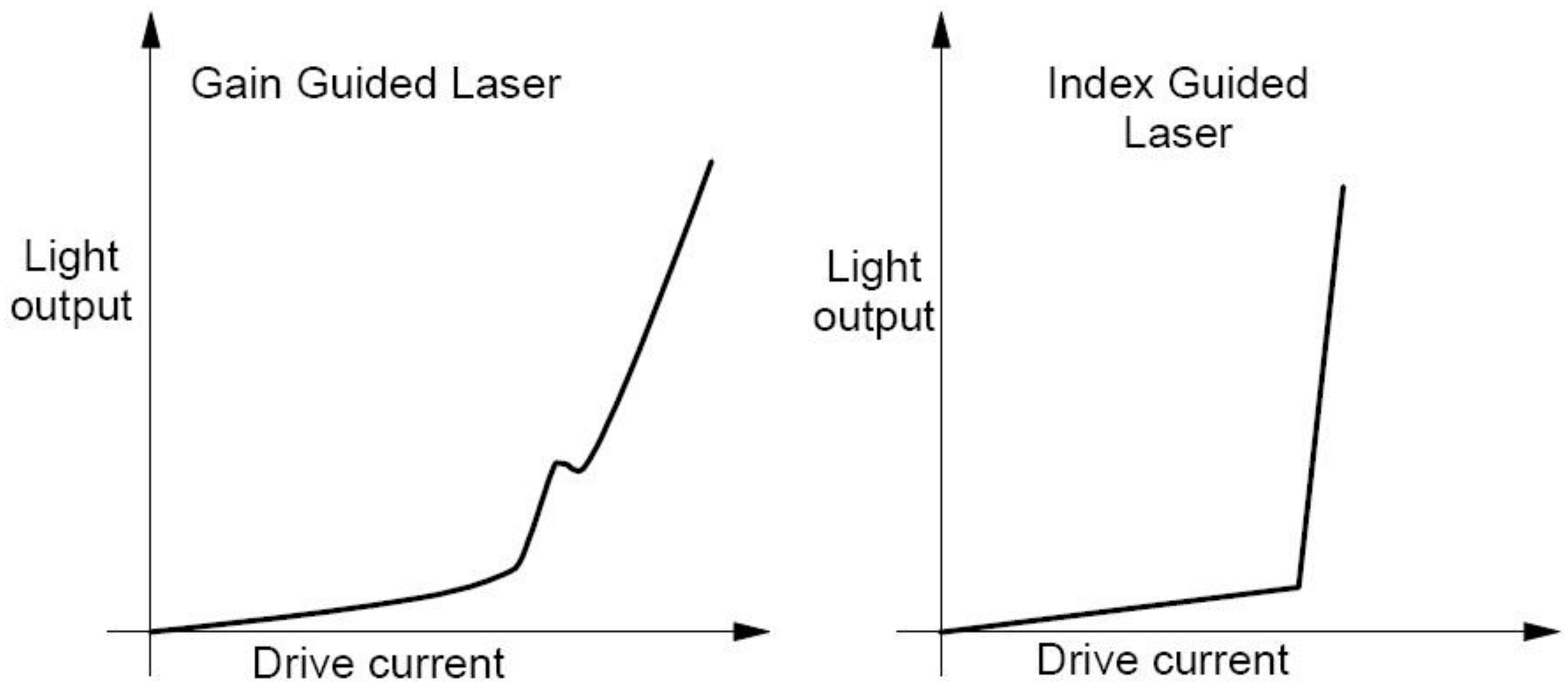


Direcţionarea luminii în laser-ul Fabry Perot



Efectul ghidarii

- Gain guided – 8÷20 linii spectrale (5÷8 nm)
- Index guided – 1÷5 linii spectrale (1÷3 nm)



Dependenta de temperatura

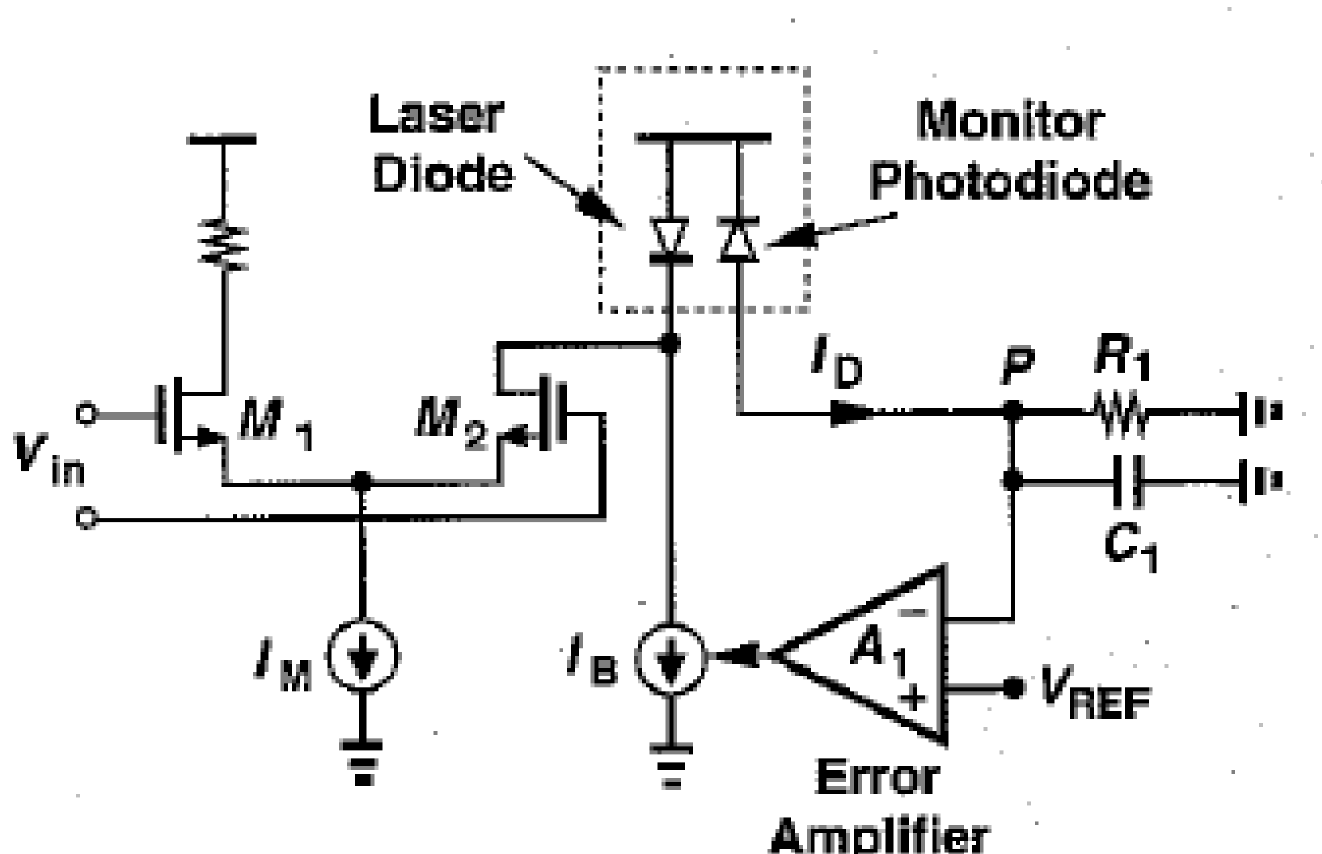
- Dependenta de temperatura a curentului de prag este exponentiala

$$I_{th} = I_0 \cdot e^{T/T_0}$$

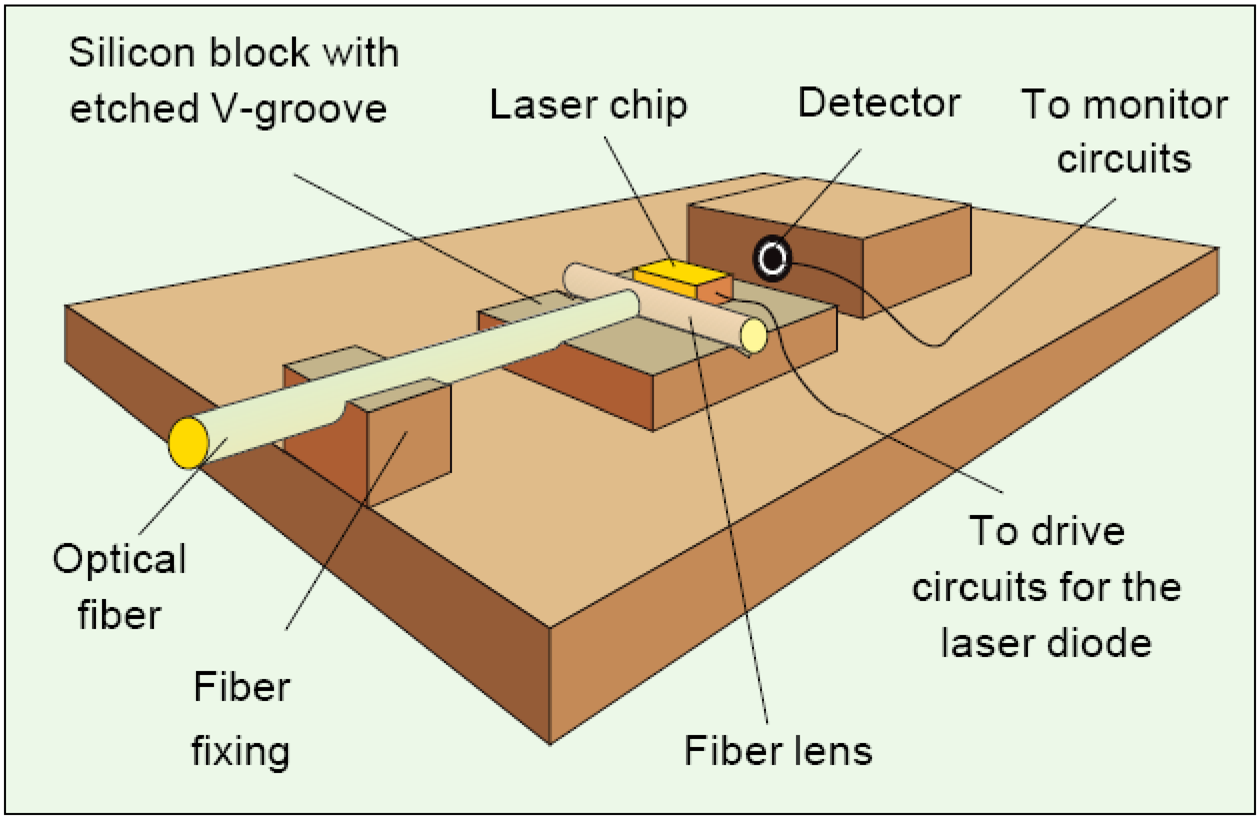
- I_0 e o constanta determinata la temperatura de referinta

Material	Lungime de unda	T_0
InGaAsP	1300 nm	60÷70 K
InGaAsP	1500 nm	50÷70 K
GaAlAs	850 nm	110÷140 K

Monitorizarea radiaţiei de spate

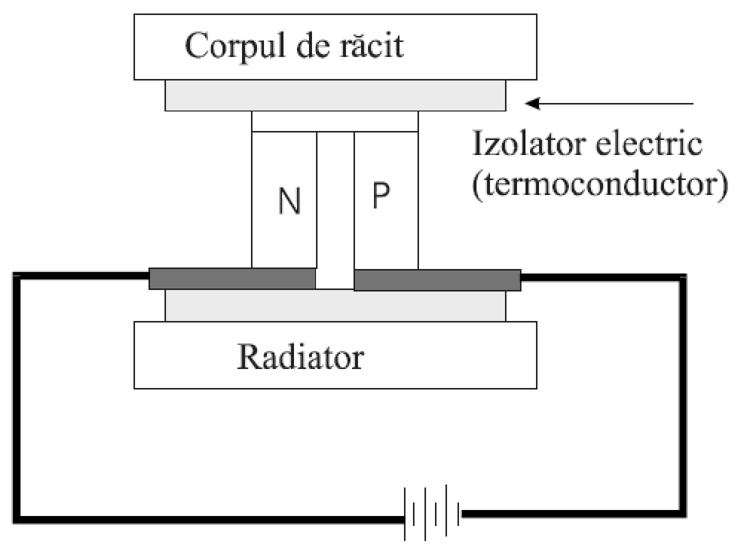


Cuplarea luminii în fibră



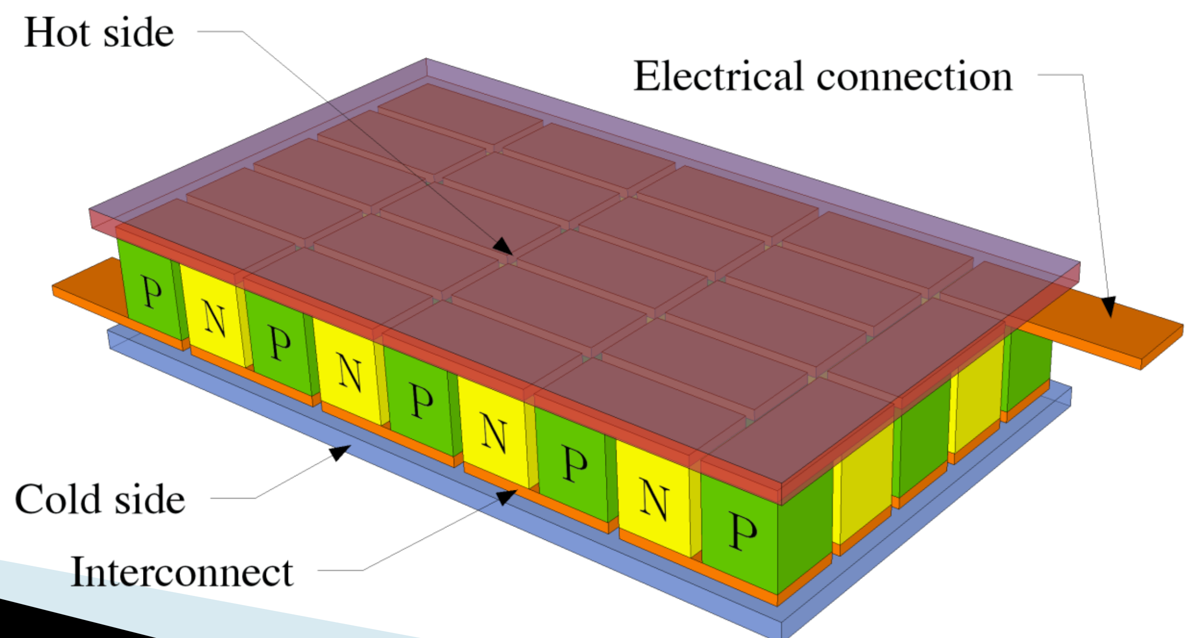
Dispozitiv termoelectric (Peltier)

- Jonctiunea intre doua materiale conductoare diferite poate genera sau absorbi caldura in functie de sensul curentului
- Tipic se utilizeaza doua regiuni semiconductoare puternic dopate (tipic telurit de bismut) conectate electric in serie iar termic in paralel

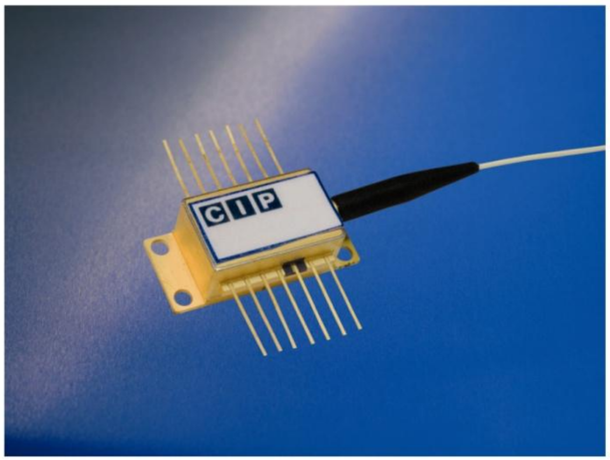


Dispozitiv termoelectric (Peltier)

- Poate produce o diferenta maxima de temperatura de 70°C
- Lucreaza la nivele mici de caldura disipata
- Devine cu atat mai ineficient cu cat fluxul termic disipat e mai mare
- De 4 ori mai putin eficiente decat sistemele cu compresie de vapori

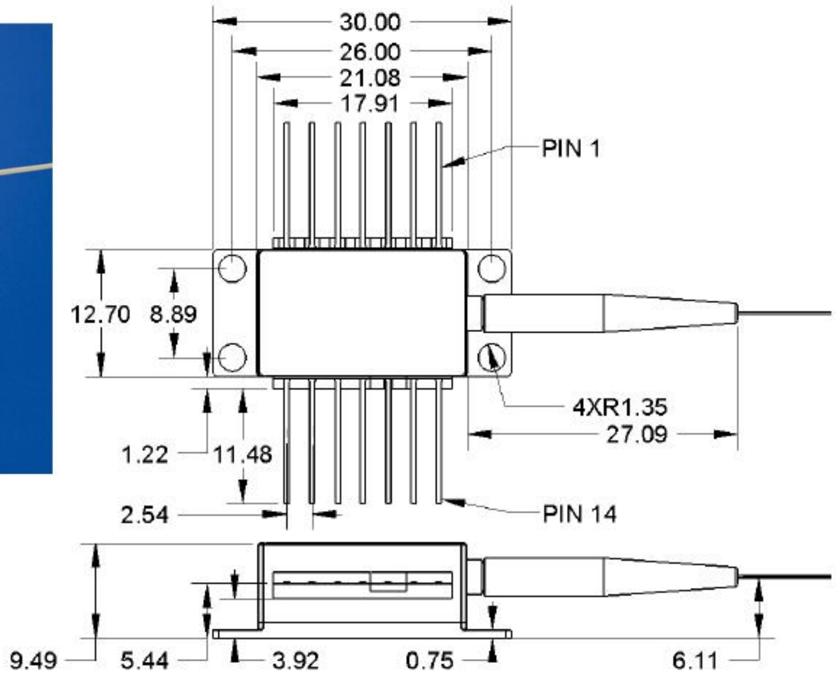


1550nm DFB Laser



Mechanical Drawing

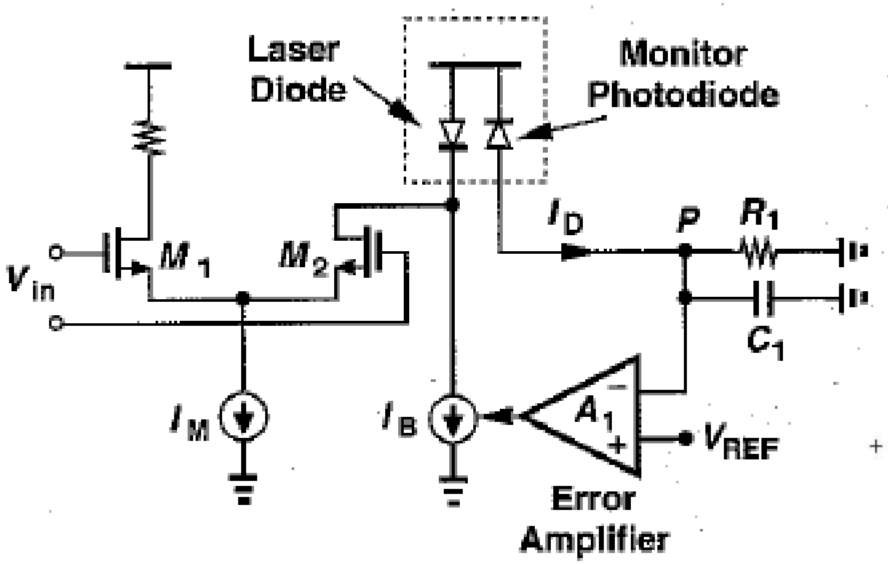
All units in mm



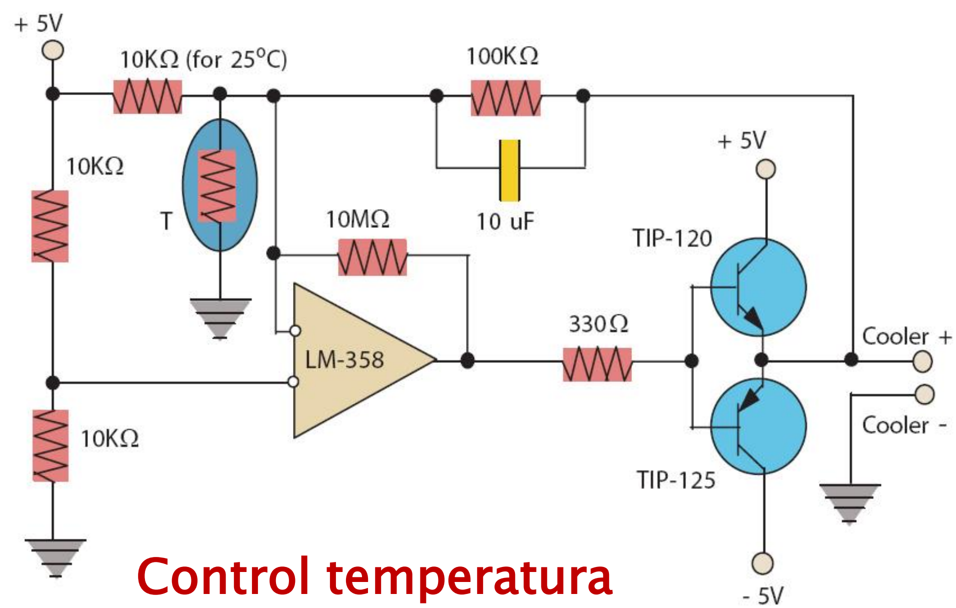
Pin out

Pin	Description
1	Thermistor
2	Thermistor
3	Laser Cathode (Bias)
4	Monitor PD Anode
5	Monitor PD Cathode
6	TEC +
7	TEC -
8	Case GND, Laser Anode
9	Case GND, Laser Anode
10	Case GND, Laser Anode
11	Case GND, Laser Anode
12	Laser Cathode (modulation)
13	Case GND, Laser Anode
14	Case GND, Laser Anode

