

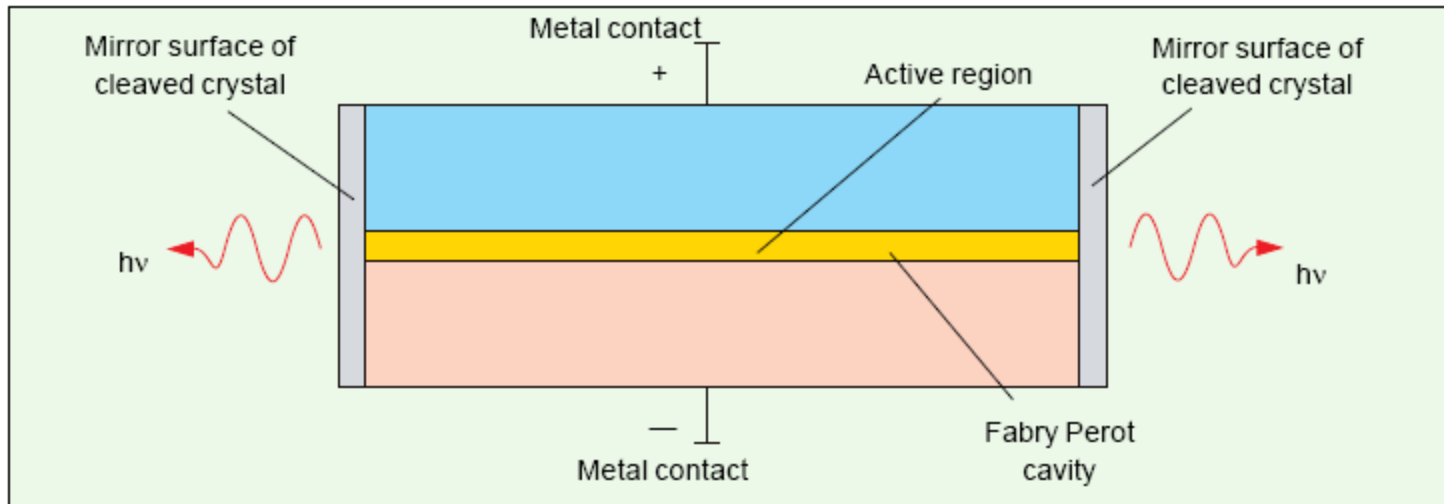
Optoelectronică, structuri și tehnologii

Curs 10
2011/2012

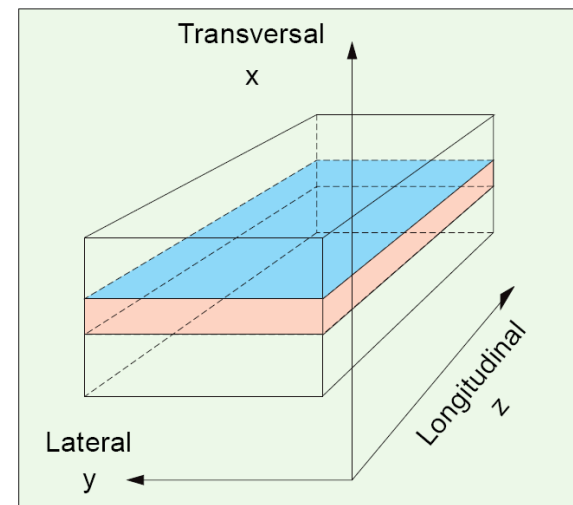
Dioda Laser

Capitolul 9
Partea a II-a

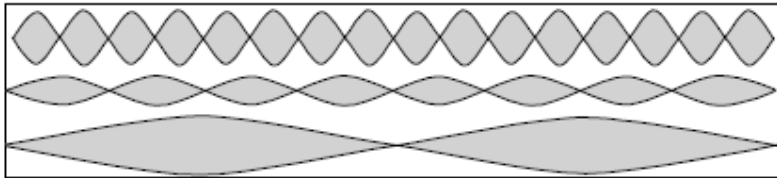
Dioda LASER Fabry Perot



Definirea directiilor in
dioda LASER



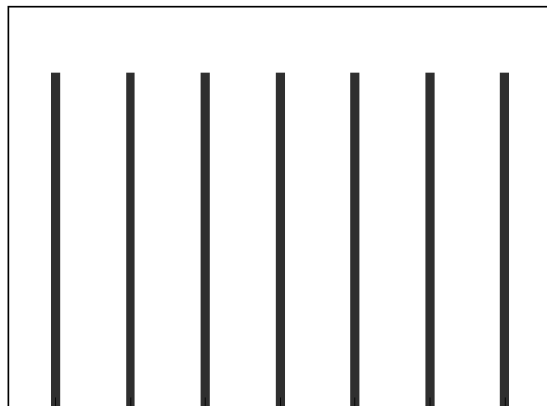
Spectrul diodei LASER



Longitudinal Modes



Lateral Modes



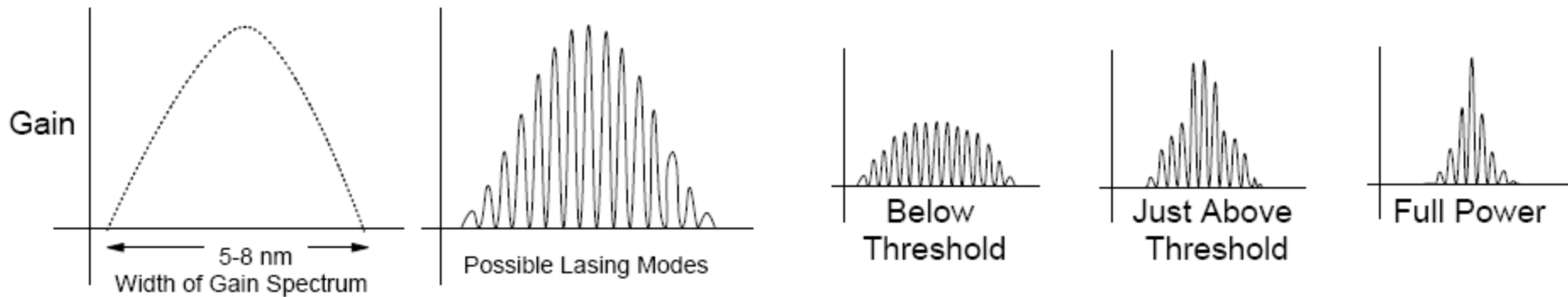
1.490 1.494 1.497 1.5 1.503 1.507 1.510
Wavelength (nm)

$$f_k = k \cdot \frac{c}{2 \cdot n \cdot L} \quad \Delta f = \frac{c}{2 \cdot n \cdot L}$$

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

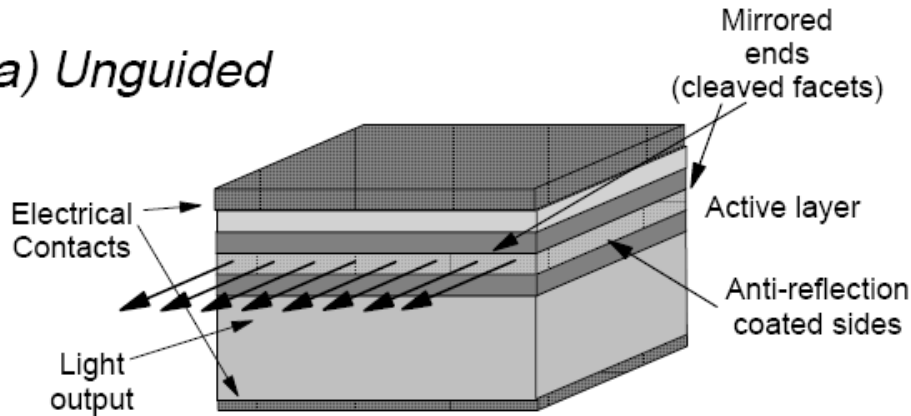
Spectrul diodei LASER

- ▶ 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)

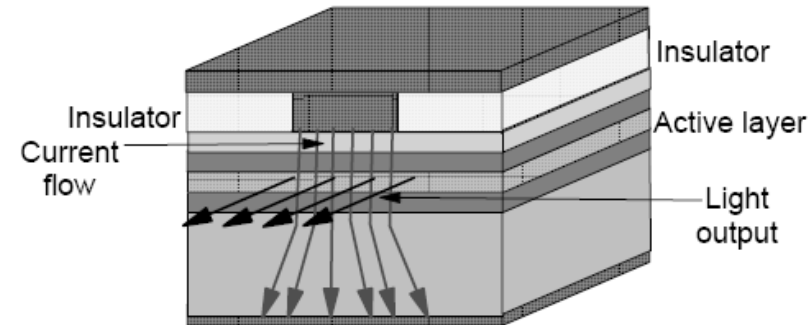


Direcționarea luminii în laser-ul Fabry Perot

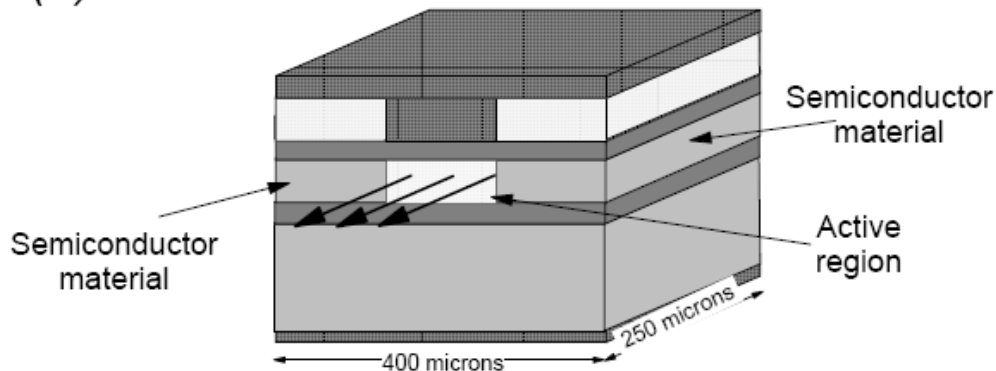
(a) Unguided



(b) Gain Guided

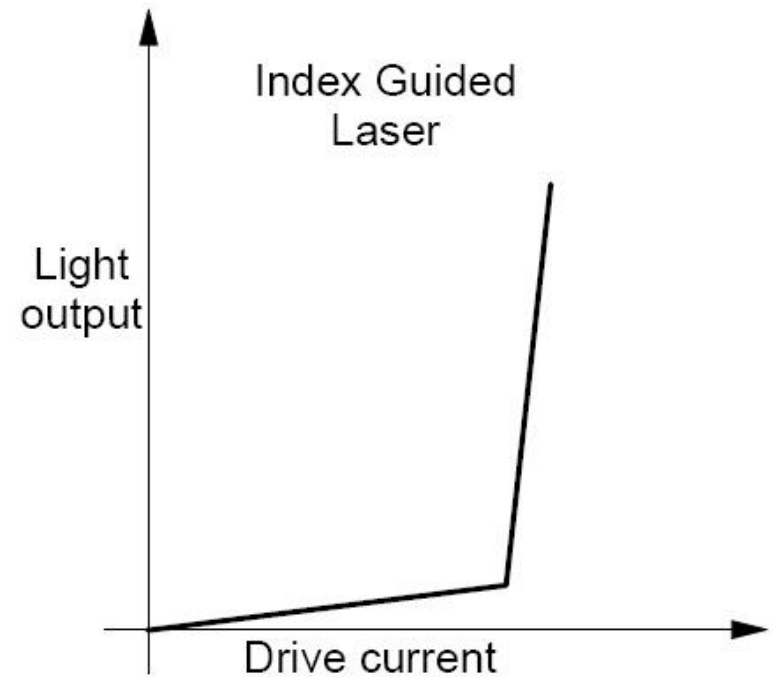
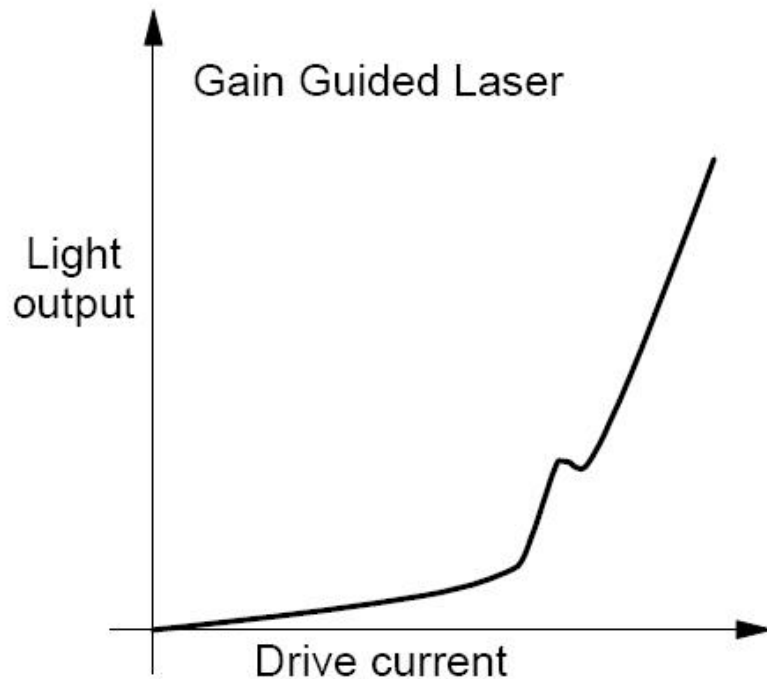


