Optoelectronică, structuri şi tehnologii

Curs 7

2016/2017

Disciplina 2016/2017

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

Recapitulare

Curs 6

Legatura

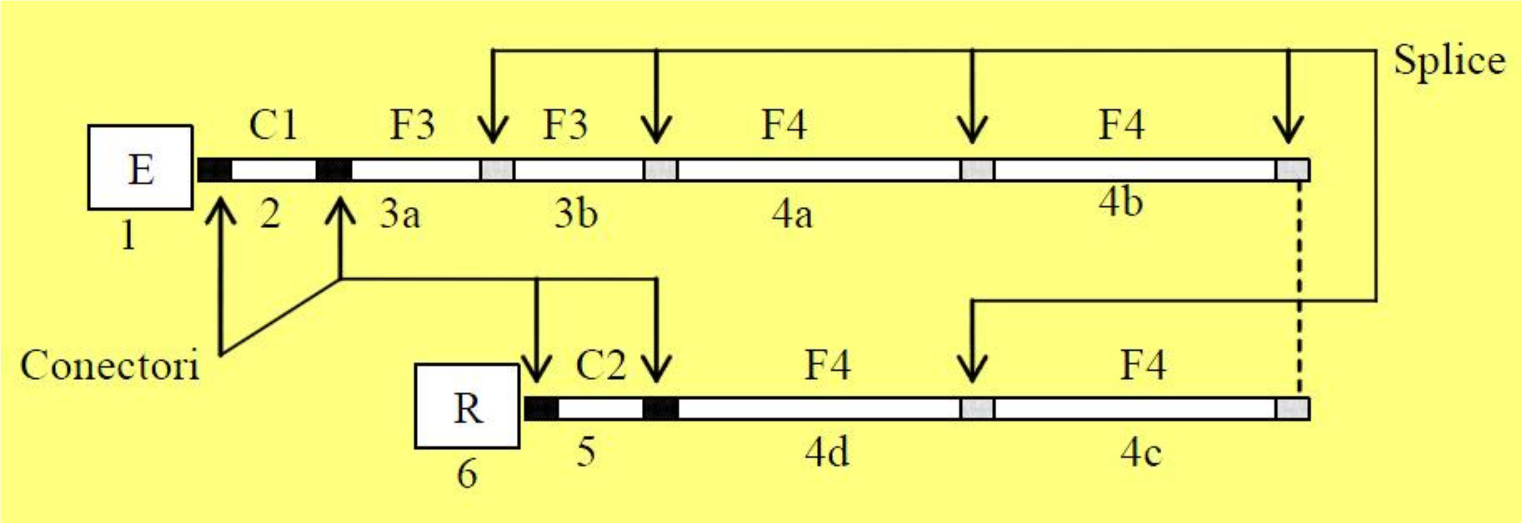
- Bilantul puterilor

Wavelength (nm)	Maximum Value* (dB/km)
1310	0.33 – 0.35
1383**	0.31 – 0.35
1490	0.21 – 0.24
1550	0.19 – 0.20
1625	0.20 – 0.23

Maximum Attenuation

$$A_{tot}[\mathrm{dB}] = \sum_i A_i[\mathrm{dB}]$$

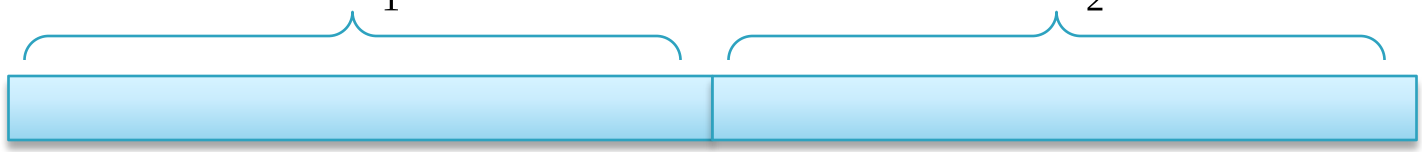
$$P_e[\mathrm{dBm}] \pm A_{tot}[\mathrm{dB}] \geq S_r[\mathrm{dBm}] + M[\mathrm{dB}]$$



Sisteme cu mai multe tipuri de fibra

- efecte **succesive** se adună liniar

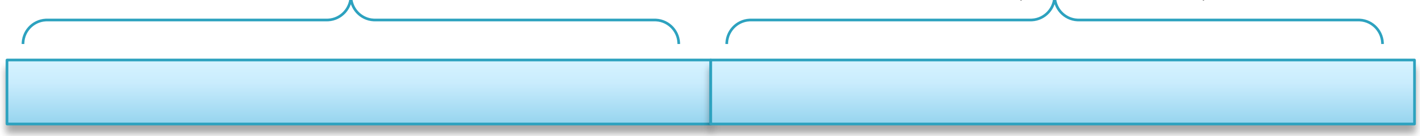
$$\Delta\tau_1 \qquad\qquad \Delta\tau_2$$



$$\Delta\tau_{tot} = \Delta\tau_1 + \Delta\tau_2$$

- dar pe fiecare fibra exista efecte **simultane** (pentru dispersie) care se adună pătratic

$$\Delta\tau_{\text{mod},1}, \Delta\tau_{cr,1} \qquad\qquad \Delta\tau_{\text{mod},2}, \Delta\tau_{cr,2}$$



$$\Delta\tau_1 = \sqrt{\Delta\tau_{cr,1}^2 + \Delta\tau_{\text{mod},1}^2}$$

$$\Delta\tau_2 = \sqrt{\Delta\tau_{cr,2}^2 + \Delta\tau_{\text{mod},2}^2}$$

Pierderi

- Atenuare in fibra
- Atenuare datorata conectorilor
- Atenuare datorata splice-urilor
- Atenuare datorata diferentelor de apertura numerica
  - apare **numai** la trecerea de la un dispozitiv cu NA mai mare la un dispozitiv cu NA mai mic
  - **neglijabil** intre 2 fibre monomod sudate
- Atenuare datorata diferentelor de diametru
  - apare **numai** la trecerea de la un dispozitiv cu diametru mai mare la un dispozitiv cu diametru mai mic
  - **bidirectional** la fibre monomod sudate

Reprezentare logaritmică

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

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

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
−3 dB	= 0.5
−10 dB	= 0.1
−20 dB	= 0.01
−30 dB	= 0.001

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
−3 dBm	= 0.5 mW
−10 dBm	= 100 μW
−30 dBm	= 1 μW
−60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

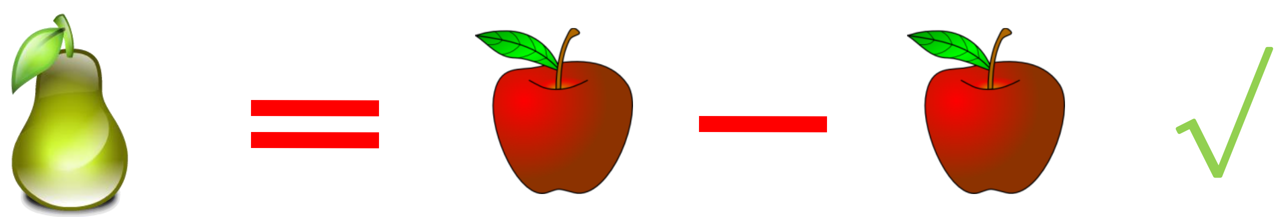
[x] + [dB] = [x]

Calculul atenuarii

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

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

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



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

LED

Dioda electroluminescenta

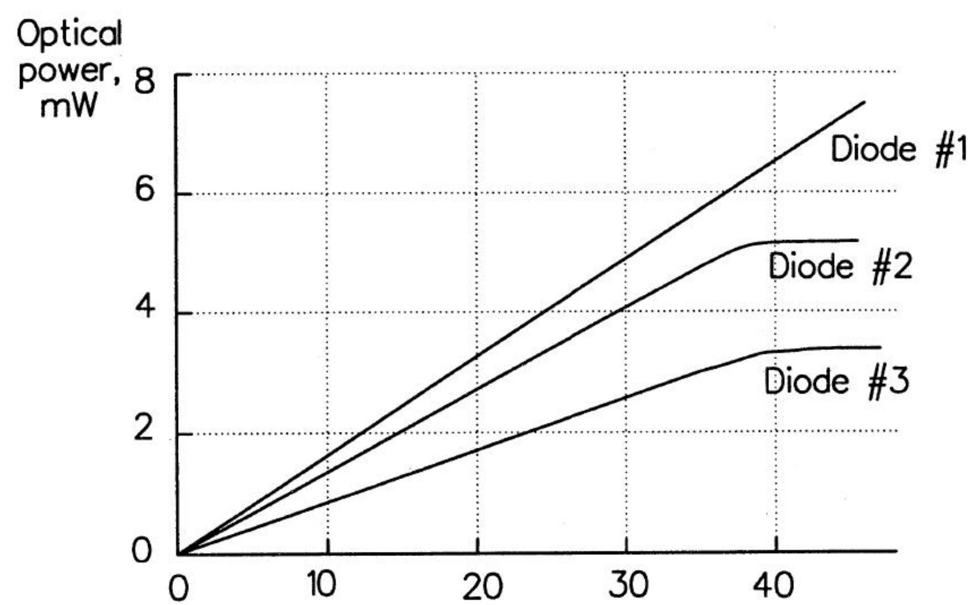
Capitolul 7

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

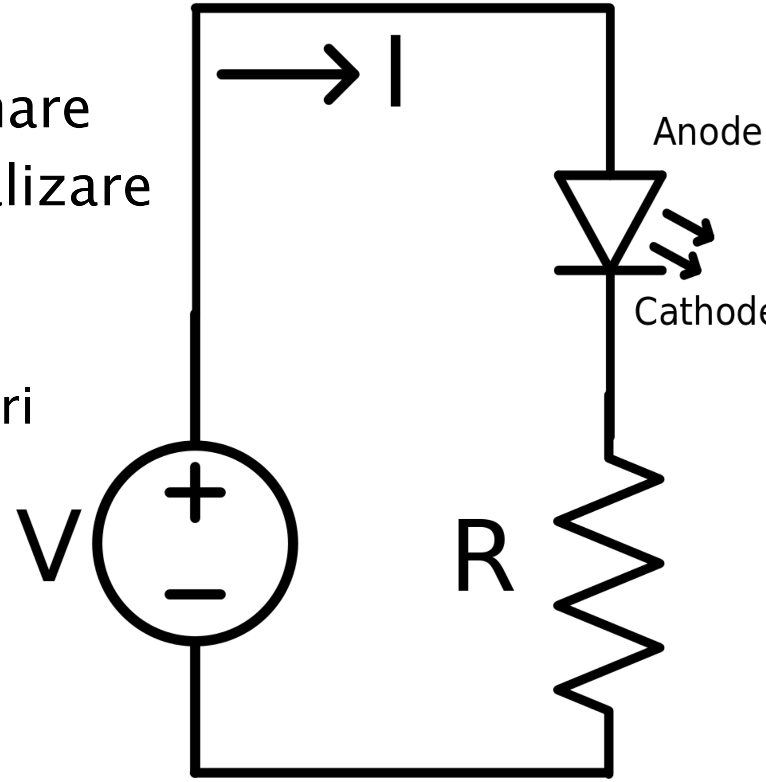


Control static LED

- Cea mai simpla schema de control: un rezistor in serie cu LED
  - **Atentie!** Tensiunea directa poate varia semnificativ (>>0.7V) si trebuie preluata din catalog
    - mai ales la intensitate luminoasa mare
    - datorita materialelor diferite de realizare a LED-urilor
    - dependenta de lungimea de unda
      - mai mica la lungimi de unda mai mari

$$I_v = f\left(I_F[\mathrm{mA}]\right) \quad [\mathrm{cd/mcd}]$$

$$I_F = \frac{V_{cc} - V_F}{R}$$



Control static LED

Ultra Bright LED Lamps Round Types

Package	Part No.	Chip: Material Emitted Color	Chip: Peak Wave Length p(nm)	Chip: Dominant Wave Length λd(nm)	Absolute Maximum Ratings: Δλ (nm)	Absolute Maximum Ratings: Pd (mw)	Absolute Maximum Ratings: If (mA)	Absolute Maximum Ratings: Peak (mA)	Electro-optical Data(At 20mA): Vf (V) Typ.	Electro-optical Data(At 20mA): Vf (V) Max	Electro-optical Data(At 20mA): Iv (mcd) Typ.	Viewing Angle 2θ 1/2 (deg)	Drawing No.
T-1 Standard 1.0" Lead 3ϕ Water Clear	BL-BF43V1	GaAlAs/ DDH Super Red	660	643±5	20	80	30	150	2.0	2.6	700	25	L-001
	BL-BG33V1	InGaAlP/ Yellow Green	573	571±5	15	100	30	150	2.2	2.6	700	25	
	BL-BG43V1	InGaN/SiC/ Bluish Green	505	505±5	30	120	30	150	3.5	4.0	3500	24	
	BL-BG63V1	InGaN/SiC/ Green	525	525±5	35	120	30	150	3.5	4.0	4000	24	
	BL-BJ23V1	InGaAlP/ Super Orange	620	615±5	17	100	30	150	2.2	2.6	1700	25	
	BL-BJ33V1	InGaAlP/ Super Orange	630	625±5	17	100	30	150	2.2	2.6	1100	25	
	BL-BJ63V1	InGaAlP/ Super Orange	610	605±5	17	100	30	150	2.2	2.6	1500	25	
	BL-BJ73V1	InGaAlP/ Super Orange	630	625±5	17	100	30	150	2.2	2.6	1500	25	
	BL-BJH3V1	InGaAlP/ Super Orange	630	625±5	17	100	30	150	2.2	2.6	2500	[illegible]	
	BL-BJG3V1	InGaAlP/ Super Orange	630	625±5	17	100	30	150	2.2	2.6	3000	25	
	BL-BK43V1	InGaAlP/ Super Yellow	590	587±5	15	100	30	150	2.2	2.6	1600	25	
	BL-BK53V1	InGaAlP/ Super Yellow	595	594±5	15	100	30	150	2.2	2.6	1500	25	
	BL-BK73V1	InGaAlP/ Super Yellow	595	594±5	15	100	30	150	2.2	2.6	[illegible]	25	
	BL-BK83V1	InGaAlP/ Super Yellow	590	587±5	15	100	30	150	2.2	2.6	[illegible]	25	
	BL-BKH3V1	InGaAlP/ Super Yellow	590	587±5	15	100	30	150	2.2	2.6	[illegible]	25	
	BL-BKG3V1	InGaAlP/ Super Yellow	590	587±5	15	100	30	150	2.2	2.6	3000	25	
	BL-BF43V4V	GaAlAs/ DDH Super Red	660	643±5	20	80	30	150	[illegible]	2.6	1200	15	
	BL-BG33V4V	InGaAlP/ Yellow Green	573	571±5	15	100	30	150	2.2	2.6	1100	[illegible]	
	BL-BG43V4V	InGaN/SiC/ Bluish Green	505	505±5	30	120	30	150	3.5	4.0	6000	[illegible]	
	BL-BG63V4V	InGaN/SiC/ Green	525	525±5	35	120	30	150	3.5	4.0	5600	[illegible]	

3.5	4.0	3500
3.5	4.0	4000
2.2	2.6	1700
2.2	2.6	1100

♦Electro-Optical Characteristics

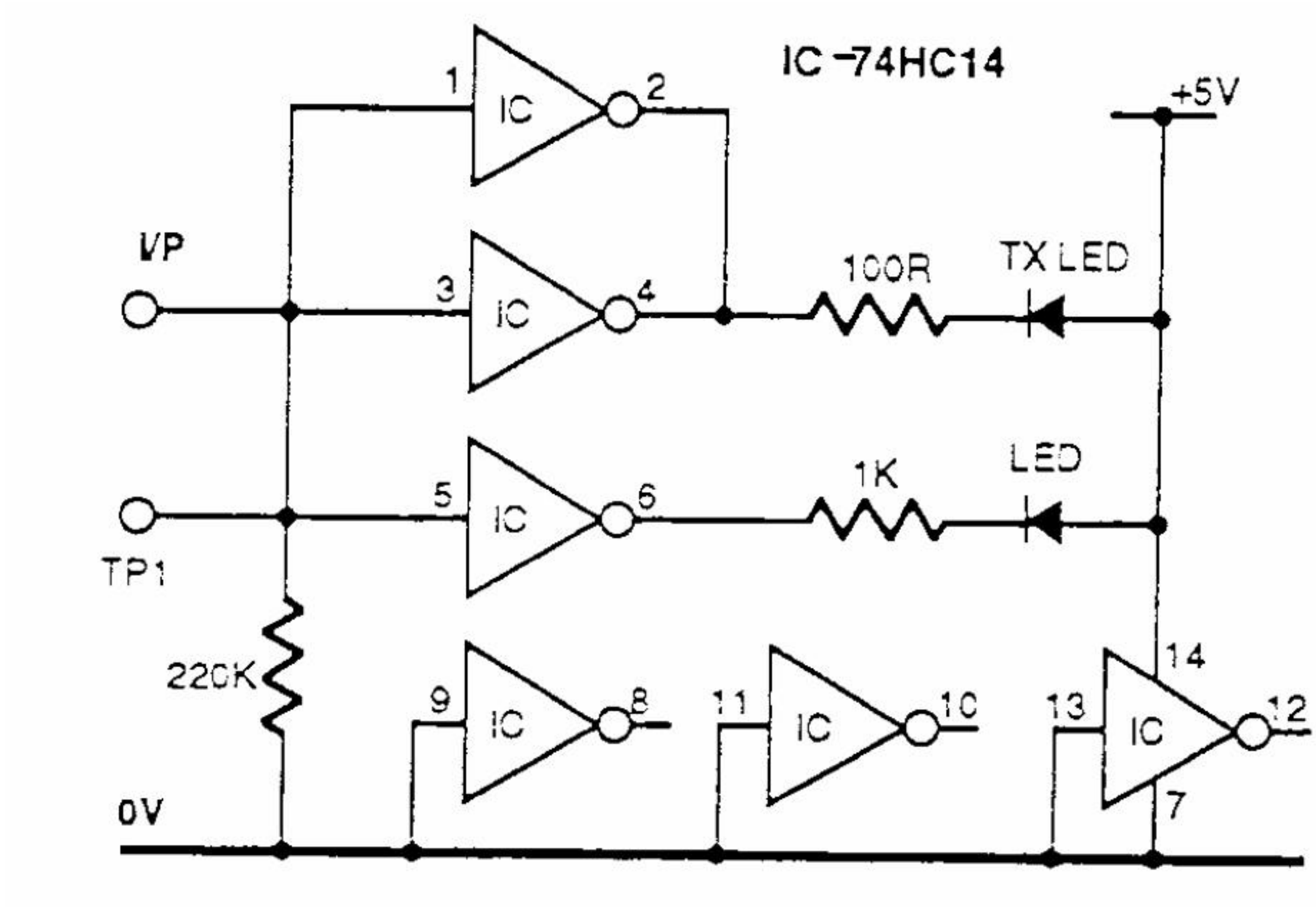
Item	Symbol	Condition	Minimum	Typical	Maximum	Unit
Forward Voltage	V_F	I_F = 240 mA		19.0		V
Brightness	I_V	I_F = 240 mA		13		cd
Total Radiated Power	Po	I_F = 240 mA		60		mW

Control dinamic LED

- Variatii mici ale tensiunii (mai ales in jurul tensiunii de deschidere) pot duce la variatii mari ale curentului
- Se prefera de multe ori controlul in curent al LED-ului