Control dioda LASER

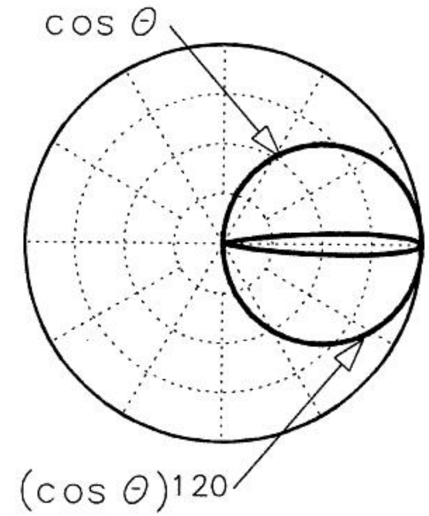


Control putere optica



Control temperatura

Directivitatea radiatiei exterioare



- Sursa lambertiana

$$P(\theta) = P_0 \cdot \cos\theta$$

  - Eficienta cuplarii in fibra

$$\eta = \frac{P_f}{P_s} = NA^2 \quad / \cdot \left(\frac{a}{r_s}\right)^2$$

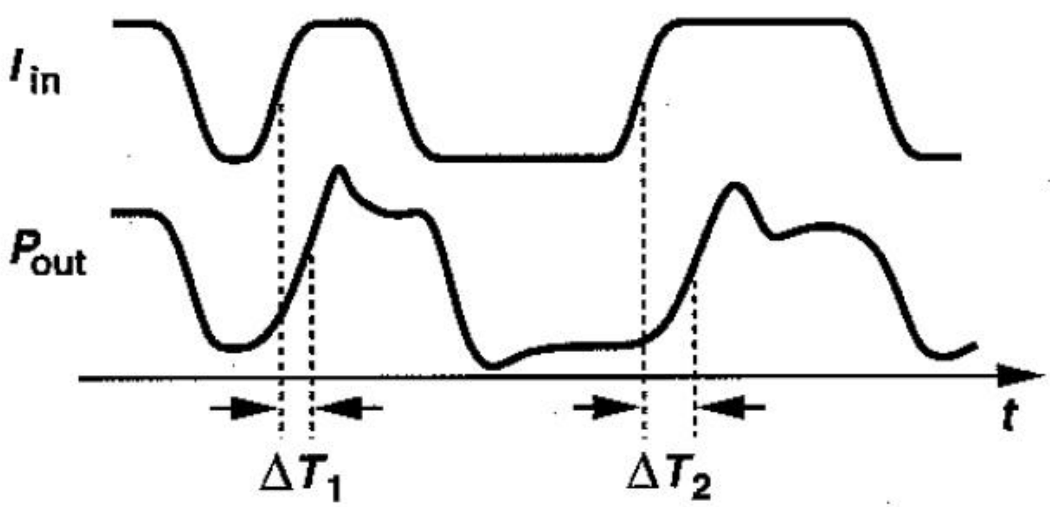
$$\eta = \frac{P_f}{P_s} = NA^2 \cdot \left(\frac{a}{r_s}\right)^2 \cdot \left(\frac{g}{g+2}\right)$$

- Aproximatie Lambertiana pentru surse cu directivitate crescuta

$$P(\theta) = P_0 \cdot \cos^m \theta \qquad \eta = \frac{P_f}{P_s} = \left(\frac{m+1}{2}\right) \cdot NA^2$$

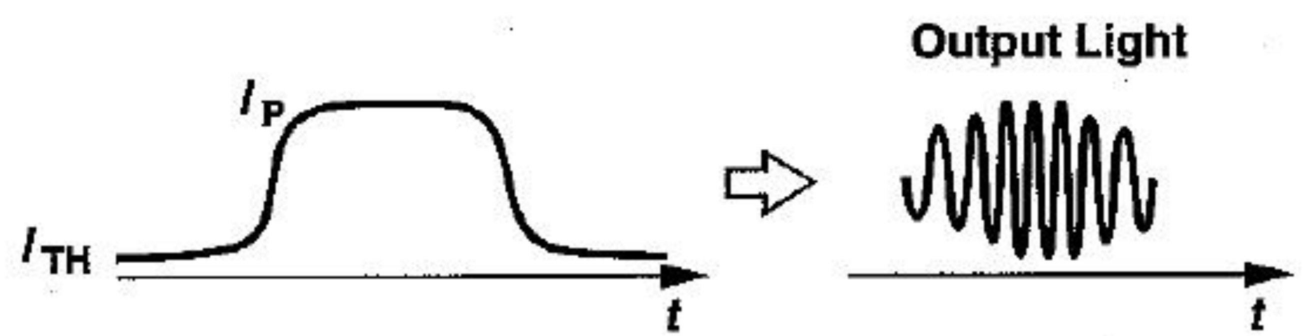
Turn-on delay

- La alimentarea cu curent a diodei laser emisia este initial spontana, devenind stimulata dupa amorsarea acesteia
- emisia spontana este un fenomen intrinsec aleator
- Intarzierea este variabila – jitter



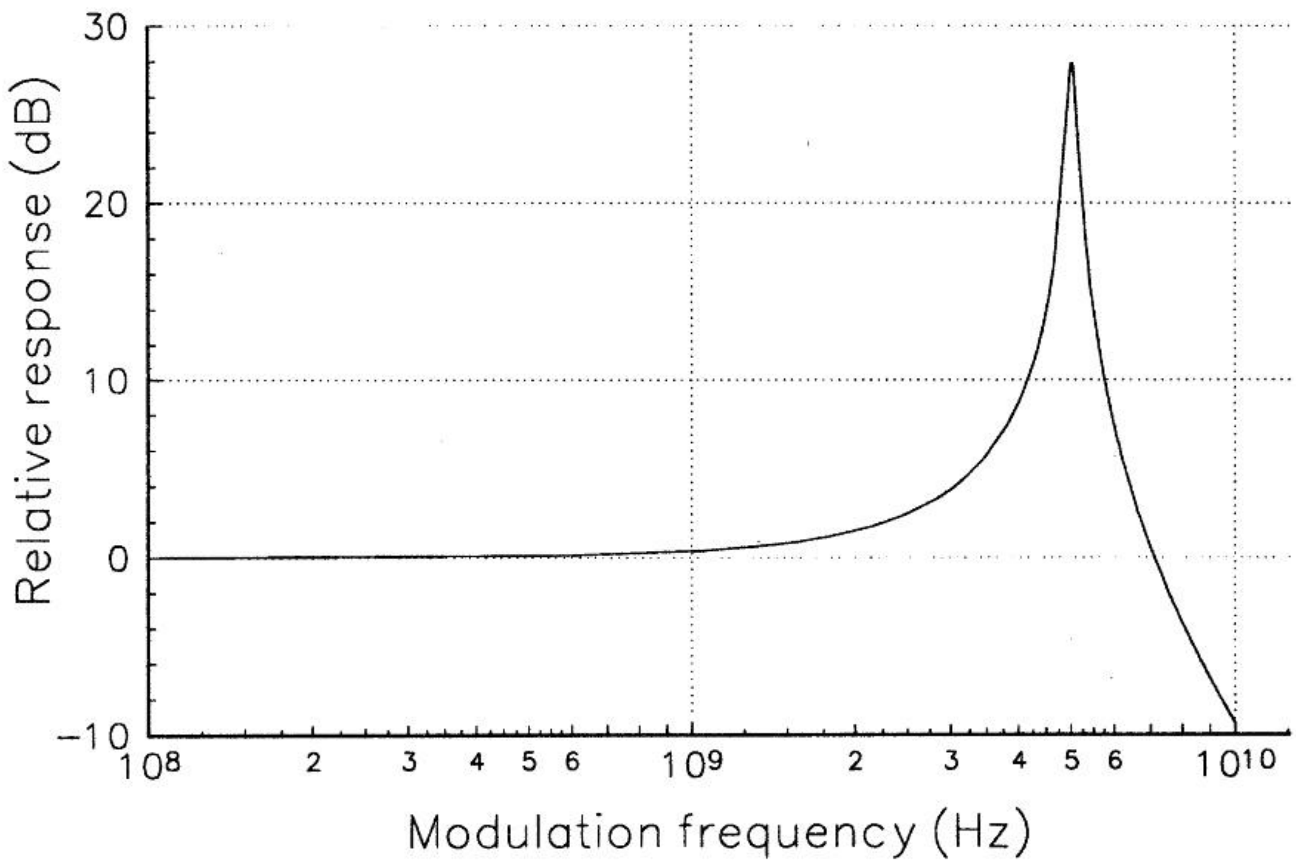
Chirping

- Frecventa de oscilatie depinde de indicele de refractie al materialului
- Indicele de refractie depinde de concentratia de purtatori
- Cand curentul este modulat in impuls apare o modulatie a frecventei luminii cu efectul cresterii latimii spectrale a diodei (un ordin de magnitudine)



Raspunsul unei diode laser

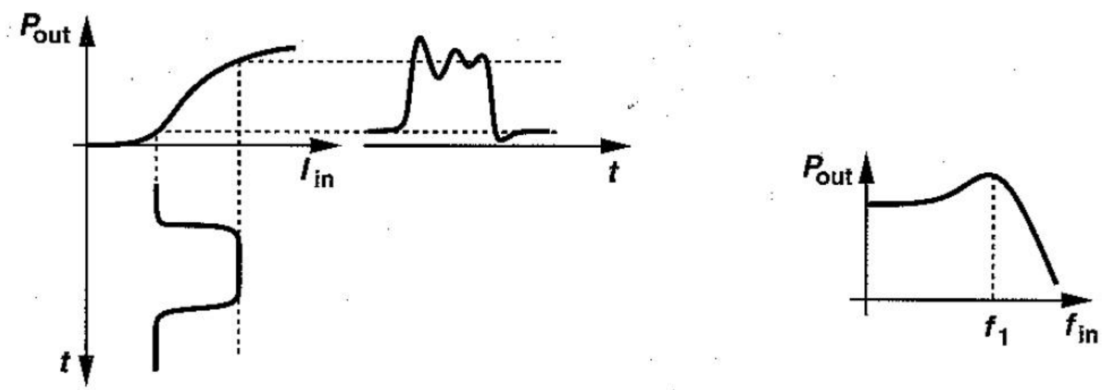
- oscilatii de relaxare – x GHz



Oscilatii de relaxare

- Generate de schimbul de energie intre electroni si fotoni
- Amorsarea emisiei stimulate duce la descresterea numarului de electroni in starea excitata, ceea ce duce la micsorarea emisiei de fotoni
- Acumularea din nou a electronilor in starea excitata duce din nou la cresterea puterii

- $f_1 = 1 \div 4$ GHz



(a) (b)

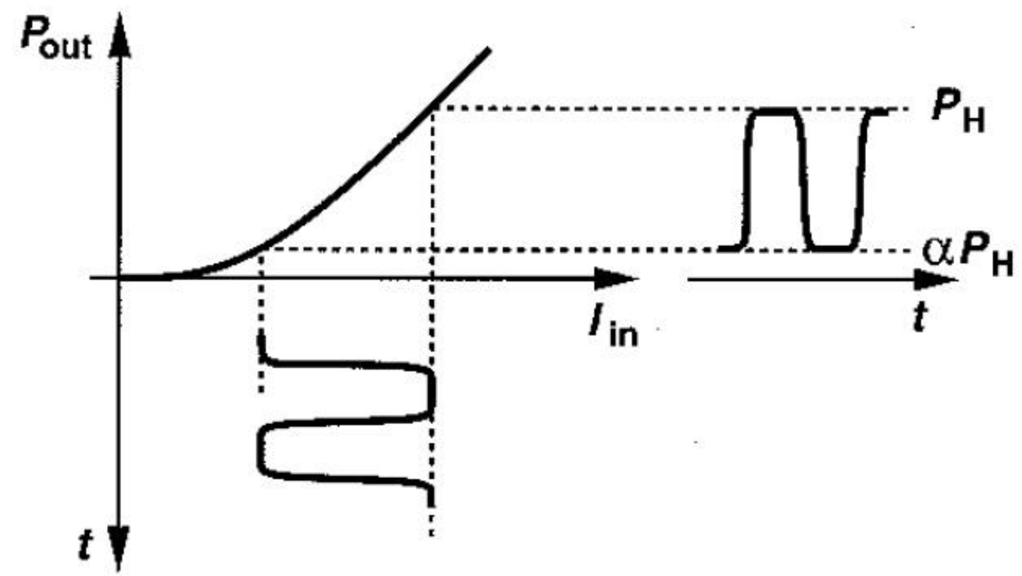
Oscilatii de relaxare

- Cresterea vitezei si minimizarea erorilor date de oscilatiile de relaxare si variatiile timpului de amorsare dioda este **partial** stinsa in timpul transmisiei unui nivel 0 logic

- Raport de stingere

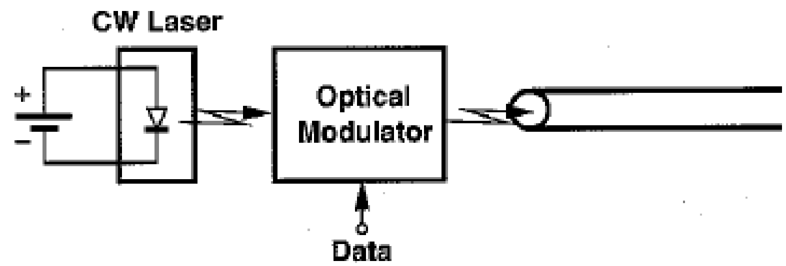
$$ER = \frac{P_H}{\alpha \cdot P_H} = \frac{1}{\alpha}$$

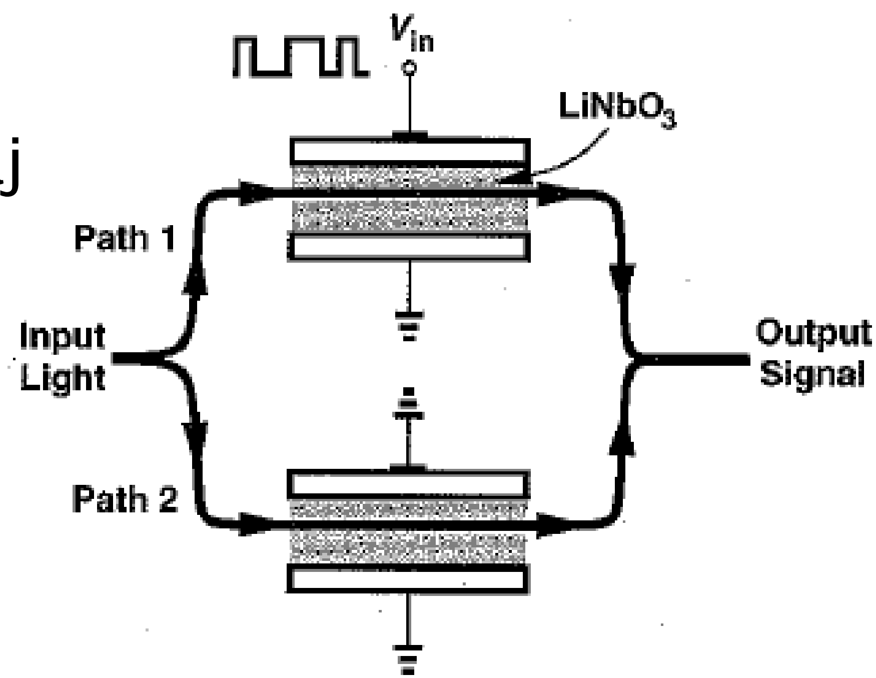
- Raportul semnal zgomot scade cu (1−α)
- Tipic ER = 10÷15dB



Modulaţie optică

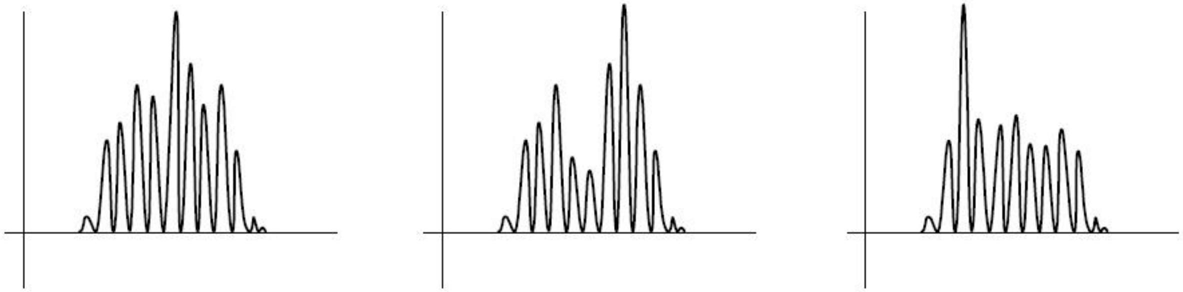
- Pentru viteze mari se prefera utilizarea emisiei continue si modularea optica a radiatiei
- In $LiNbO_3$ viteza luminii depinde de campul electric, ceea ce permite introducerea unui defazaj egal cu **π (180°)**
- Creste complexitatea circuitului de control
- Tensiuni de 4÷6 V necesare





Alte caracteristici DL

- Mode hopping – salt de mod (hole burning)

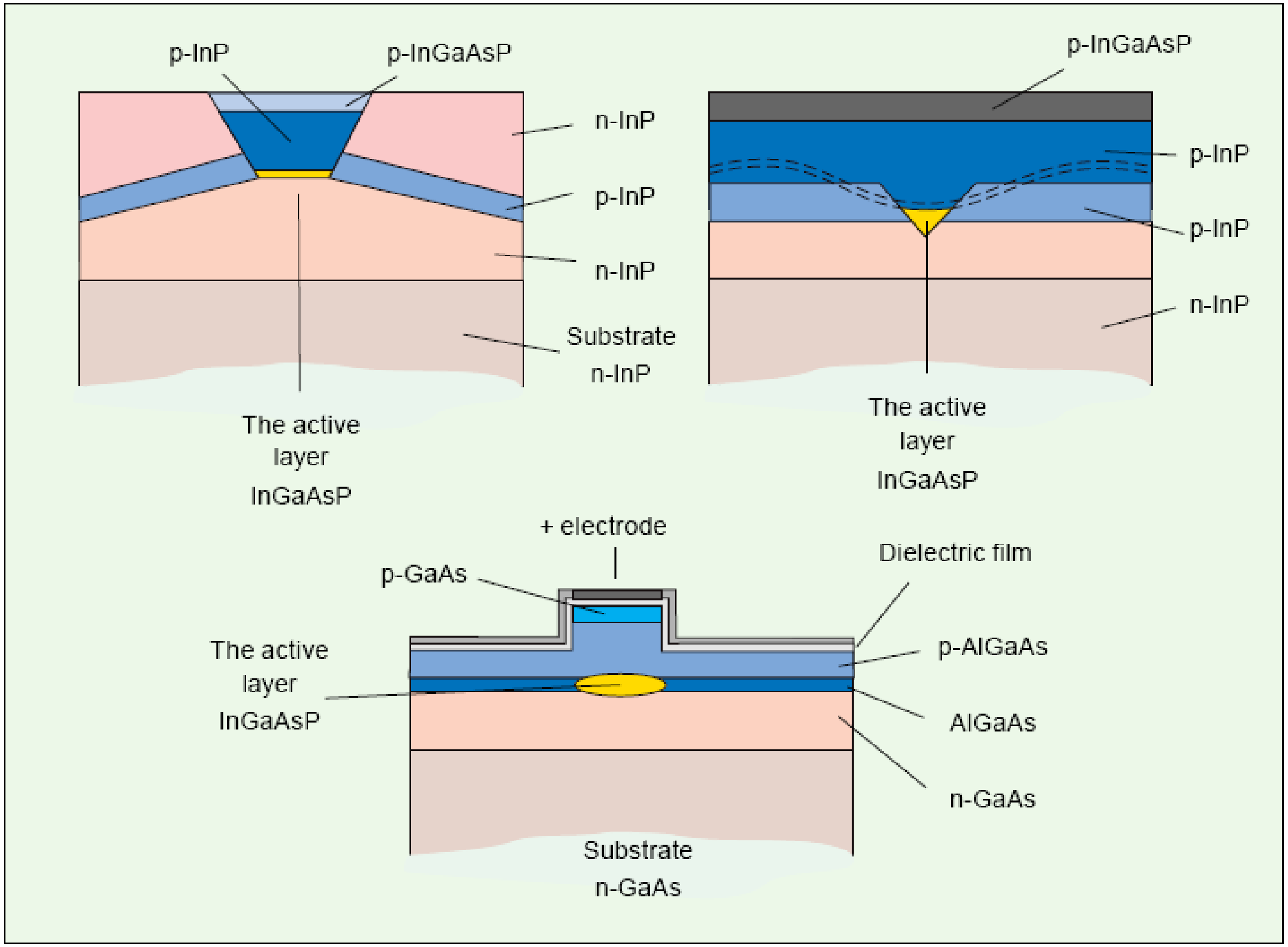


- RIN – Relative Intensity Noise (generat de emisia spontana)
- Zgomot de faza (idem) – necesitatea modulatiei in amplitudine
- Zgomot intercavitati (reflexiile din exterior in zona activa)
- Drift – variatia parametrilor cu varsta si temperatura (in special distanta intre oglinzi)