(c) Index Guided

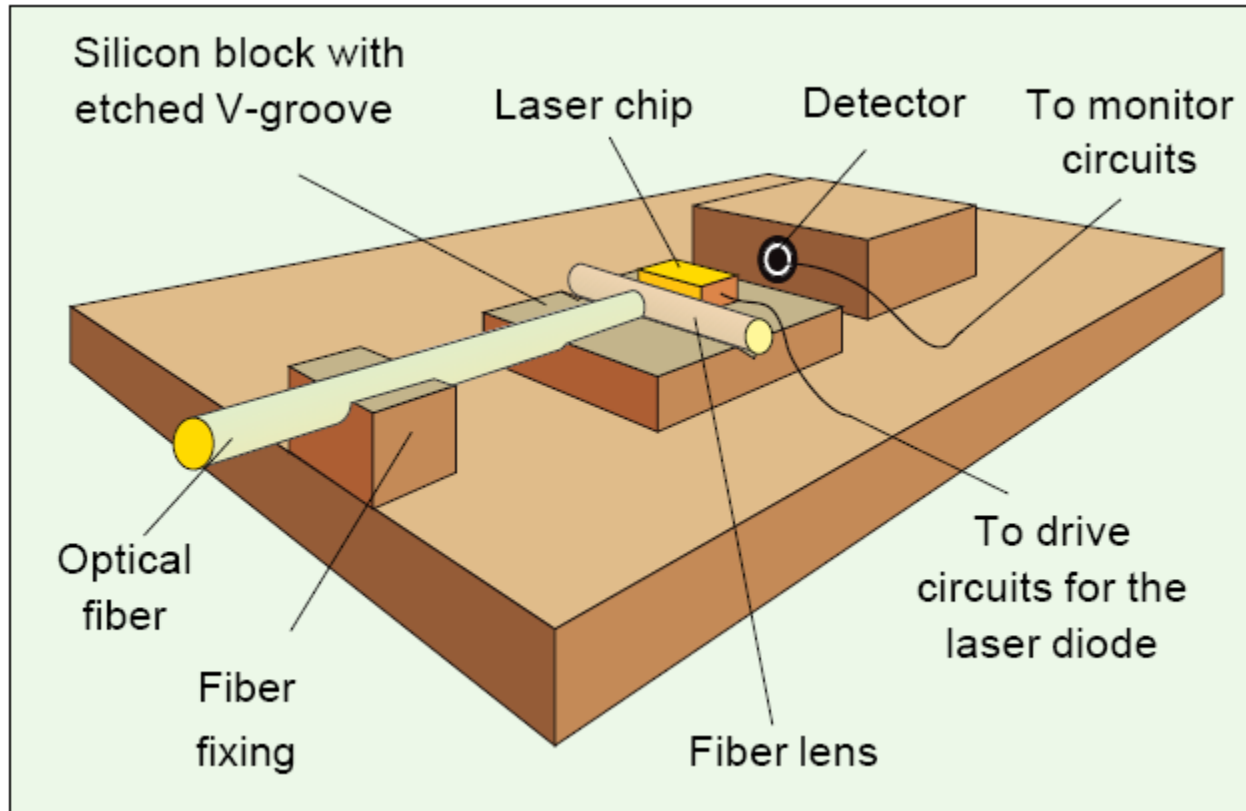


Efectul ghidarii

- ▶ 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 (valabil si la LED)

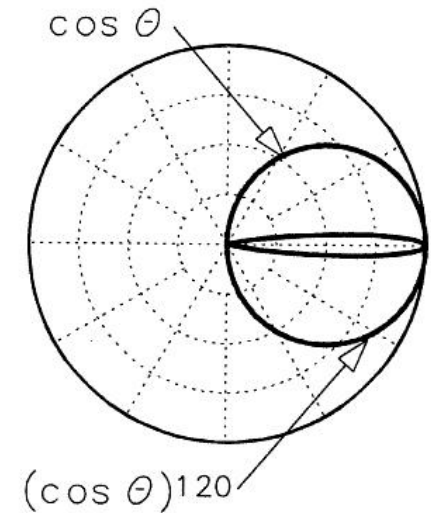
$$\eta = \frac{P_f}{P_s} = NA^2 \cdot \left(\frac{a}{r_s} \right)^2$$

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

- ▶ Aproximatie Lambertiana pentru surse cu directivitate crescuta

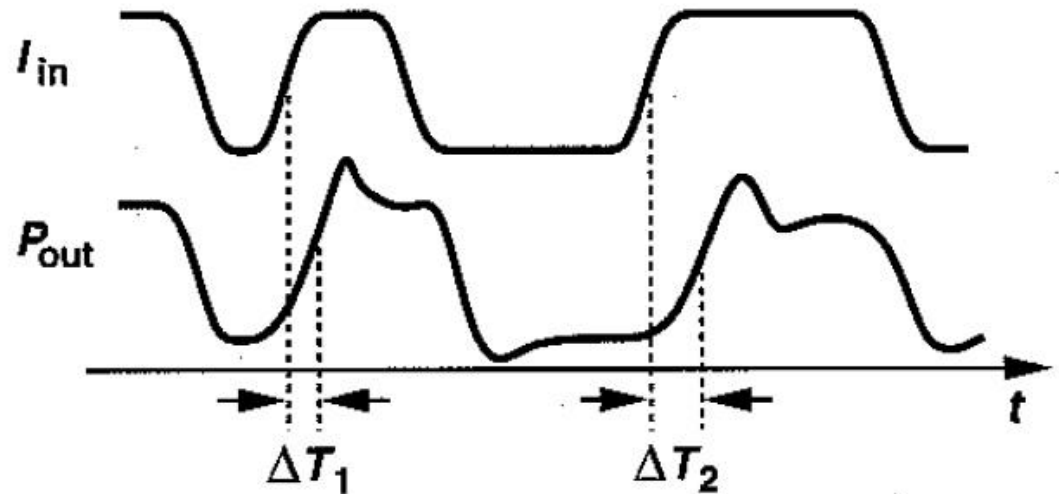
$$P(\theta) = P_0 \cdot \cos^n \theta$$

$$\eta = \frac{P_f}{P_s} = \left(\frac{n+1}{2} \right) \cdot NA^2$$



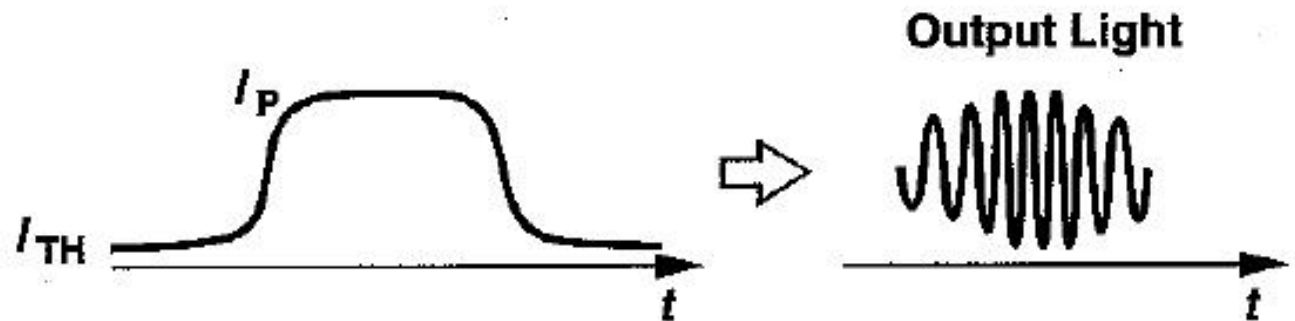
Turn-on delay

- ▶ 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

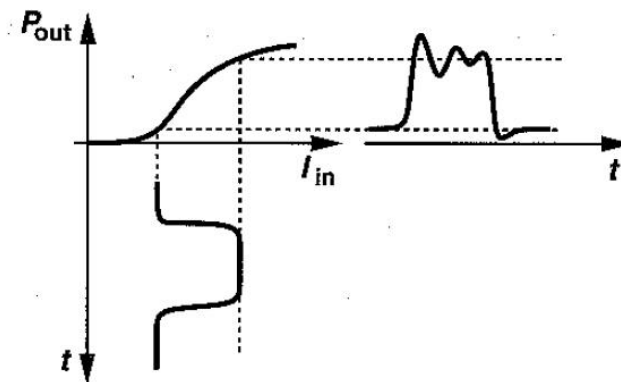
- ▶ Frecventa de oscilatie depinde de indicele de refractie al materialului
- ▶ Indicele de refractie depinde de concentratia de purtatori
- ▶ Cand curentul este modulat in impuls apare o modulatie a frecventei luminii cu efectul cresterii latimii spectrale a diodei (un ordin de magnitudine)



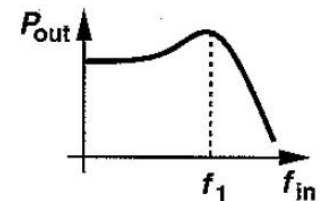
Oscilatii de relaxare

- ▶ 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 micșorarea emisiei de fotoni
- ▶ Acumularea din nou a electronilor in starea excitata duce din nou la cresterea puterii

▶ $f_1 = 1 \div 4 \text{ GHz}$



(a)



(b)

Oscilatii de relaxare

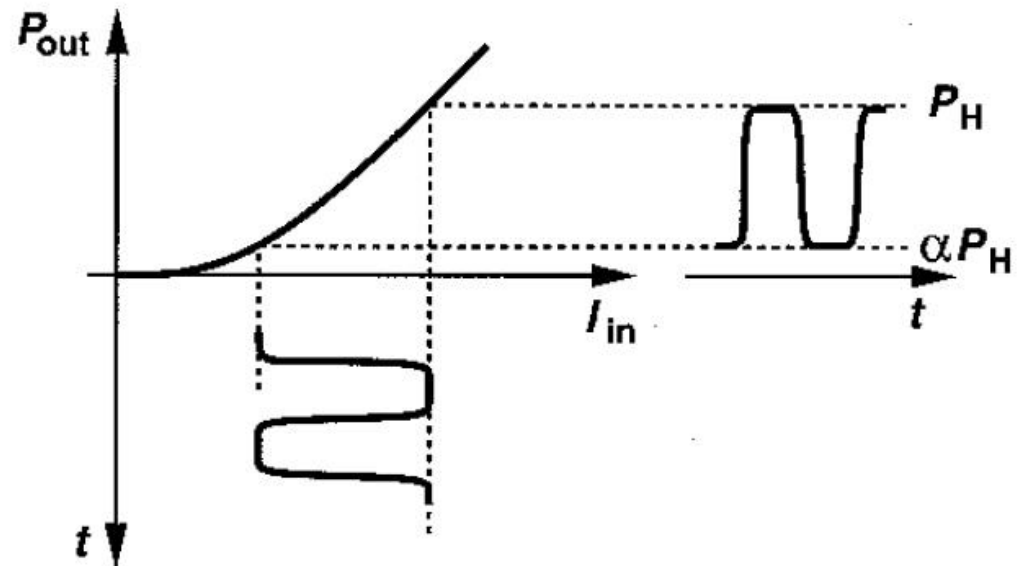
- ▶ Cresterea vitezei si minimizarea erorilor date de oscilatiile de relaxare si variatiile timpului de amorsare dioda este **partial** stinsa in timpul transmisiei unui nivel 0 logic