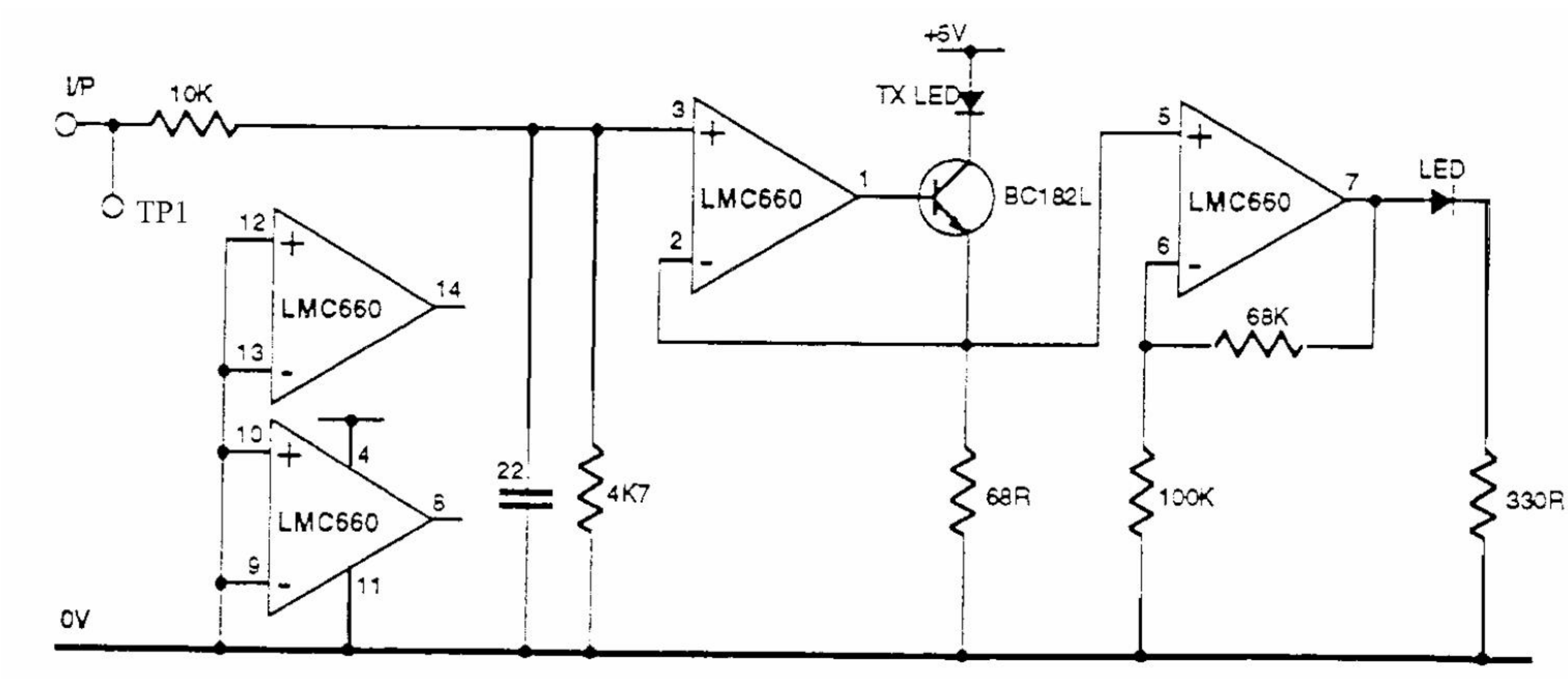
Control dinamic LED, Lab 1

- Control in tensiune
  - Schema electrică a emiţătorului în impuls



Control dinamic LED, Lab 1

- Control in curent
  - Schema electrică a emiţătorului optic analogic



Continuare

Dioda Laser

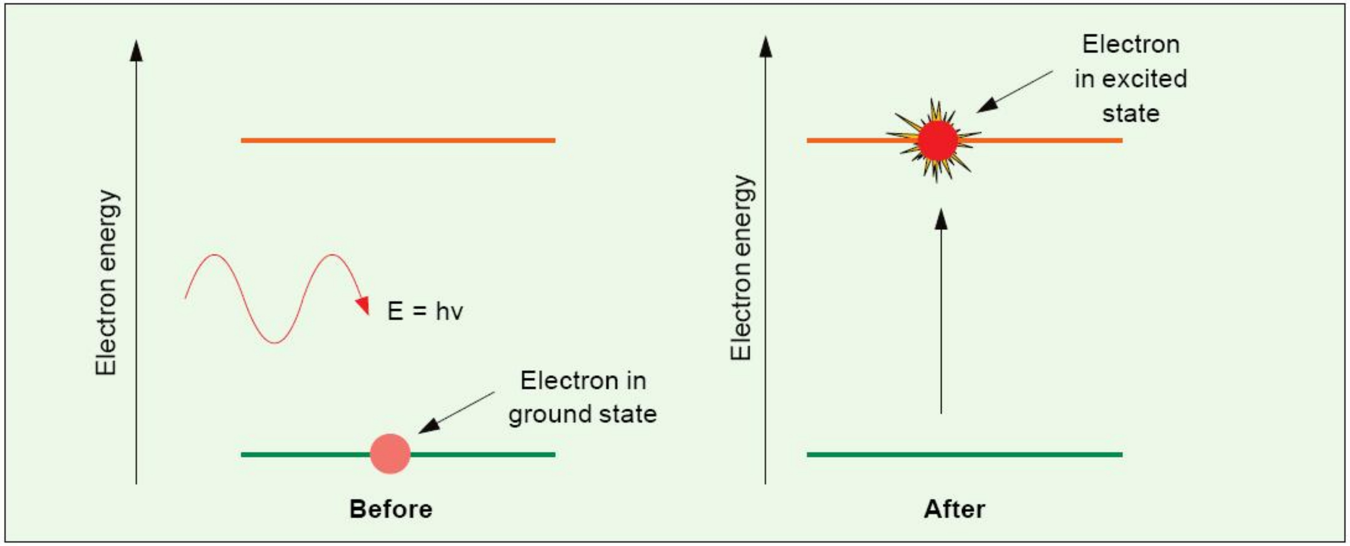
Capitolul 8

Caracteristici dioda laser

- Avantaje
  - Putere optica ridicata (50mW functionare continua, 4W functionare in impulsuri)
  - Precizie ridicata a controlului (impulsuri cu latimea de ordinul fs – femptosecunde) – viteza mare de lucru
  - Spectru ingust, teoretic LASER ofera o singura linie spectrala
  - Lumina coerenta si directiva (~80% poate fi cuplata in fibra)
- Dezavantaje
  - Cost (dispozitiv si circuit de comanda: controlul puterii si al temperaturii)
  - Durata de viata
  - Senzitivitate crescuta cu temperatura
  - Modulatie analogica dificila (de obicei cu dispozitive externe)
  - Lungime de unda fixa

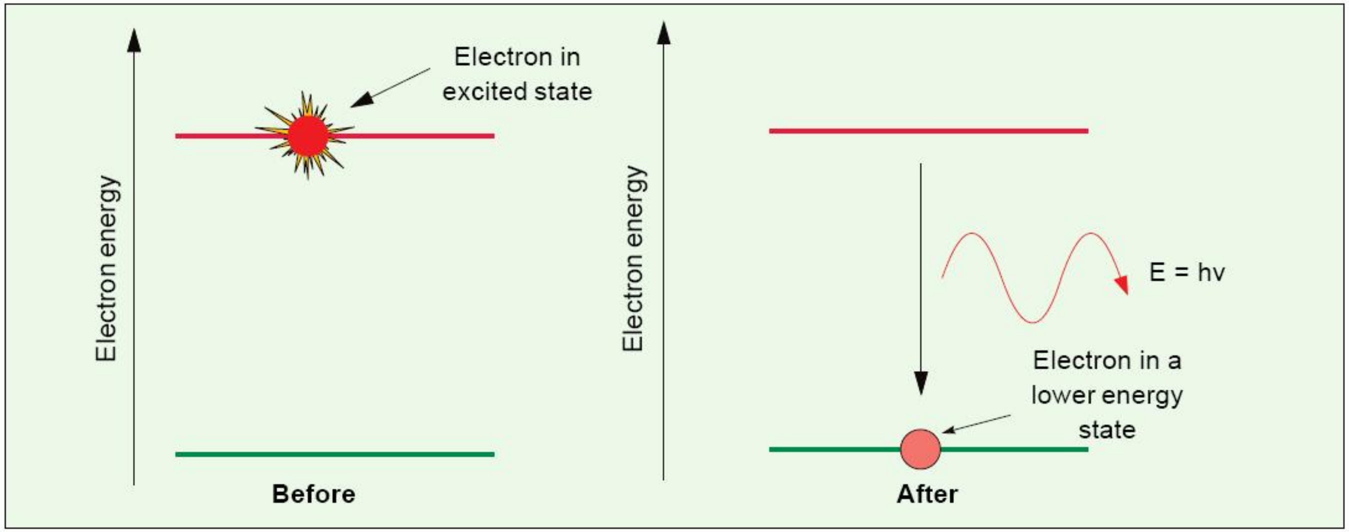
Dioda LASER – Principiu de operare

- 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



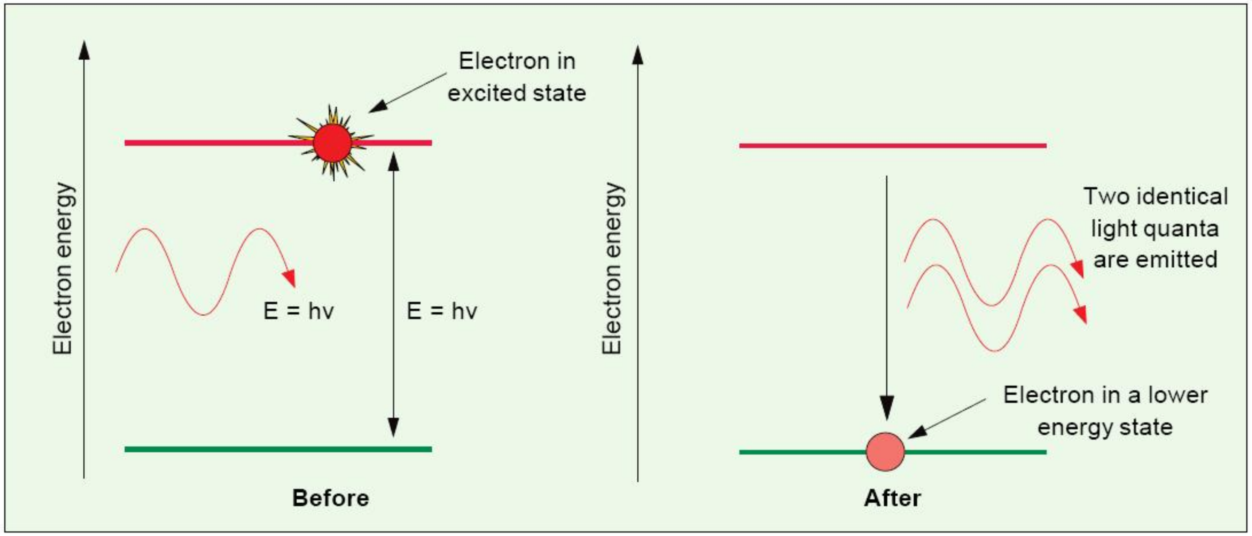
Dioda LASER – Principiu de operare

- 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



Detalii constructive

- Recombinarea unei perechi electron–gol necesita conservarea impulsului
- In Si si Ge aceasta conditie presupune aparitia unui foton intermediar (tranzitie indirecta) a carui energie se transforma in caldura
- Se utilizeaza aliaje de Ga Al As sau In Ga As P
- Spatierea atomilor in diferitele straturi trebuie sa fie egala (toleranta 0.1%) pentru a nu se introduce defecte mecanice la jonctiune
  - limitare a aliajelor utilizabile
  - aparitia defectelor
    - creste ineficienta (recombinari neradiative)
    - scade durata de viata a dispozitivului

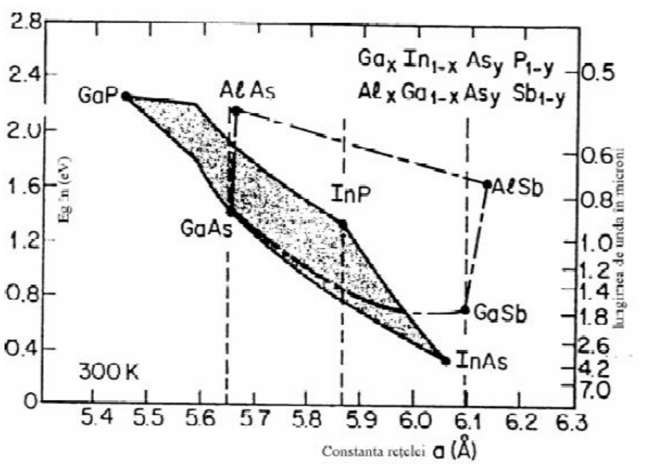
Lăţimea benzii interzise/lungime de undă pentru materialele uzuale

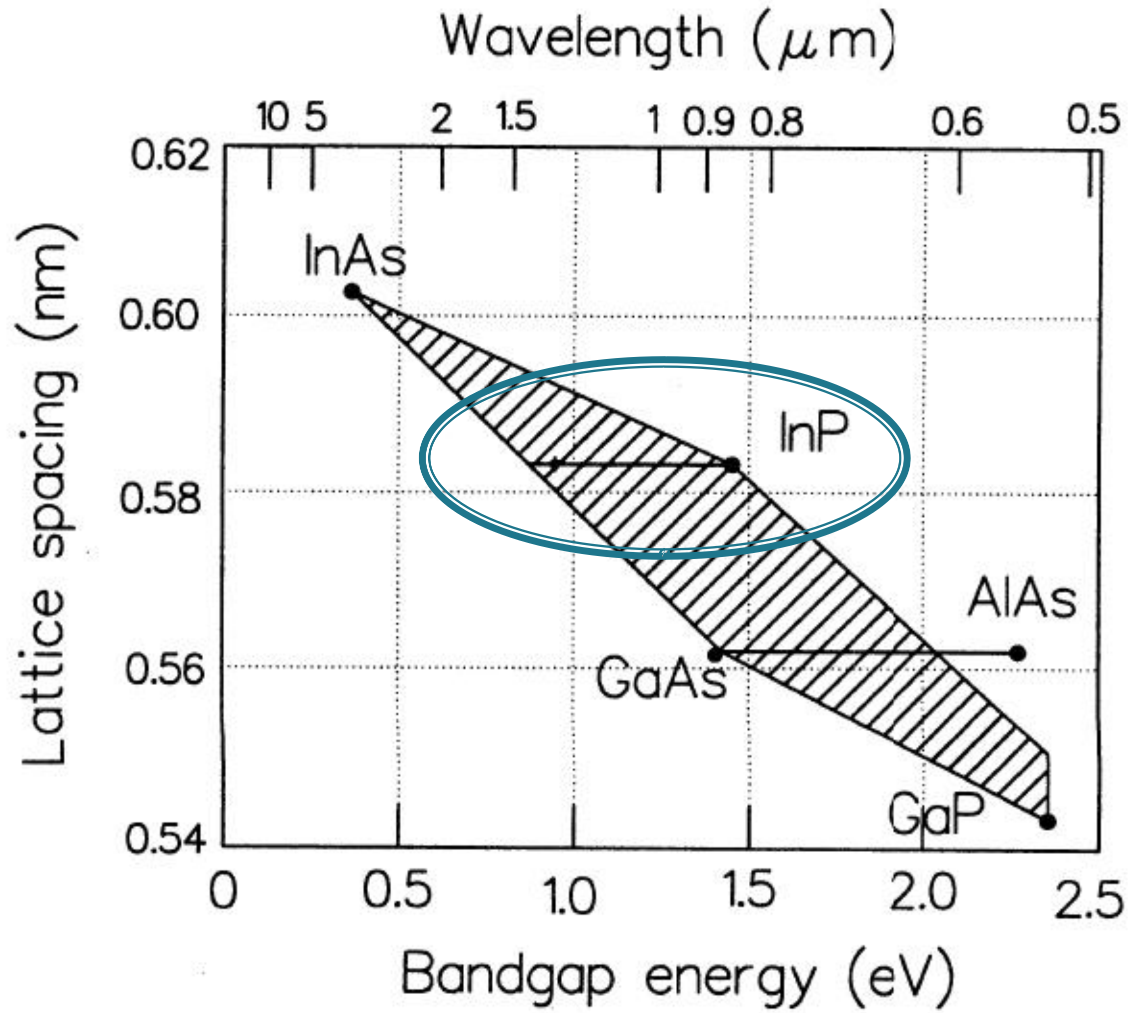
Material	Formula	Wavelength Range λ (μm)	Bandgap Energy W_g (eV)
Indium Phosphide	InP	0.92	1.35
Indium Arsenide	InAs	3.6	0.34
Gallium Phosphide	GaP	0.55	2.24
Gallium Arsenide	GaAs	0.87	1.42
Aluminium Arsenide	AlAs	0.59	2.09
Gallium Indium Phosphide	GaInP	0.64-0.68	1.82-1.94
Aluminium Gallium Arsenide	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 $6.6261 \cdot 10^{-34}$ Ws²
- 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, **$\Delta\lambda$**

Dependenţa benzii interzise de constanta reţelei



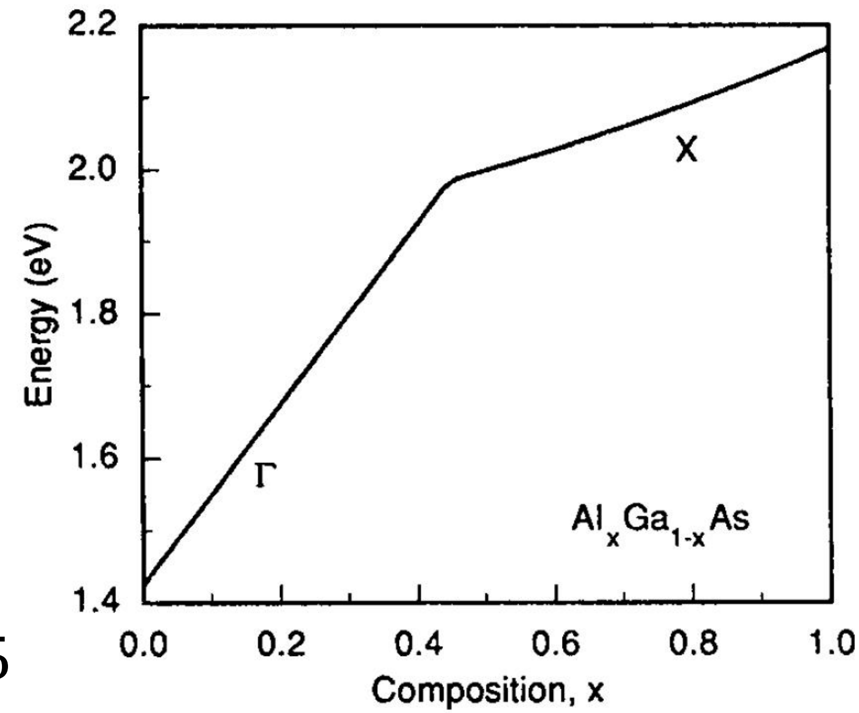


Materiale

- 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)
  - $In_xGa_{1-x}As_yP_{1-y}$
  - x,y concentratii relative in aliaj a materialelor corespunzatoare
  - x,y alese din considerente privind
    - lungimea de unda
    - spatierea atomilor