Diode LASER cu heterojuncţiune

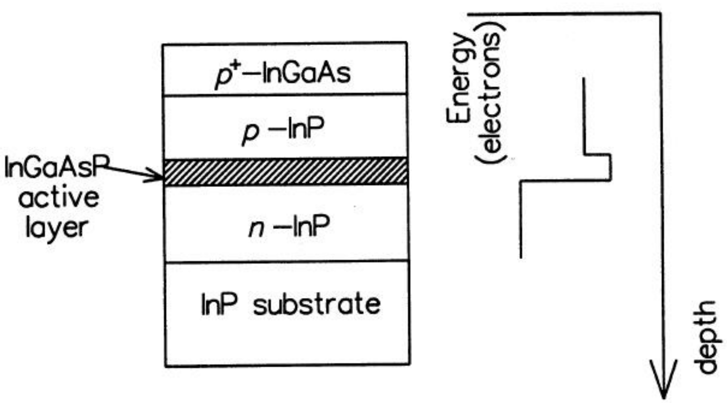
Heterojunctiune ingropata

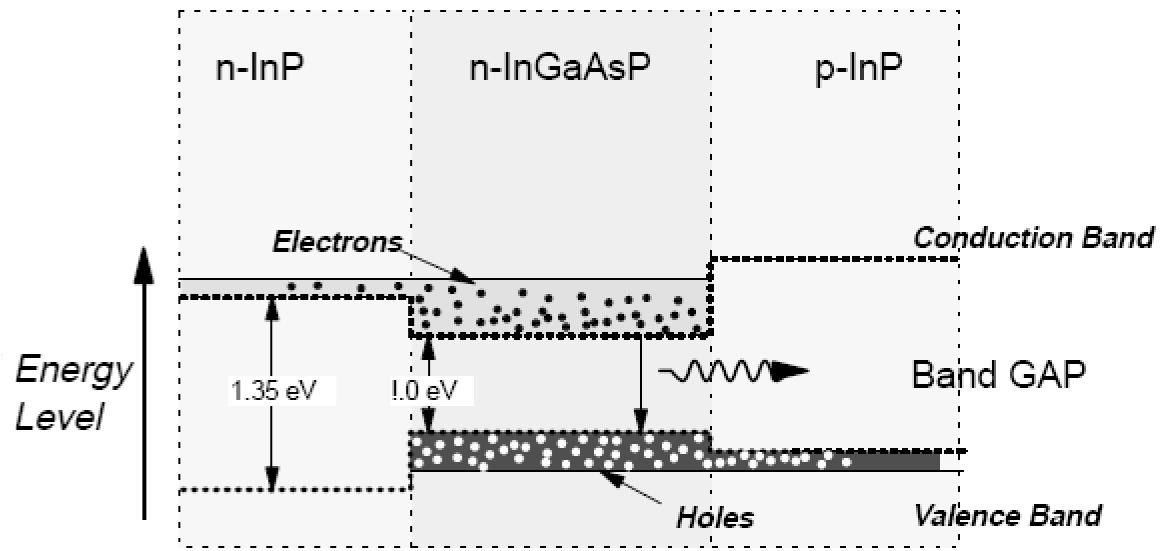
Heterojunctiune muchie (ridge)



Heterojuncţiuni – principiu

- Concentrare verticala a purtatorilor
  - Electronii sunt atrasi din zona n in zona activa
  - O bariera energetica existenta intre zona activa si zona n concentreaza electronii in zona activa
  - Situatie similara corespunzatoare golurilor
  - Purtatorii sunt concentrati in zona activa, crescand eficienta



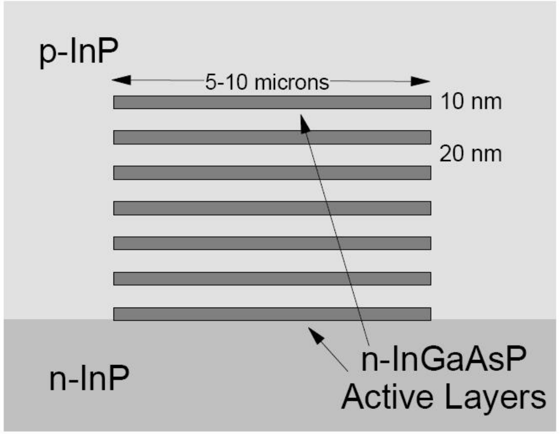


Quantum Well Laser

- Cand lumina e pastrata in cavitati mai mici decat lungimea de unda nu mai poate fi modelata prin unda, modelul devine cuantic
- Daca inaltimea zonei active scade la 5-20 nm comportarea diodei laser se schimba
  - energia necesara pentru inversarea de populatie se reduce, deci curentul de prag scade
  - dimensiunea redusa a zonei active duce la scaderea puterii maxime

Quantum Well Laser

- multiple straturi subtiri suprapuse – Multiple Quantum Well

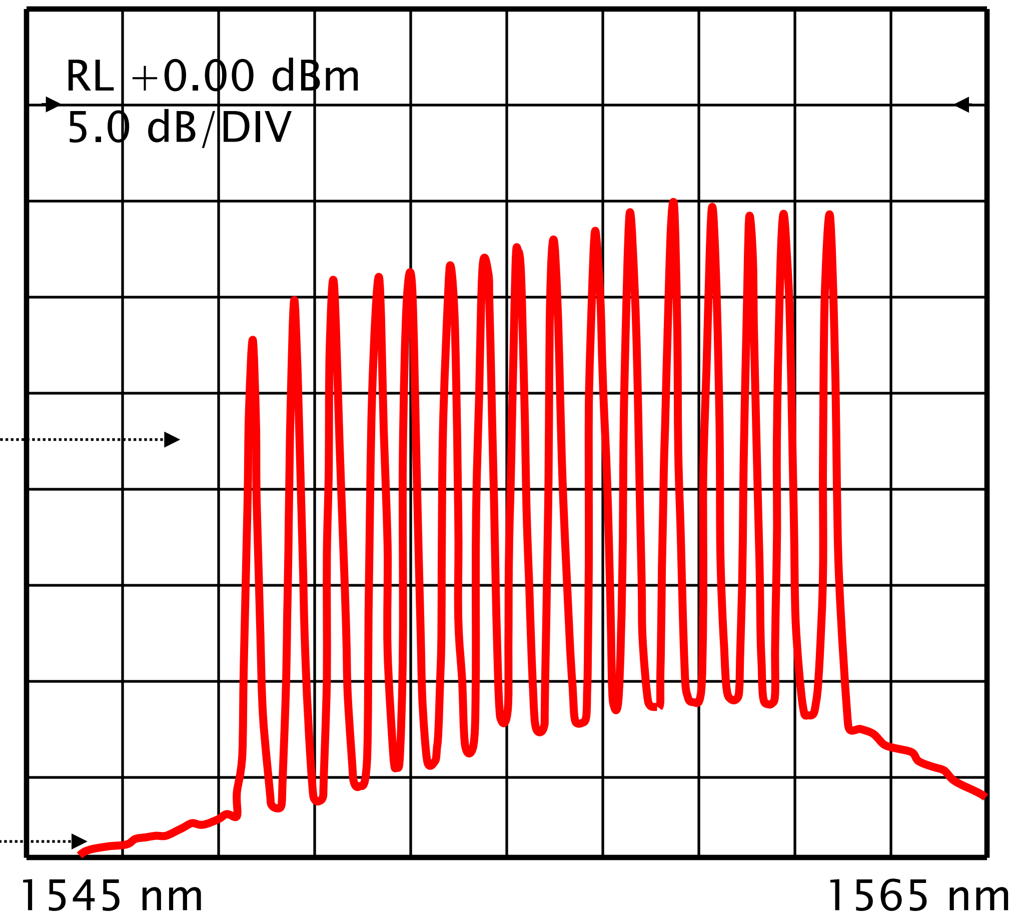


- Avantaje
  - curent de prag redus
  - stabilitate crescuta a frecventei la functionarea in impuls
  - latime mica a liniilor spectrale
  - zgomot redus

Spectrul WDM – Wavelength Division Multiplexing

Canale: 16
Spaţiere: 0.8 nm

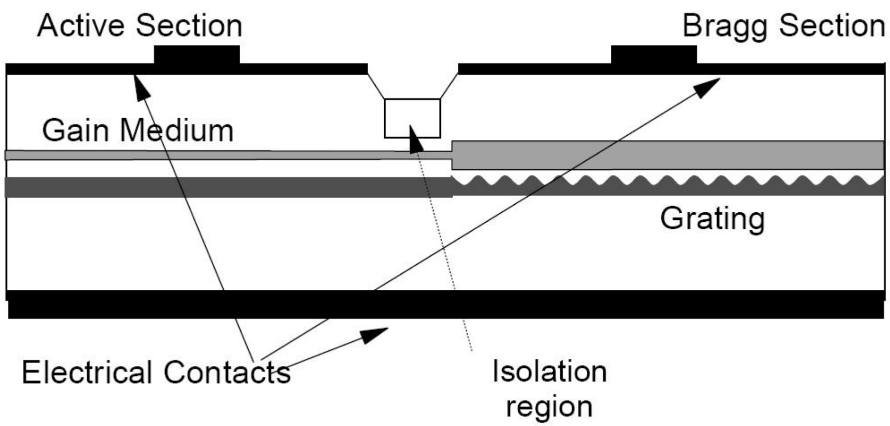
Emisie spontană
Amplificată (ASE)

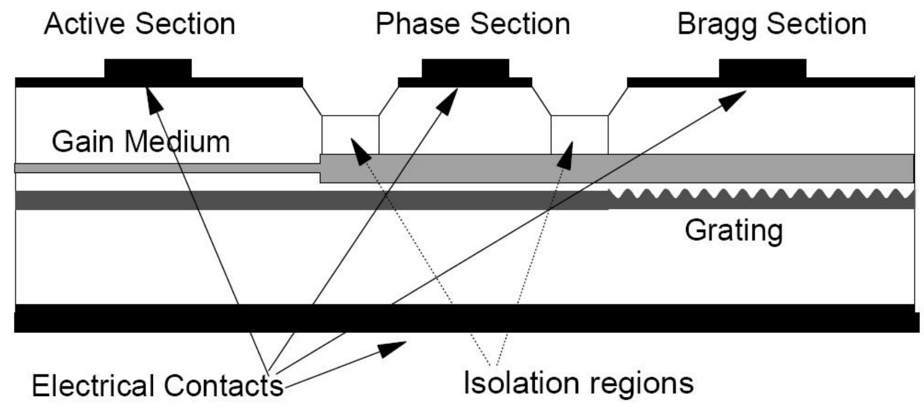


Diode laser reglabile

- Necesitate
  - In sistemele WDM exista necesitatea (in propuneri pentru arhitecturi viitoare de retele) pentru reglaj foarte rapid al lungimii de unda pe un anume canal – zeci de ns
  - In aceleasi sisteme intervine necesitatea rutarii prin lungime de unda – timp de reglaj necesar de ordinul secundelor)
  - realizarea cererilor de date – timp de reglaj de ordinul sute de μs
  - reglarea emitatorilor individuali in sistemele WDM
    - lipsa necesitatii controlului strict la productia diodelor
    - degradarea lungimii de unda in timp

Diode laser reglabile

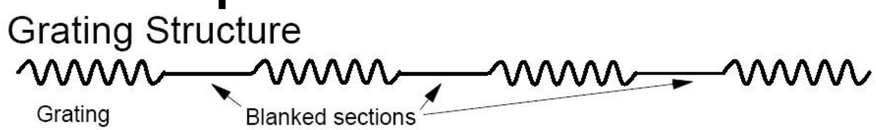




- Curentul trece prin zona activa ducand la amplificarea luminii
- curentul ce parcurge zona corespunzatoare reflectorului Bragg modifica indicele de refractie al acestei zone deci lungimea de unda
- zona centrala suplimentara permite reglaj fin suplimentar in jurul valorii impuse de reflectorul Bragg

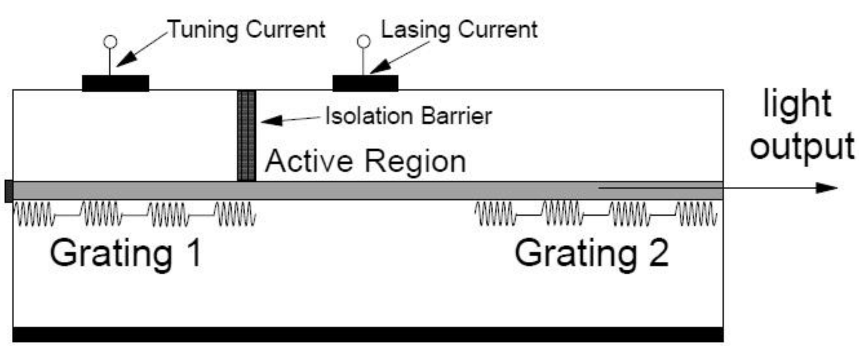
Diode laser reglabile

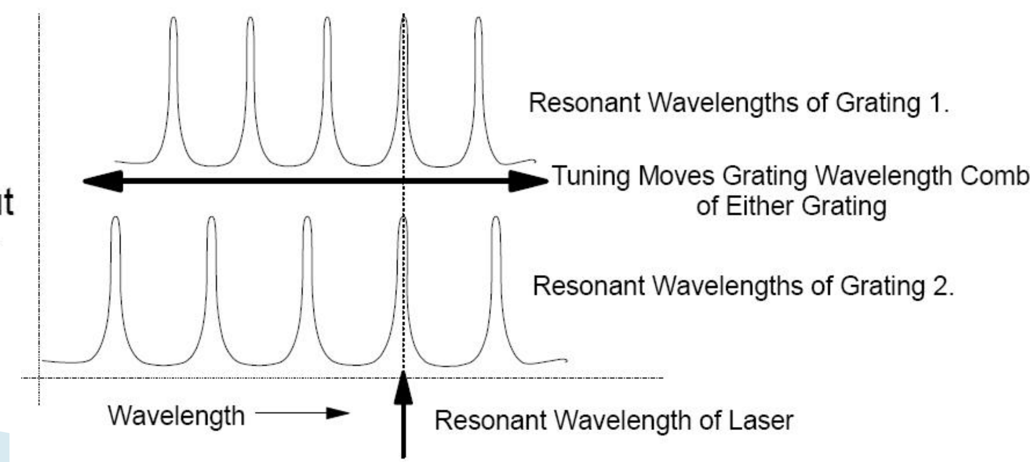
- Dezavantajul metodelor anterioare e dat de limita redusa a reglajului (~10nm)
- Reflectorul Bragg esantionat (periodic) produce spectru de filtrare discret



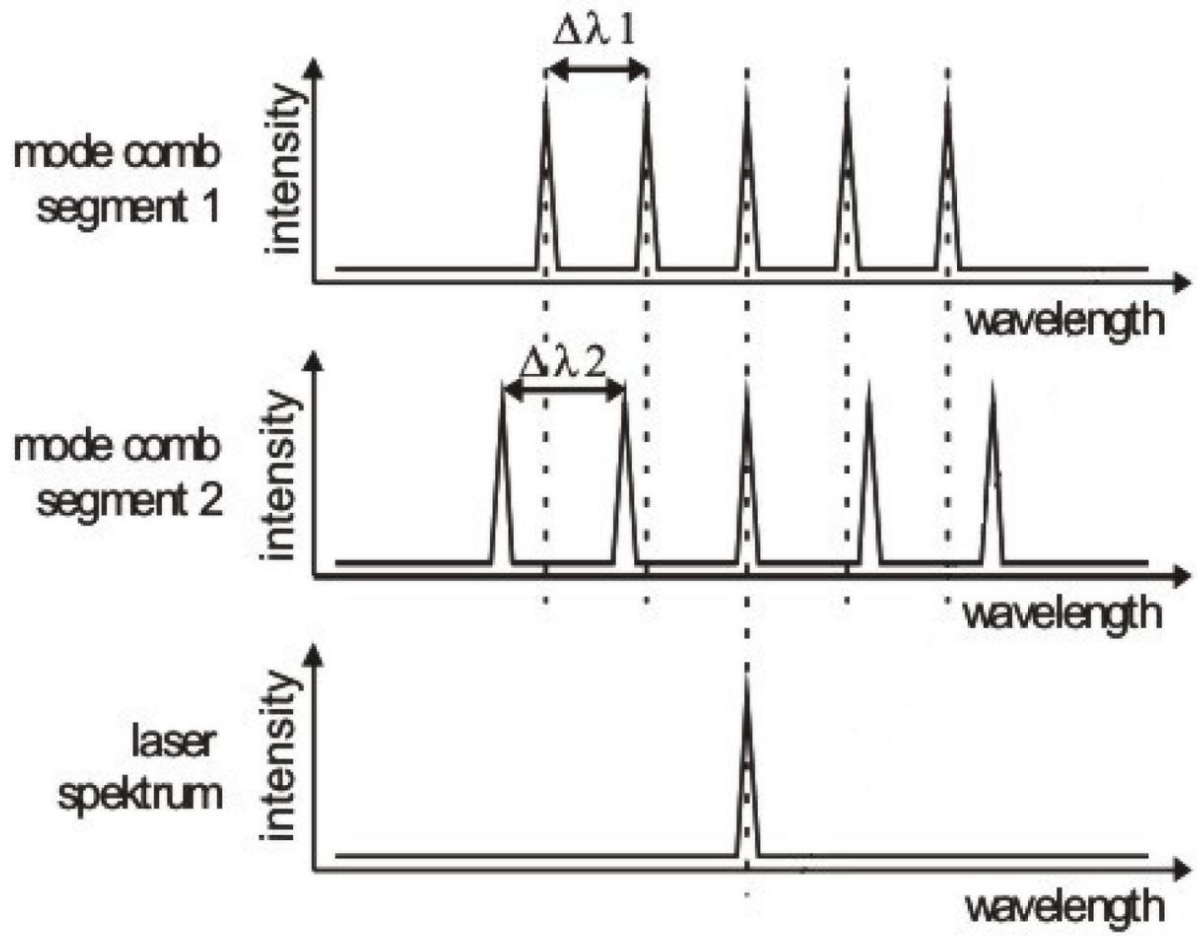
Dezavantaj : reglajul e discret

- Regland unul din reflectori se obtine rezonanta la suprapunerea celor doua spectre

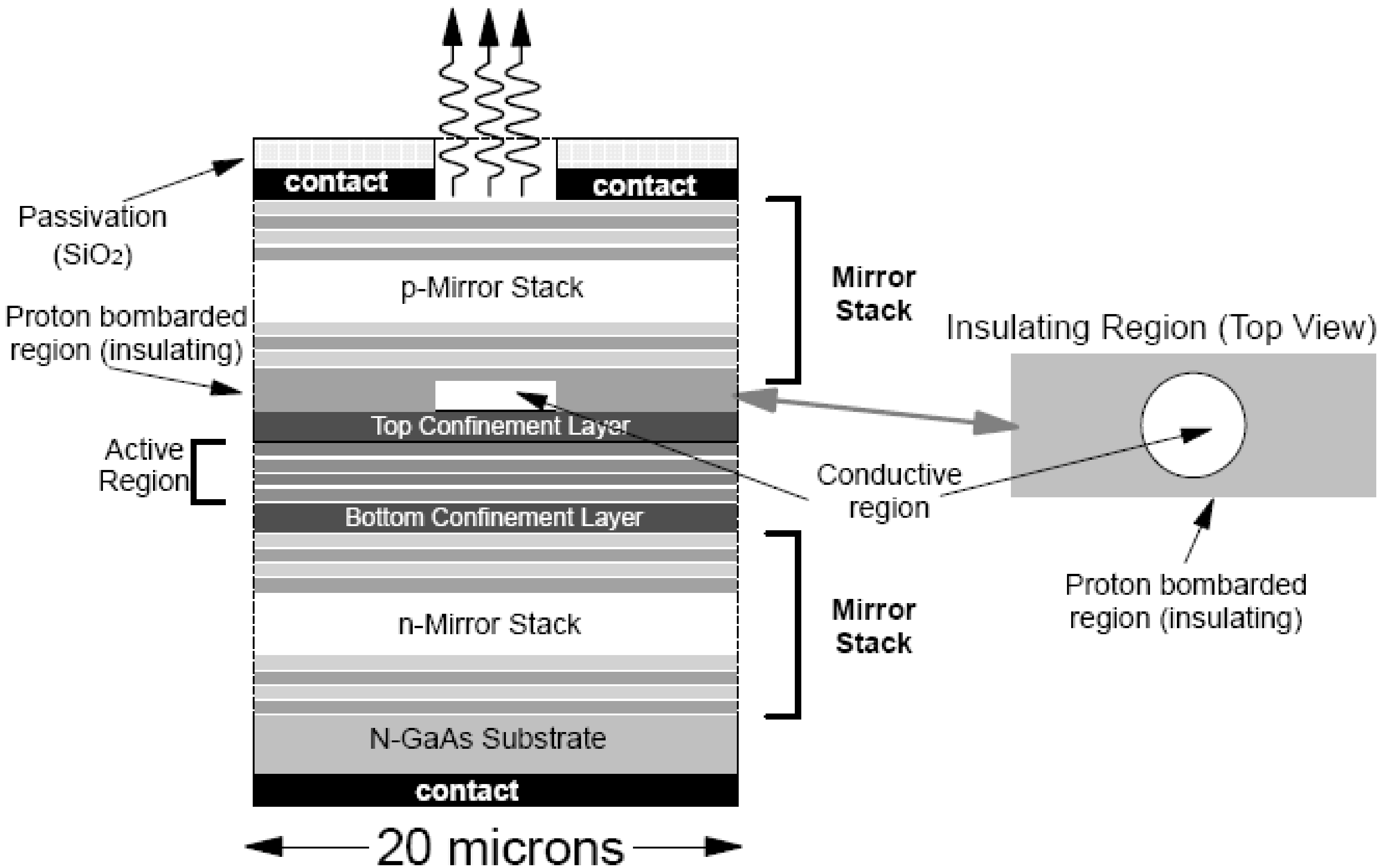




Diode laser reglabile

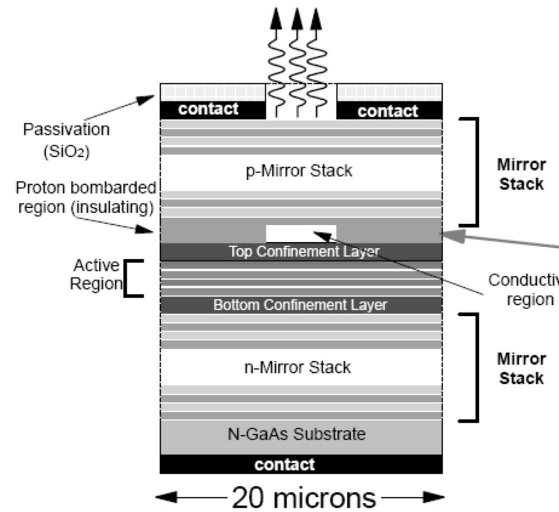


Vertical Cavity Surface Emitting Lasers (VCSEL)