- ▶ Raport de stingere

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

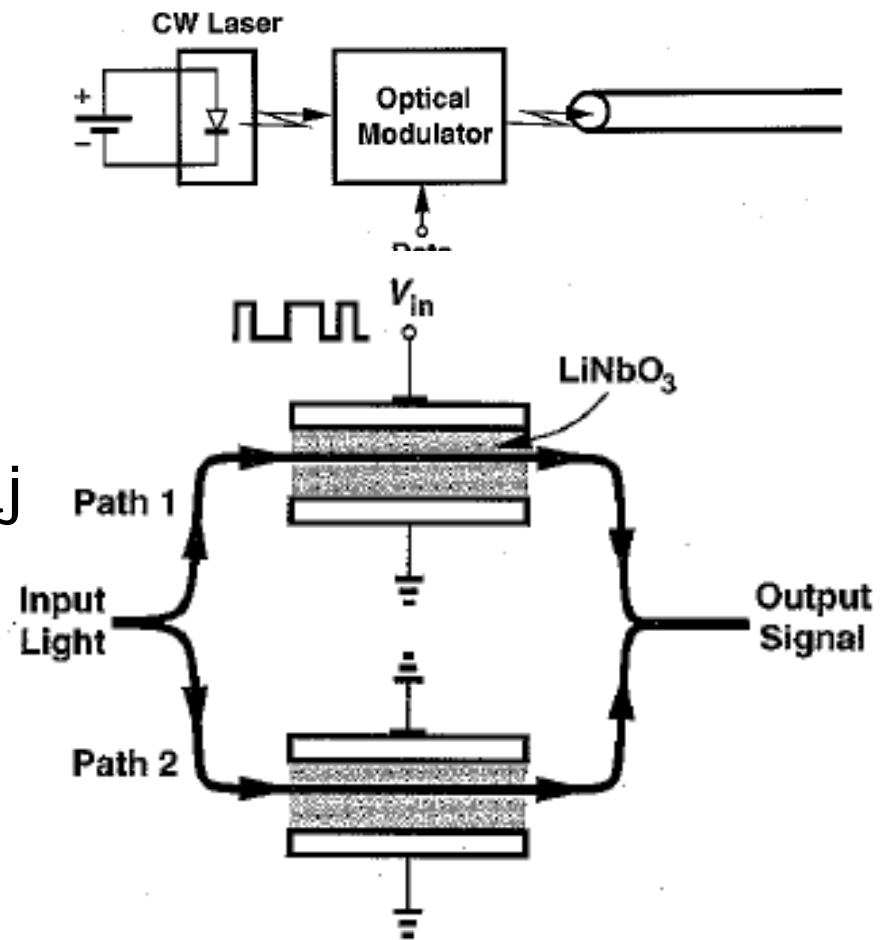
- ▶ Raportul semnal zgomot scade cu $(1-\alpha)$

- ▶ Tipic $ER = 10 \div 15 \text{dB}$



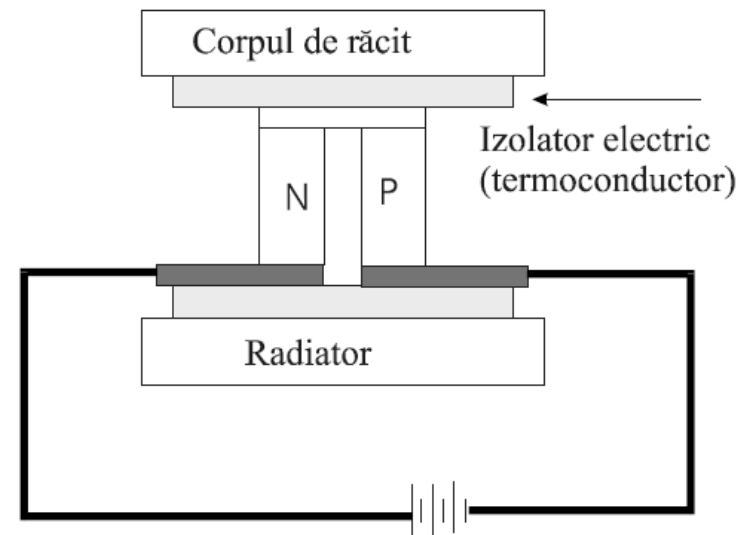
Modulație optică

- ▶ Pentru viteze mari se prefera utilizarea emisiei continue și modularea optică a radiației
- ▶ În LiNbO_3 viteza luminii depinde de câmpul electric, ceea ce permite introducerea unui defazaj egal π
- ▶ Crește complexitatea circuitului de control
- ▶ Tensiuni de 4÷6 V necesare



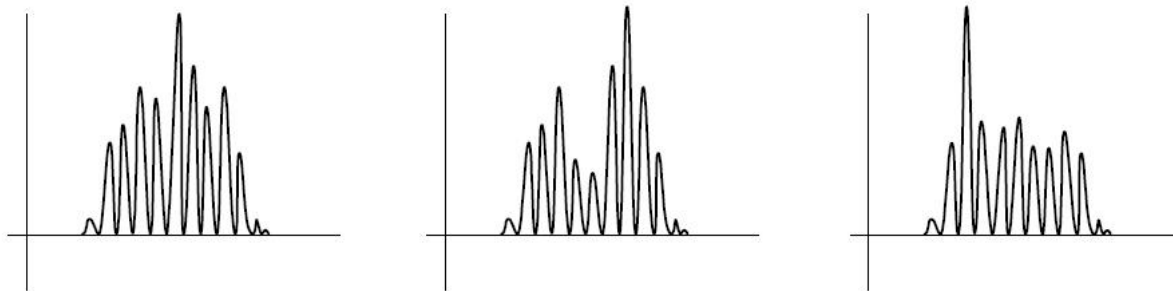
Dispozitiv termoelectric (Peltier)

- ▶ 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



Alte caracteristici

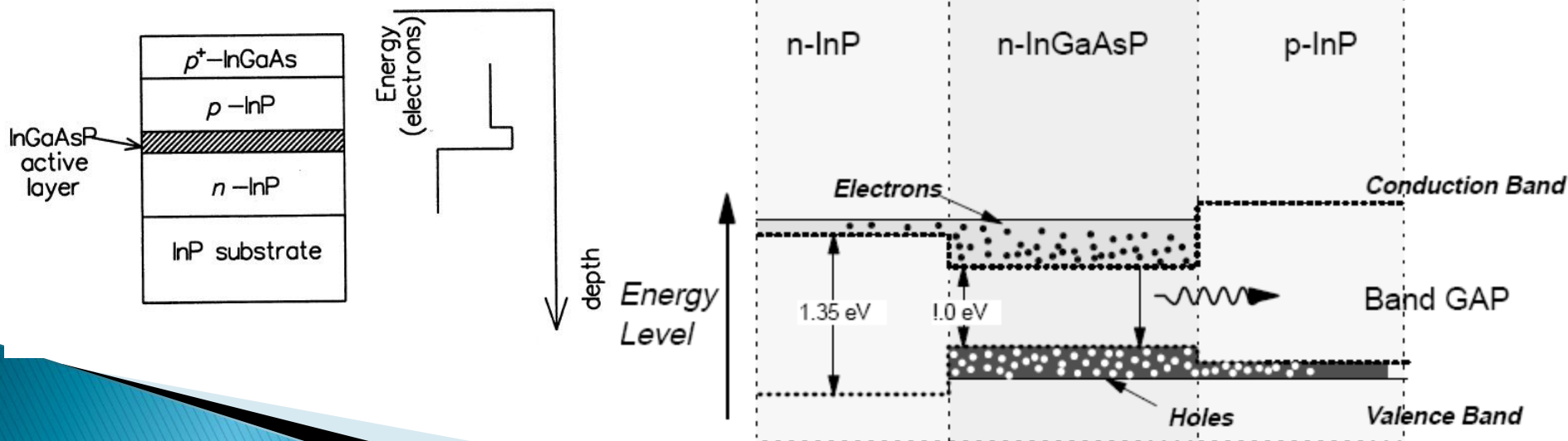
- ▶ Mode hopping – salt de mod (hole burning)



- ▶ 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)

Heterojunții – principiu

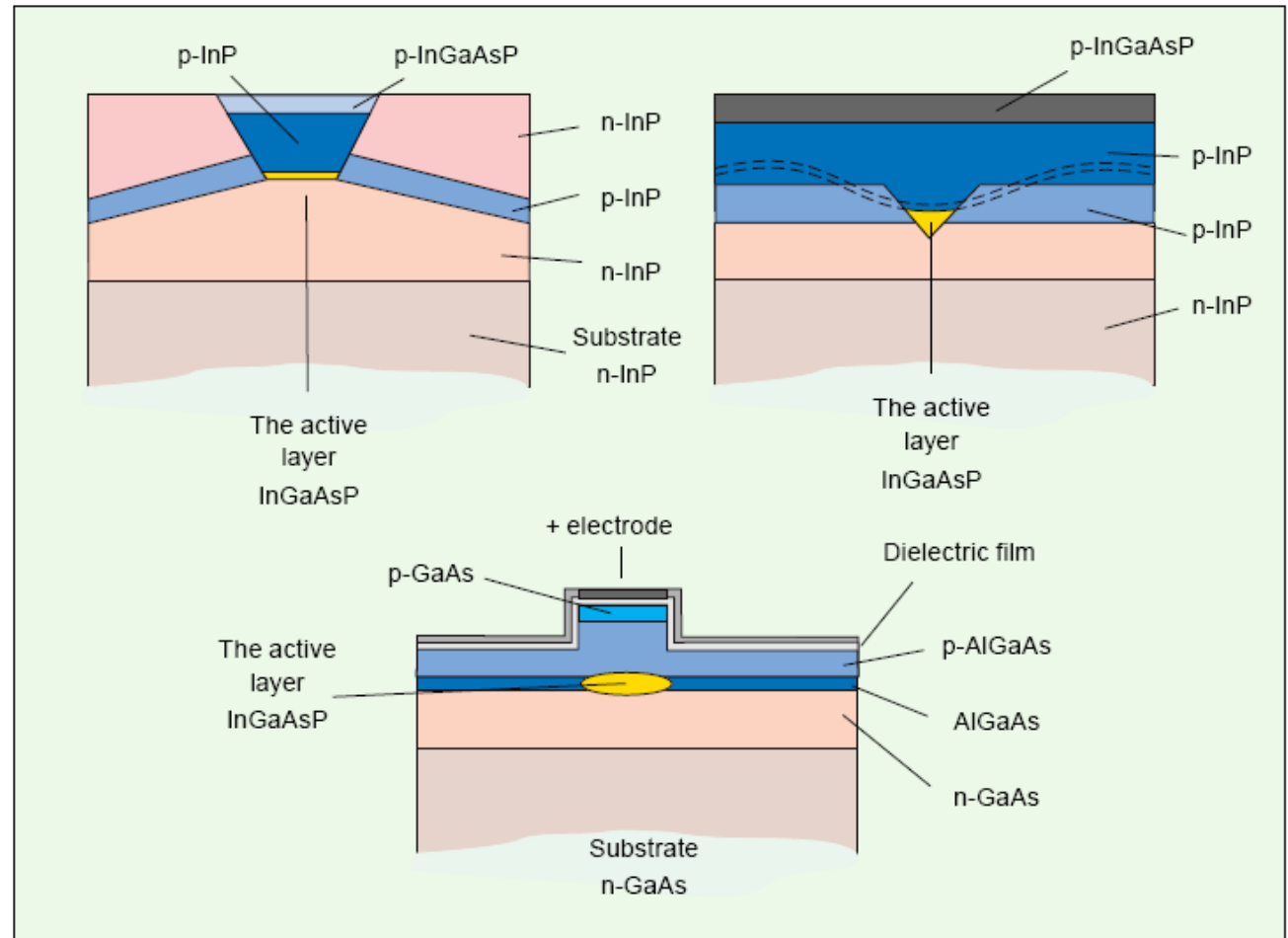
- ▶ Concentrare verticală a purtătorilor
 - Electronii sunt atrași din zona n în zona activă
 - O barieră energetică existentă între zona activă și zona n concentrează electronii în zona activă
 - Situație similară corespunzătoare golurilor
 - Purtătorii sunt concentrați în zona activă, crescând eficiența