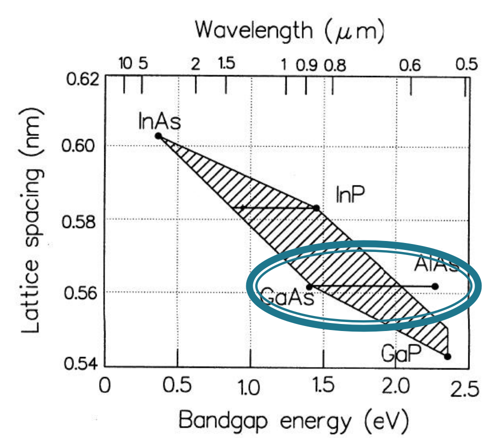
Materiale

- 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

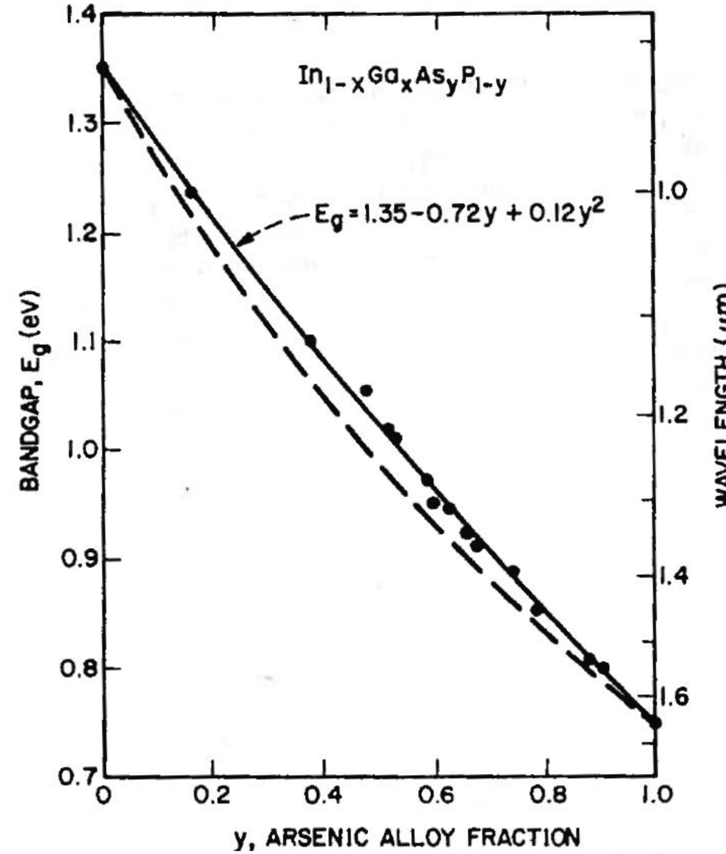
- Lungimi de unda mari
  - $In_xGa_{1-x}As_yP_{1-y}$
  - Tipic substratul este InP
    - Spatierea atomilor (lattice spacing) corespunzatoare InP

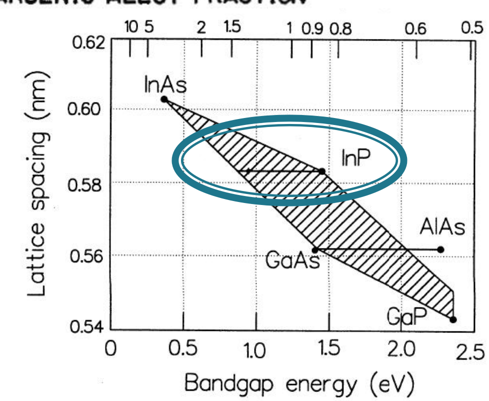
$$x = \frac{0.4526 \cdot y}{1 - 0.031 \cdot y}$$

  - 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,
    - $In_{0.282}Ga_{0.718}As_{0.611}P_{0.389}$





Principii LASER

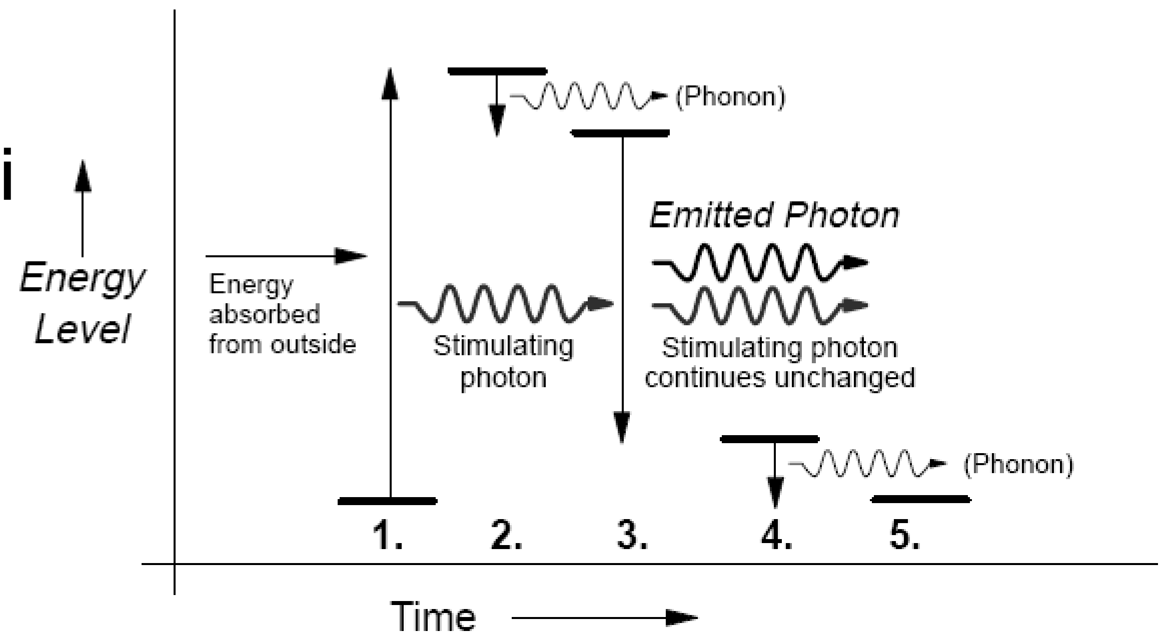
- Inversiune de populatie
  - necesara deoarece electronii au capabilitatea de a absorbi energie **la aceeasi frecventa** la care are loc emisia stimulata
  - se defineste probabilistic: probabilitatea de emisie stimulata sa fie mai mare decat probabilitatea de absorbtie

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

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

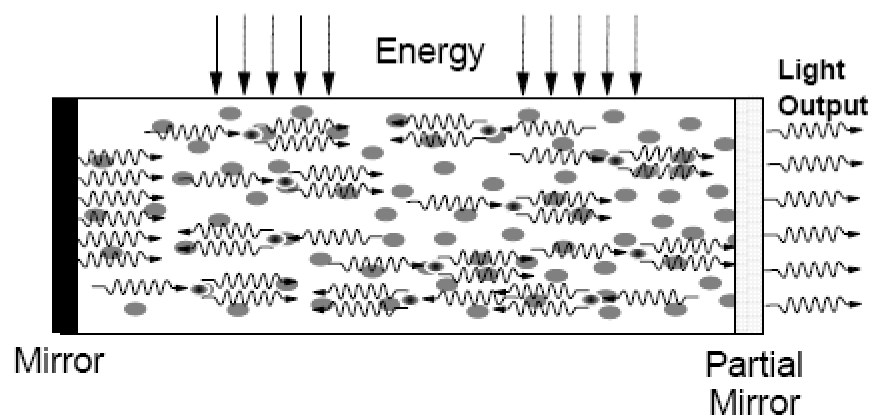
Materiale cu 4 nivele energetice

- 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



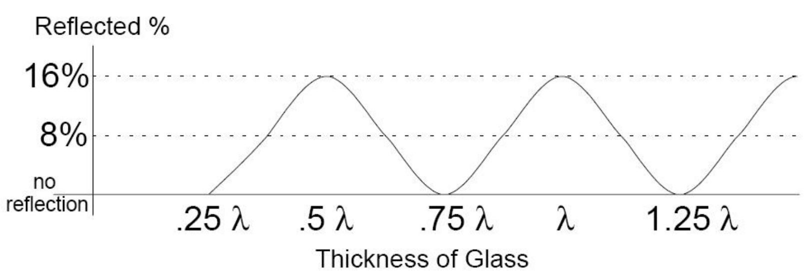
Dioda LASER – Principiu de realizare

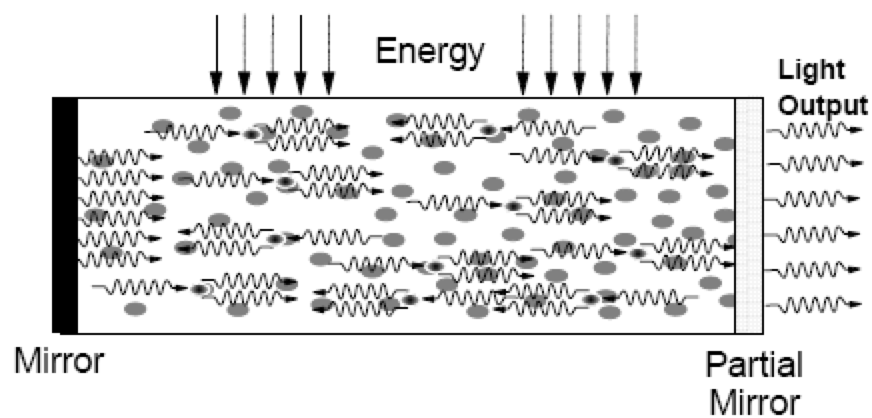
- Pentru ca emisia stimulata sa apara, fotonii emisi trebuie sa ramana in contact cu materialul o perioada mai mare de timp – 2 oglinzi necesare
- Pentru a permite extragerea radiatiei e necesar ca una din oglinzi sa fie partial reflectanta



Dioda LASER – Principiu de realizare

- Pentru diodele laser utilizate in comunicatii reflectivitatea oglinzilor nu trebuie sa fie foarte mare
- Interfata semiconductor aer ofera un coeficient de reflexie de ~6% dar poate ajunge la 36% pentru lungimea de unda de operare (vezi lamela dielectrica)





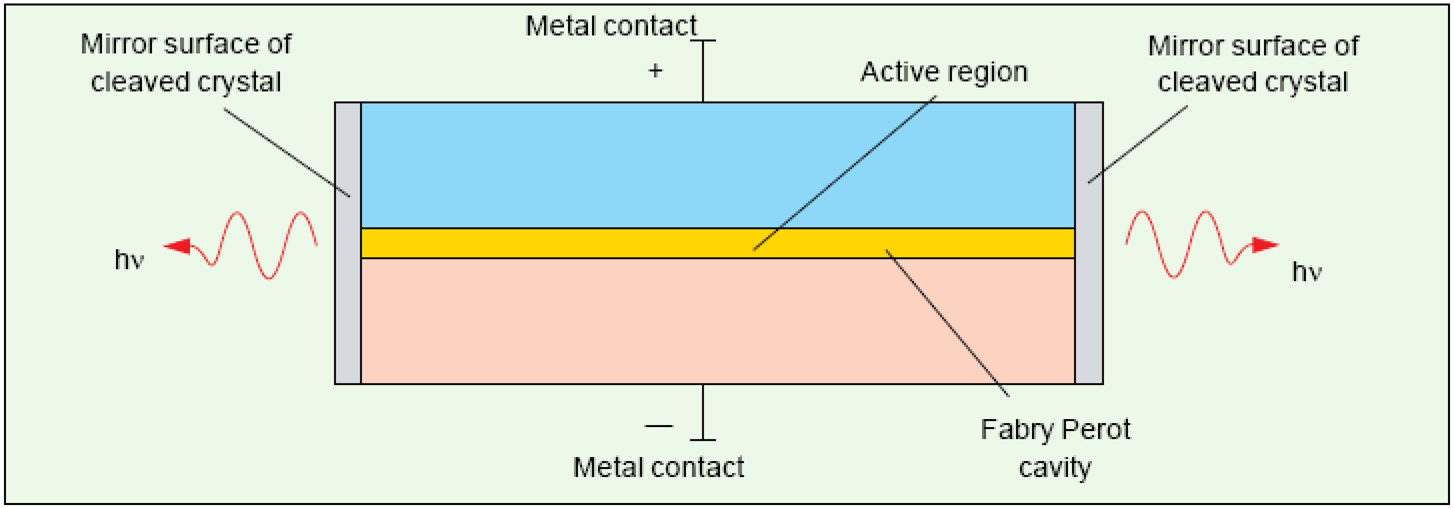
Dioda LASER – Principiu de realizare

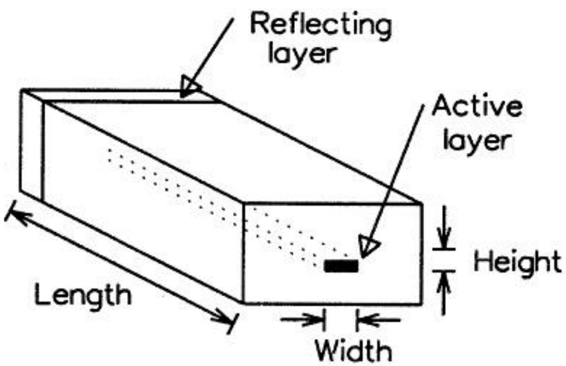
- Pentru a realiza
  - coerenta radiatiei
  - interferenta constructiva intre radiatiile incidente si reflectate de oglinzi,
- distanta intre oglinzi trebuie sa fie un multiplu a jumatate din lungimea de unda

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

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

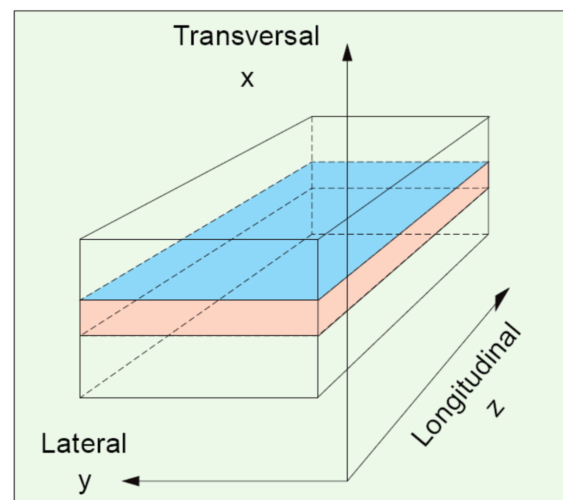
Dioda LASER Fabry Perot



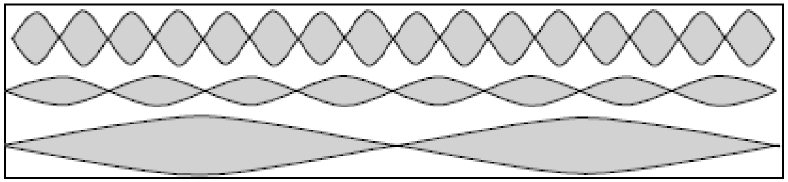


Height: 0.1 – 0.2 μm
Length: 250 – 500 μm
Width: 5 – 15 μm
Sides: rough–cut
Front: cleaved
Back: 100% reflector

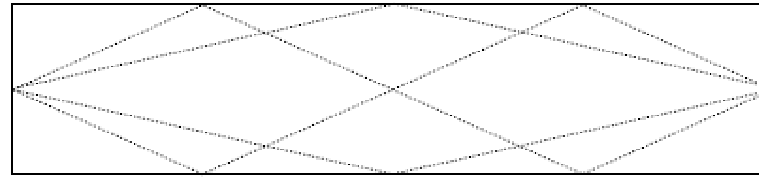
Definirea directiilor in dioda LASER



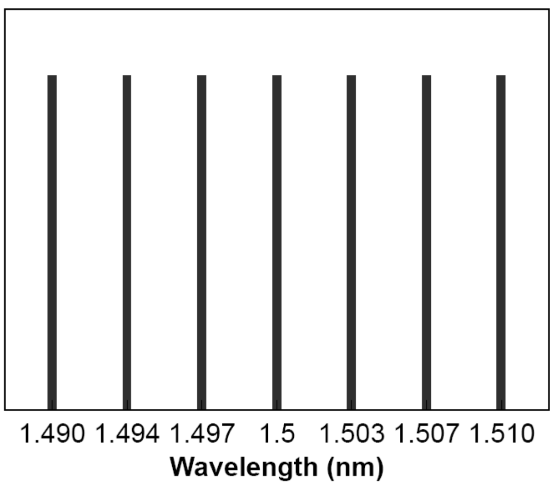
Spectrul diodei LASER



Longitudinal Modes



Lateral Modes

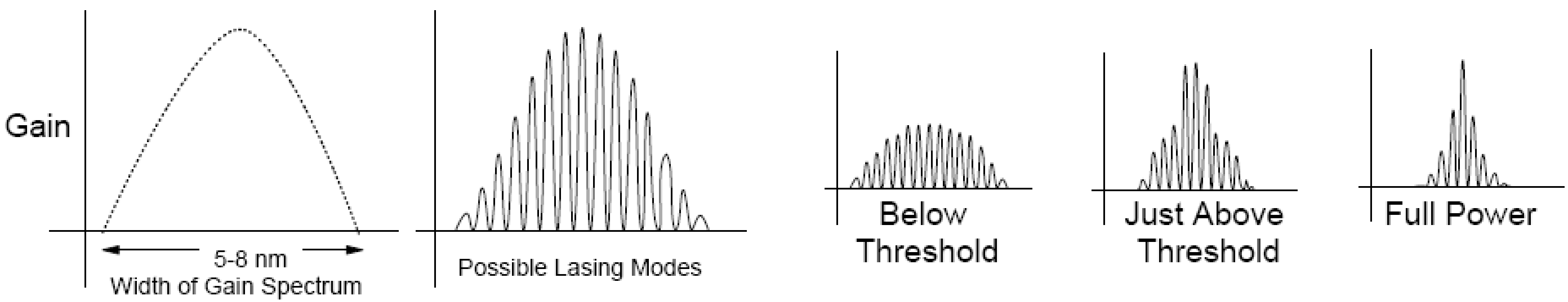


$$f_k = k \cdot \frac{c_0}{2 \cdot n \cdot L} \qquad \Delta f = \frac{c_0}{2 \cdot n \cdot L}$$

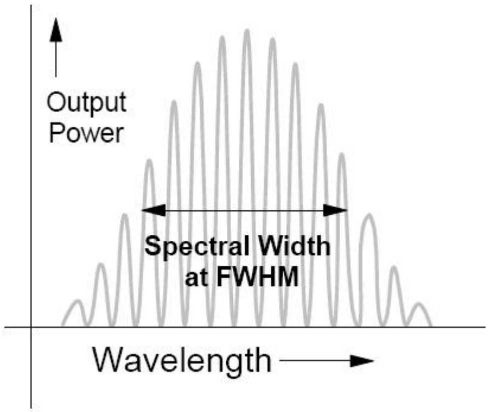
$$\Delta\lambda \cong \frac{\lambda_0^2}{2 \cdot n \cdot L}$$

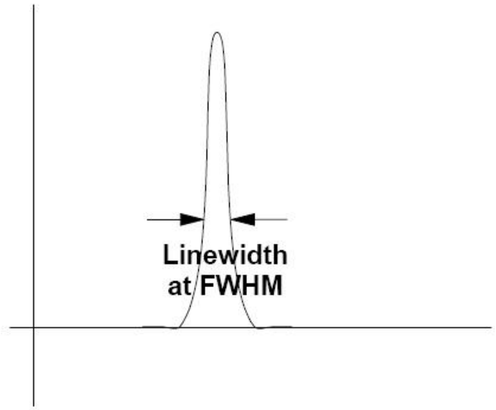
Spectrul diodei LASER

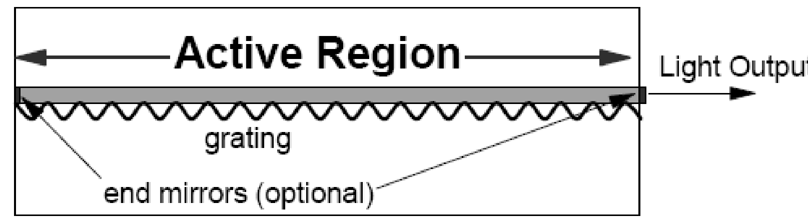
- Castigul diodei laser (eficacitatea aparitiei emisiei stimulate) depinde
  - de caracteristicile energetice ale materialului din care e realizata dioda
  - de energia pompata din exterior (curentul prin dioda)