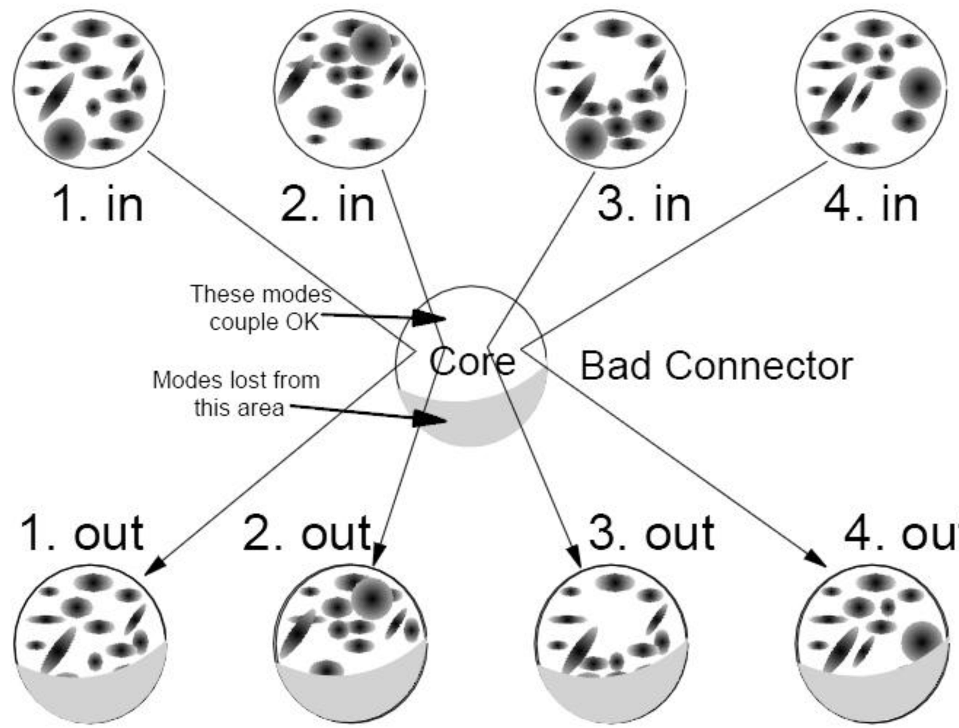
Vertical Cavity Surface Emitting Lasers (VCSEL)

- Oglinzile pot fi realizate din straturi succesive din semiconductori cu indici de refractie diferiti – reflector Bragg
- **Prelucrarea laterala se rezuma la taierea materialului**
  - Caracteristici
    - puteri de ordinul 1mW
    - lungimi de unda 850 si 980 nm
    - radiatie de iesire <u>circulara</u> cu divergenta redusa
    - Curenti de prag foarte mici (5mA) si putere disipata redusa
    - circuite de control speciale nu sunt necesare
    - Banda de modulatie mare (2.4GHz)
    - Stabilitate mare cu temperatura si durata de viata



VCSEL

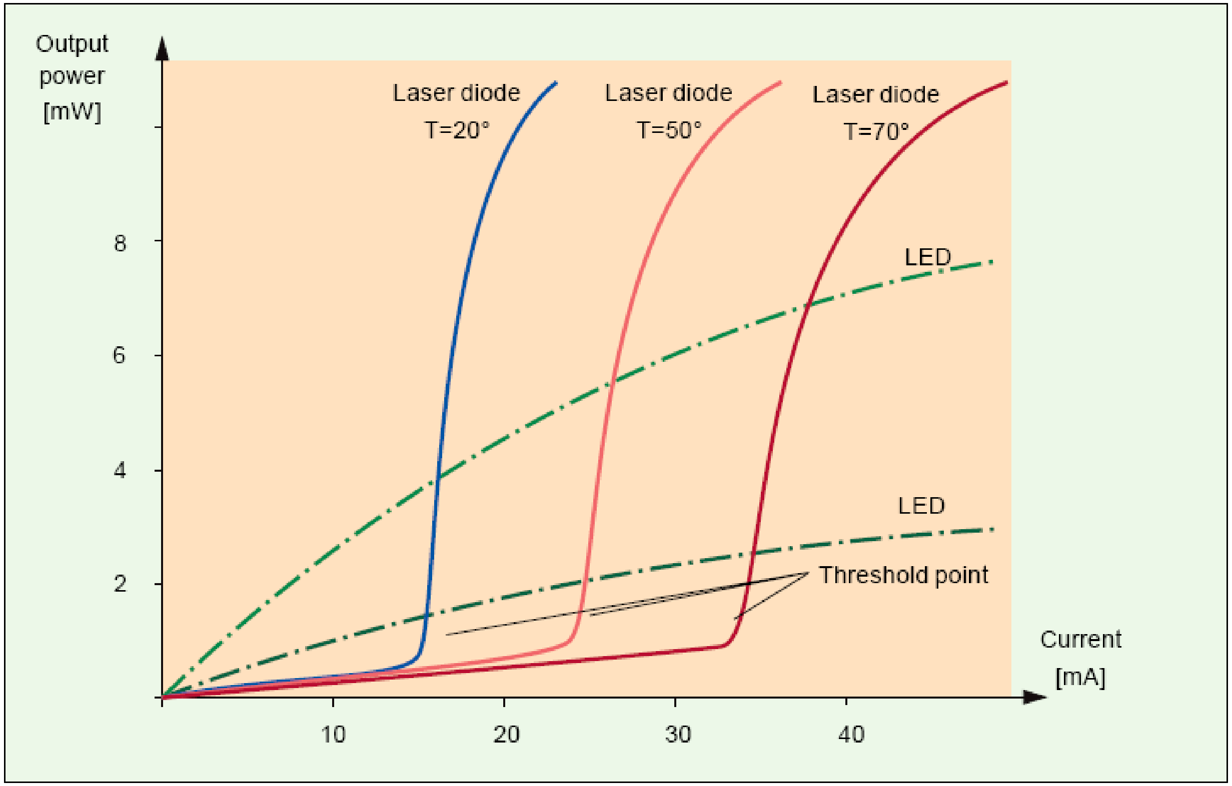
- Caracteristici
  - VCSEL produce mai multe moduri transversale
    - insensibila la pierderile selective la mod din fibrele multimod (principala limitare in utilizarea diodelor laser in fibrele multimod)



Parametri dioda LASER

Temperatura si îmbatrânire

- Curentul de prag variaza cu temperatura si cu timpul
- Variatia tipica 1–2%/°C



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Material	Lungime de unda	T_0
InGaAsP	1300 nm	60÷70 K
InGaAsP	1500 nm	50÷70 K
GaAlAs	850 nm	110÷140 K

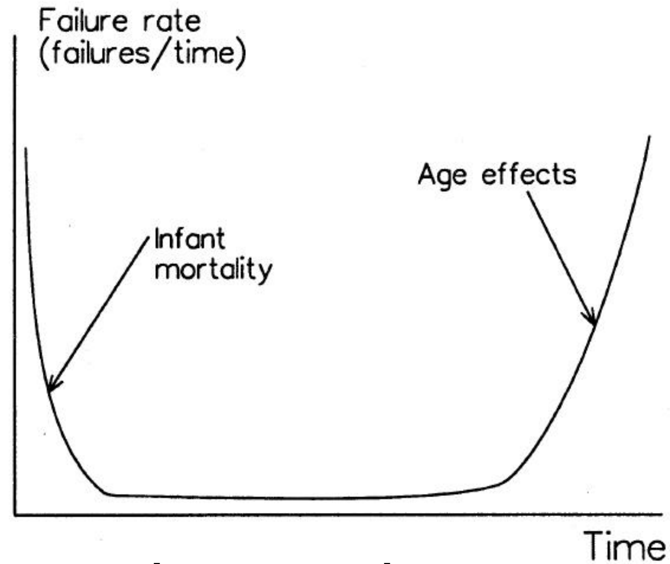
Degradare in timp

- Puterea scade in timp exponential

$$P(t) = P_0 \cdot e^{-t/\tau_m}$$

- τ_m – timpul de viata
- Diodele laser sunt supuse la conditii extreme de lucru
  - densitati de curent in zona activa $2000 \div 5000 A/cm^2$
  - densitati de putere optica: $10^5 \div 10^6 W/cm^3$
- Diverse definitii ale timpului de viata fac comparatiile dificile

Degradare in timp



- Cresterea curentului duce la scaderea duratei de viata

$$\tau_m \sim J^{-n}$$

  - n = 1.5÷2 (empiric)
  - dublarea curentului duce la scaderea de 3-4 ori a duratei de viata
- Cresterea temperaturii duce la scaderea duratei de viata

$$\tau_m \sim e^{E/kT}$$

  - E = 0.3÷0.95eV (valoarea tipica in teste 0.7eV)
  - cresterea temperaturii cu 10 grade injumatateste durata de viata

Parametri

- Coerenta radiatiei emise
  - LED: $t_c \approx 0.5ps$, $L_c \approx 15\mu m$
  - LASER : $t_c \approx 0.5ns$, $L_c \approx 15cm$

$$L_c = c \cdot t_c = \frac{\lambda_0^2}{\Delta\lambda}$$

- Stabilitatea frecventei
  - detectie necoerenta (modulatie in amplitudine)
  - mai ales in sistemele multicanal
- Timpul de raspuns
- Viteza, interval de reglaj

Eficienta

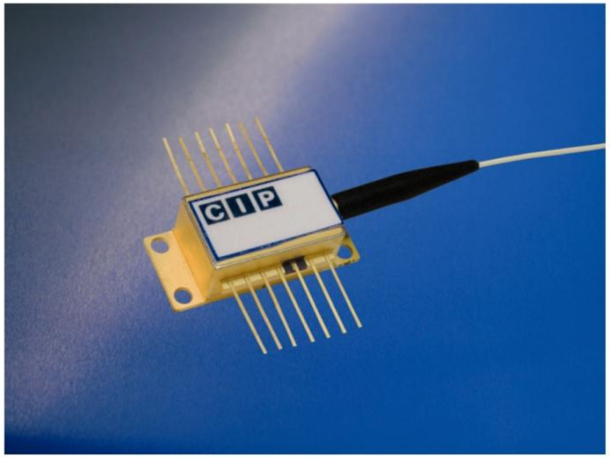
- eficienta de conversie electro–optic (randament)

$$\eta = \frac{P_{out}(optic)}{P_{in}(electric)} = \frac{P_o}{V_f \cdot I_f} \approx \frac{r \cdot (I_f - I_{th})}{V_f \cdot I_f}$$

- tipic, randamente sub 10% sunt intalnite
- eficienta cuantica
  - interna
  - externa

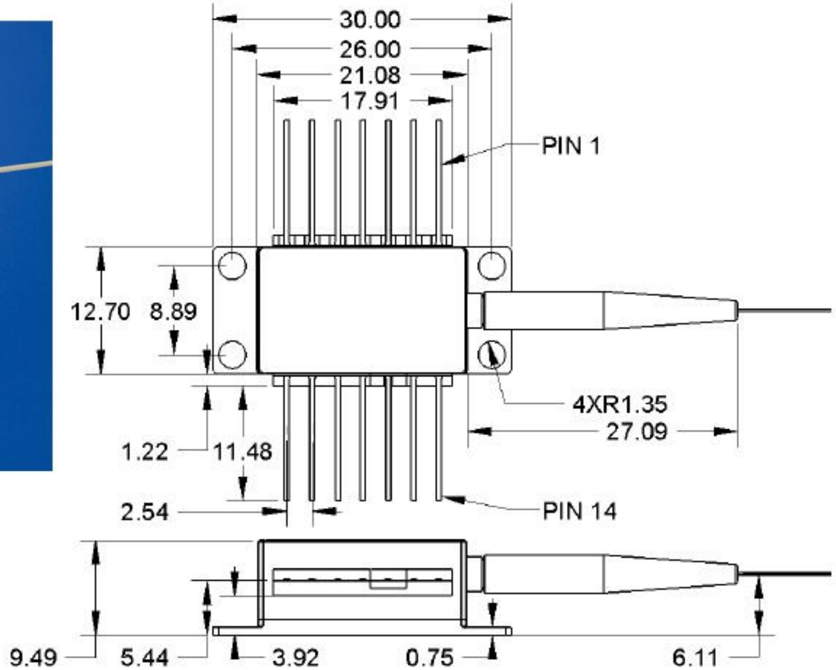
$$\eta = \frac{n_f}{n_e} \qquad \eta = \frac{\Delta P / h\nu}{\Delta I / e} = r \cdot \frac{e}{h\nu}$$

1550nm DFB Laser



Mechanical Drawing

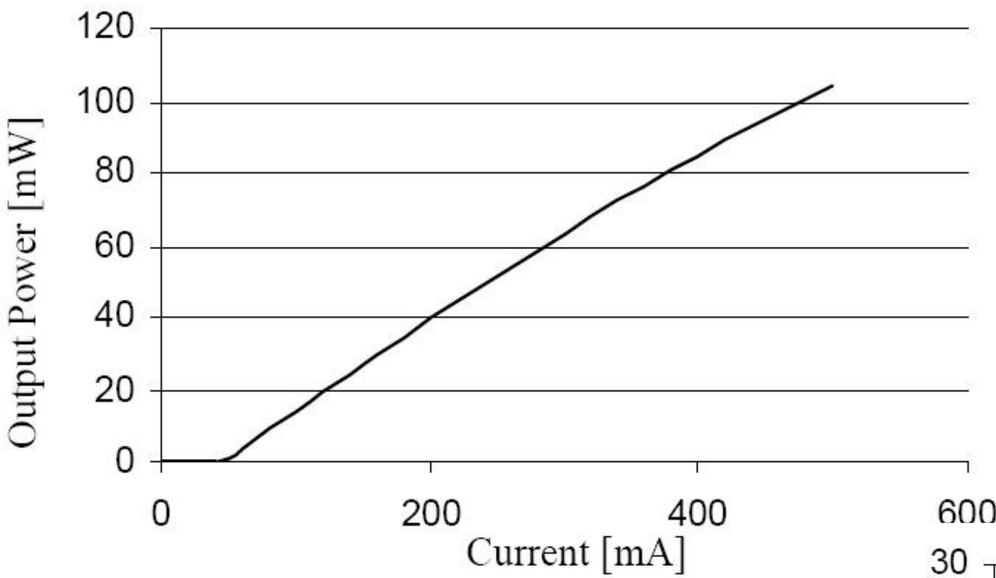
All units in mm

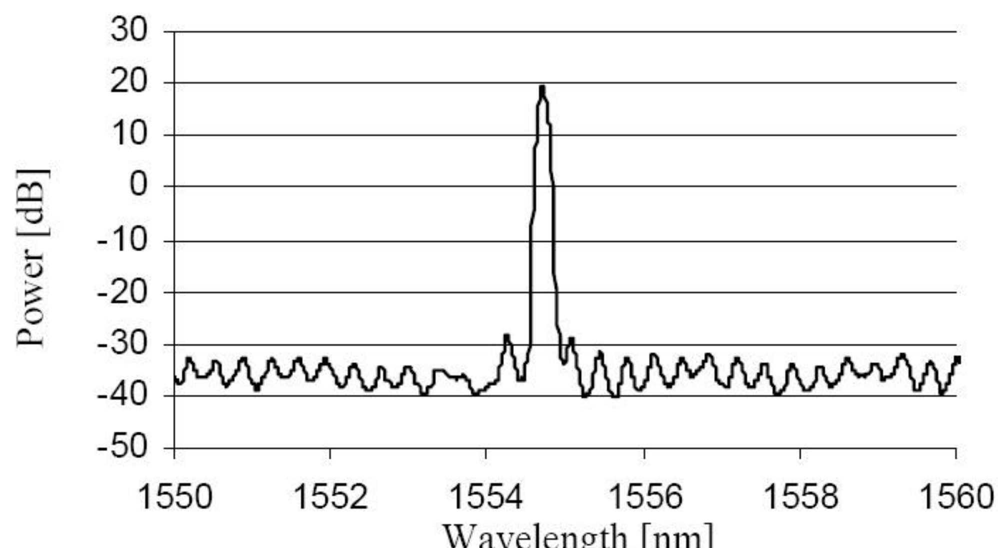


Pin out

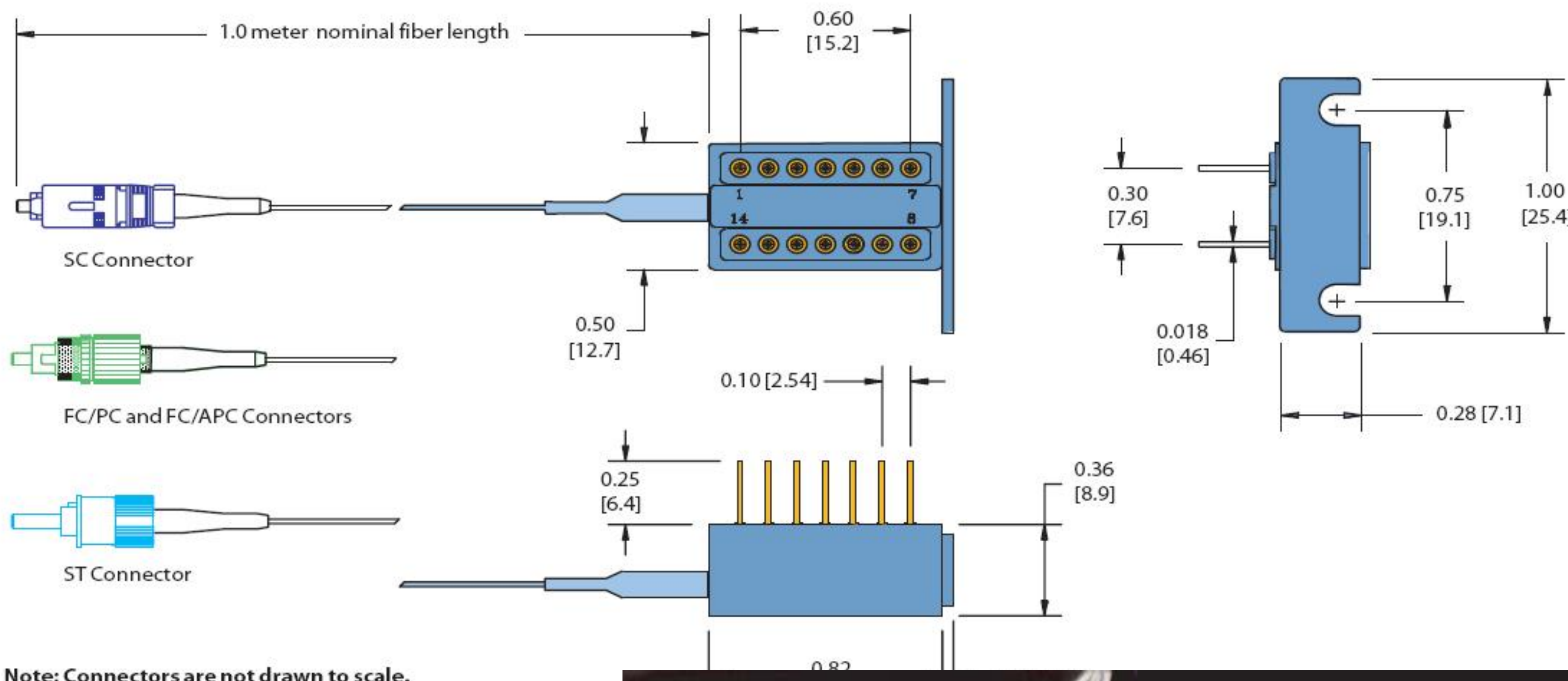
Pin	Description
1	Thermistor
2	Thermistor
3	Laser Cathode (Bias)
4	Monitor PD Anode
5	Monitor PD Cathode
6	TEC +
7	TEC -
8	Case GND, Laser Anode
9	Case GND, Laser Anode
10	Case GND, Laser Anode
11	Case GND, Laser Anode
12	Laser Cathode (modulation)
13	Case GND, Laser Anode
14	Case GND, Laser Anode