Diode LASER cu heterojunctiune

heterojunctiune
ingropata

Heterojunctiune
muchie (ridge)

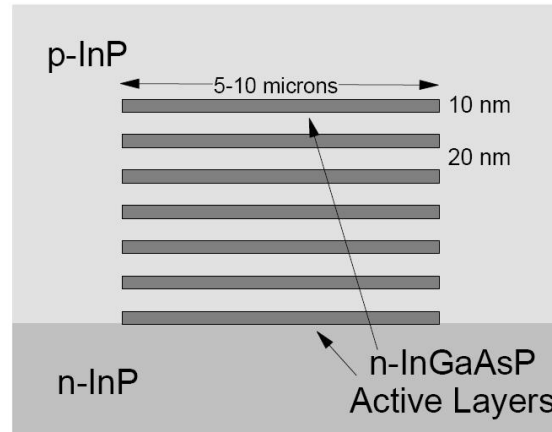


Quantum Well Laser

- ▶ 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

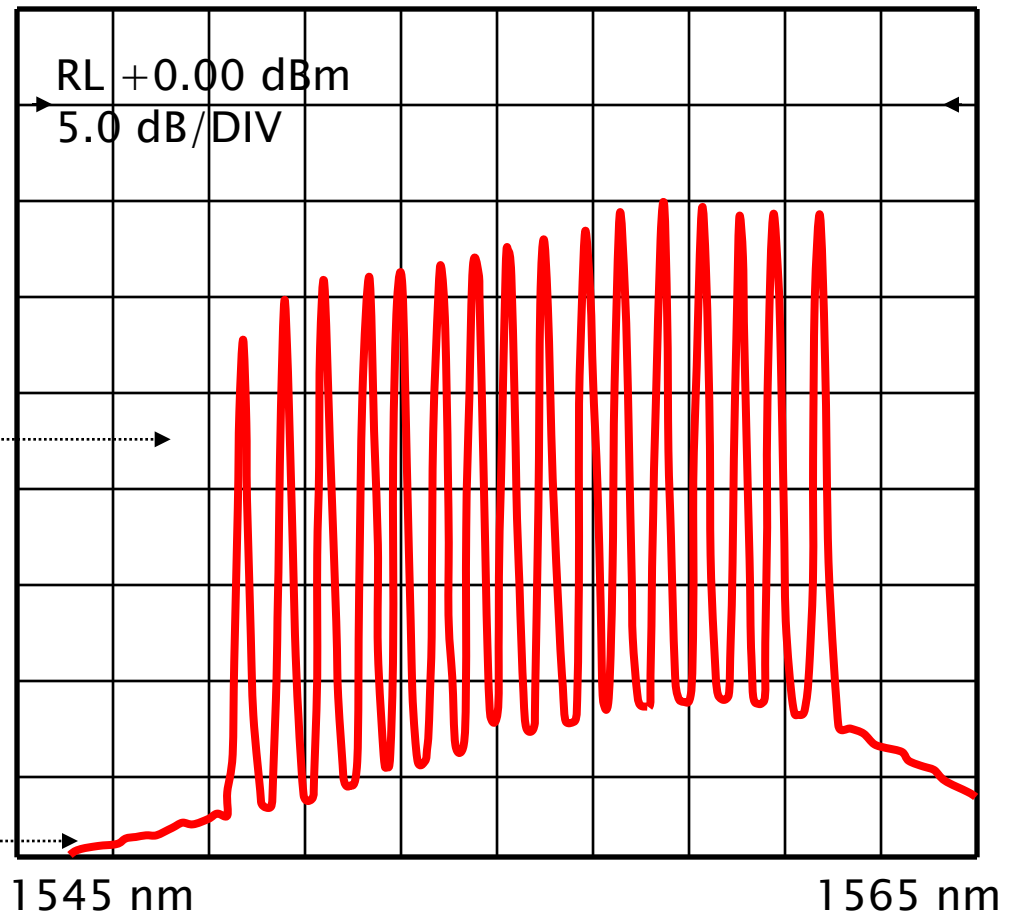
- ▶ multiple straturi subtiri suprapuse – Multiple Quantum Well



- ▶ **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
Spațiere: 0.8 nm

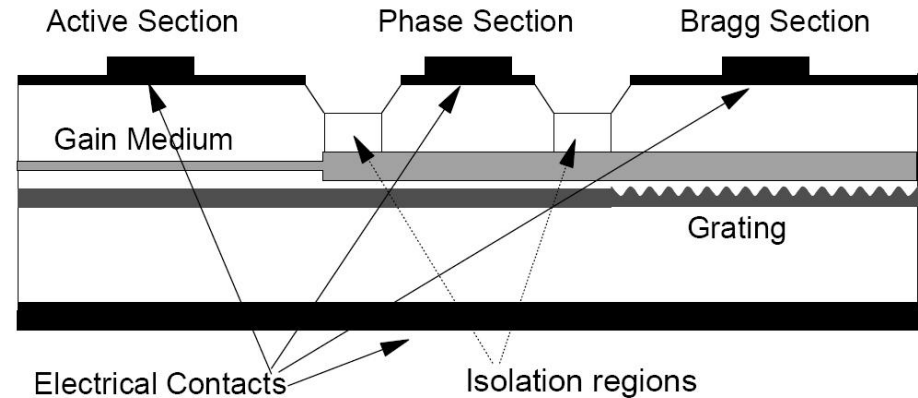
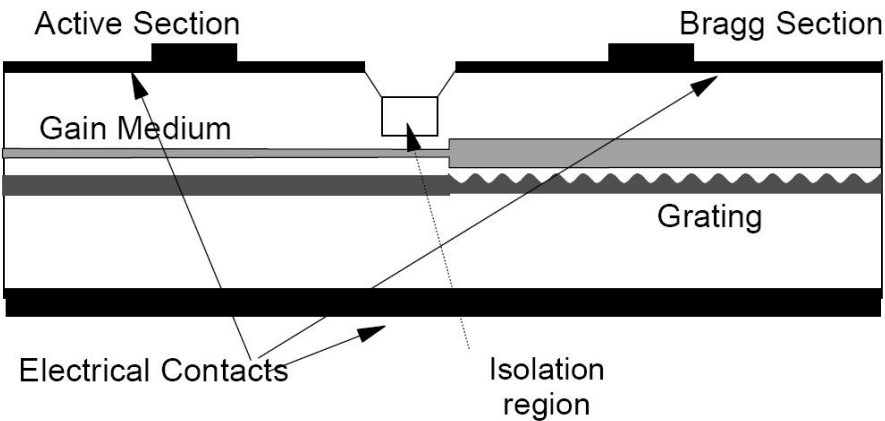
Emisie spontană
Amplificată (ASE)

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 μ s
- reglarea emitatorilor individuali in sistemele WDM
 - lipsa necesitatii controlului strict la productia diodelor
 - degradarea lungimii de unda in timp

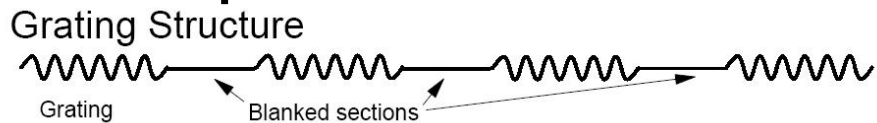
Diode laser reglabile



- ▶ 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

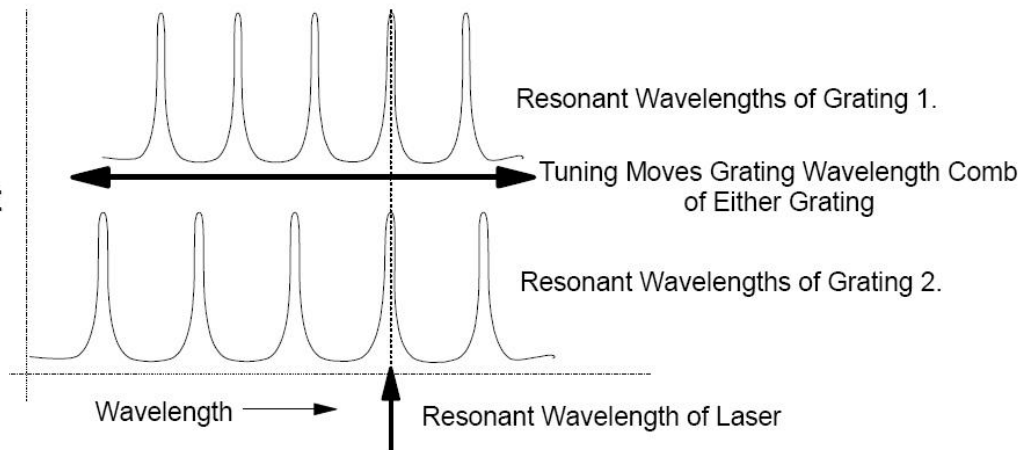
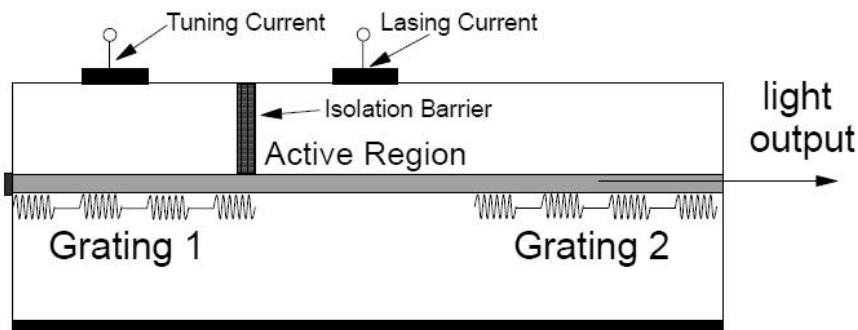
Diode laser reglabile

- ▶ Dezavantajul metodelor anterioare e dat de limita redusa a reglajului ($\sim 10\text{nm}$)
- ▶ Reflectorul Bragg esantionat (periodic) produce spectru de filtrare discret