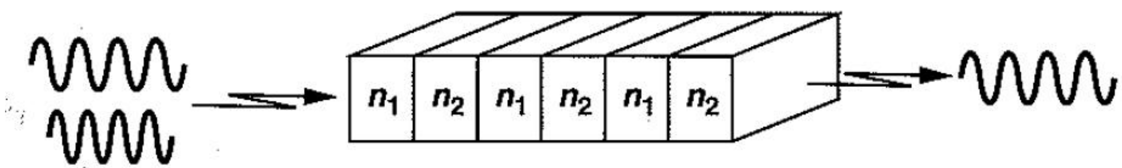


Distributed Feedback (DFB) Lasers

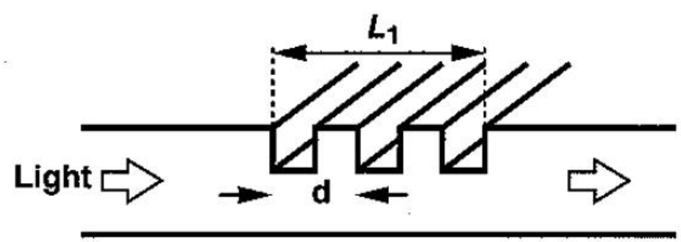








(a)

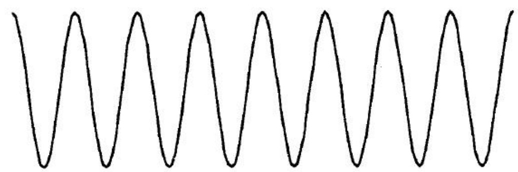


(b)

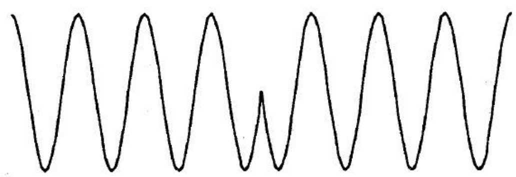
Filtre spatiale in regiunea activa

Distributed Feedback (DFB) Lasers

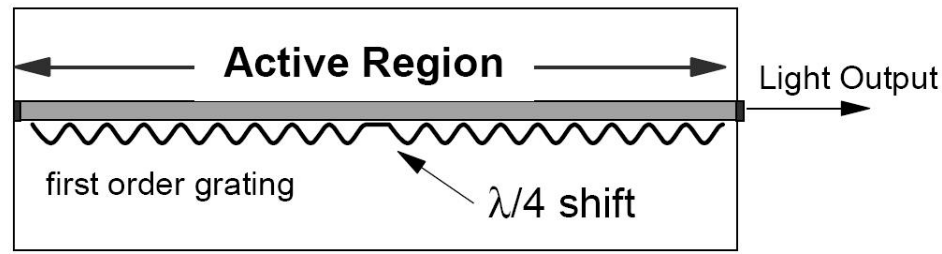
- Pentru operarea in impulsuri, un salt de λ/4 ingusteaza suplimentar spectrul diodei laser

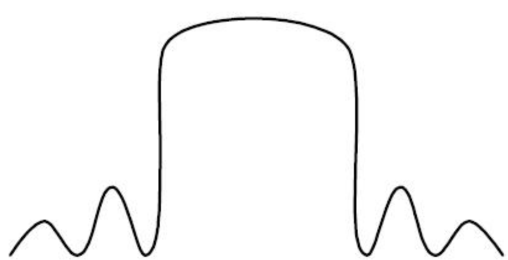


(a)

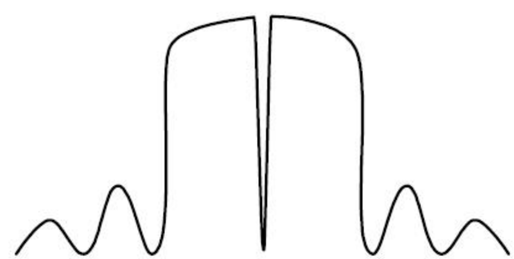


(b)





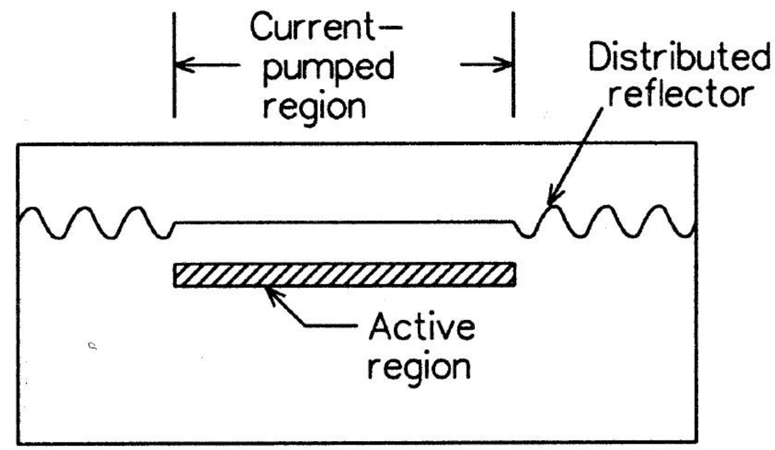
Reflection Characteristic
without Phase Shift

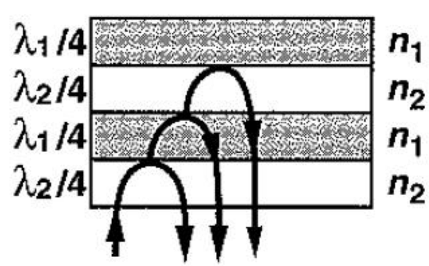


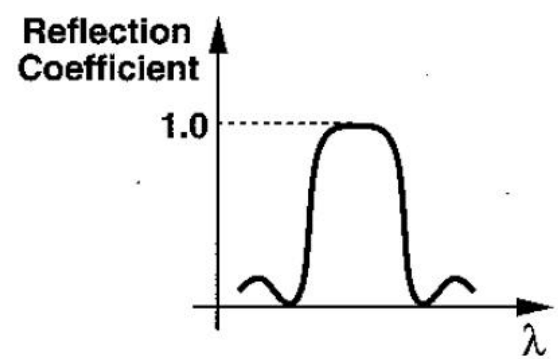
Reflection Characteristic
Phase Shifted grating

Distributed Bragg Reflector (DBR) Lasers

- Se utilizeaza suprafete reflective selective pentru filtrare optica





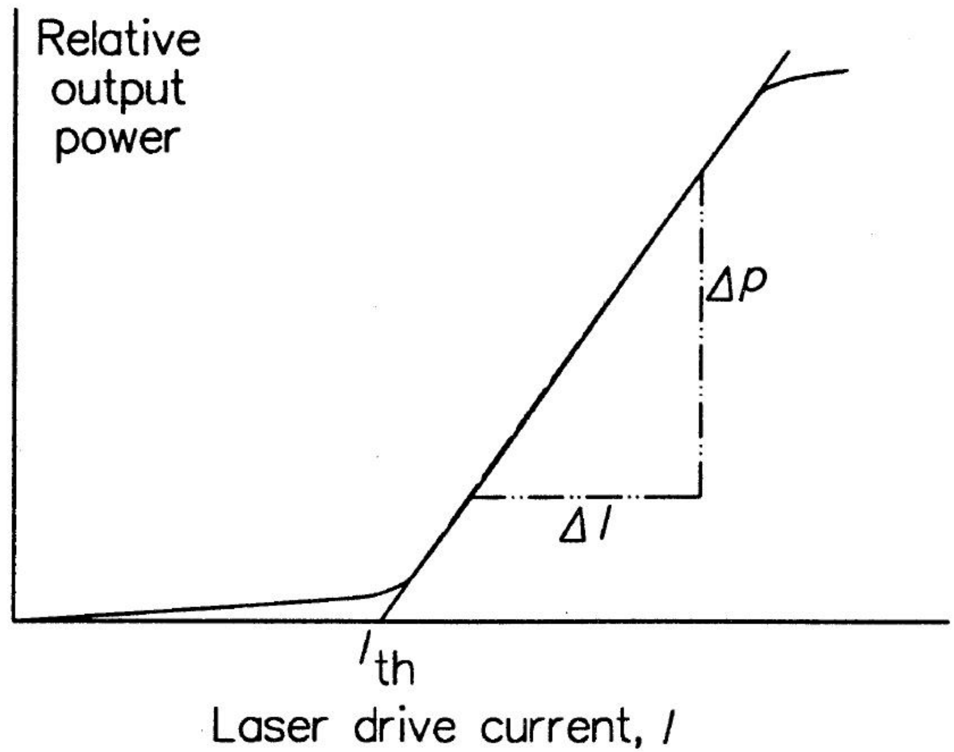


Caracteristici curent tensiune

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

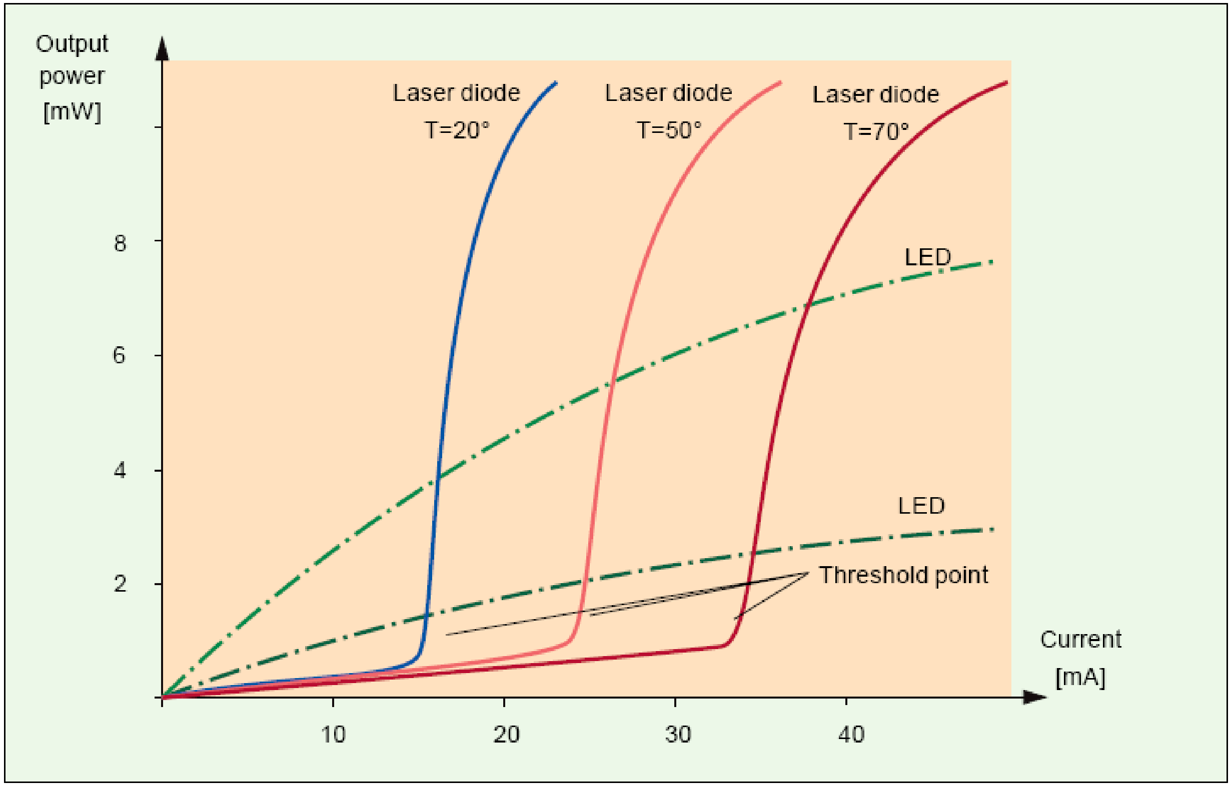
$$I > I_{th}$$

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



Temperatura si îmbatrânire

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

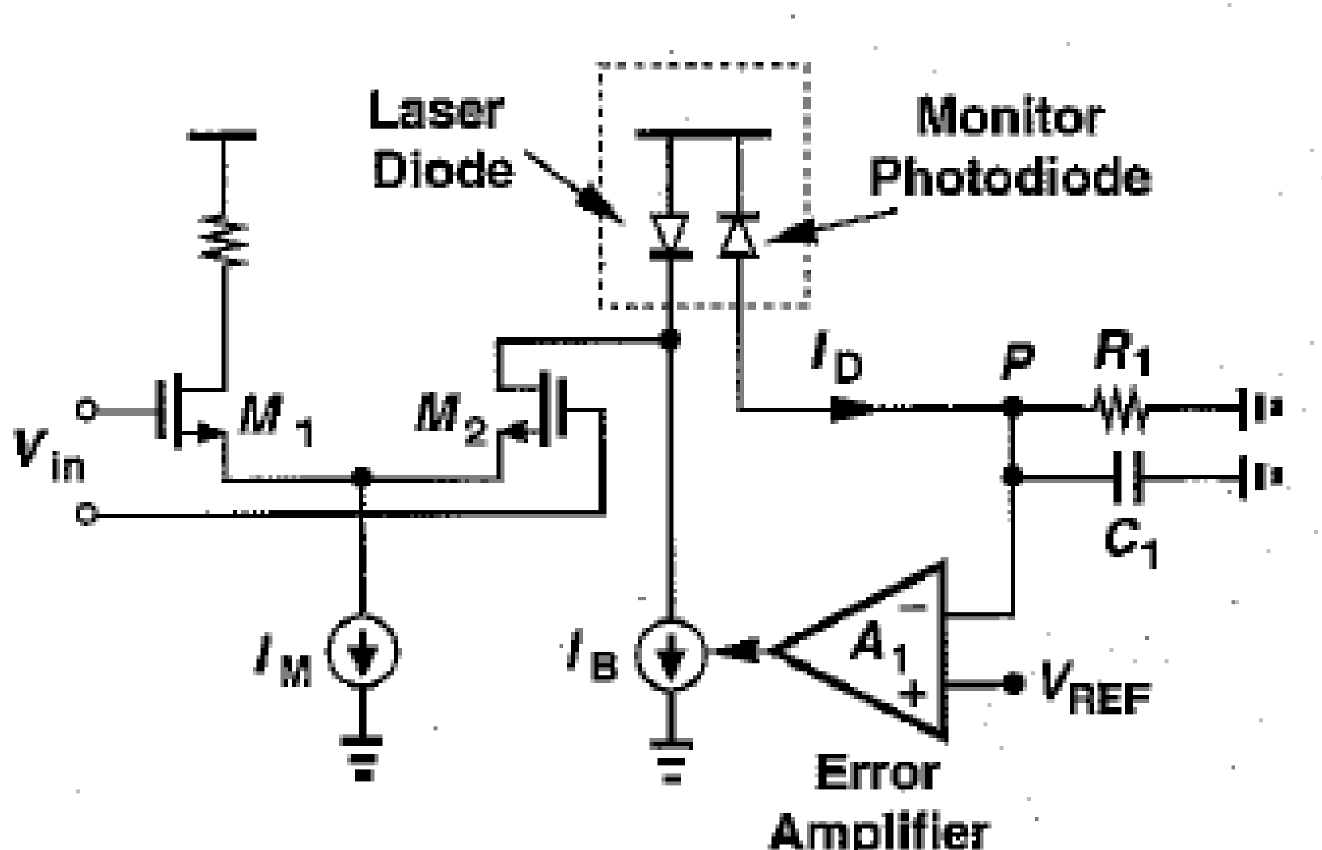


Dependenta de temperatura

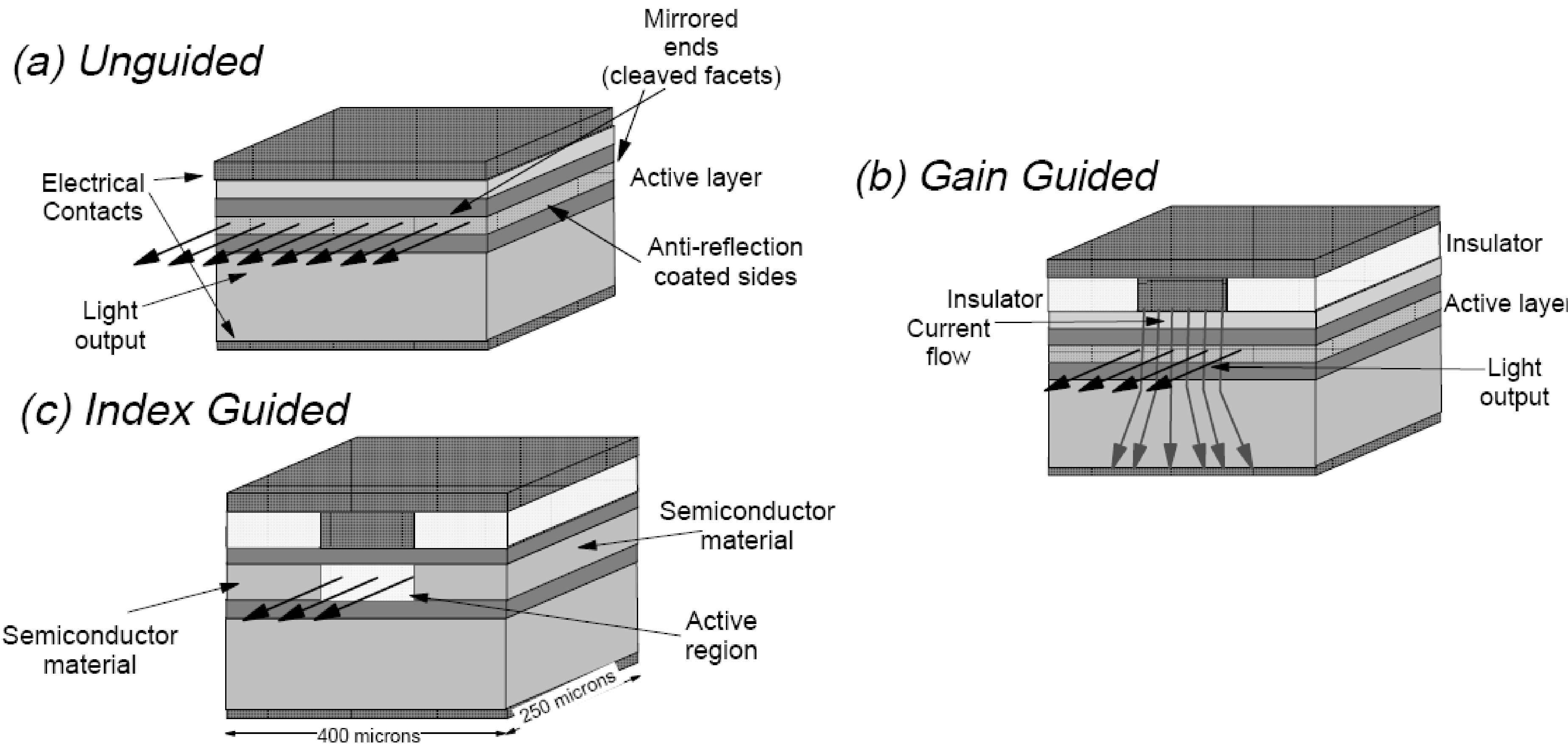
- Dependenta de temperatura a curentului de prag este exponentiala
- $$I_{th} = I_0 \cdot e^{T/T_0}$$
- I_0 e o constanta determinata la temperatura de referinta