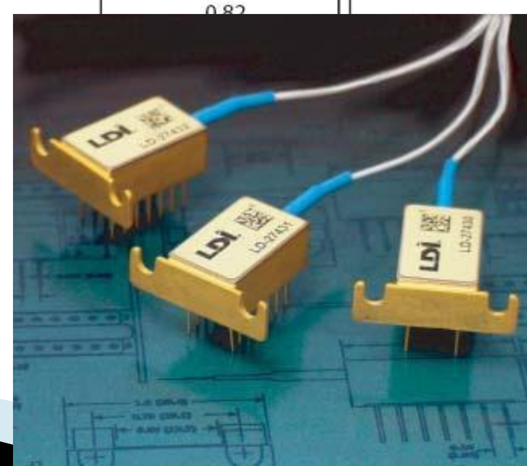
1550nm DFB Laser

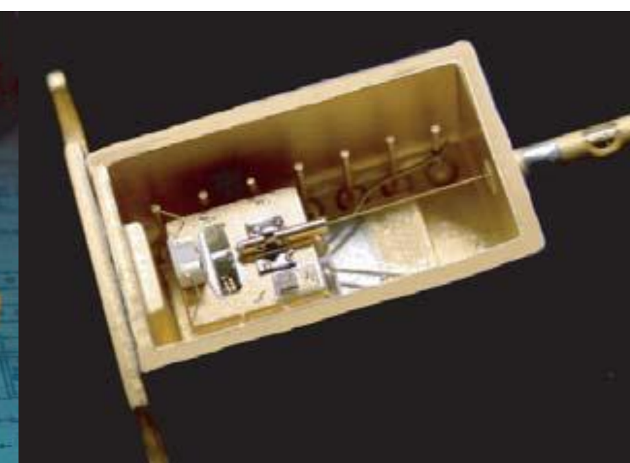




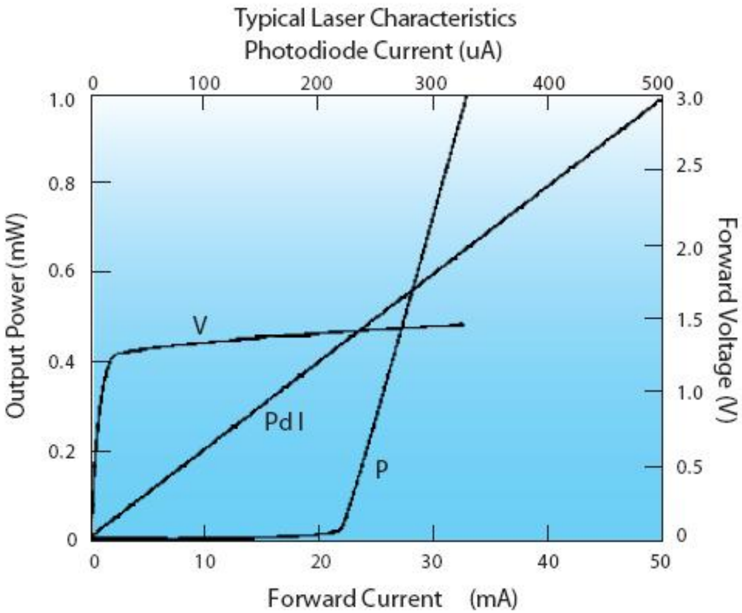
1550nm MQW Laser

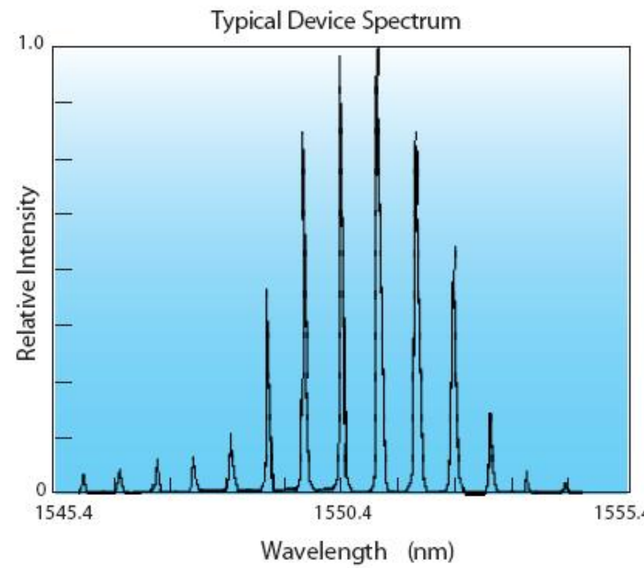






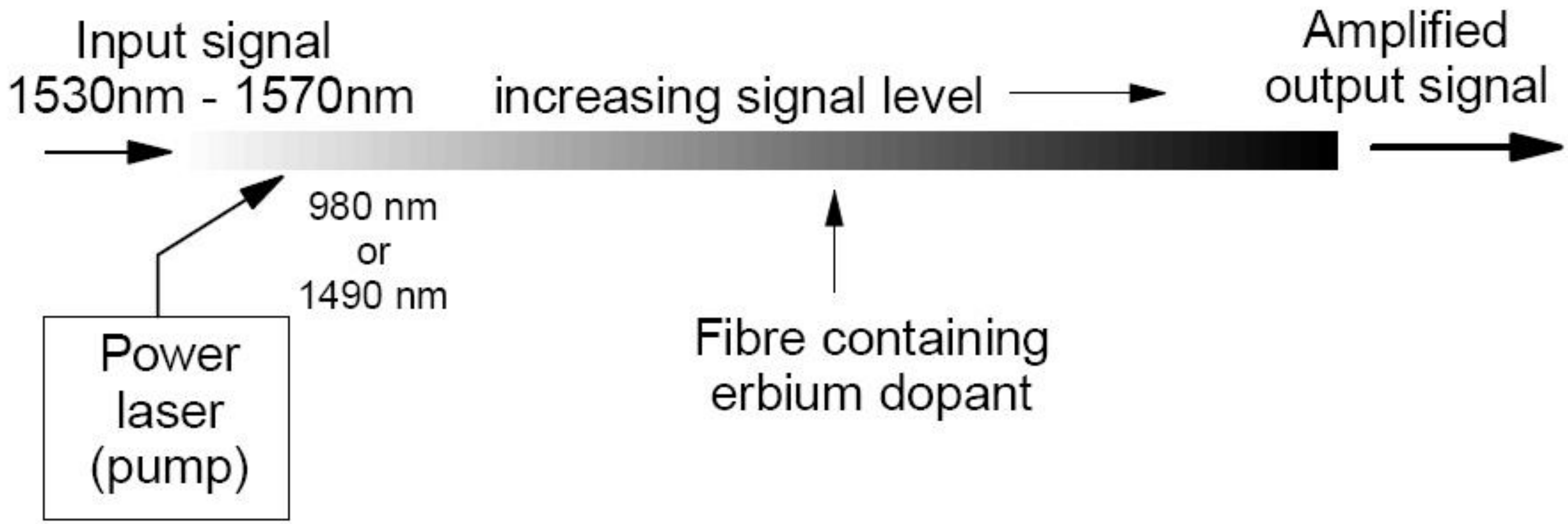
1550nm MQW Laser



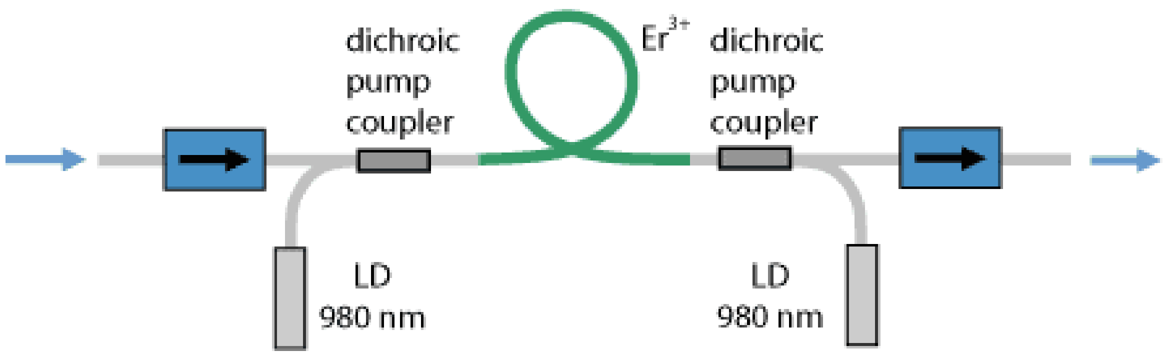


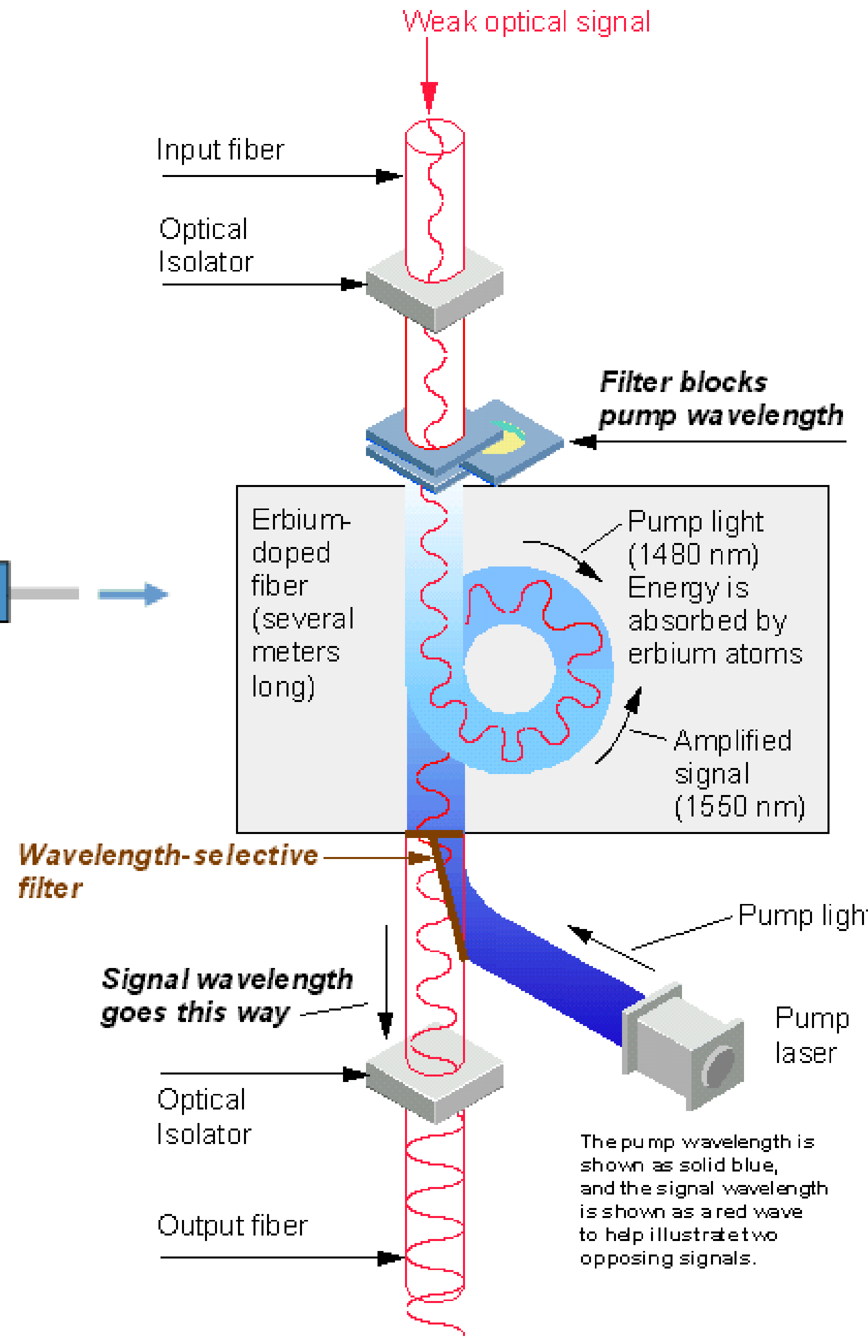
EDFA

- Erbium Dopped Fiber Amplifier

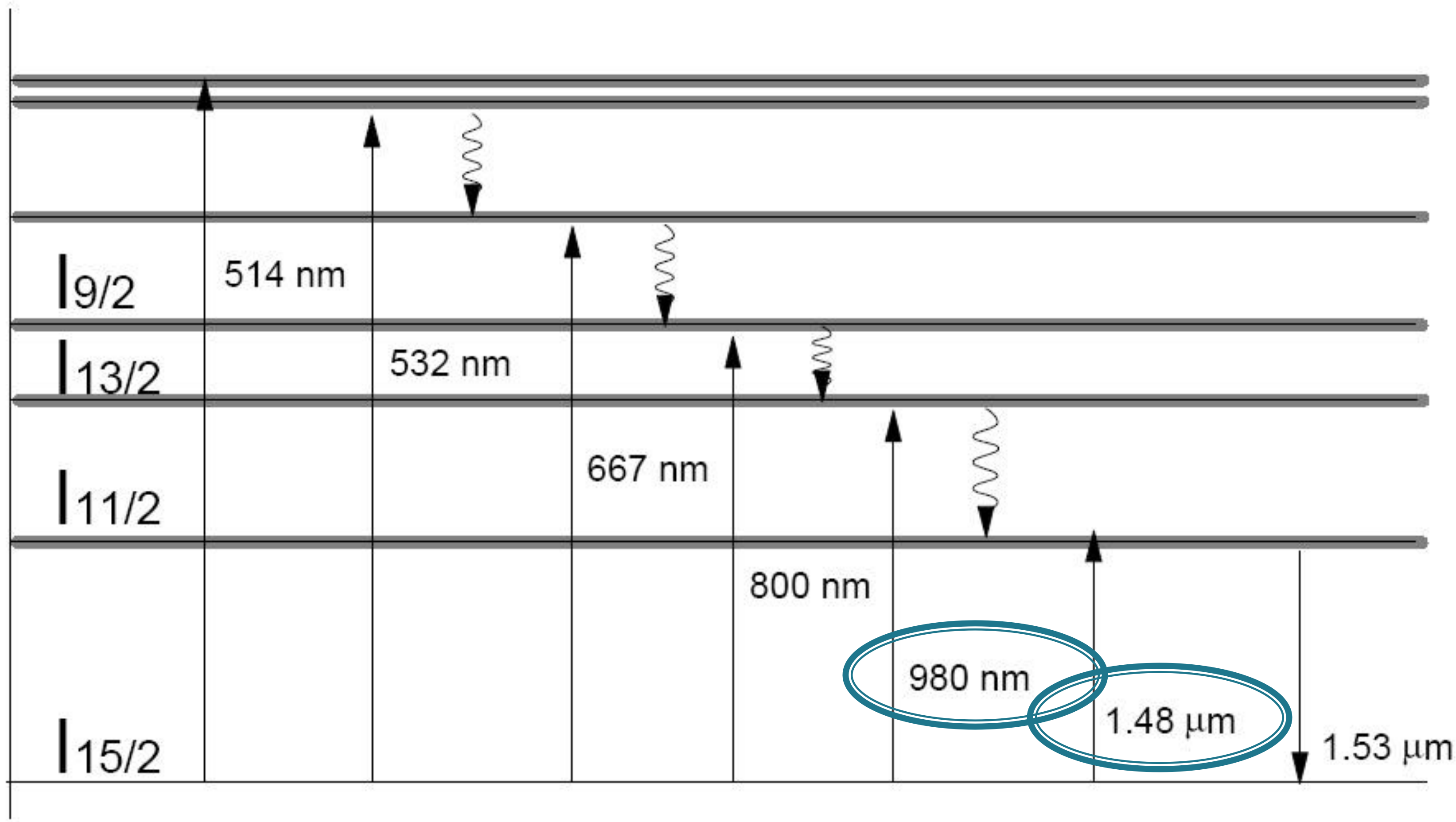


EDFA


dichroic pump coupler
Er3+
dichroic pump coupler
LD 980 nm
LD 980 nm


Weak optical signal
Input fiber
Optical Isolator
Filter blocks pump wavelength
Erbium-doped fiber (several meters long)
Pump light (1480 nm) Energy is absorbed by erbium atoms
Amplified signal (1550 nm)
Wavelength-selective filter
Pump light
Signal wavelength goes this way
Pump laser
Optical Isolator
Output fiber
The pump wavelength is shown as solid blue, and the signal wavelength is shown as a red wave to help illustrate two opposing signals.