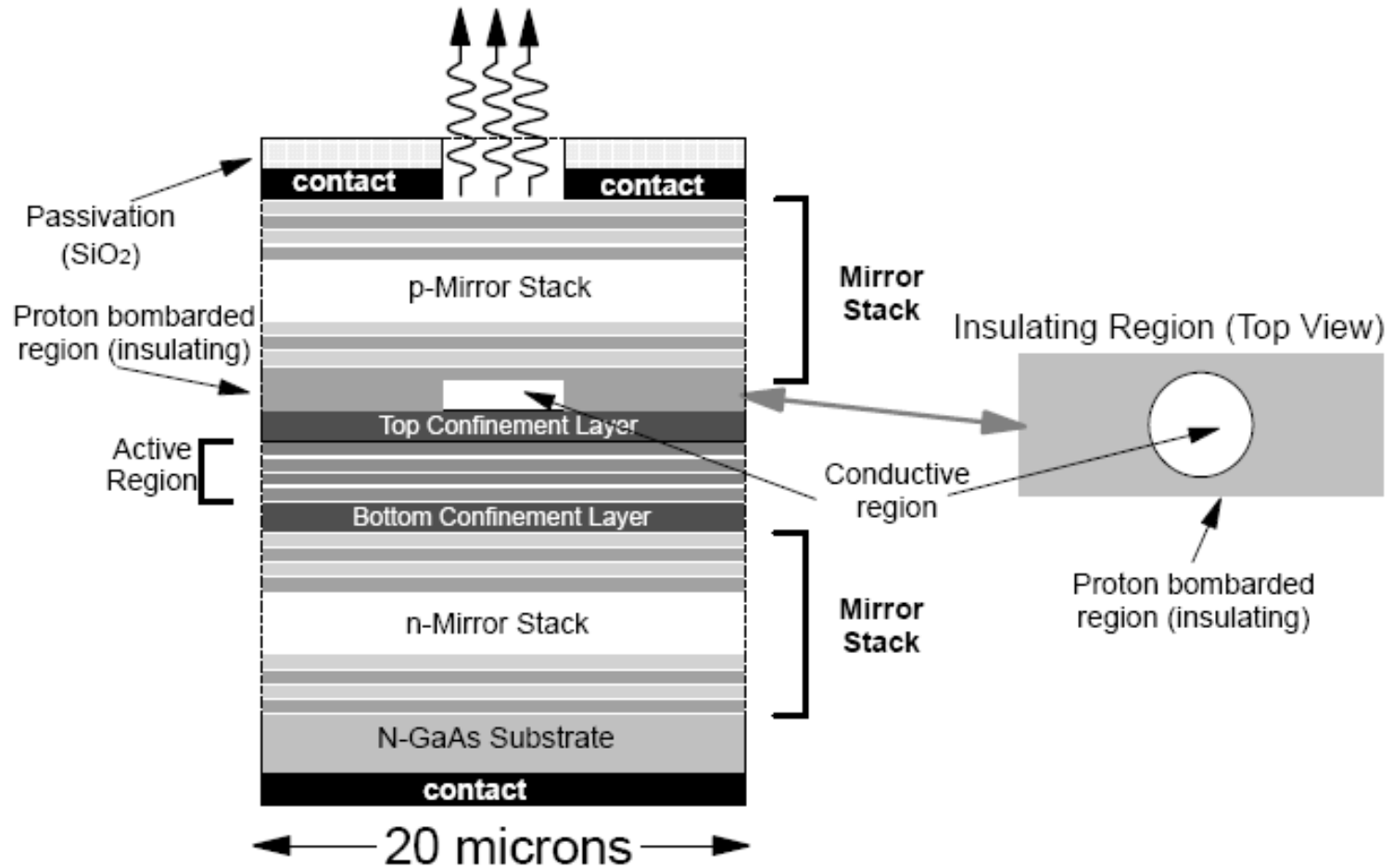


Dezavantaj :
reglajul e discret

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

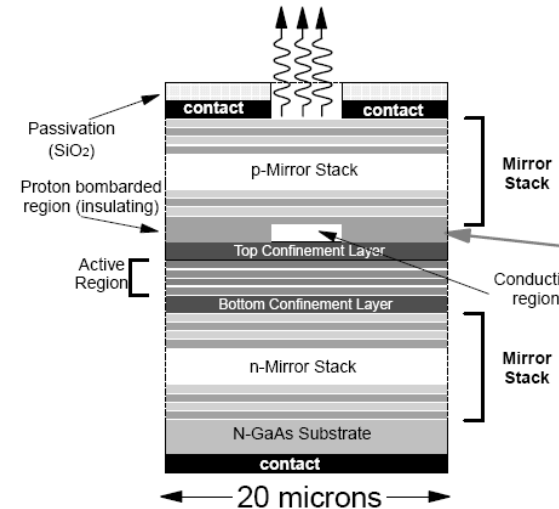


Vertical Cavity Surface Emitting Lasers (VCSEL)



VCSEL

- ▶ Oglinzile pot fi realizate din straturi succesive din semiconductori cu indici de refractie diferiti - reflector Bragg
- ▶ Prelucrarea laterala se rezuma la taierea materialului
- ▶ Numarul total de straturi poate ajunge la 500
- ▶ Caracteristici
 - ▶ puteri de ordinul 1 mW
 - ▶ lungimi de unda 850 si 980 nm
 - ▶ radiatie de iesire circulara cu divergenta redusa



VCSEL

▶ Caracteristici

- puteri de ordinul 1 mW
- lungimi de unda 850 si 980 nm
- radiatie de iesire circulara cu divergenta redusa
- VCSEL produce mai multe moduri transversale
 - insensibila la pierderile selective la mod din fibrele multimod (principala limitare in utilizarea diodelor laser in fibrele multimod)
- 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

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

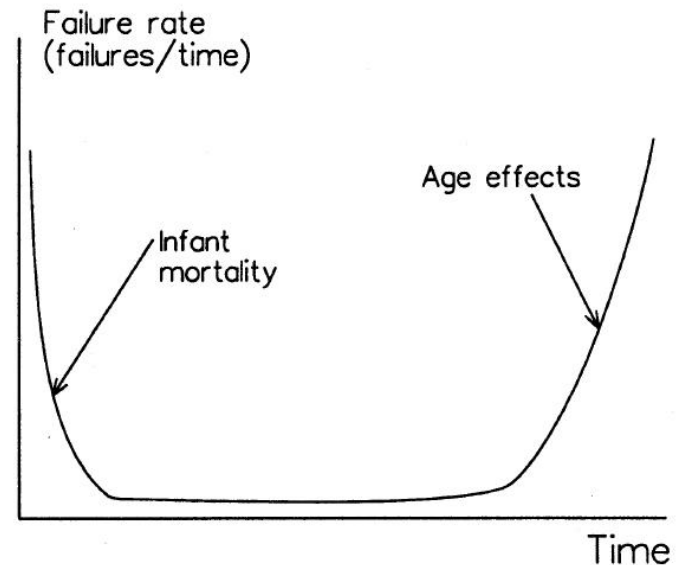
Degradare in timp

- ▶ 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 $2000 \div 5000 \text{ A/cm}^2$
 - densitati de putere optica: $10^5 \div 10^6 \text{ W/cm}^2$
- ▶ Diverse definitii ale timpului de viata fac comparatiile dificile

Degradare in timp



- ▶ Cresterea curentului duce la scaderea duratei de viata

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

- ▶ $n = 1.5 \div 2$ (empiric)
- ▶ Cresterea temperaturii duce de asemenea la scaderea duratei de viata

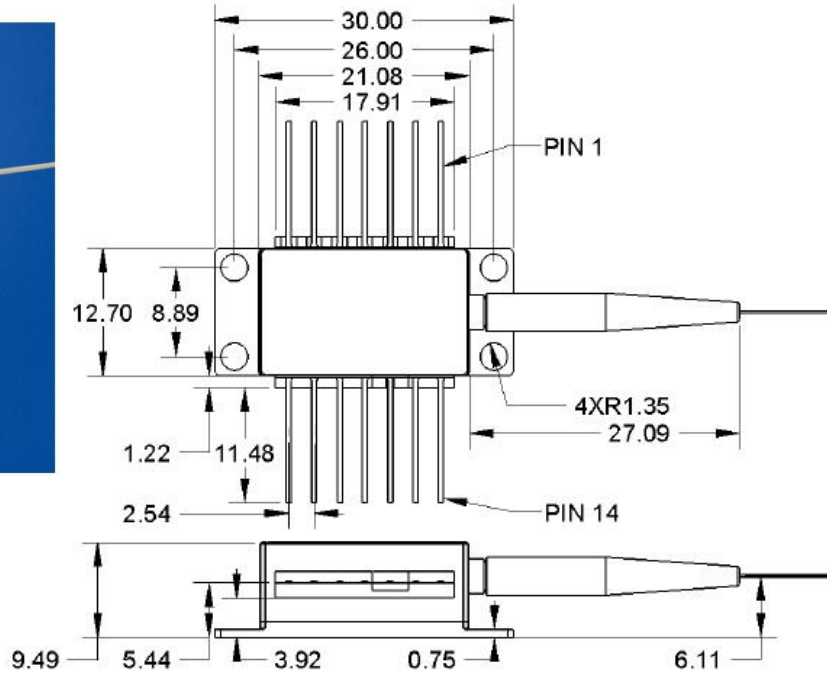
$$\tau_m \sim e^{E/kT}$$

- ▶ $E = 0.3 \div 0.95 \text{eV}$ (valoarea tipica in teste 0.7eV)

1550nm DFB Laser

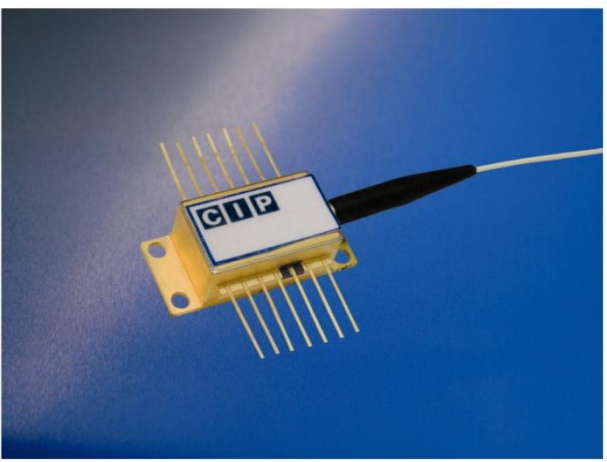
Mechanical Drawing

All units in mm

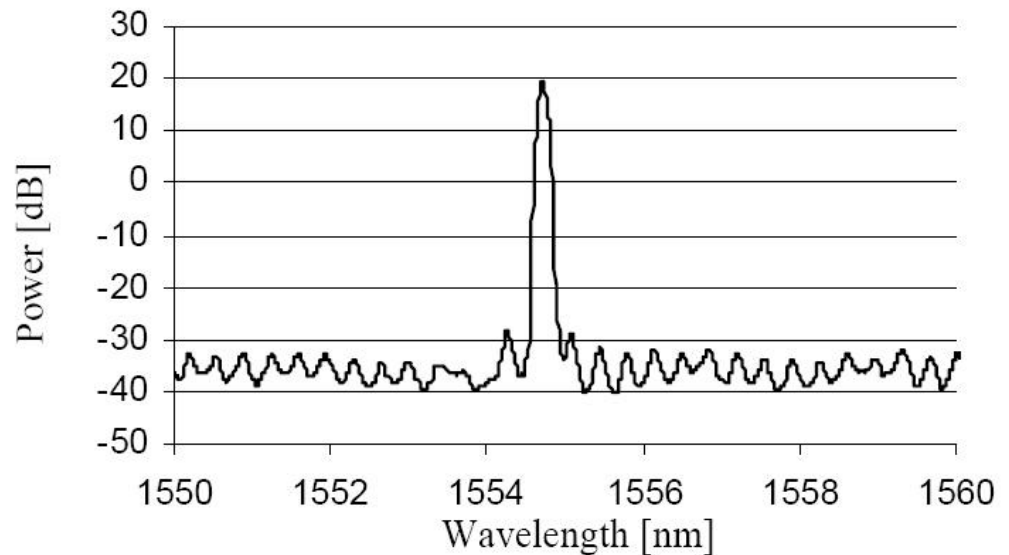
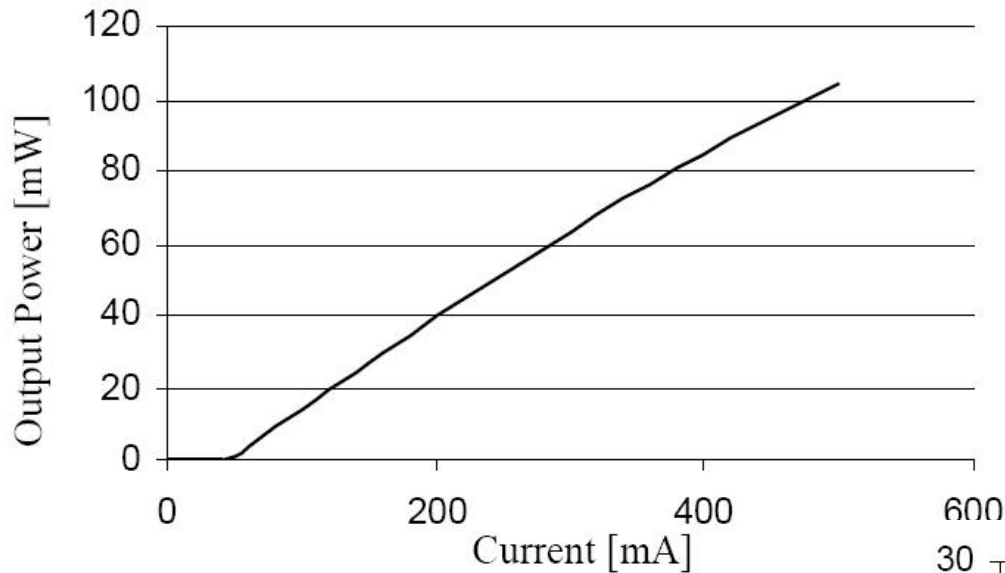