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

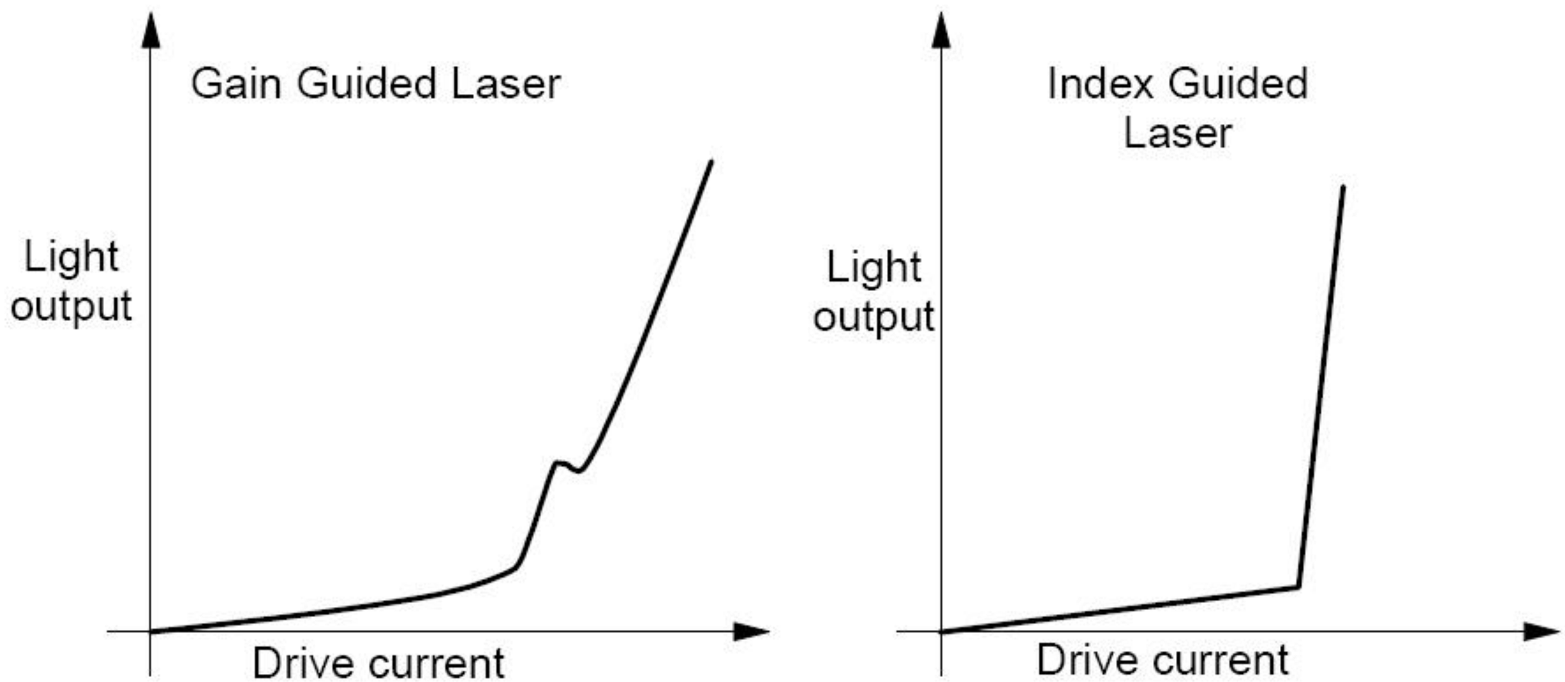


Direcţionarea luminii în laser-ul Fabry Perot

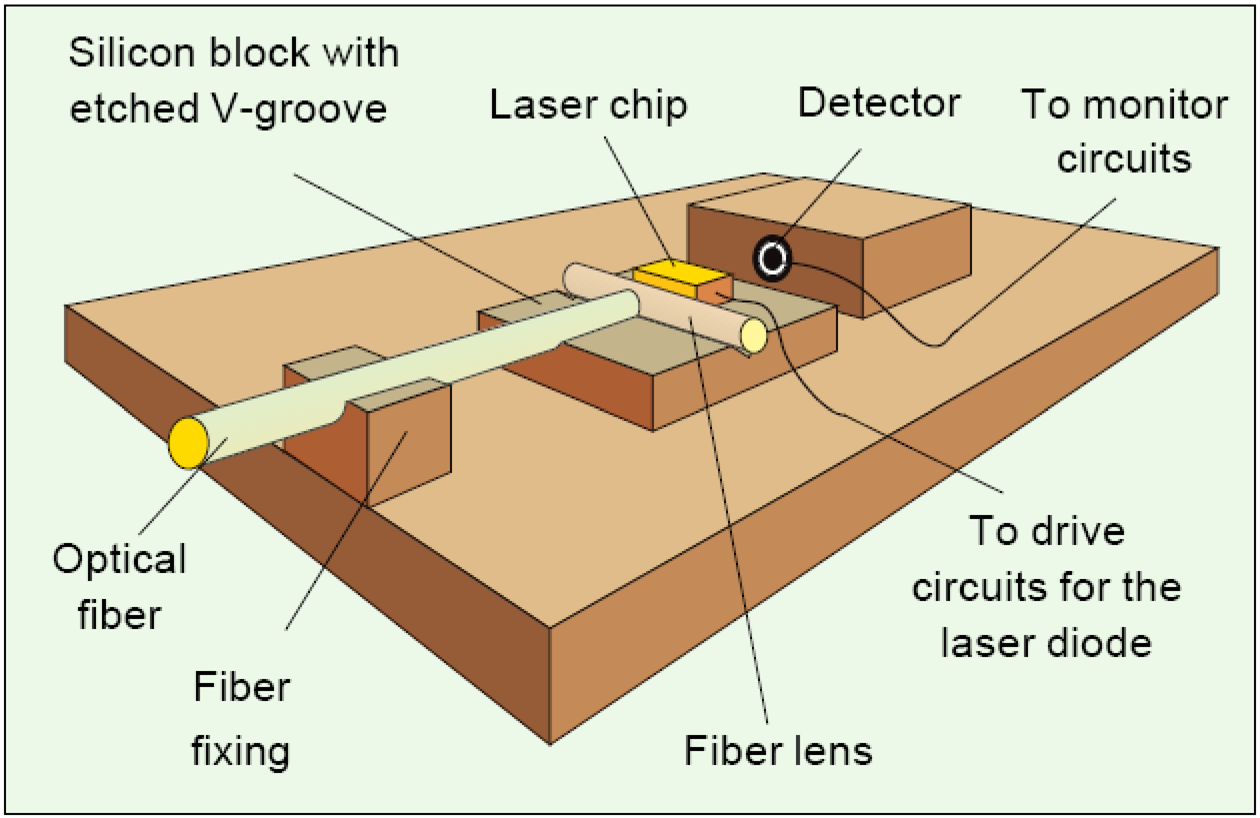


Efectul ghidarii

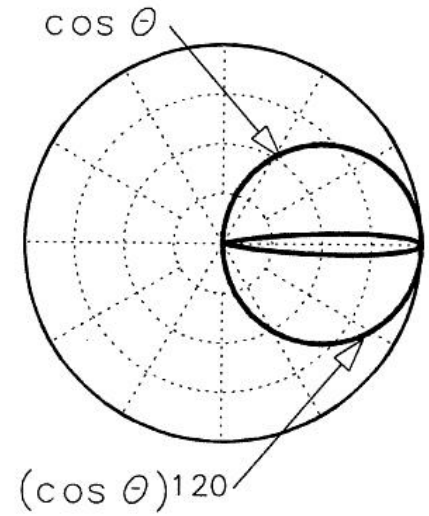
- Gain guided – 8÷20 linii spectrale (5÷8 nm)
- Index guided – 1÷5 linii spectrale (1÷3 nm)



Cuplarea luminii în fibră



Directivitatea radiatiei exterioare



- Sursa lambertiana

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

  - Eficienta cuplarii in fibra

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

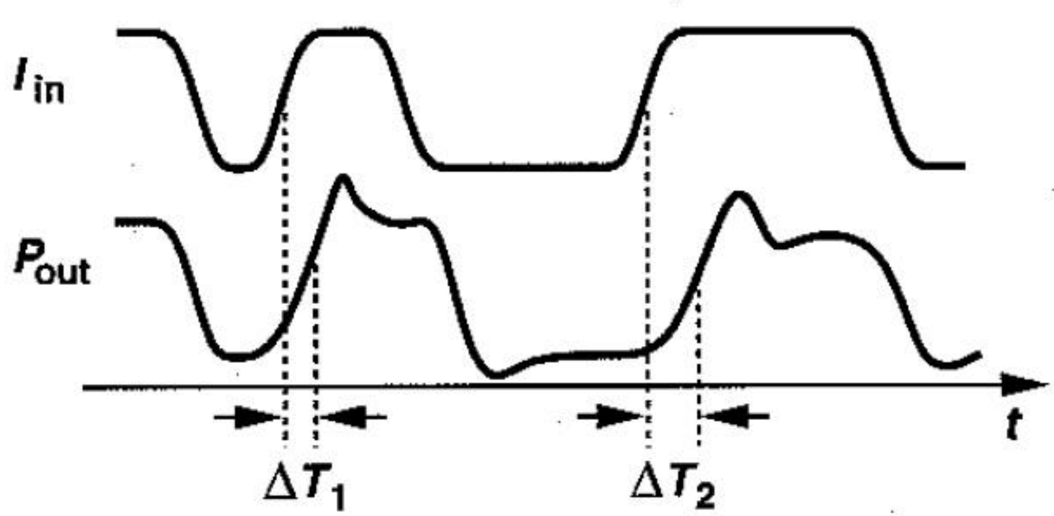
$$\eta = \frac{P_f}{P_s} = NA^2 \cdot \left(\frac{a}{r_s}\right)^2 \cdot \left(\frac{g}{g+2}\right)$$

- Aproximatie Lambertiana pentru surse cu directivitate crescuta

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

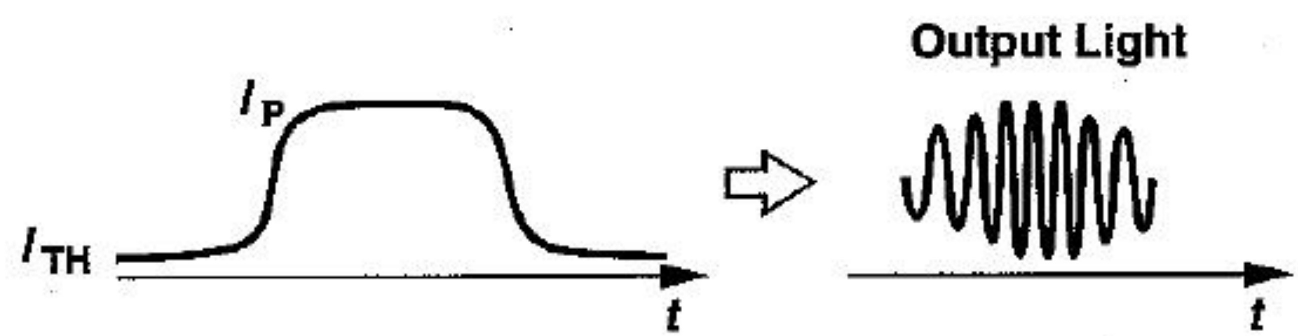
Turn-on delay

- 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



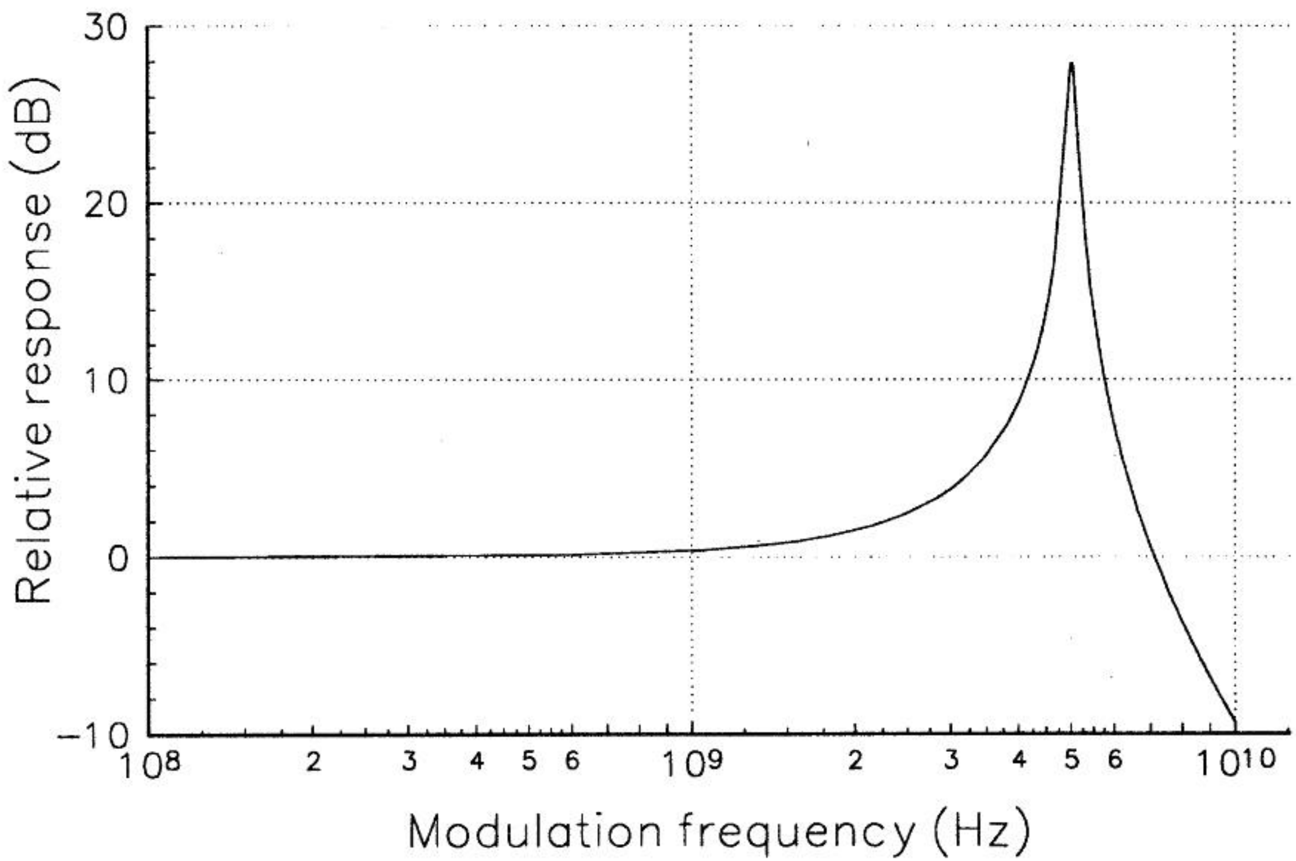
Chirping

- 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)



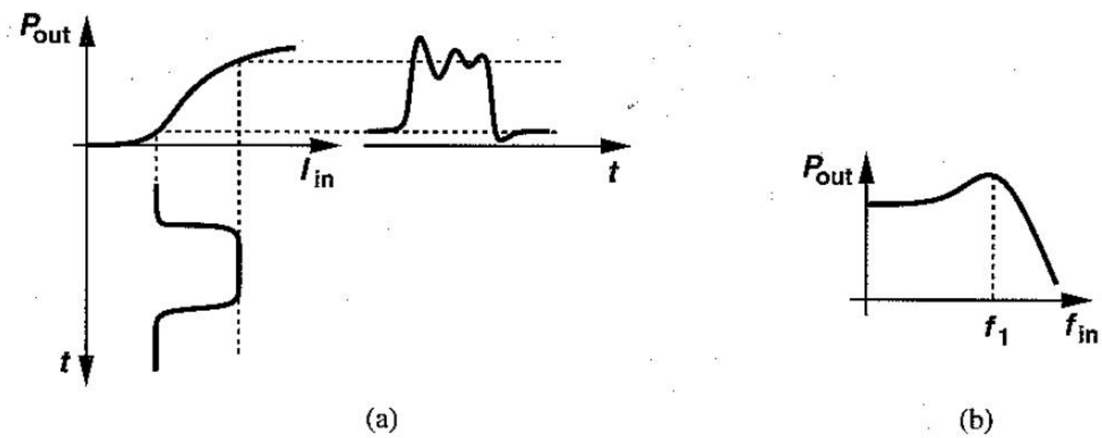
Raspunsul unei diode laser

- 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



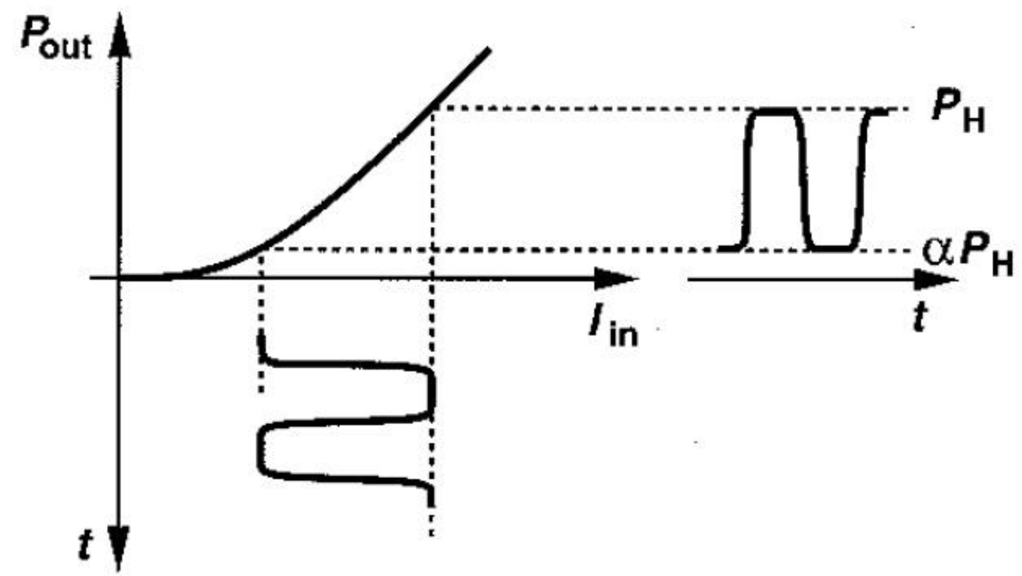
Oscilatii de relaxare

- 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

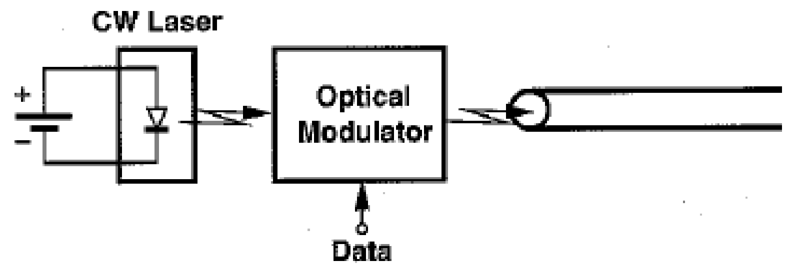
$$ER = \frac{P_H}{\alpha \cdot P_H} = \frac{1}{\alpha}$$