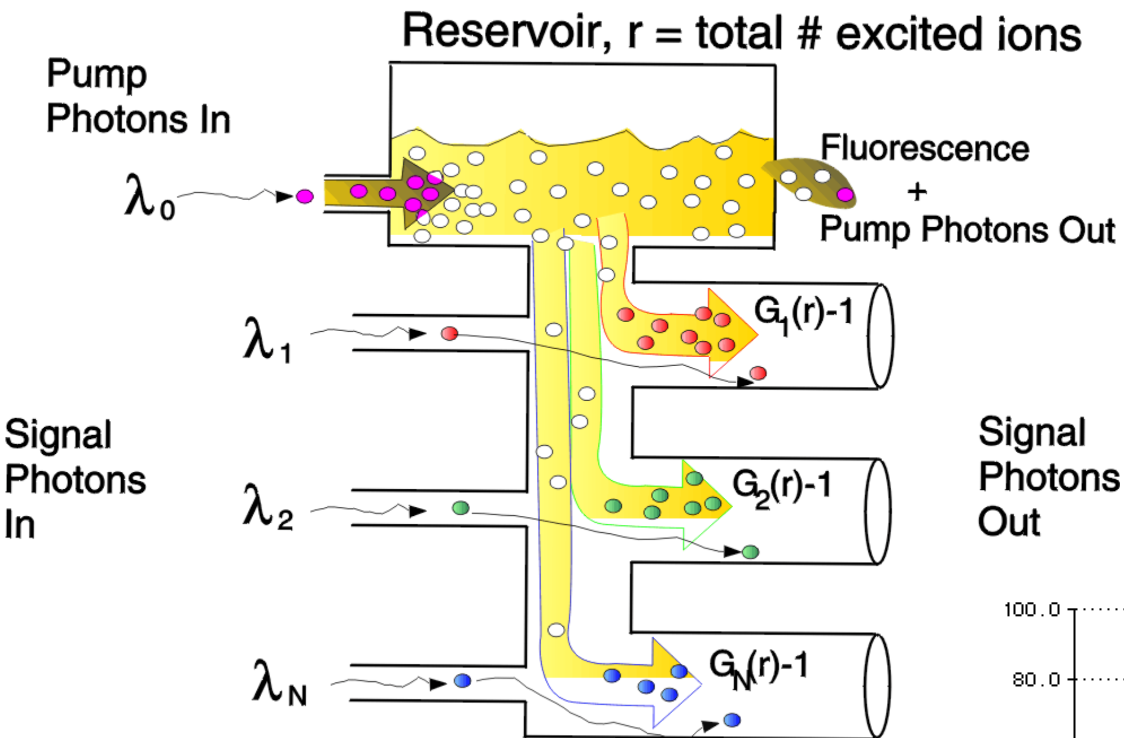
EDFA – Erbium

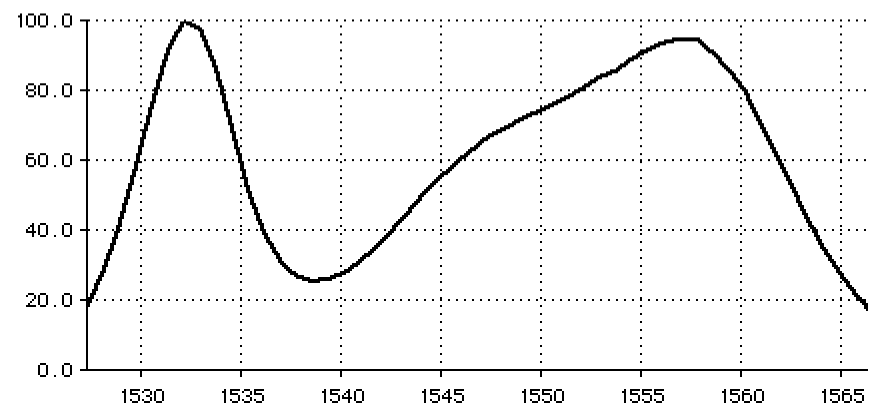


I9/2
I13/2
I11/2
I15/2
514 nm
532 nm
667 nm
800 nm
980 nm
1.48 µm
1.53 µm

EDFA

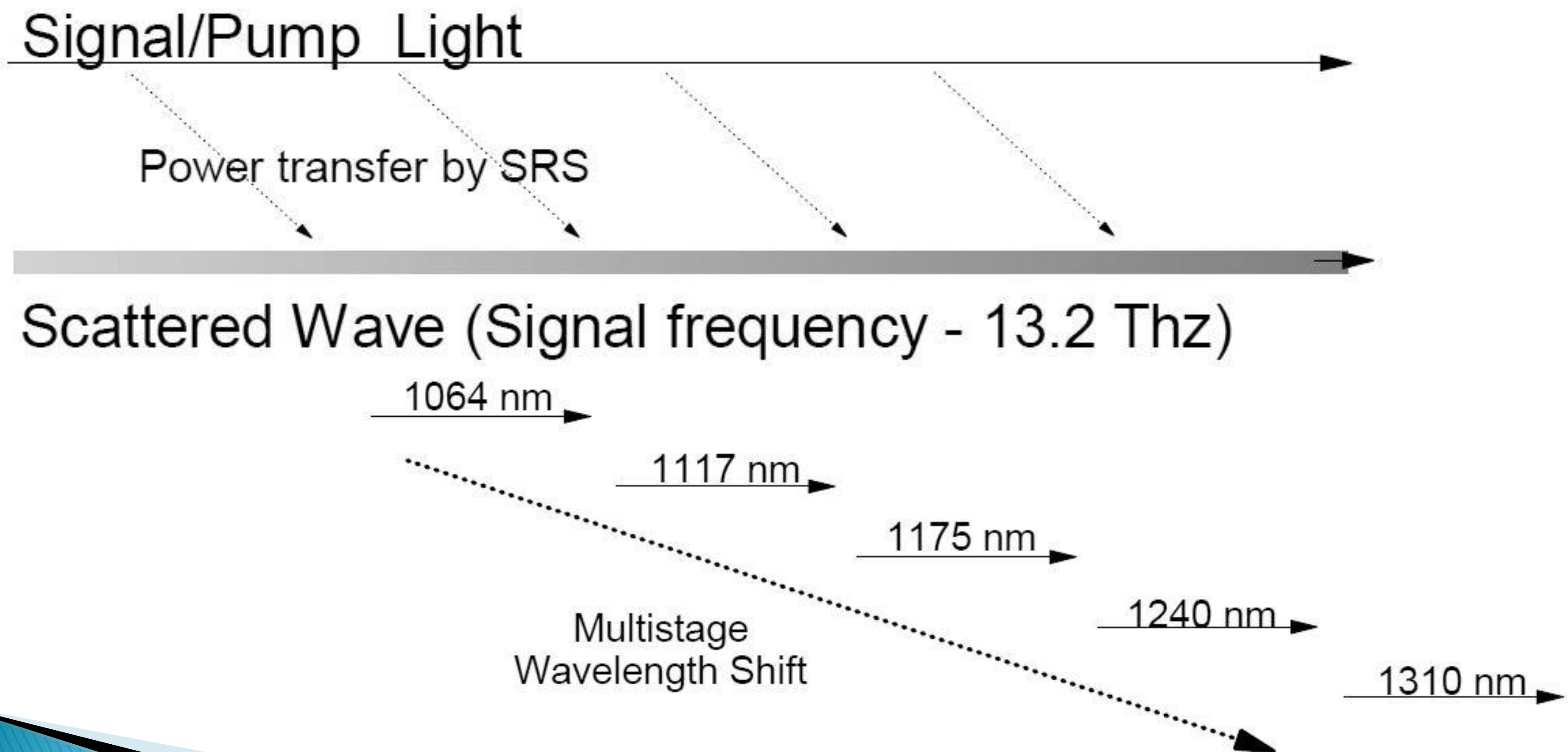
How to think of an EDFA



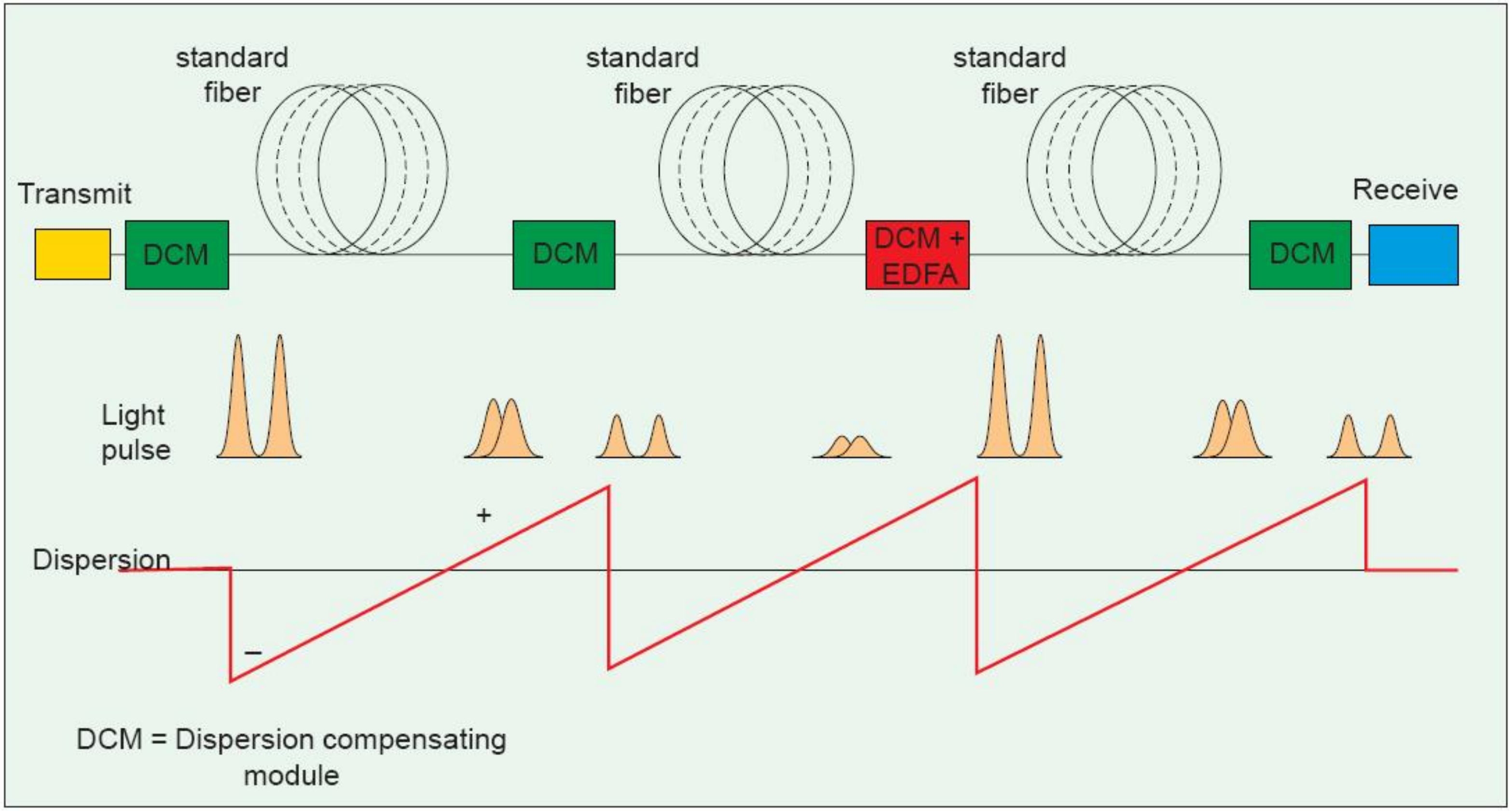


Amplificator cu efect Raman

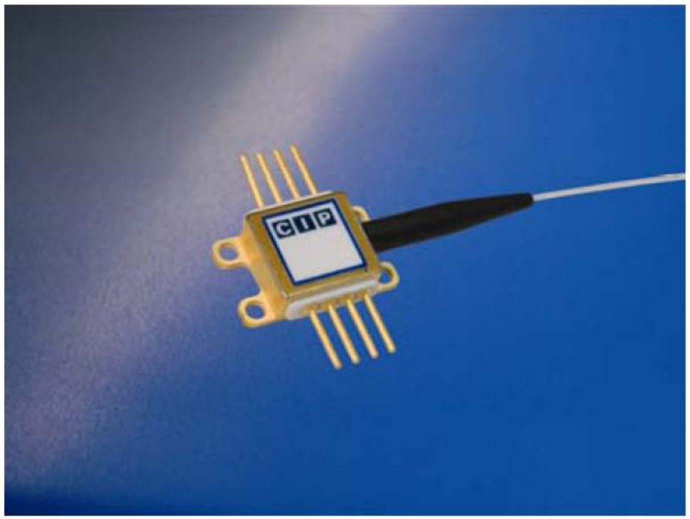
- Bazat pe efect Raman

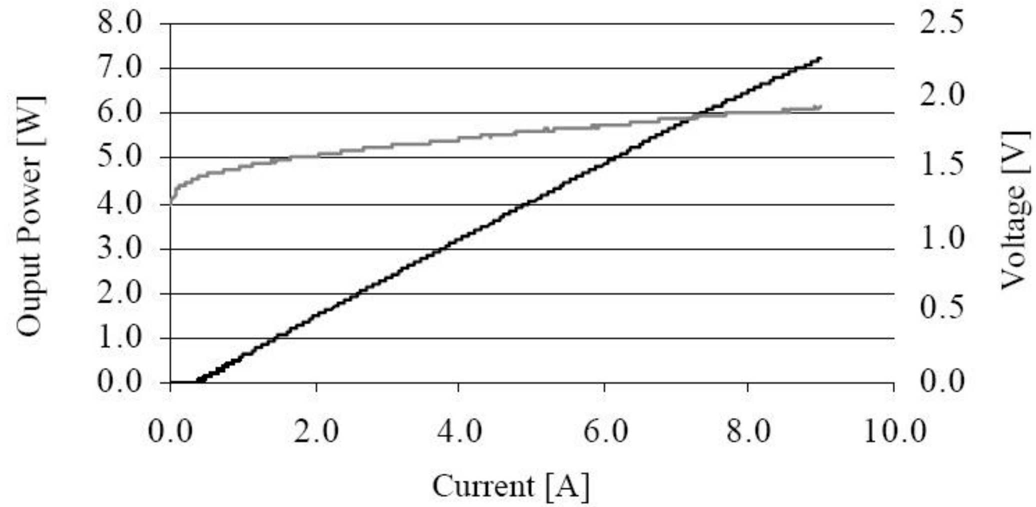


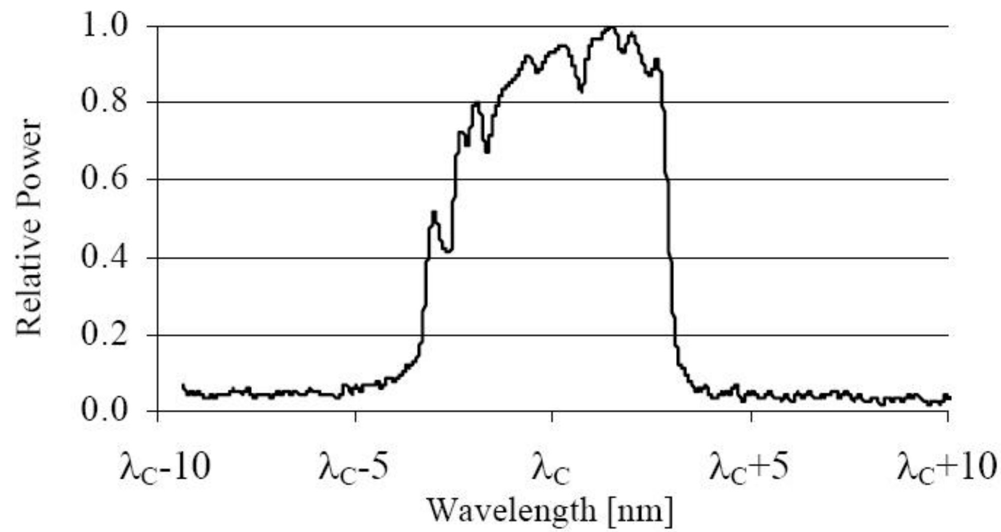
Utilizare amplificatoare optice



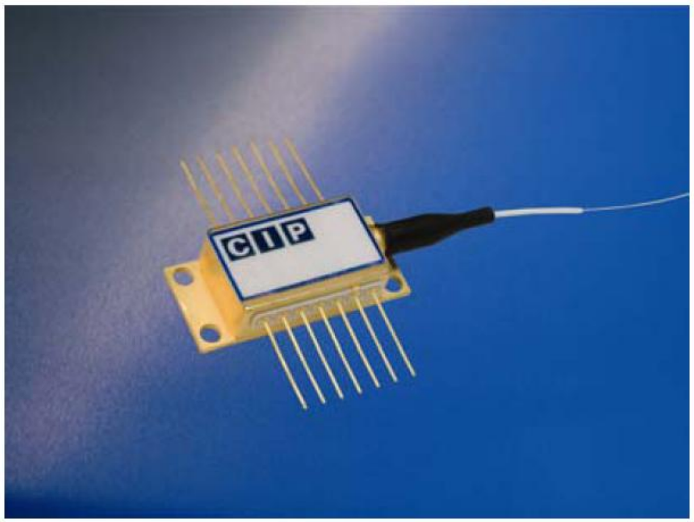
7W 980 nm Multimode Pump Laser

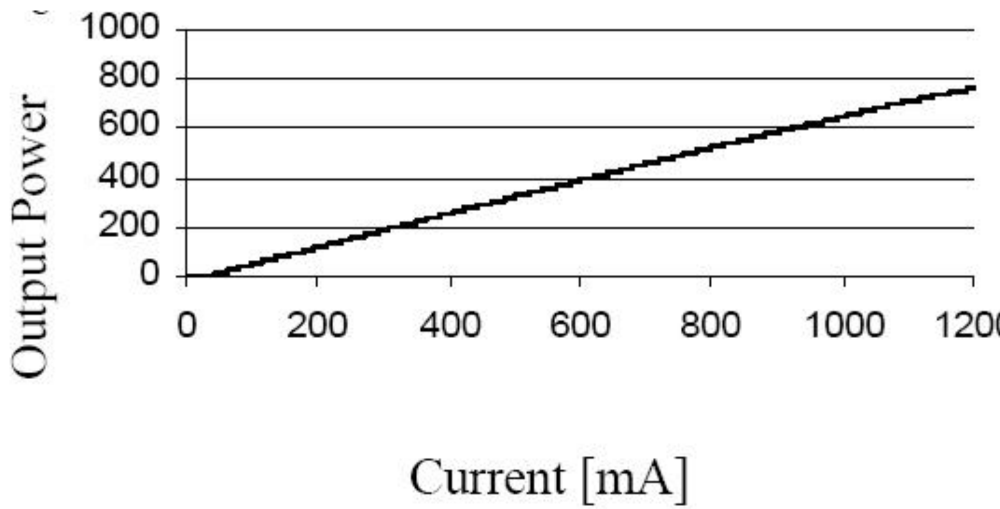


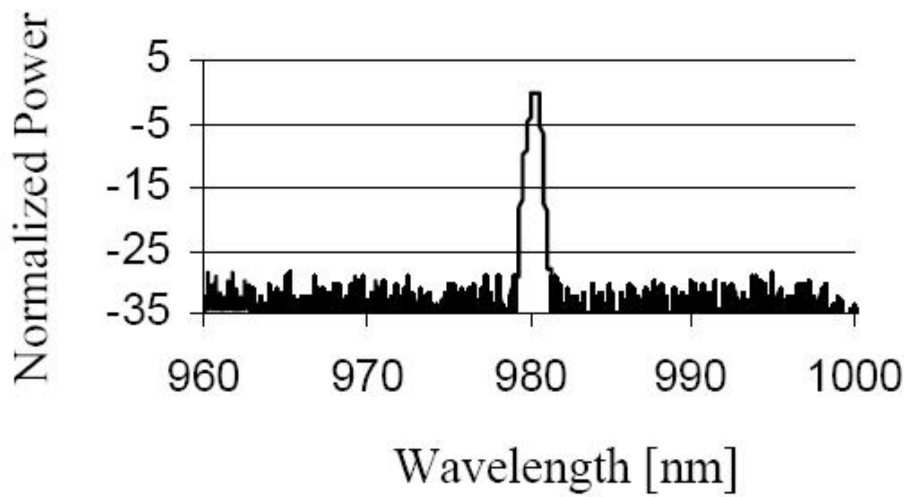




600mW 980 nm Singlemode Pump Laser

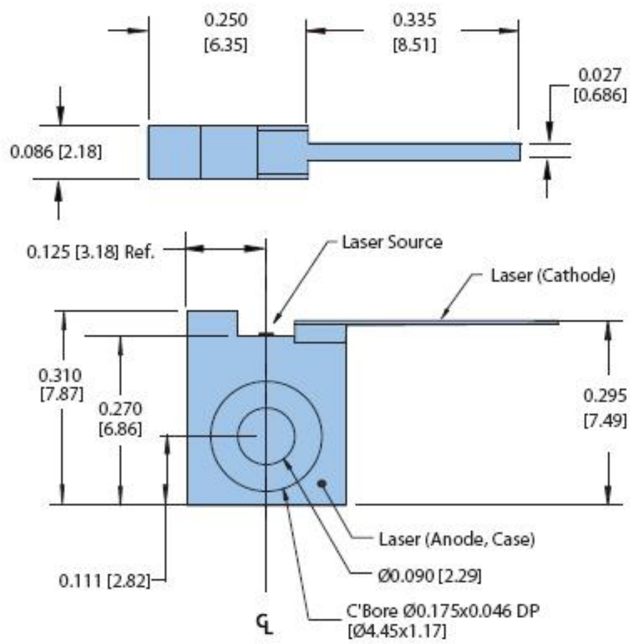




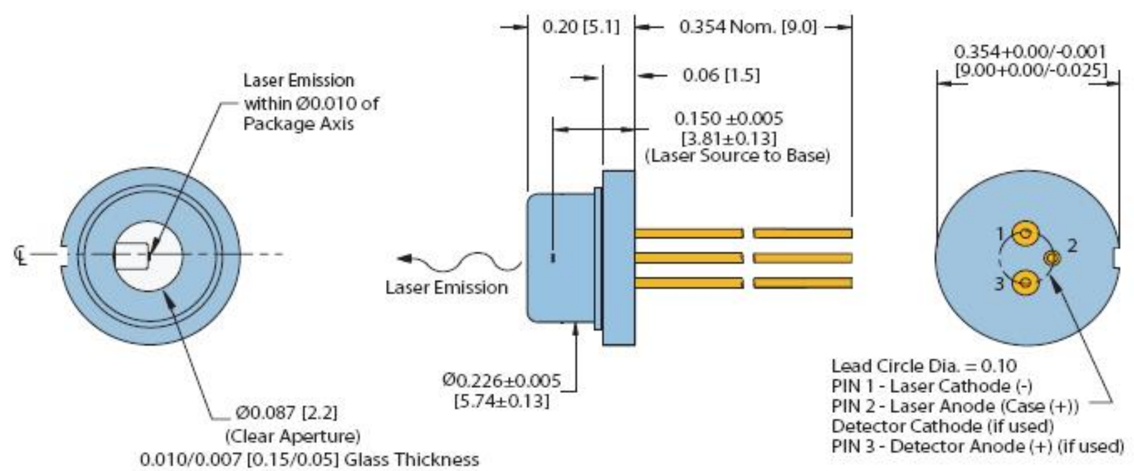


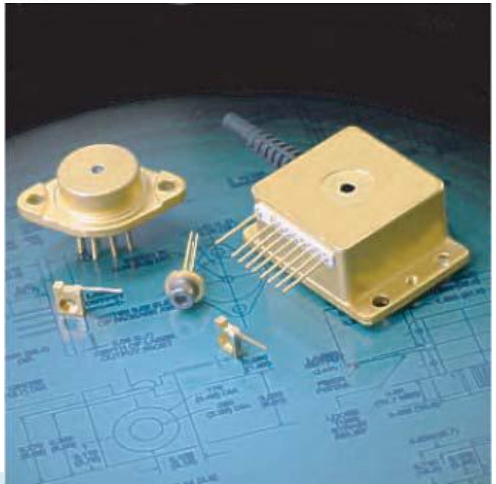
6 W, CW, 800nm

C-Mount Package



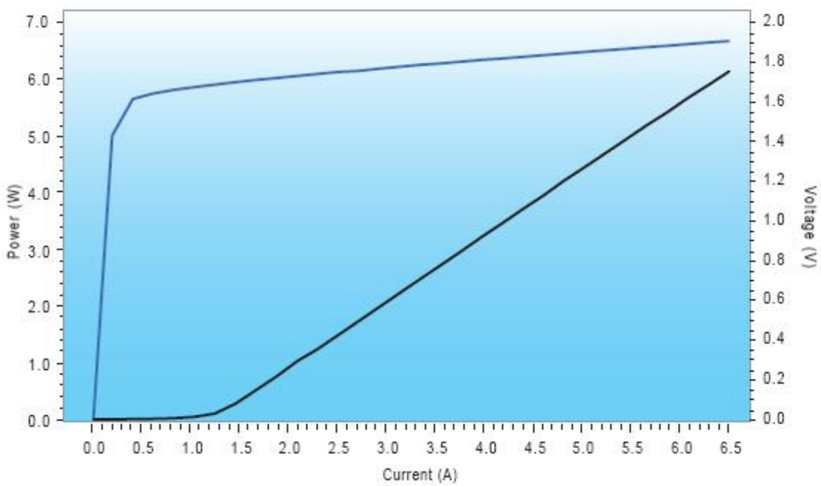
9mm Package



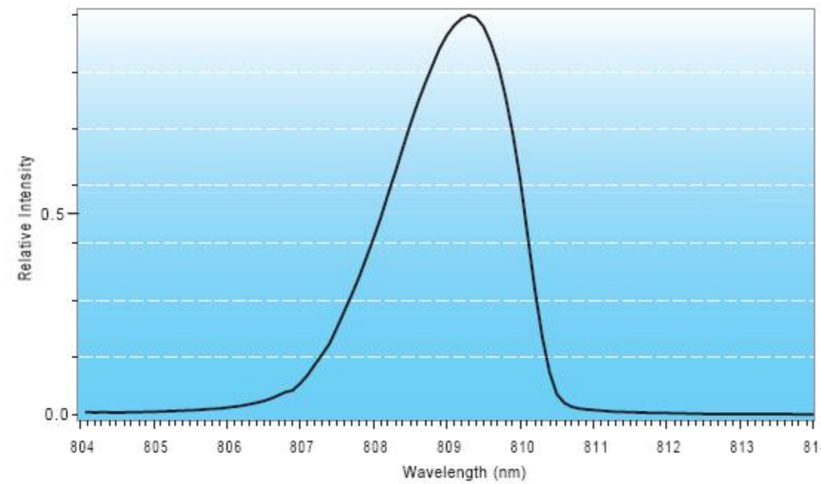


6 W, CW, 800nm

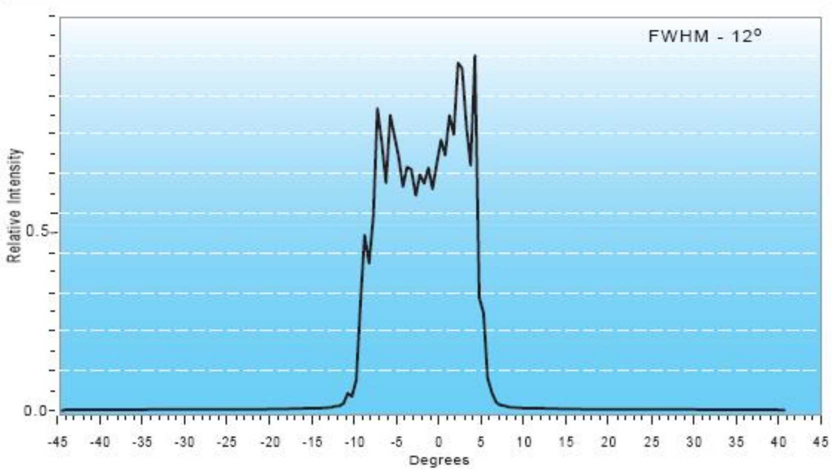
Typical L/I, V/I Graph



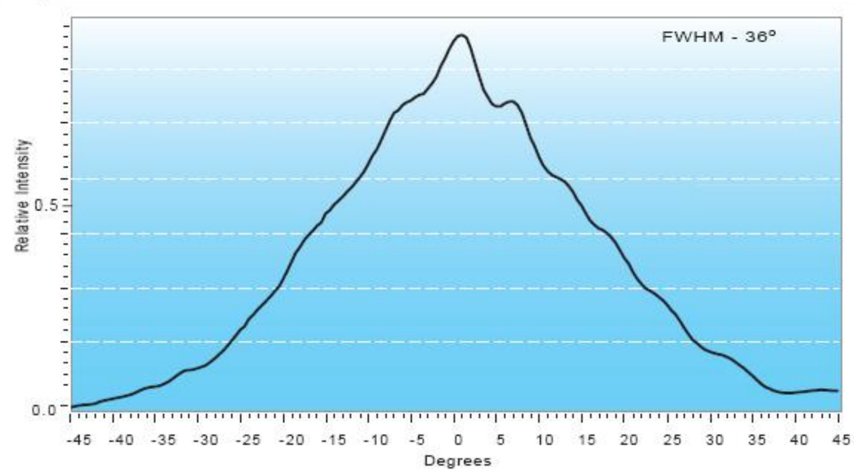
Wavelength Distribution



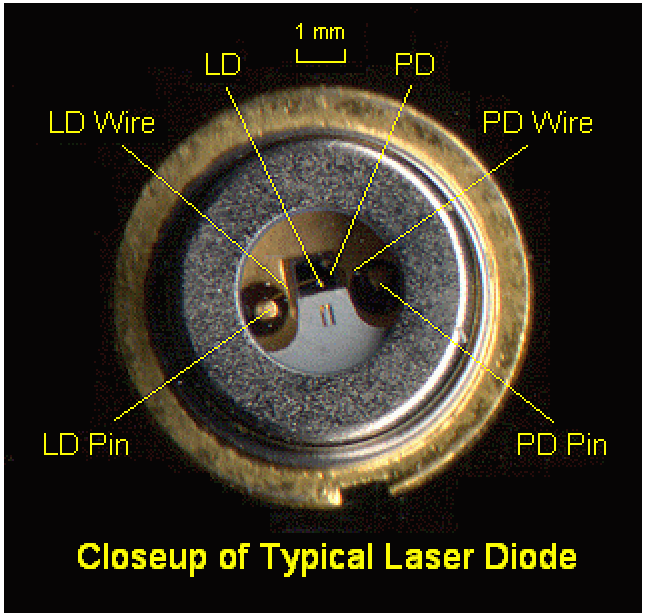
Typical Beam Divergence **Parallel**

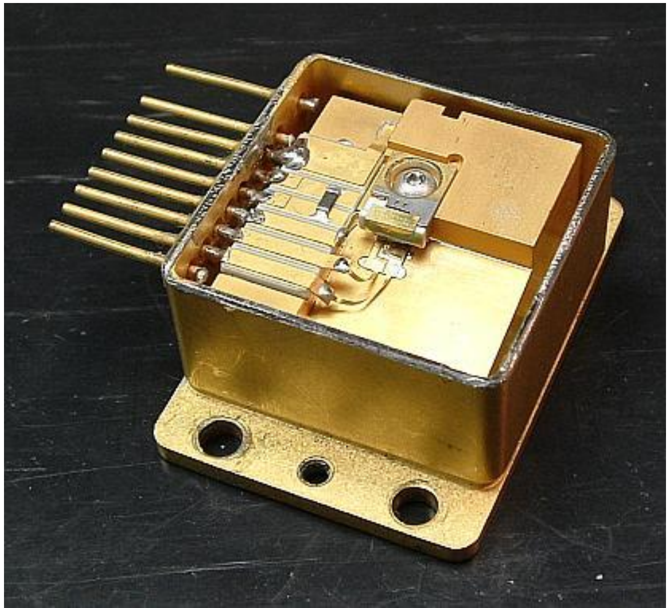


Typical Beam Divergence **Perpendicular**



CW Laser, 650 nm

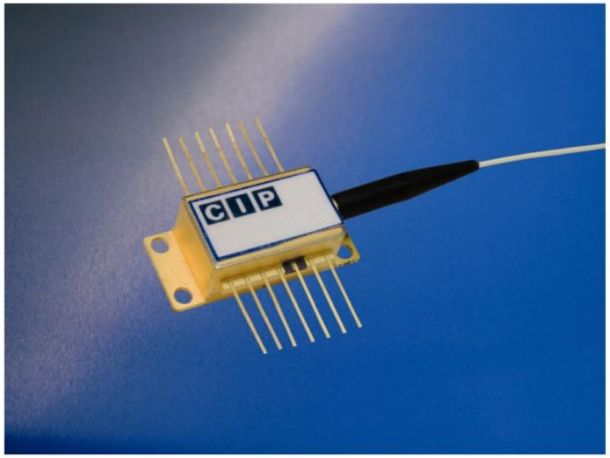




Lungimi de unda

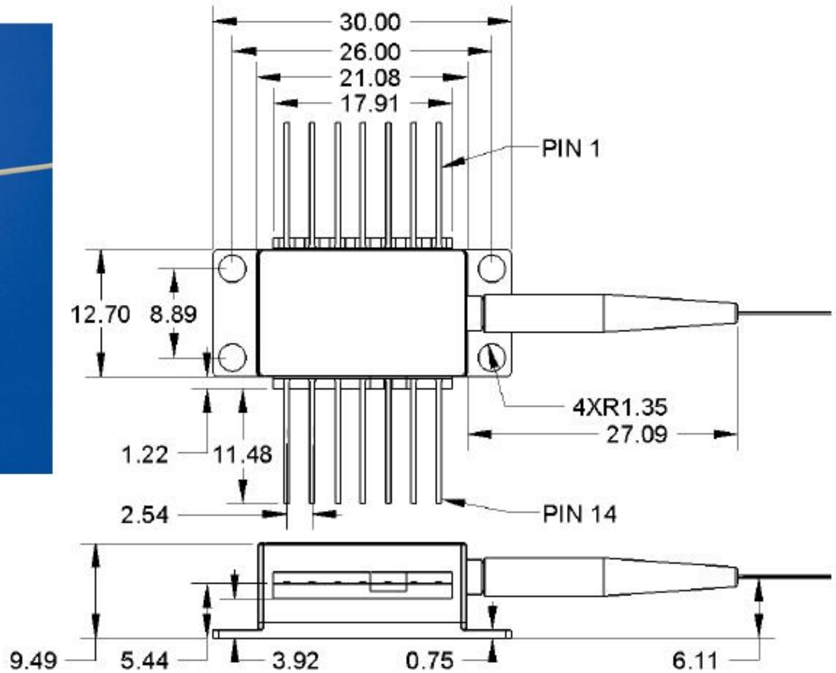
- **405 nm** – InGaN blue-violet laser, in Blu-ray Disc and HD DVD drives
- **445–465 nm** – InGaN blue laser multimode diode recently introduced (2010) for use in mercury-free high-brightness data projectors
- **510–525 nm** – Green diodes recently (2010) developed by Nichia and OSRAM for laser projectors.
- **635 nm** – AlGaInP better red laser pointers, same power subjectively twice as bright as 650 nm
- **650–660 nm** – GaInP/AlGaInP CDDVD, cheap red laser pointers
- **670 nm** – AlGaInP bar code readers, first diode laser pointers (now obsolete, replaced by brighter 650 nm and 671 nm DPSS)
- **760 nm** – AlGaInP gas sensing: O_2
- **785 nm** – GaAlAs Compact Disc drives
- **808 nm** – GaAlAs pumps in DPSS Nd:YAG lasers (e.g., in green laser pointers or as arrays in higher-powered lasers)
- **848 nm** – laser mice
- **980 nm** – InGaAs pump for optical amplifiers, for Yb:YAG DPSS lasers
- **1,064 nm** – AlGaAs fiber-optic communication, DPSS laser pump frequency
- **1,310 nm** – InGaAsP, InGaAsN fiber-optic communication
- **1,480 nm** – InGaAsP pump for optical amplifiers
- **1,512 nm** – InGaAsP gas sensing: NH_3
- **1,550 nm** – InGaAsP, InGaAsNSb fiber-optic communication
- **1,625 nm** – InGaAsP fiber-optic communication, service channel