Pin out

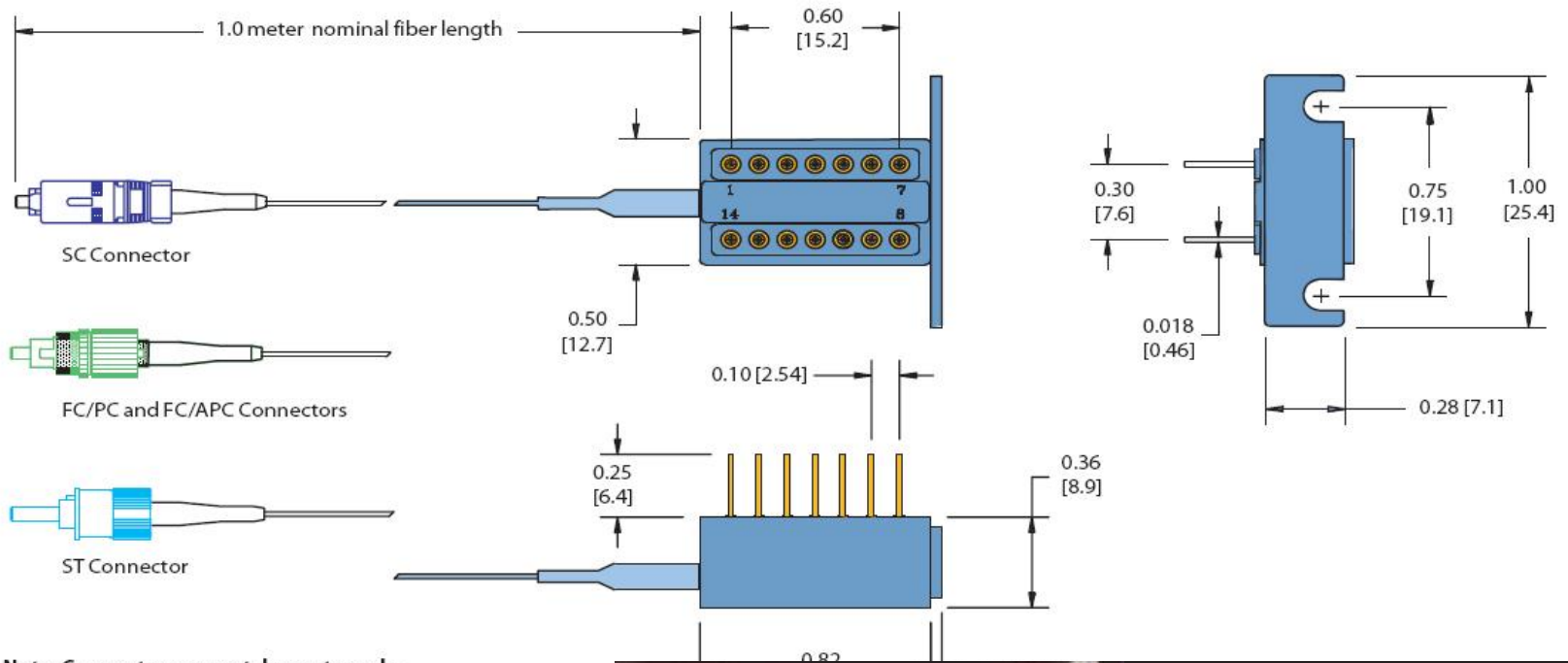
Pin	Description
1	Thermistor
2	Thermistor
3	Laser Cathode (Bias)
4	Monitor PD Anode
5	Monitor PD Cathode
6	TEC +
7	TEC -
8	Case GND, Laser Anode
9	Case GND, Laser Anode
10	Case GND, Laser Anode
11	Case GND, Laser Anode
12	Laser Cathode (modulation)
13	Case GND, Laser Anode
14	Case GND, Laser Anode



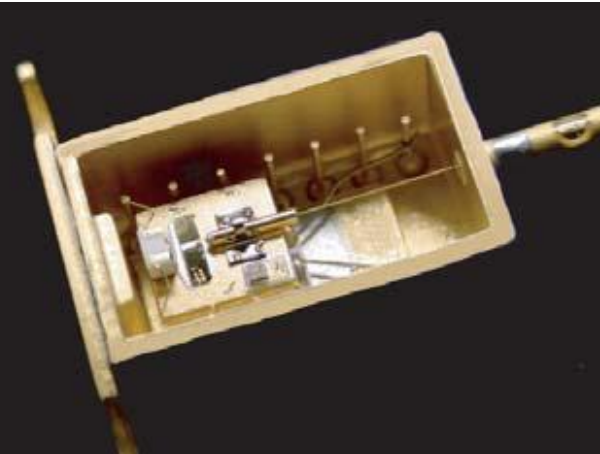
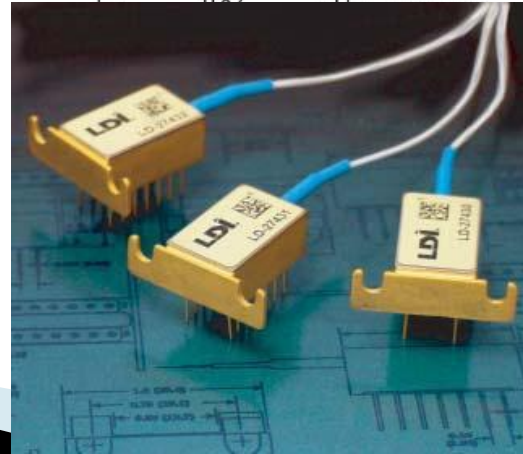
1550nm DFB Laser



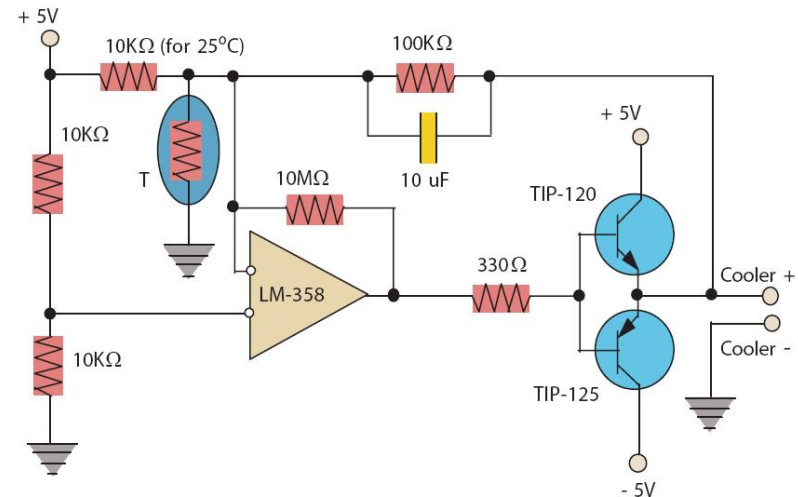
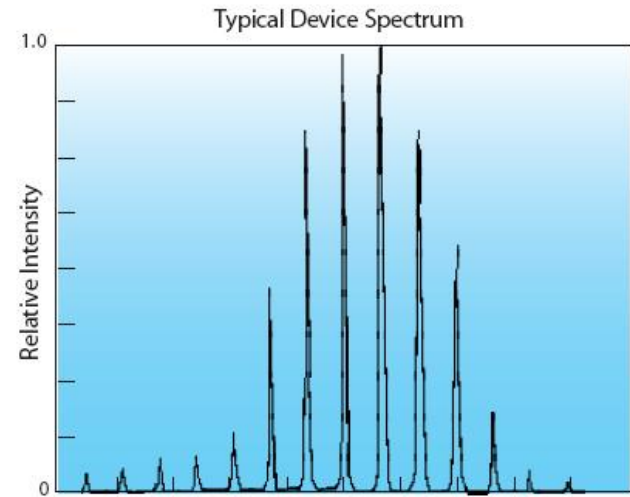
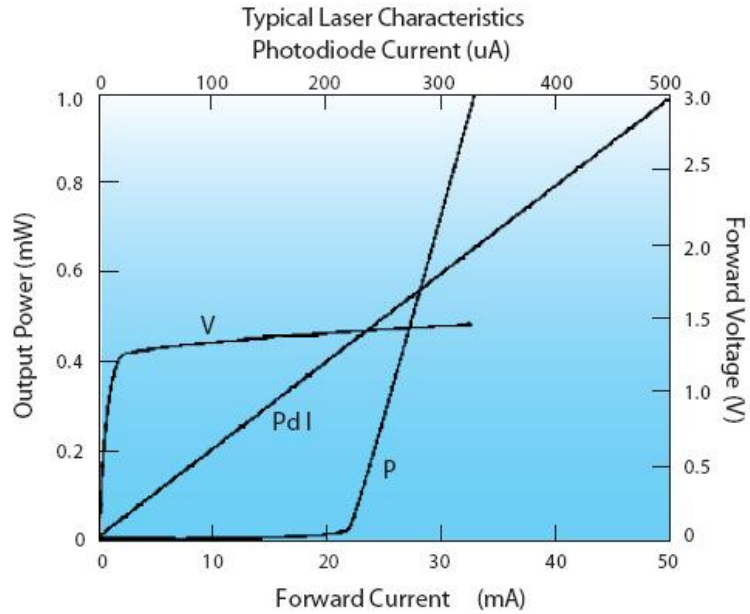
1550nm MQW Laser



Note: Connectors are not drawn to scale.