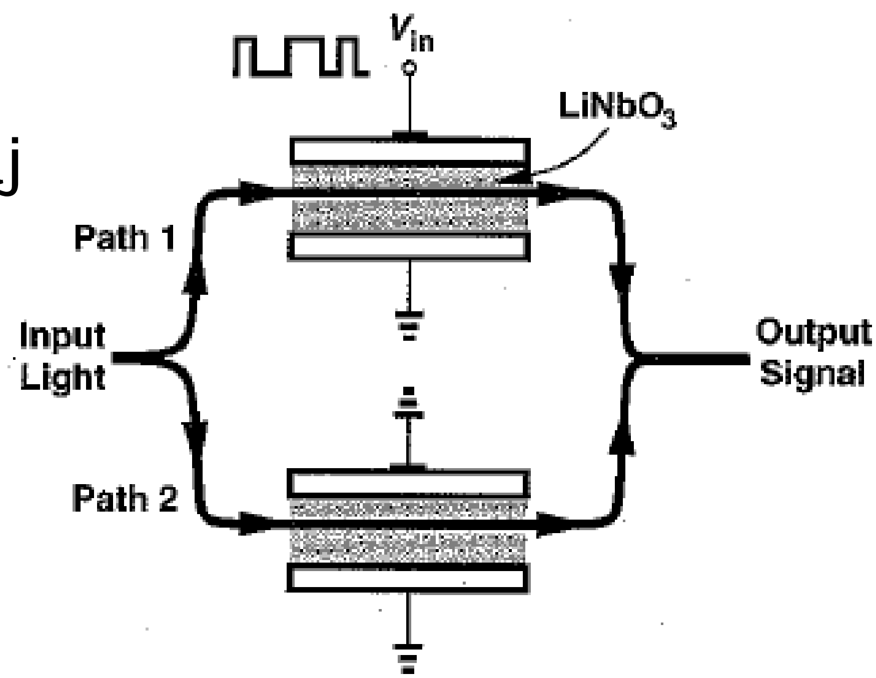
- Raportul semnal zgomot scade cu (1−α)
- Tipic ER = 10÷15dB



Modulaţie optică

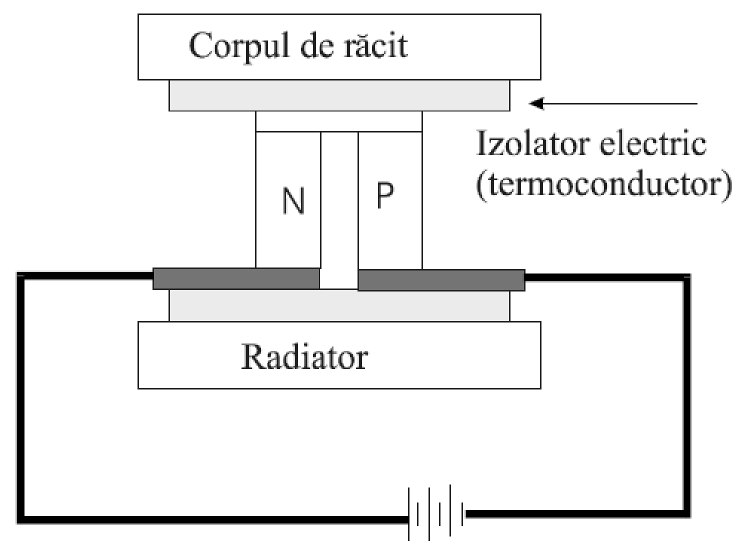
- Pentru viteze mari se prefera utilizarea emisiei continue si modularea optica a radiatiei
- In $LiNbO_3$ viteza luminii depinde de campul electric, ceea ce permite introducerea unui defazaj egal π
- Creste complexitatea circuitului de control
- Tensiuni de 4÷6 V necesare





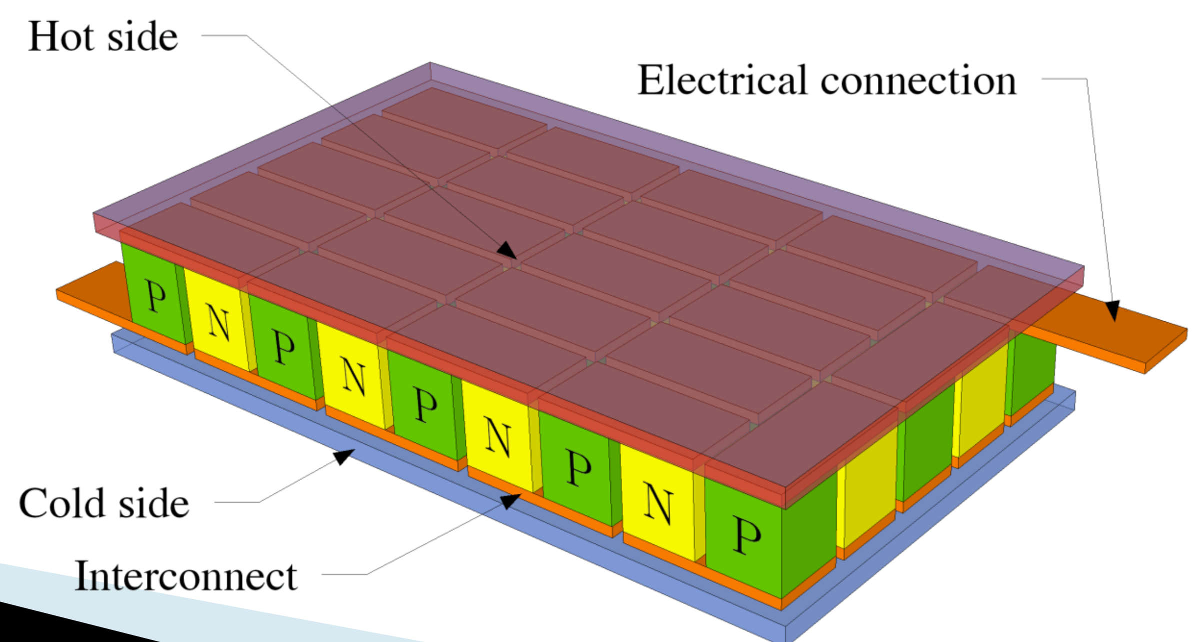
Dispozitiv termoelectric (Peltier)

- 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

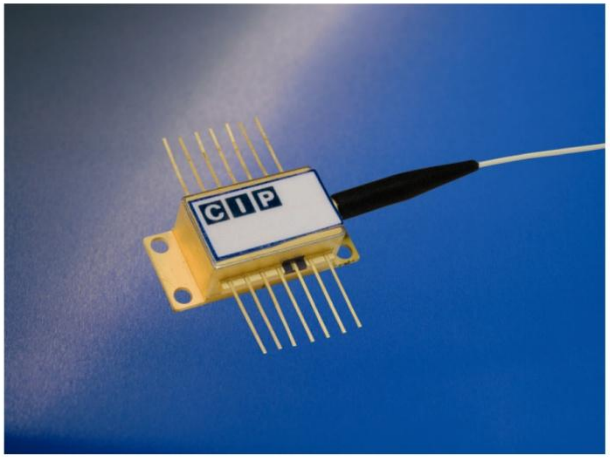


Dispozitiv termoelectric (Peltier)

- 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

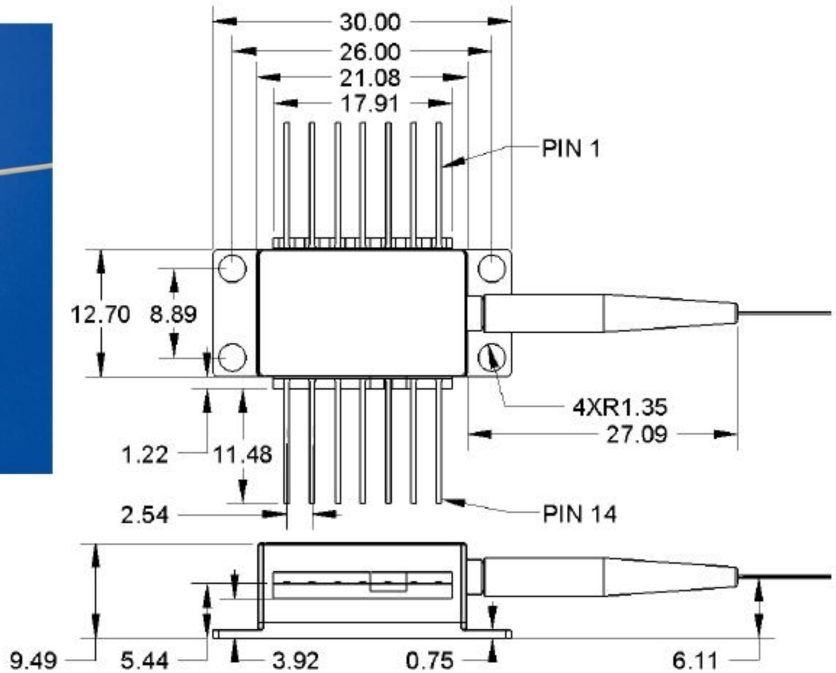


1550nm DFB Laser



Mechanical Drawing

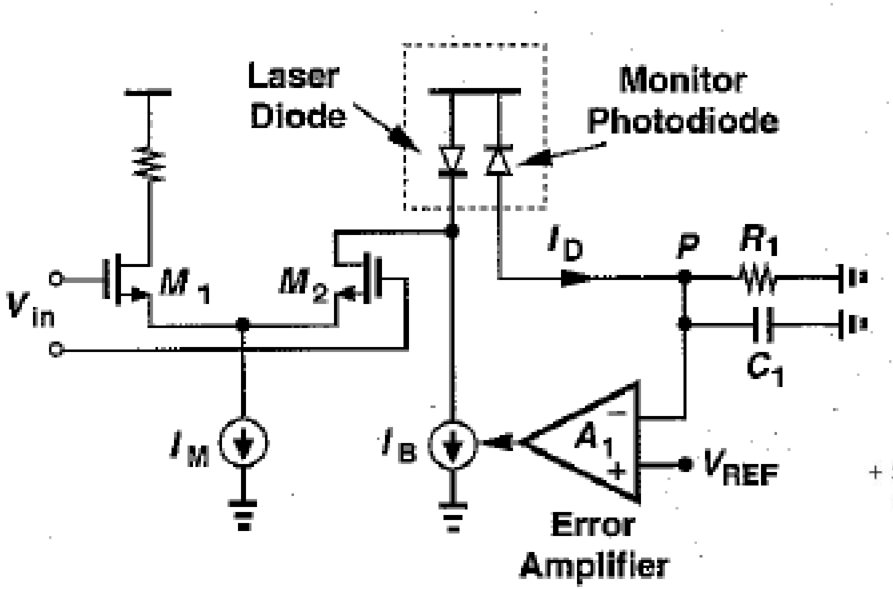
All units in mm



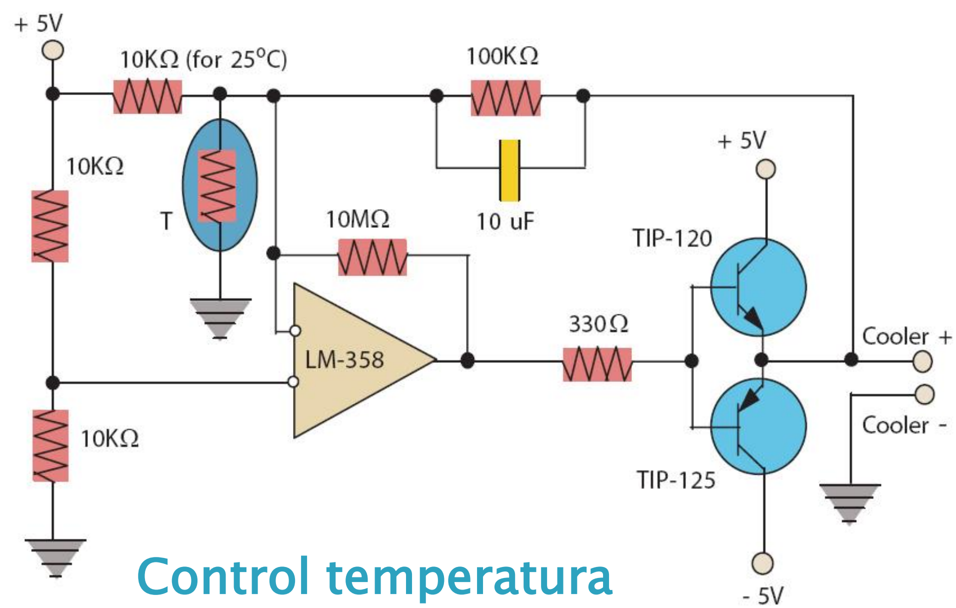
Pin out

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



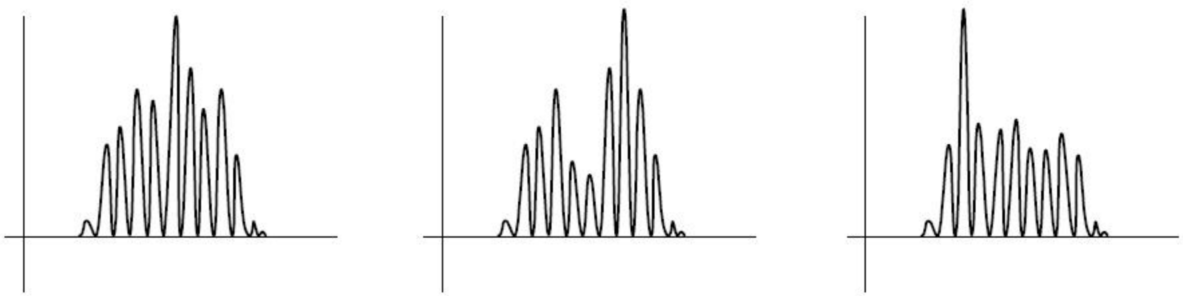
Control putere optica



Control temperatura

Alte caracteristici DL

- Mode hopping – salt de mod (hole burning)

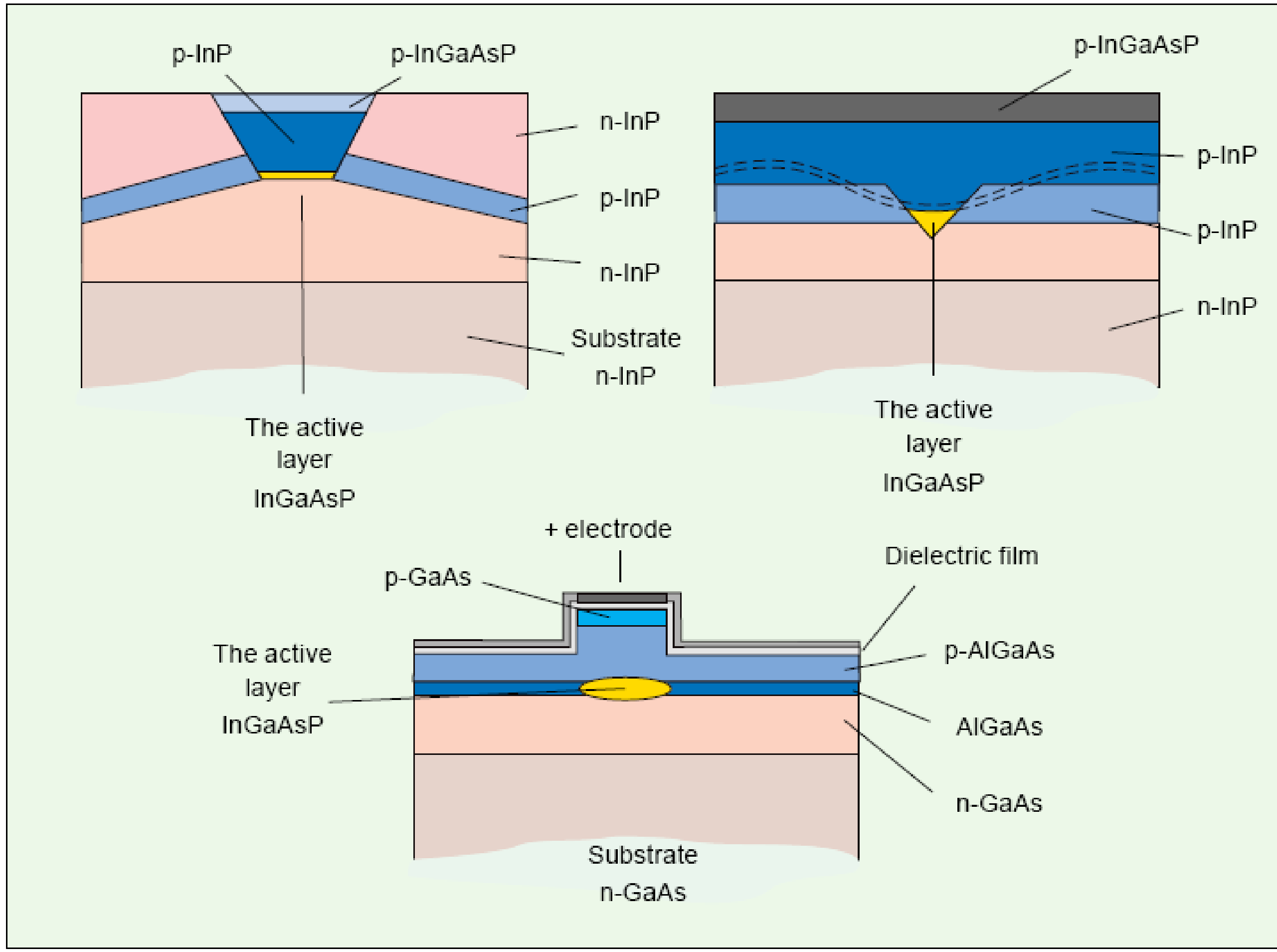


- RIN – Relative Intensity Noise (generat de emisia spontana)
- Zgomot de faza (idem) – necesitatea modulatiei in amplitudine
- Zgomot intercavitati (reflexiile din exterior in zona activa)
- Drift – variatia parametrilor cu varsta si temperatura (in special distanta intre oglinzi)

Diode LASER cu heterojuncţiune

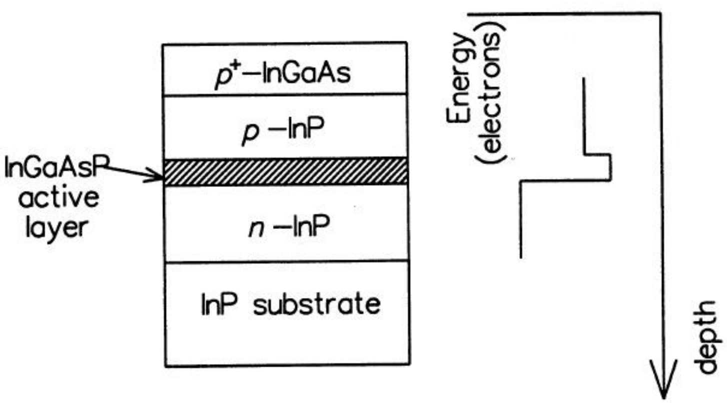
Heterojunctiune ingropata

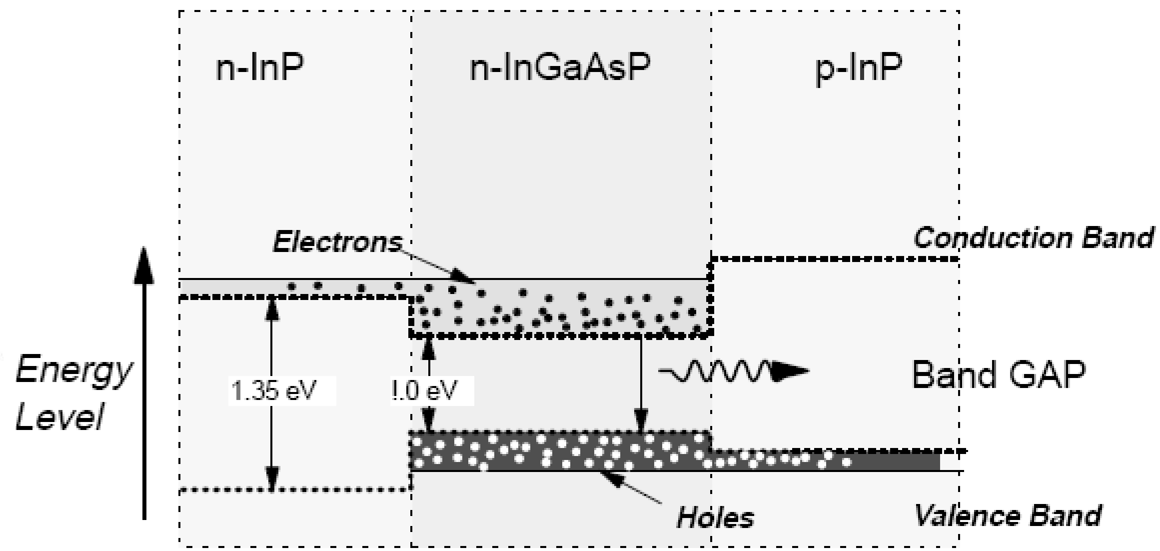
Heterojunctiune muchie (ridge)