- **1,654 nm** – InGaAsP gas sensing: CH_4
- **1,877 nm** – GaInAsSb gas sensing: H_2O
- **2,004 nm** – GaInAsSb gas sensing: CO_2
- **2,330 nm** – GaInAsSb gas sensing: CO
- **2,680 nm** – GaInAsSb gas sensing: CO_2
- **3,030 nm** – GaInAsSb gas sensing: C_2H_2
- **3,330 nm** – GaInAsSb gas sensing: CH_4

1550nm DFB Laser



Mechanical Drawing

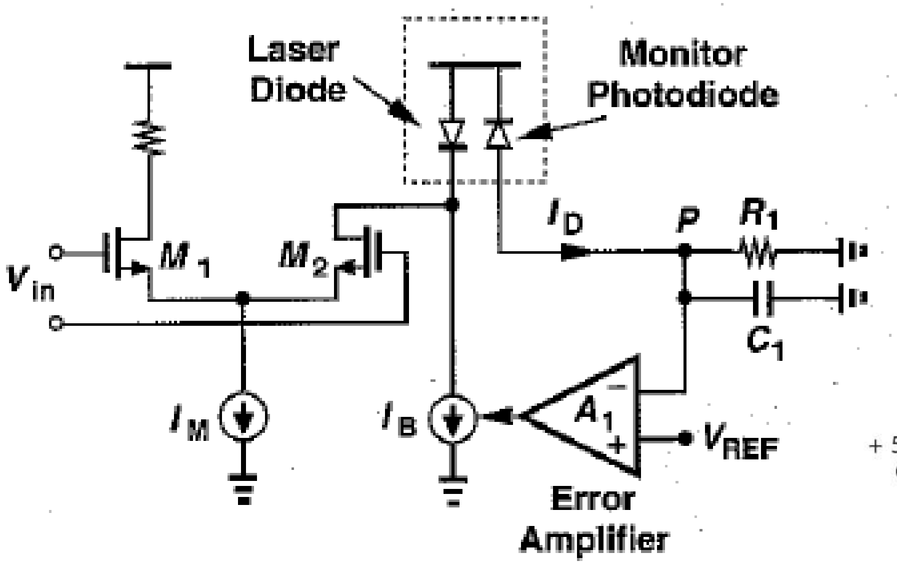
All units in mm



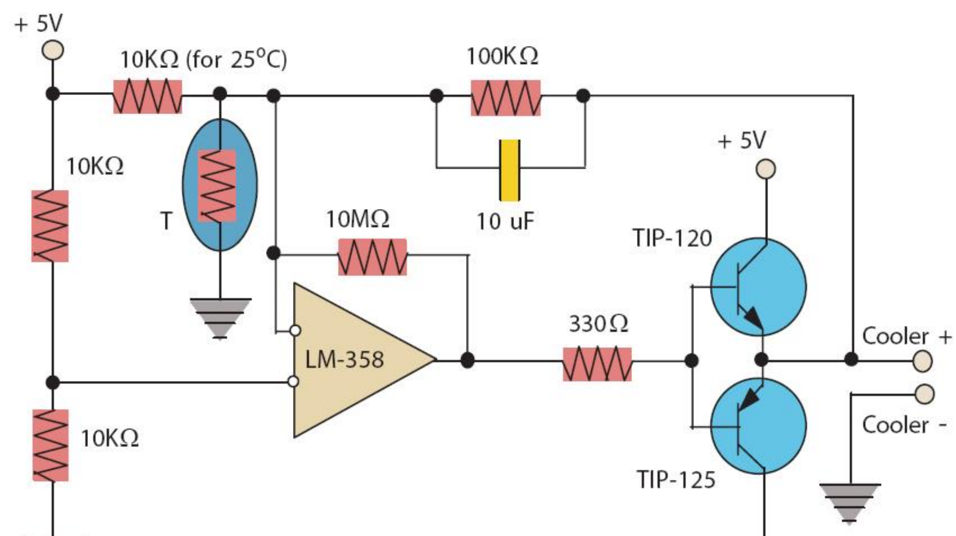
Pin out

Pin	Description
1	Thermistor
2	Thermistor
3	Laser Cathode (Bias)
4	Monitor PD Anode
5	Monitor PD Cathode
6	TEC +
7	TEC -
8	Case GND, Laser Anode
9	Case GND, Laser Anode
10	Case GND, Laser Anode
11	Case GND, Laser Anode
12	Laser Cathode (modulation)
13	Case GND, Laser Anode
14	Case GND, Laser Anode

Control dioda LASER



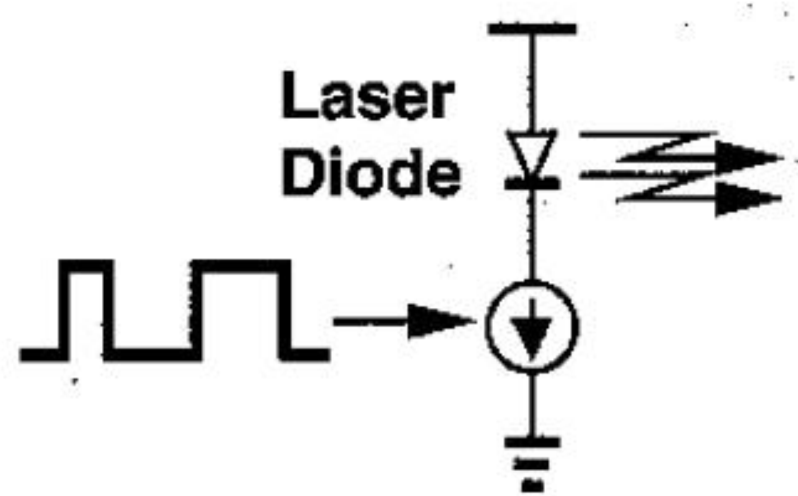
Control putere optica



Control temperatura

Dioda LASER

- Ca si in cazul LED, pentru DL intensitatea luminoasa emisa este o functie de curentul prin dioda
  - aproape exclusiv, DL sunt controlate in curent
  - controlul in curent are avantajul unei viteze mai mari de lucru

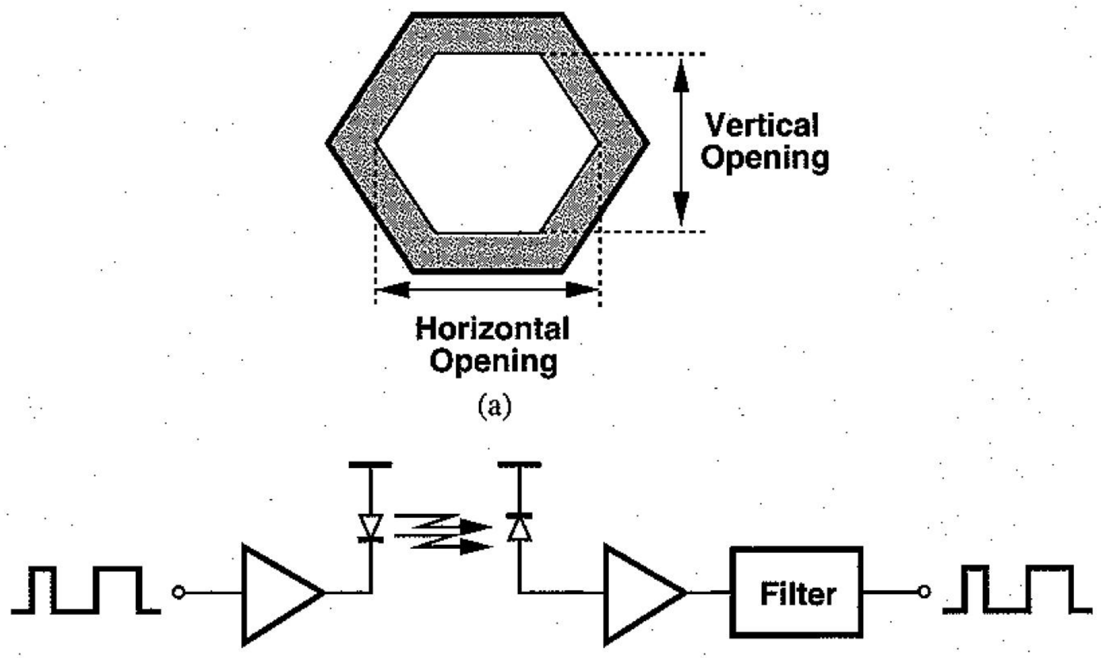


Dioda LASER

- Cerinte pentru driver-ele de diode laser
  - viteza mare de basculare pentru minimizarea interferentei intersimbol
  - curent mare de iesire
  - capacitatea de a rezista la variatiile de tensiune pe dioda Laser
- Cerintele sunt dificil de respectat deoarece sunt contradictorii
  - viteza mare presupune micsorarea dimensiunii componentelor
  - micsorarea dimensiunii
    - scade tensiunea de strapungere
    - scade capabilitatea de curent/putere disipata

Caracteristici driver-e DL

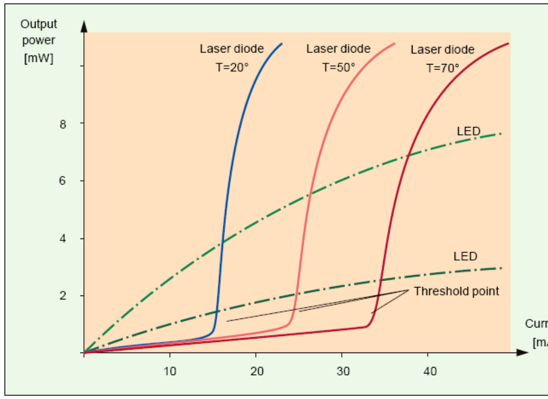
- Viteza
  - caracterizata de timpii de crestere si de cadere
  - suma acestora trebuie sa fie mult mai mica decat perioada de bit la viteza nominala de lucru
- Testarea vitezei de lucru
  - standardizata
  - “eye diagram”



(a)
(b)

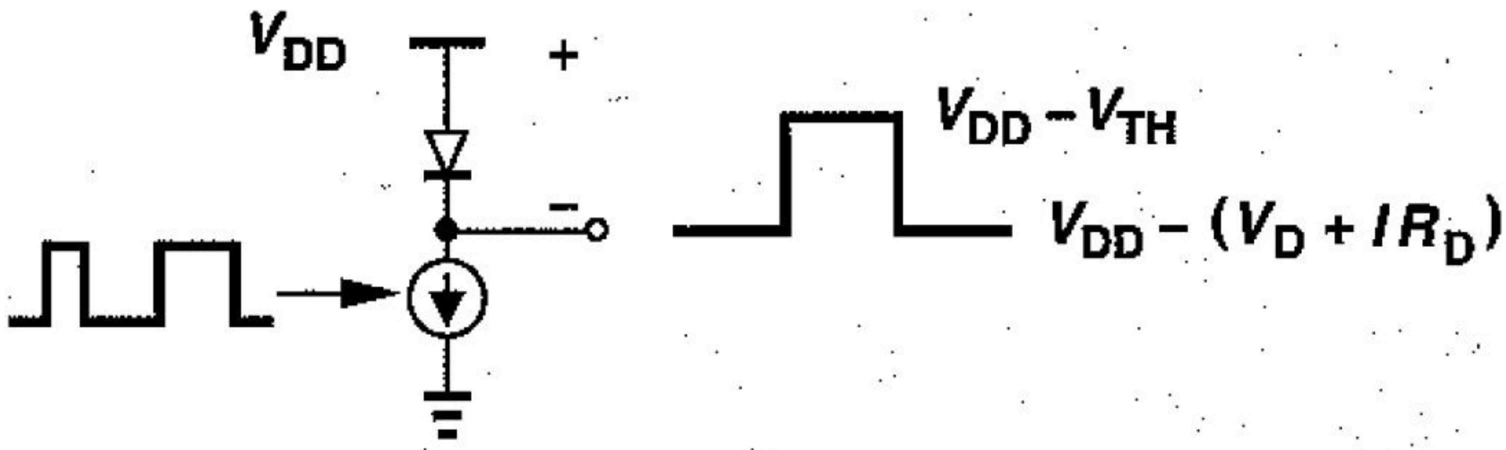
Caracteristici driver-e DL

- Curent de iesire
  - laserele trebuie polarizate in vecinatatea pragului, astfel incat o mica variatie de curent sa poata deschide dioda
  - driver-ele de DL trebuie sa poata furniza:
    - un curent de “polarizare”
    - un curent de “modulatie”
  - Curentul de “polarizare” (~ de prag) variaza cu temperatura si varsta diodei extrem de mult
  - Curentul de “modulatie” (semnal) nu depinde de aceste elemente deoarece pentru DL
    - pragul depinde de temperatura si varsta
    - panta este aproximativ constanta



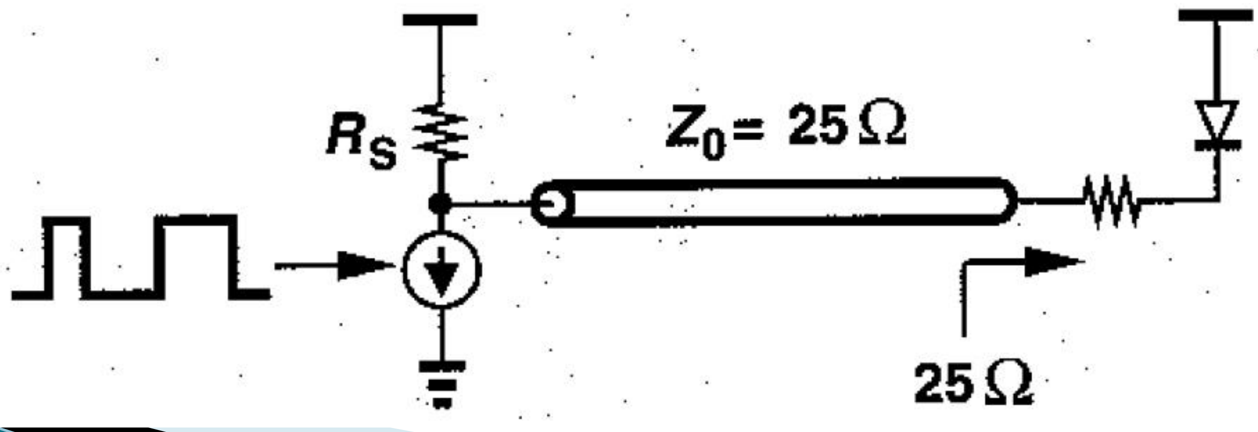
Caracteristici driver-e DL

- Variatii de tensiune pe dioda LASER
  - generate de variatiile mari de curent si rezistenta interna a diodei