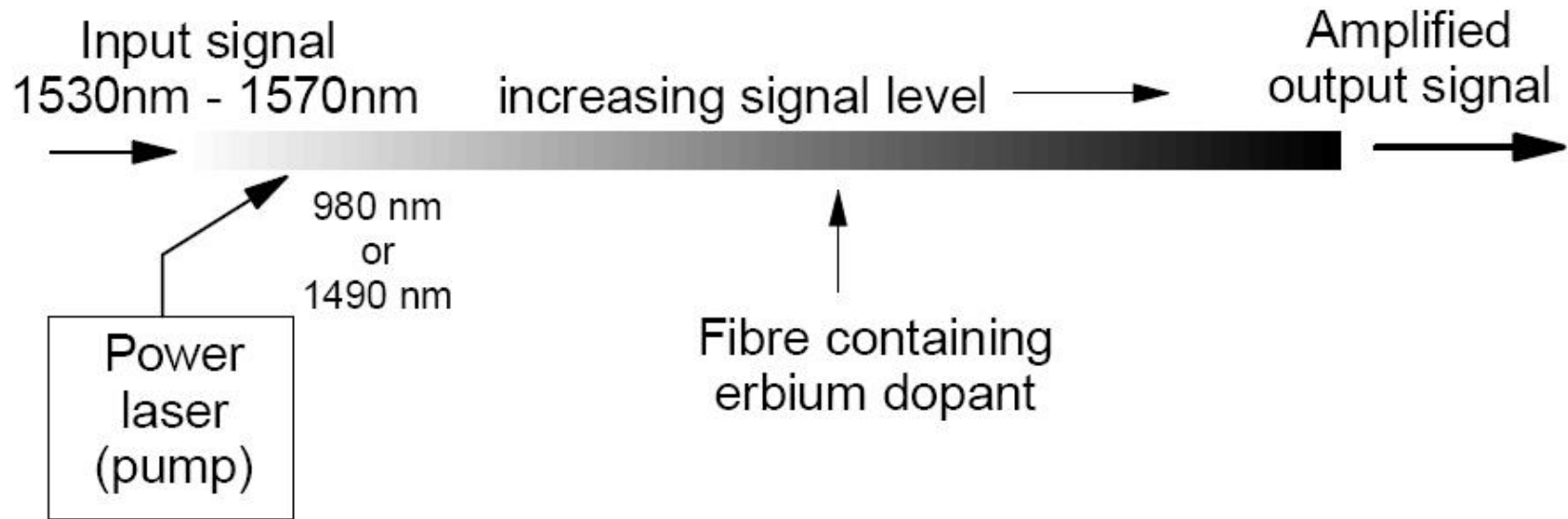


1550nm MQW Laser

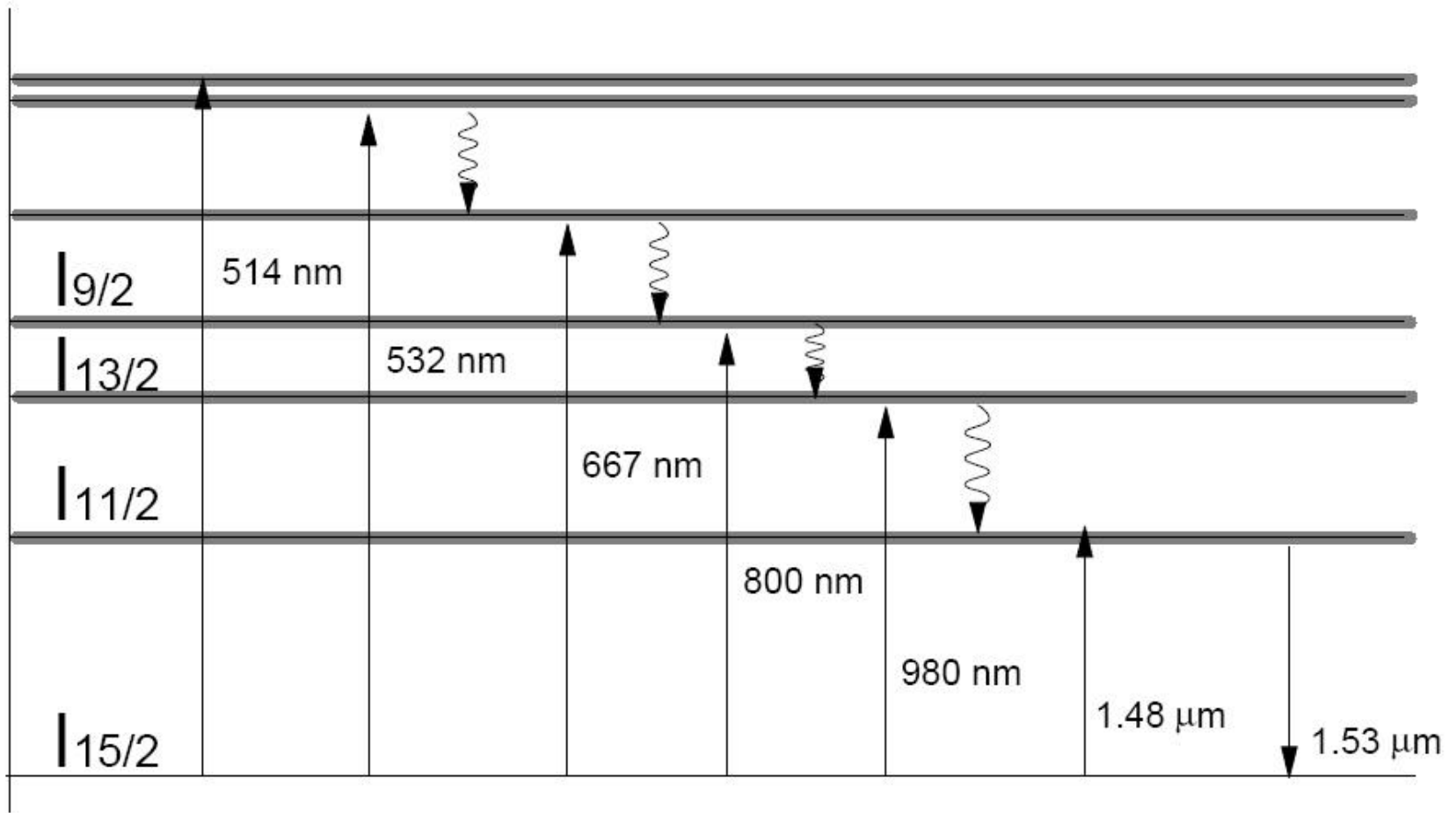


EDFA

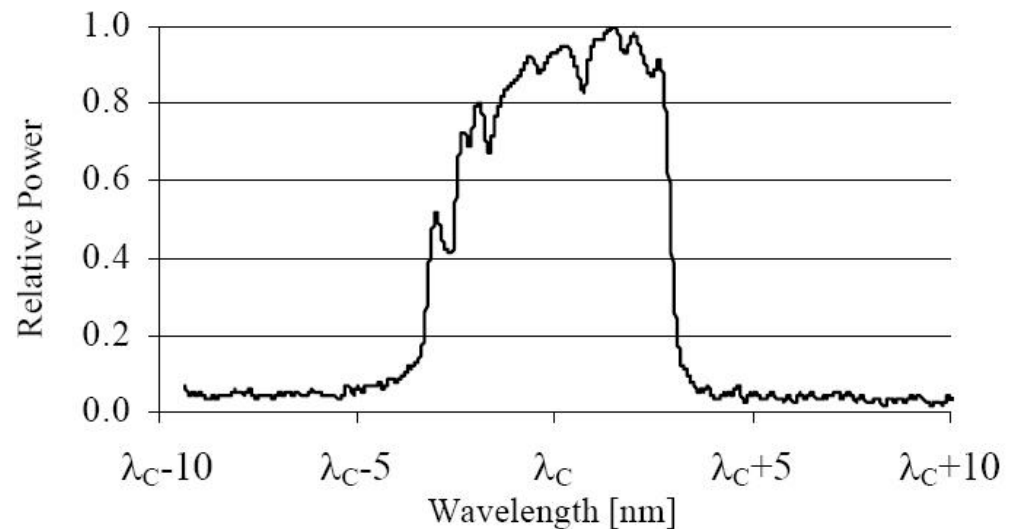
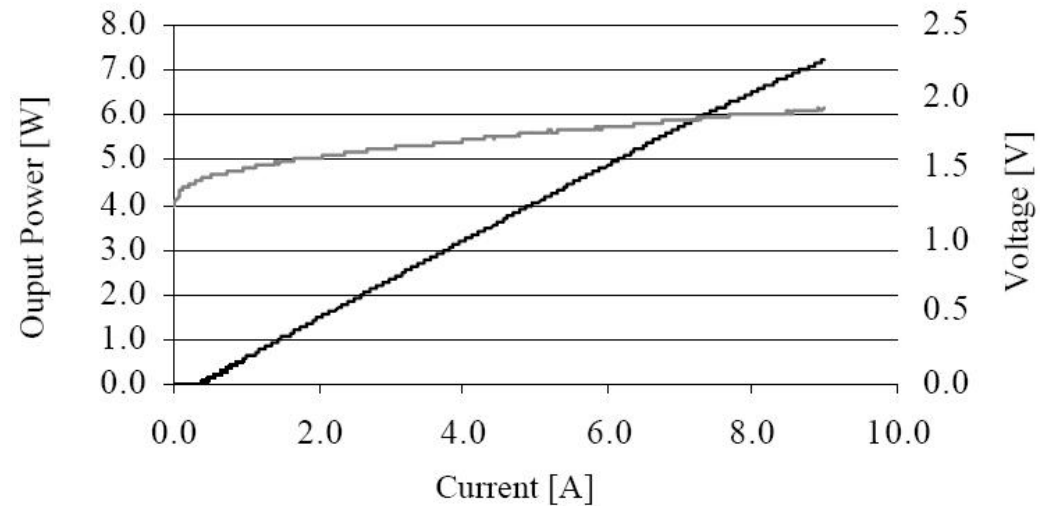
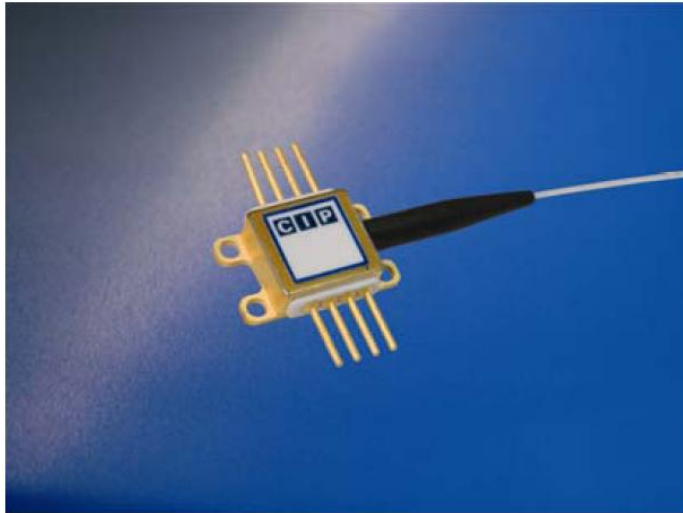
▶ Erbium Doped Fiber Amplifier



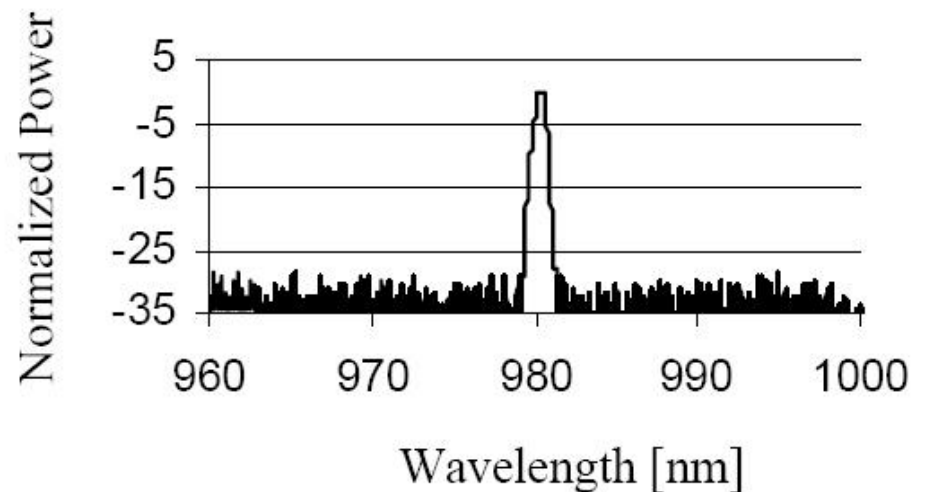
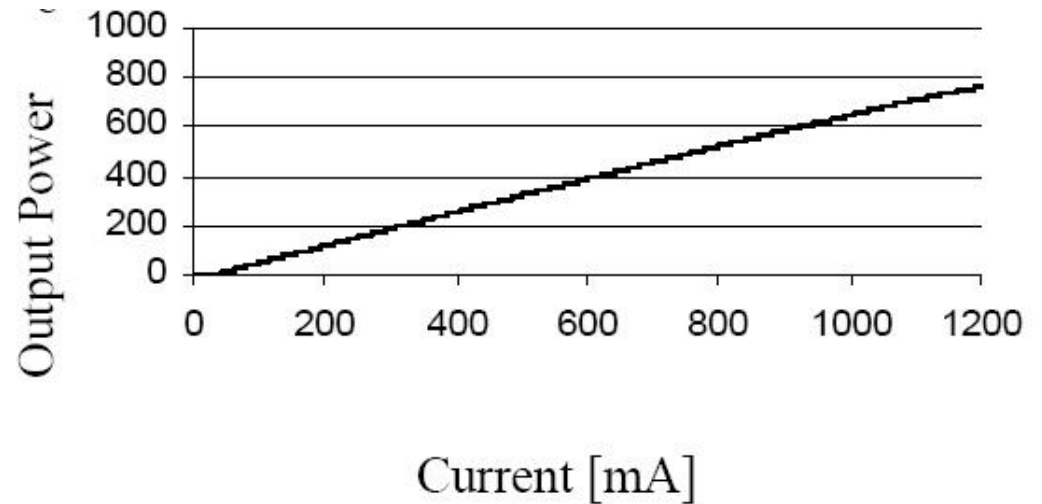
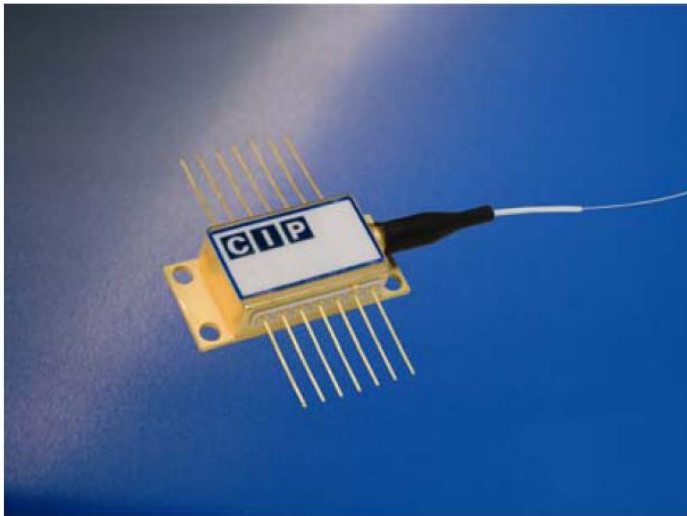
EDFA