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



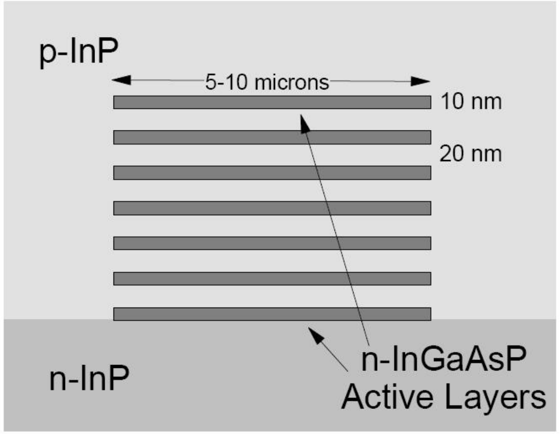


Quantum Well Laser

- 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

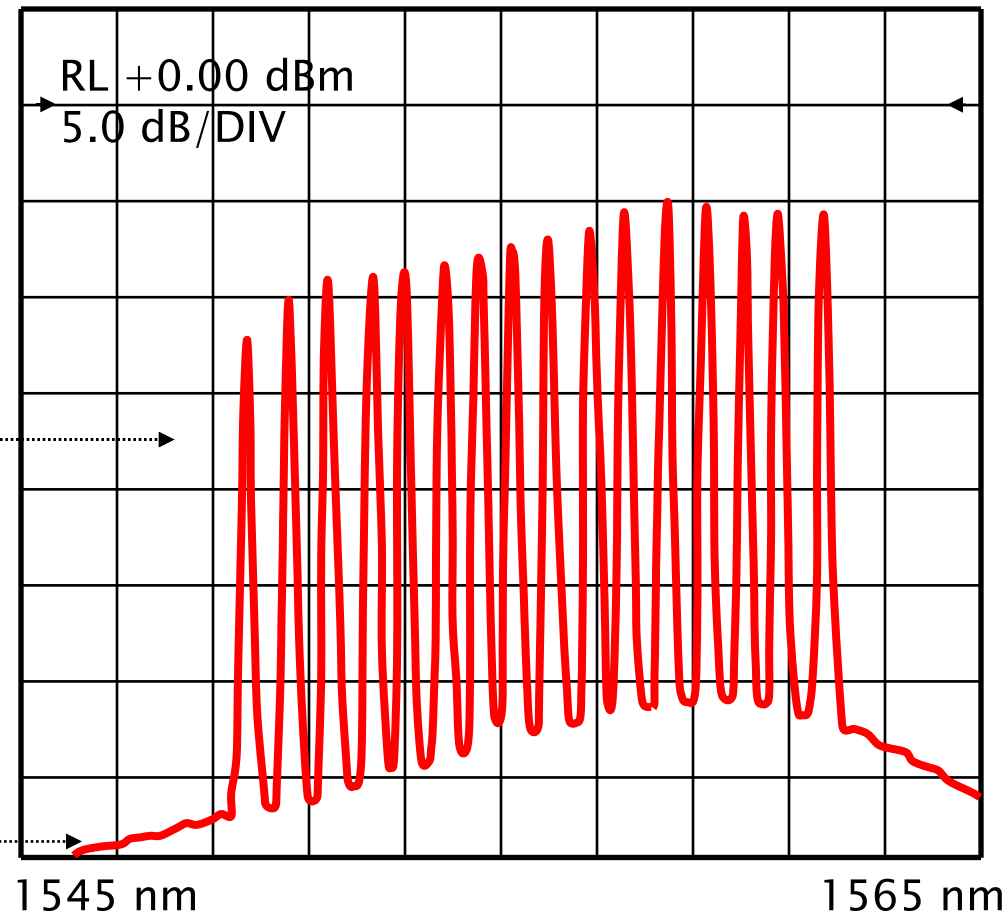


- Avantaje
  - curent de prag redus
  - stabilitate crescuta a frecventei la functionarea in impuls
  - latime mica a liniilor spectrale
  - zgomot redus

Spectrul WDM – Wavelength Division Multiplexing

Canale: 16
Spaţiere: 0.8 nm

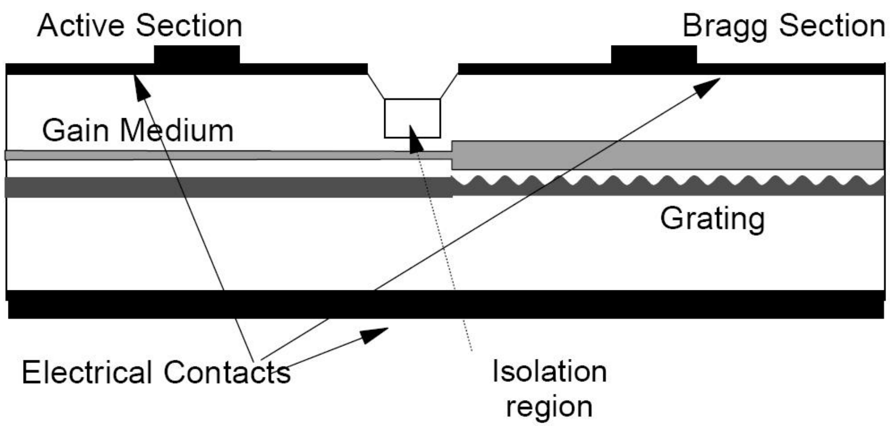
Emisie spontană
Amplificată (ASE)

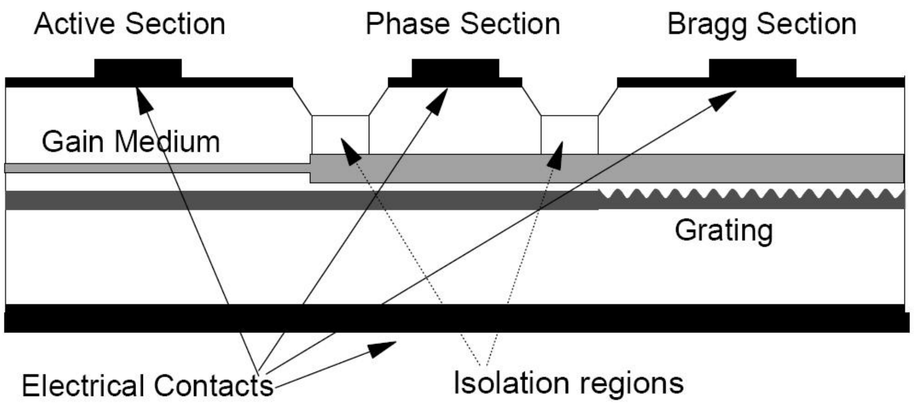


Diode laser reglabile

- 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

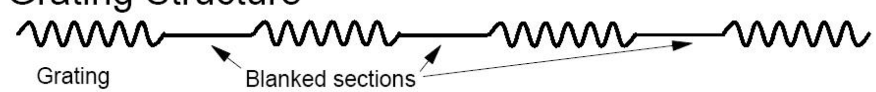




- Curentul trece prin zona activa ducand la amplificarea luminii
- curentul ce parcurge zona corespunzatoare reflectorului Bragg modifica indicele de refractie al acestei zone deci lungimea de unda
- zona centrala suplimentara permite reglaj fin suplimentar in jurul valorii impuse de reflectorul Bragg

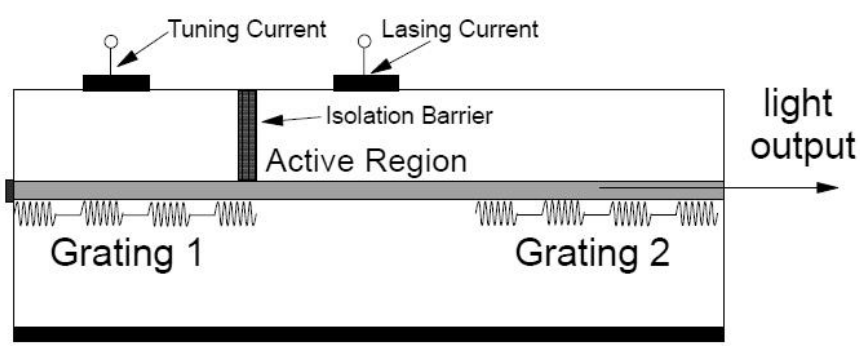
Diode laser reglabile

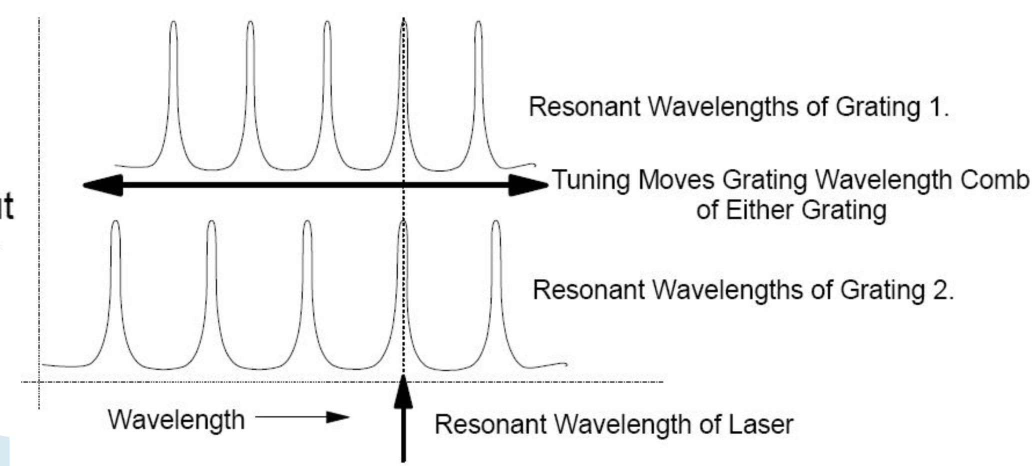
- Dezavantajul metodelor anterioare e dat de limita redusa a reglajului (~10nm)
- Reflectorul Bragg esantionat (periodic) produce spectru de filtrare discret



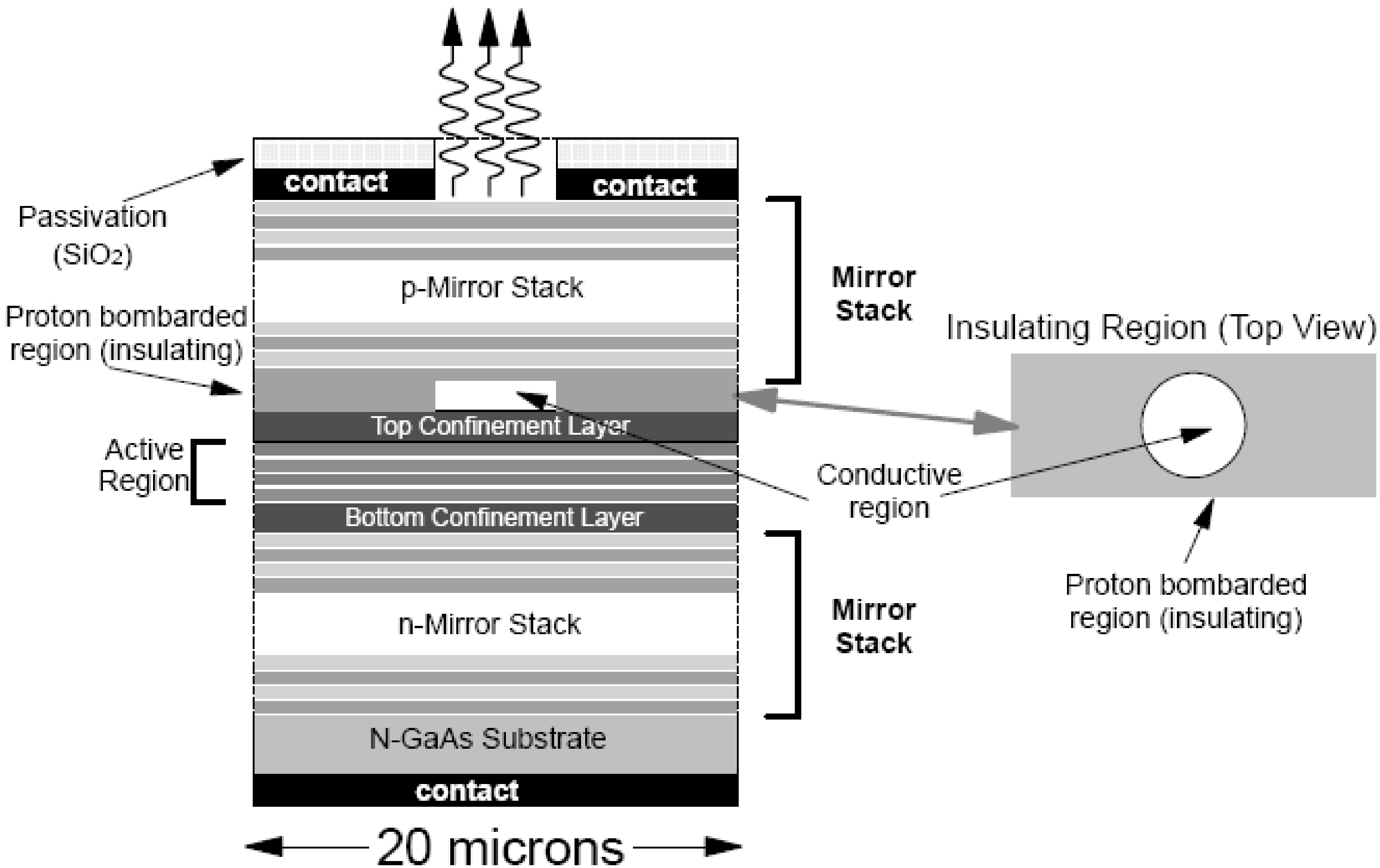
Dezavantaj : reglajul e discret

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

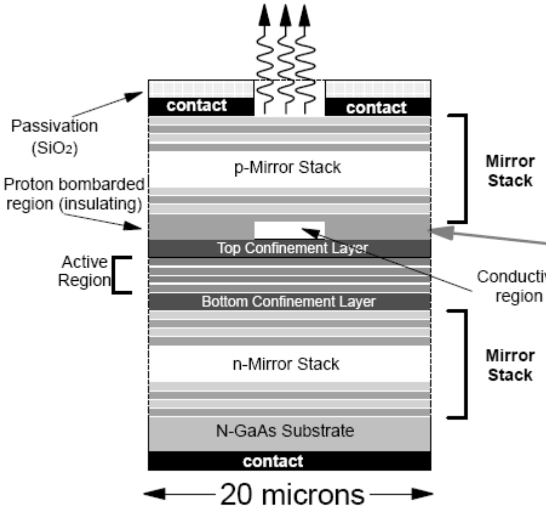




Vertical Cavity Surface Emitting Lasers (VCSEL)



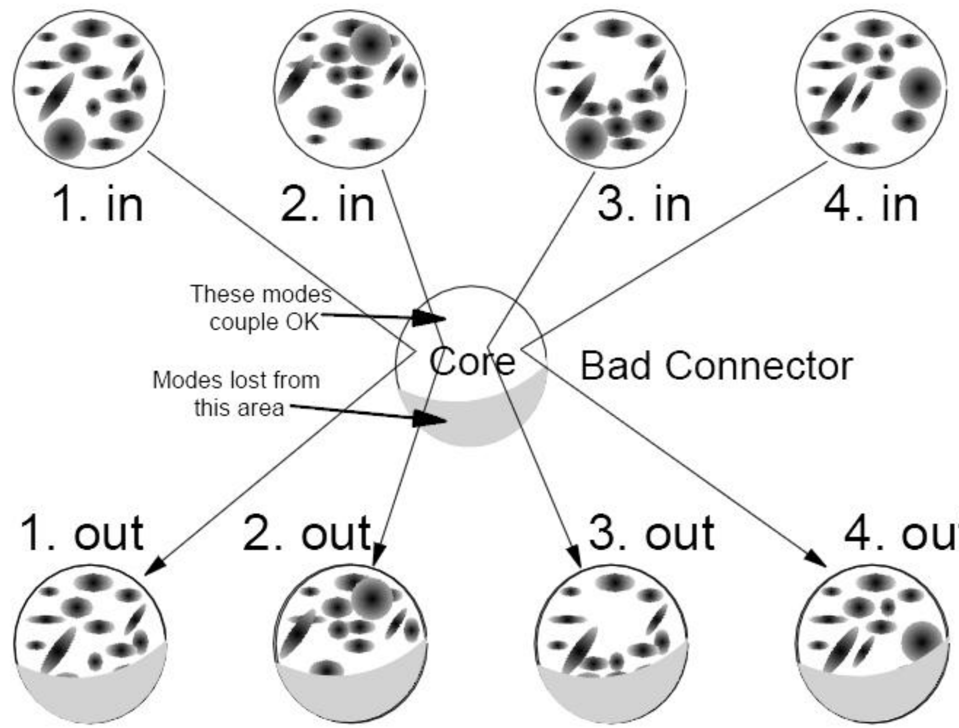
Vertical Cavity Surface Emitting Lasers (VCSEL)



- 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 circulara 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

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
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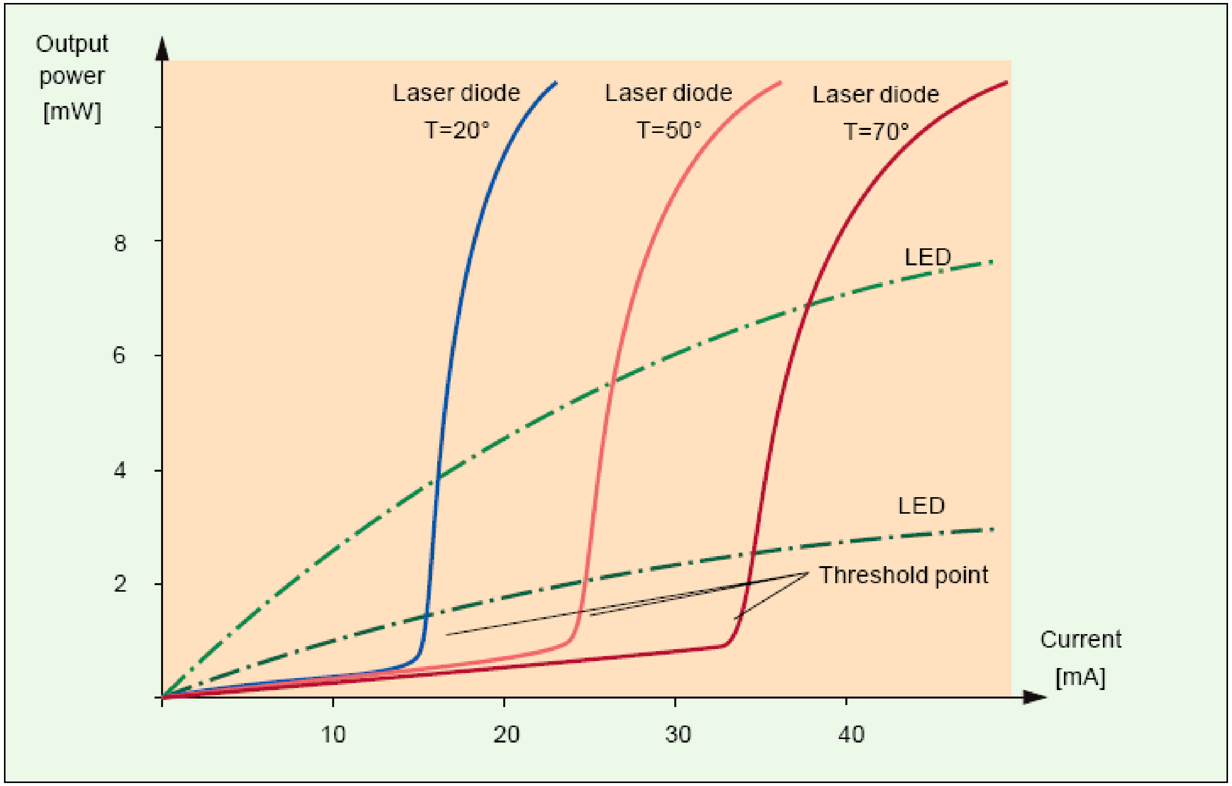
Temperatura si îmbatrânire