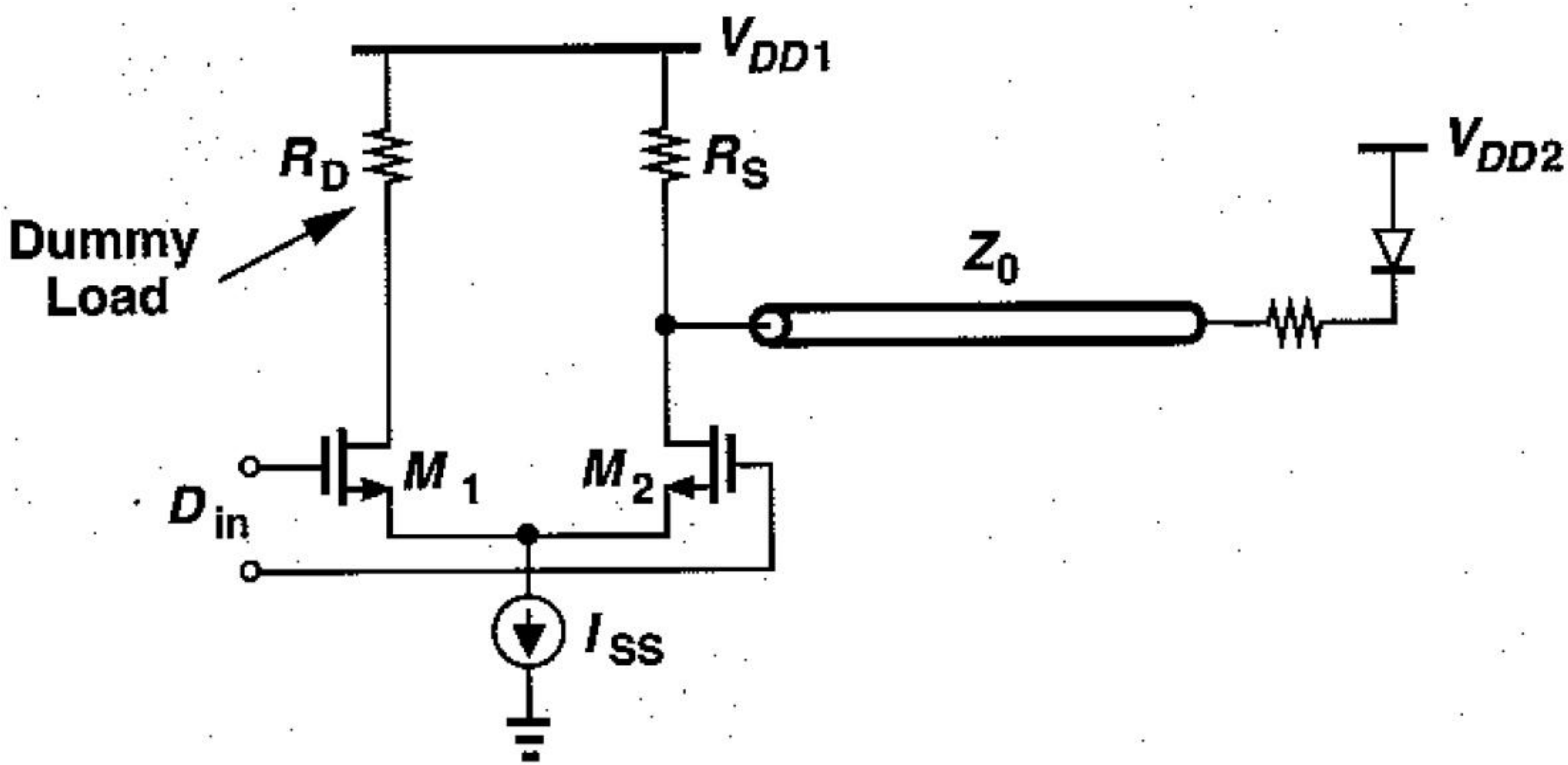
Caracteristici driver-e DL

- Impedante de intrare si iesire
- Se lucreaza la viteze mari (1Gb/s, 10Gb/s)
  - se aplica considerente de proiectare a circuitelor de microunde
  - Intrarea in amplificator are tipic o impedanta de 50Ω
  - Iesirea trebuie adaptata la impedanta diodei Laser
    - daca aceasta impedanta e prea mica, se creste la valori adecvate (~25Ω) prin introducerea unui rezistor in serie



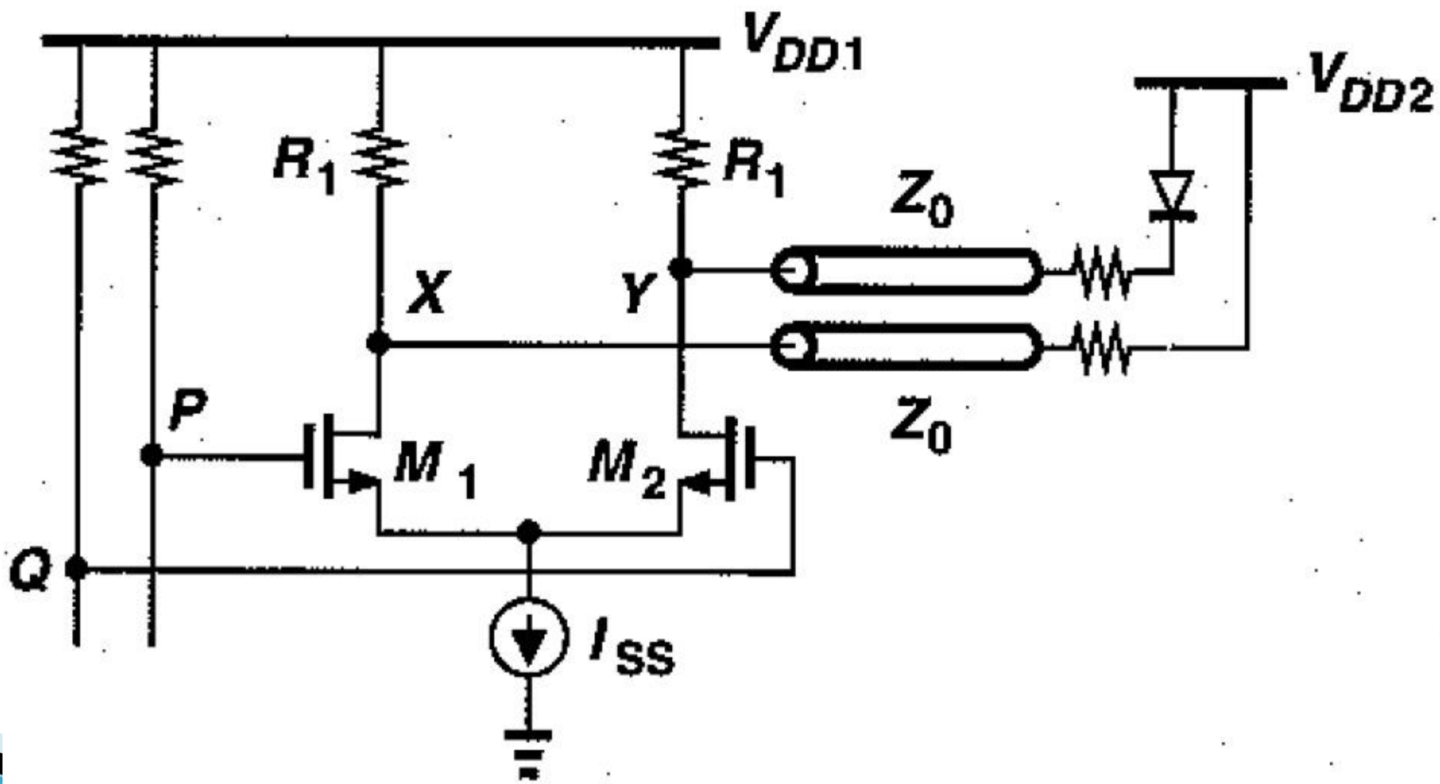
Principii de proiectare

- Tipic etajul de iesire se realizeaza diferential



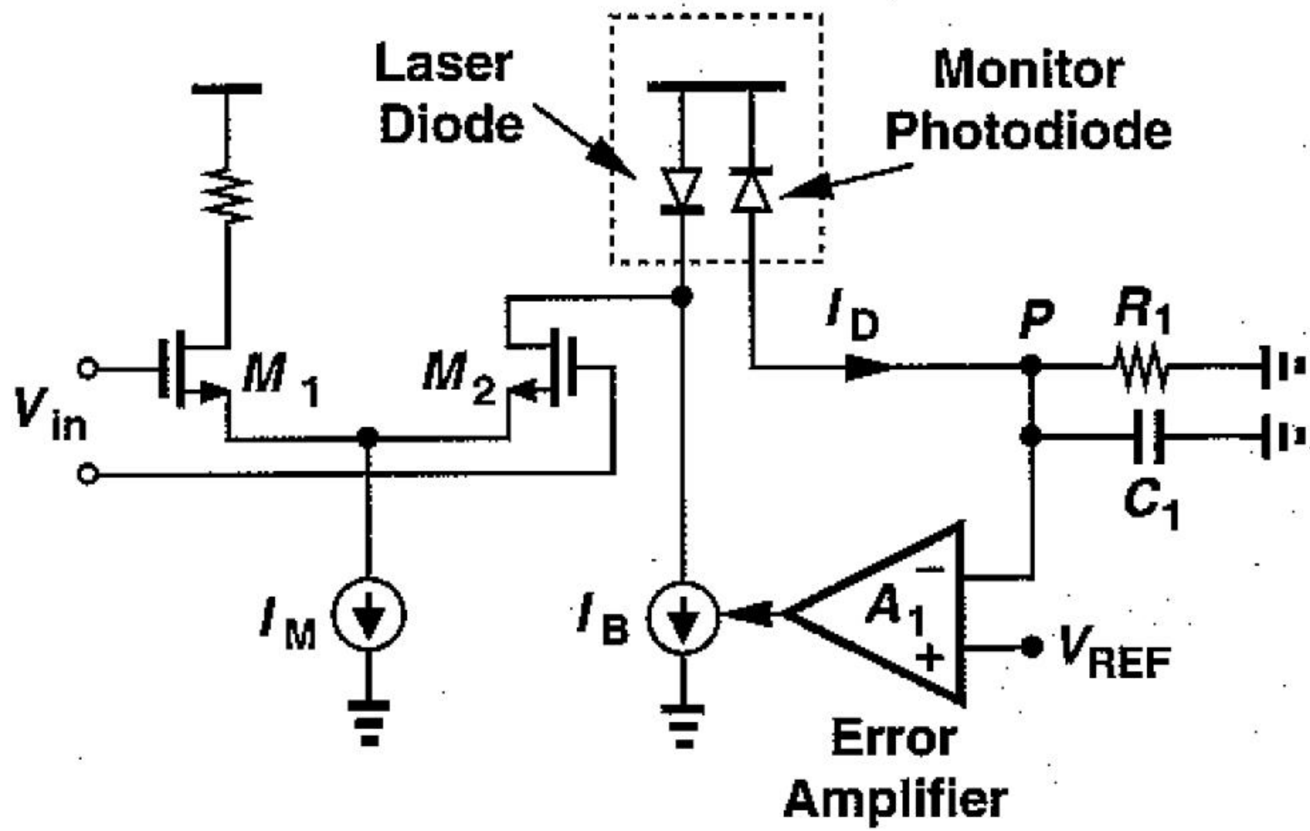
Principii de proiectare

- La viteze mari se utilizeaza tipic tranzistoare unipolare si etajul diferential se realizeaza simetric



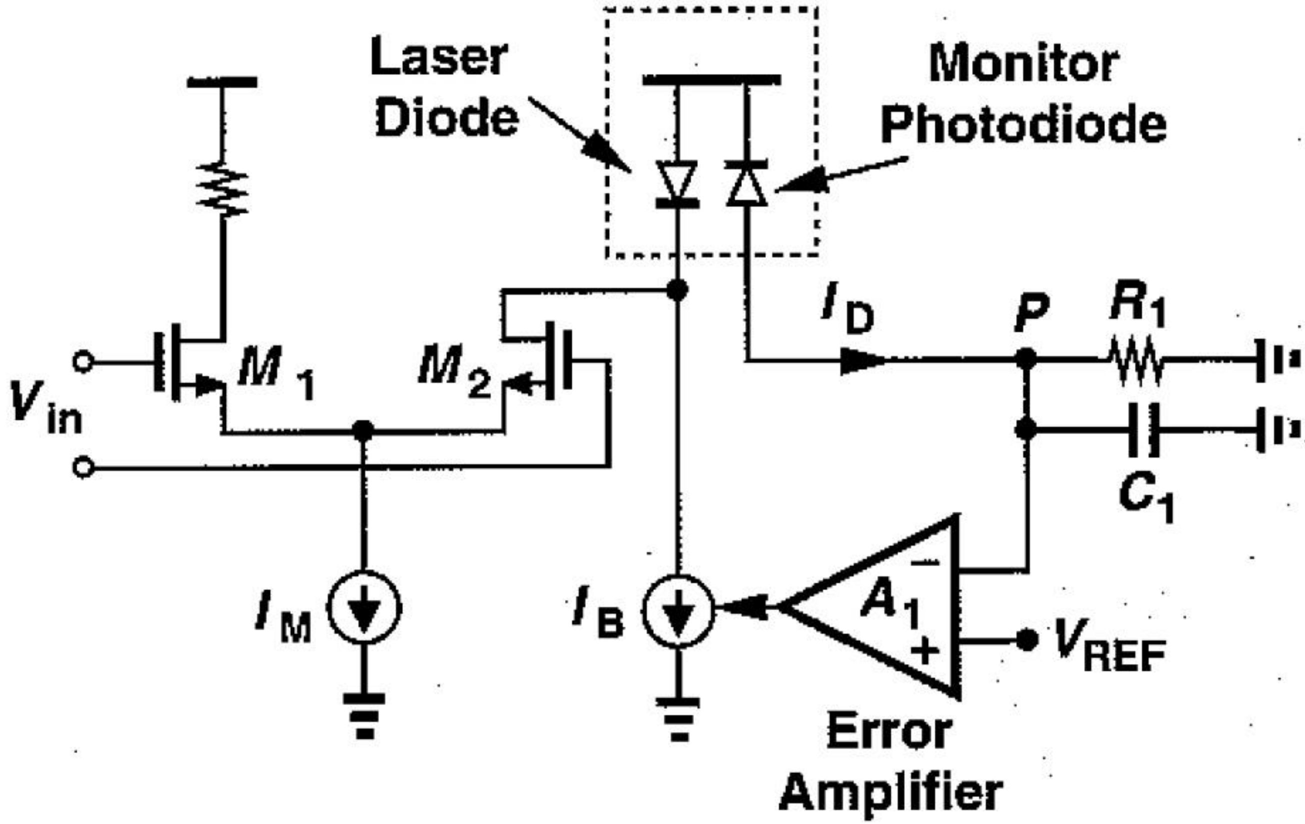
Controlul puterii in DL

- Necesar datorita variatiei curentului de "polarizare"



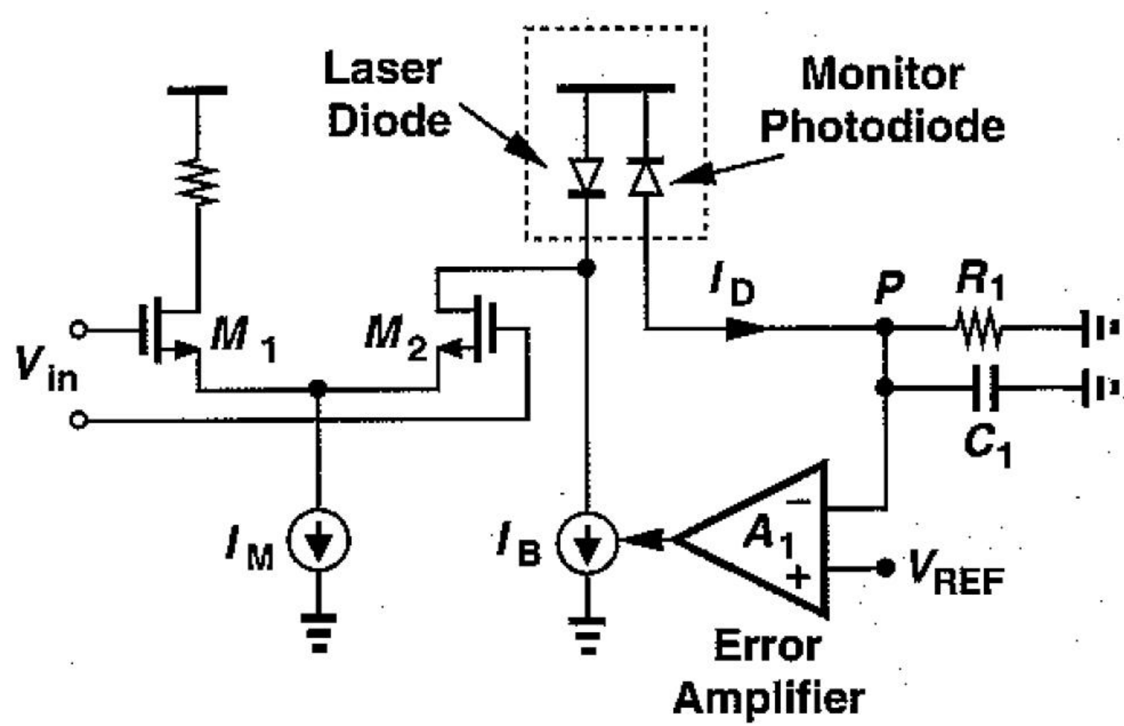
Controlul puterii in DL

- circuitul RC din schema de reglaj a curentului de polarizare realizeaza o filtrare trece sus a semnalului



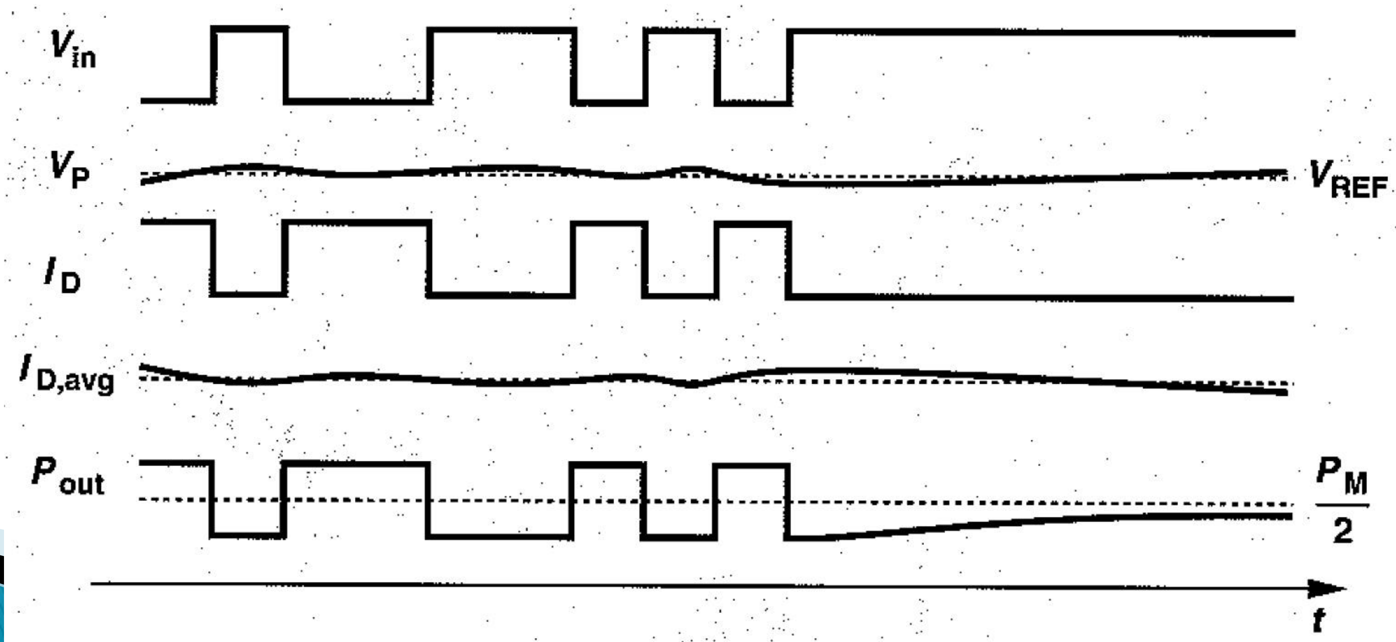
Controlul puterii in DL

- La frecvente prea mici de lucru bucla de reatie e suficient de rapida pentru a urmari si anula curentul de semnal



Controlul puterii in DL

- Bucla de reactie are efect si in cazul unei suite lungi de biti 1 transmisi
  - In acest caz, la limita curentul emis de dioda laser in starea OFF ajunge jumatate din curentul corespunzator starii ON
  - Capacitatea de filtrare din bucla trebuie aleasa mare pentru a minimiza acest efect
  - daca valoarea e prea ridicata e necesara o capacitate externa circuitului integrat



Contact

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- rdamian@etti.tuiasi.ro