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



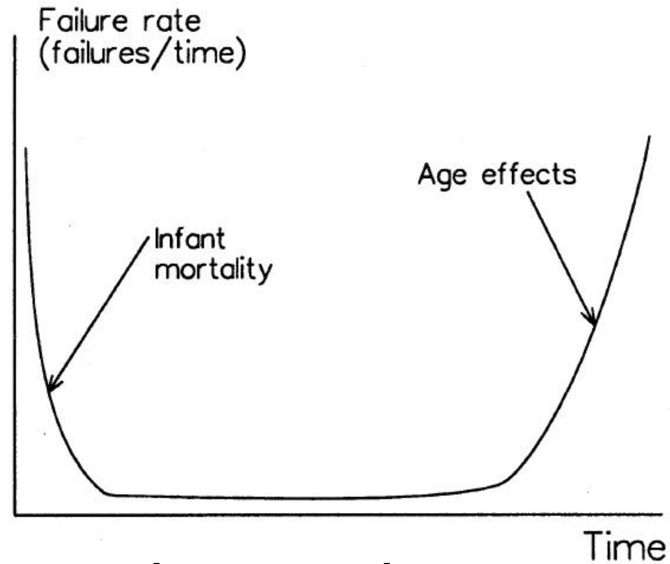
Degradare in timp

- 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

Caracteristici curent tensiune

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

$I < I_{th}$ regim LED

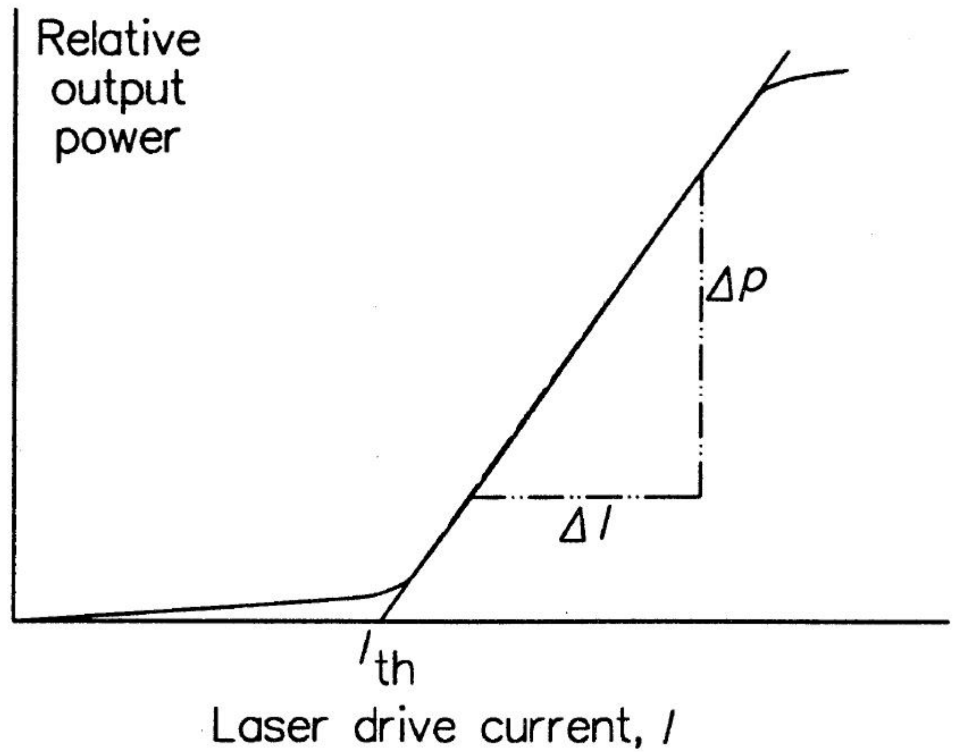
ineficient!, $P_o \cong 0$

$I > I_{th}$ 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



Eficienta

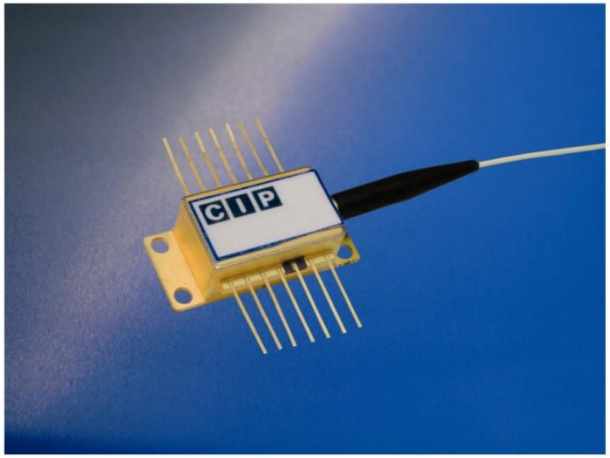
- eficienta de conversie electro-optic (randament)

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

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

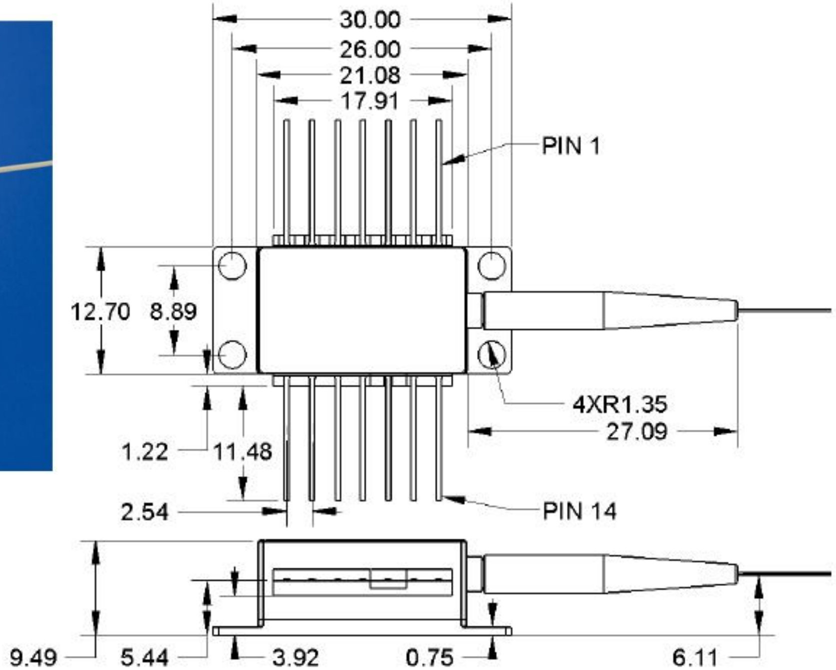
$$\eta = \frac{n_f}{n_e} \qquad \eta = \frac{\Delta P / h\nu}{\Delta I / e} = r \cdot \frac{e}{h\nu}$$

1550nm DFB Laser



Mechanical Drawing

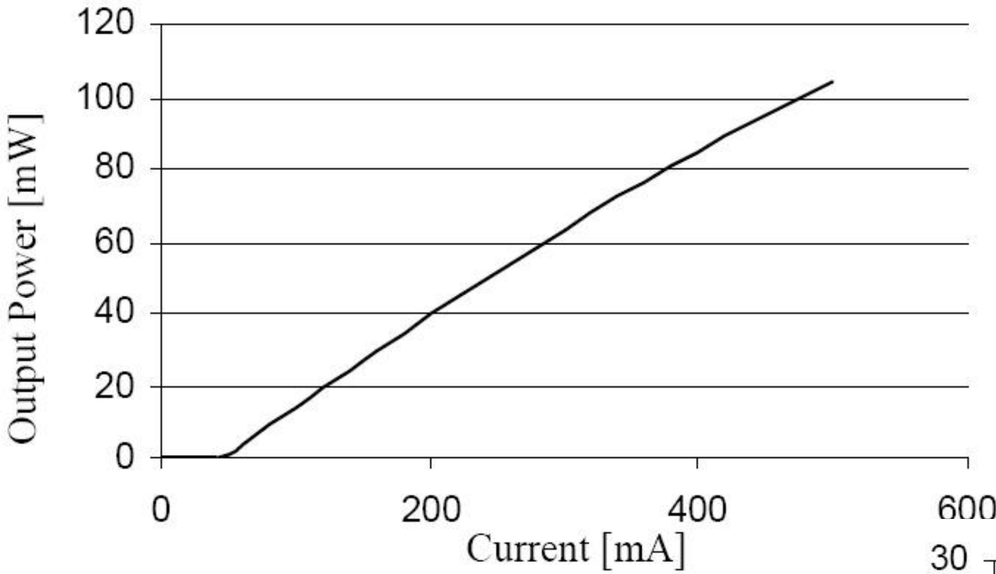
All units in mm

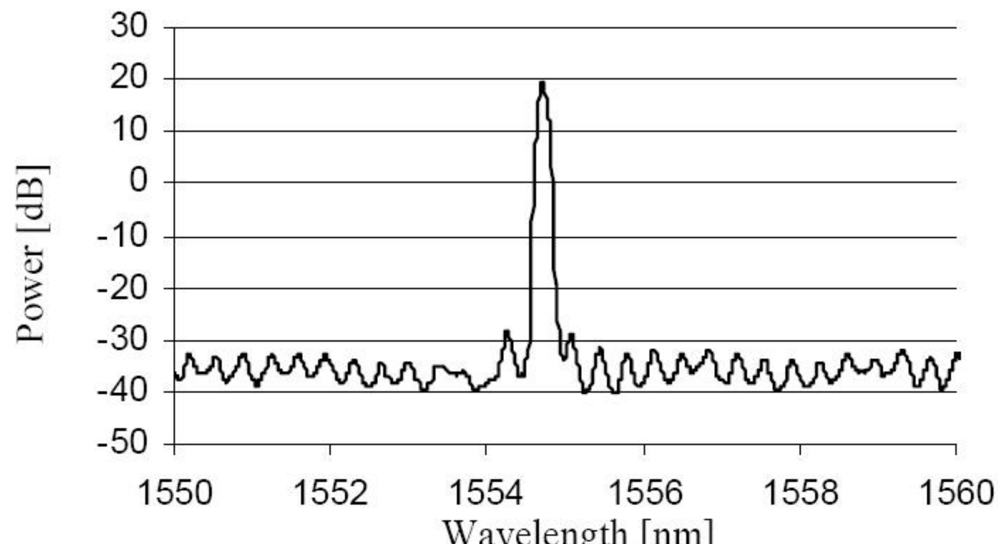


Pin out

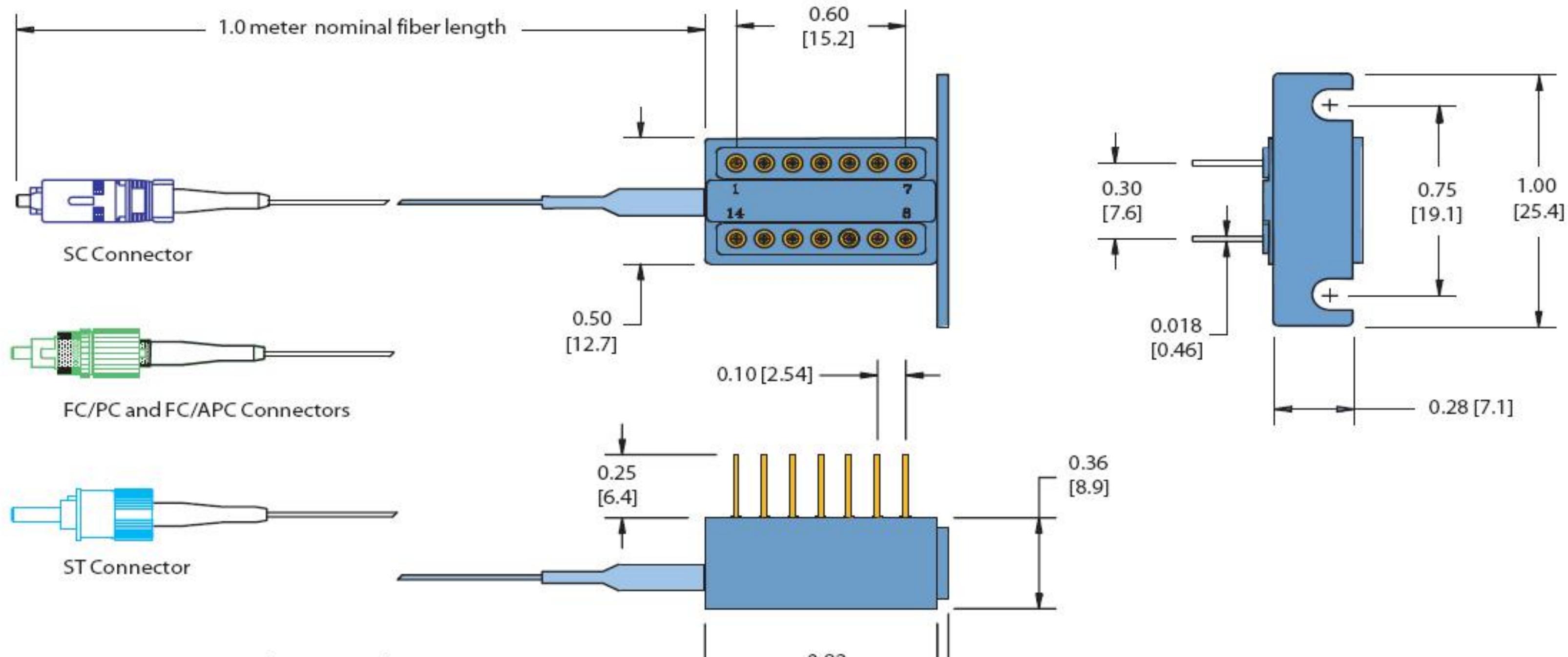
Pin	Description
1	Thermistor
2	Thermistor
3	Laser Cathode (Bias)
4	Monitor PD Anode
5	Monitor PD Cathode
6	TEC +
7	TEC -
8	Case GND, Laser Anode
9	Case GND, Laser Anode
10	Case GND, Laser Anode
11	Case GND, Laser Anode
12	Laser Cathode (modulation)
13	Case GND, Laser Anode
14	Case GND, Laser Anode

1550nm DFB Laser

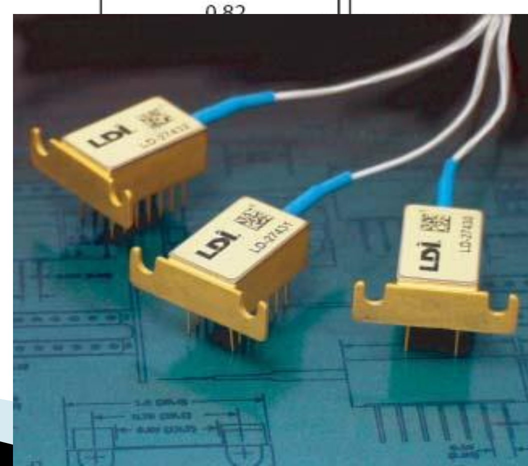


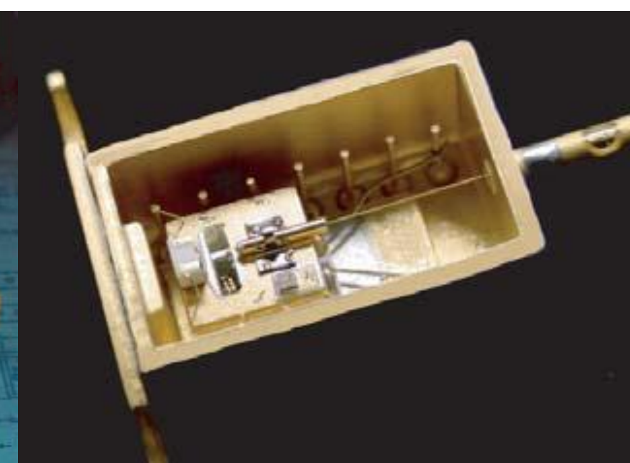


1550nm MQW Laser

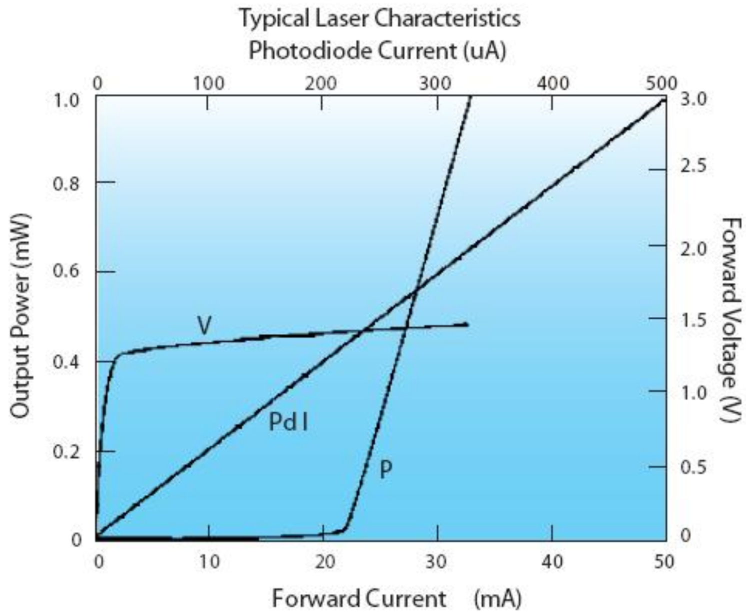


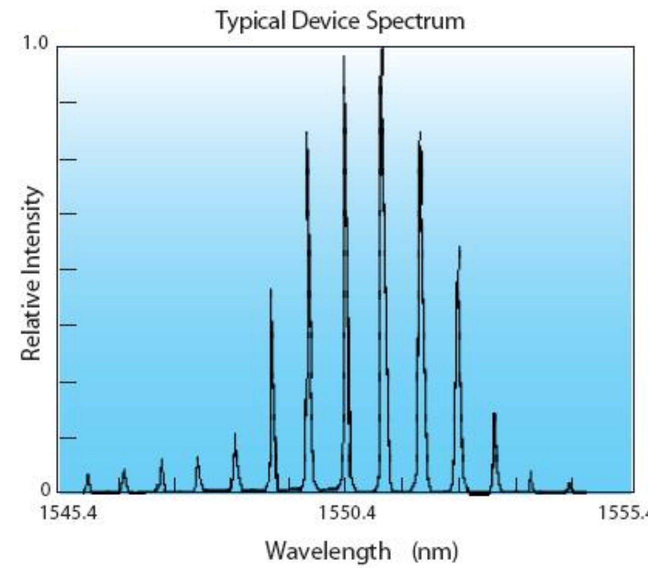
Note: Connectors are not drawn to scale.





1550nm MQW Laser





Contact

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