7W 980 nm Multimode Pump Laser

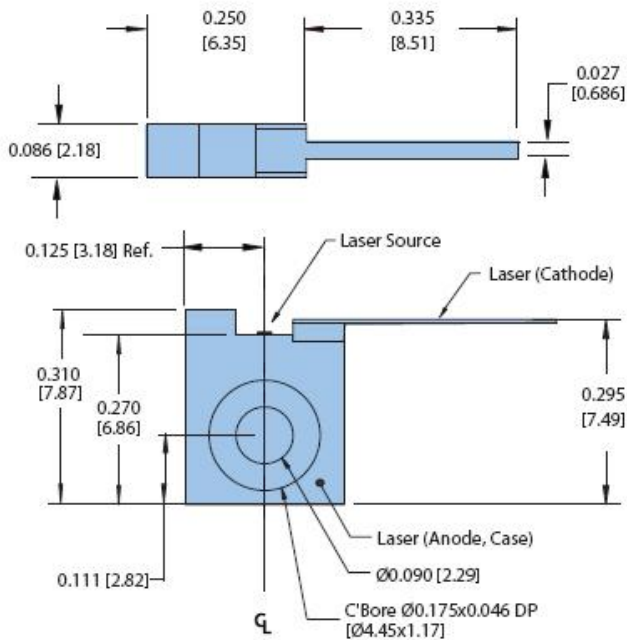


600mW 980 nm Singlemode Pump Laser

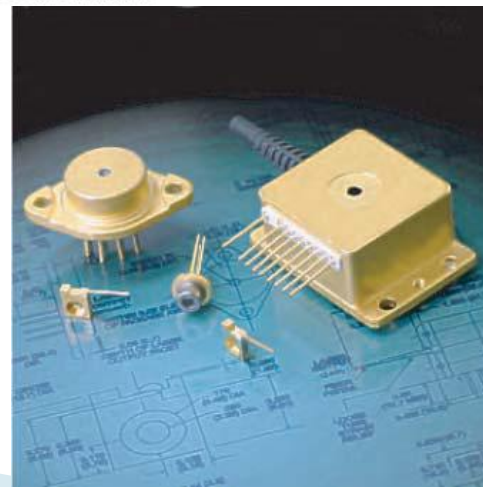
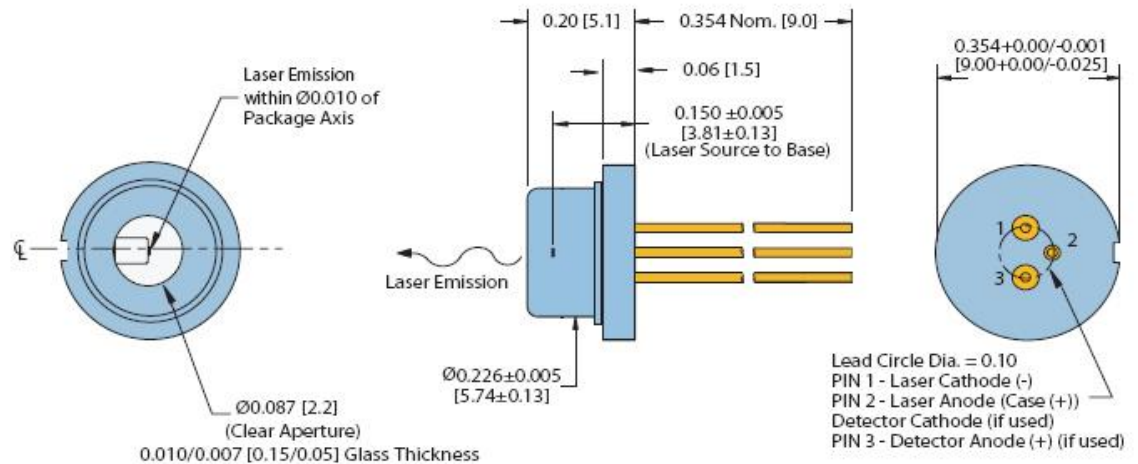


6 W, CW, 800nm

C-Mount Package

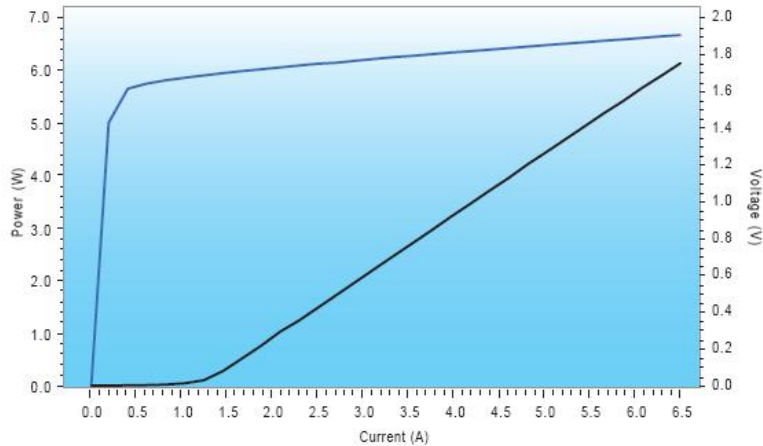


9mm Package

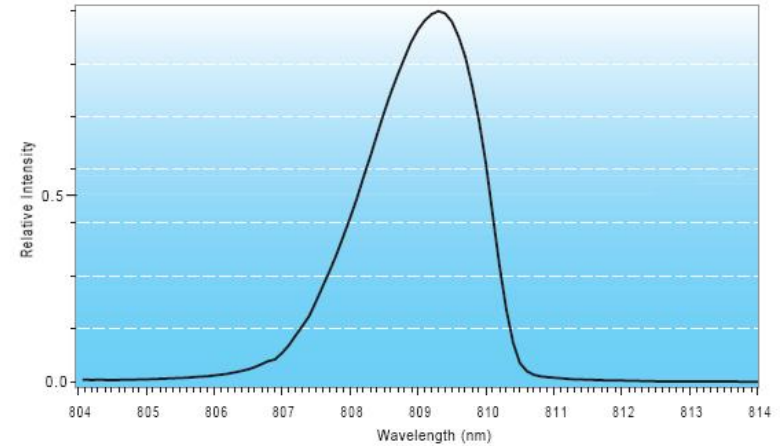


6 W, CW, 800nm

Typical L/I, V/I Graph

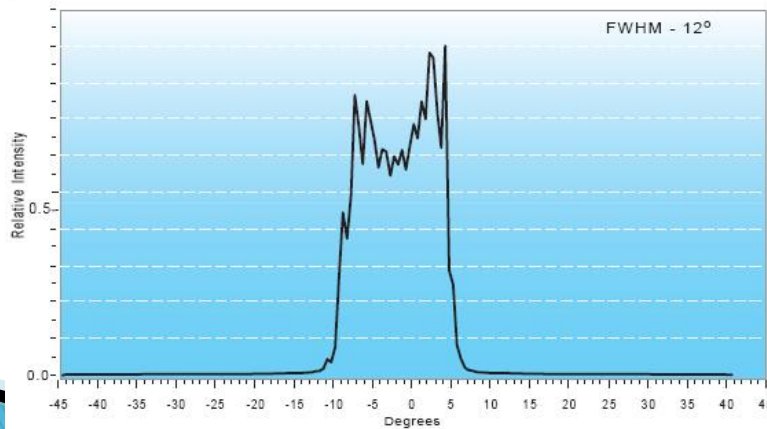


Wavelength Distribution



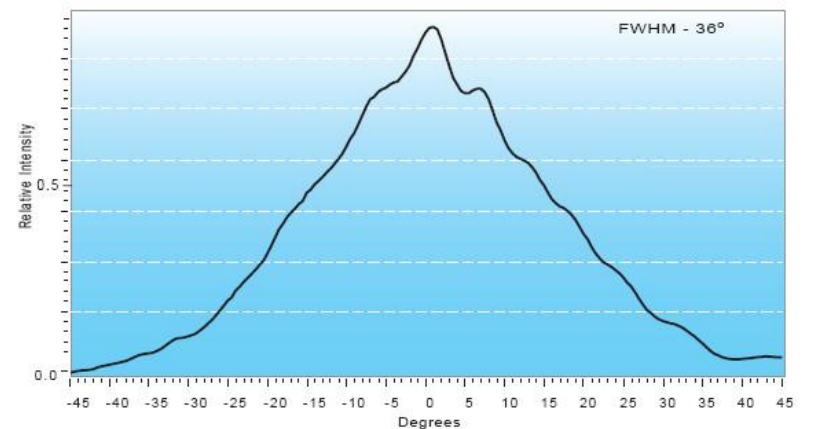
Typical Beam Divergence

Parallel

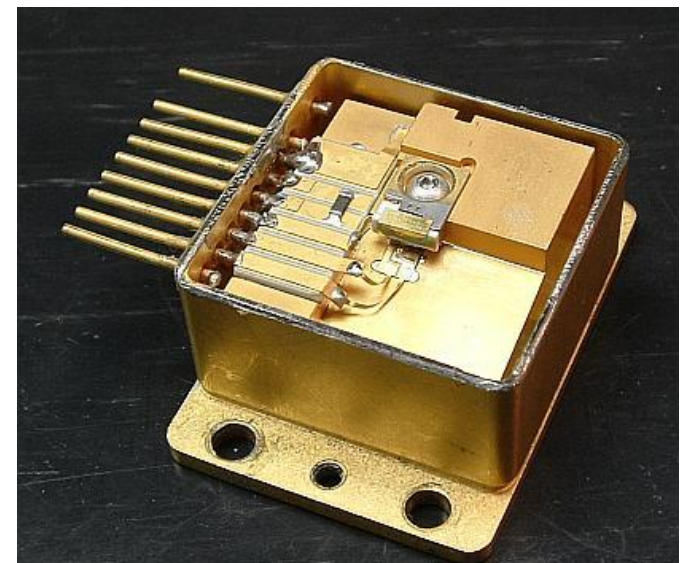
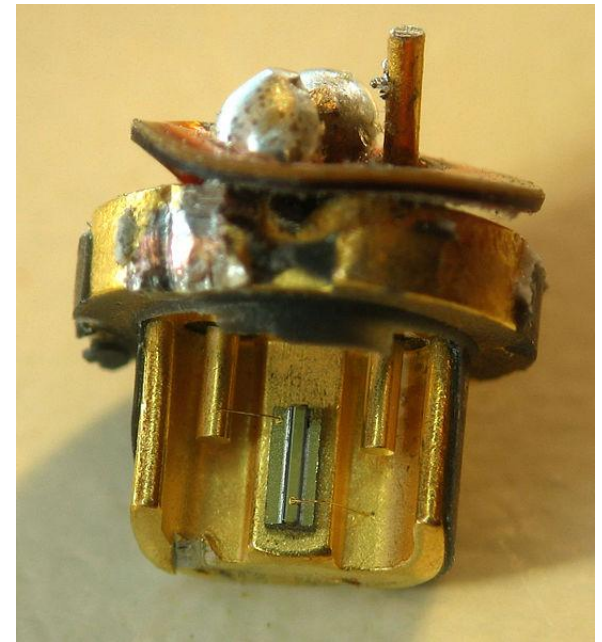
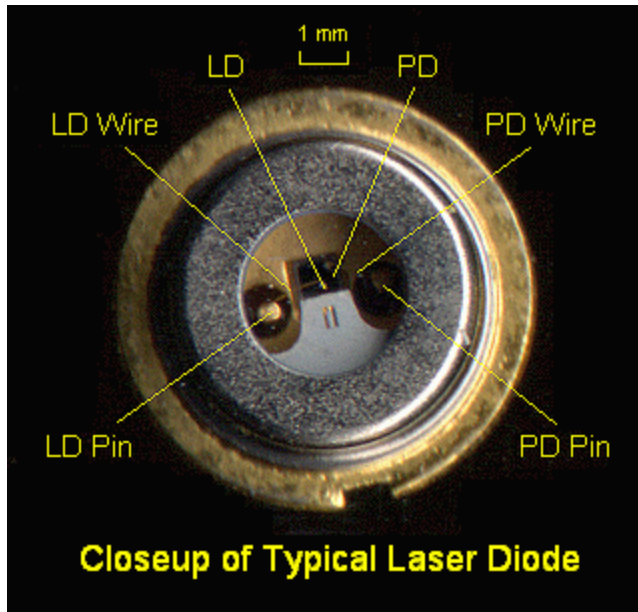


Typical Beam Divergence

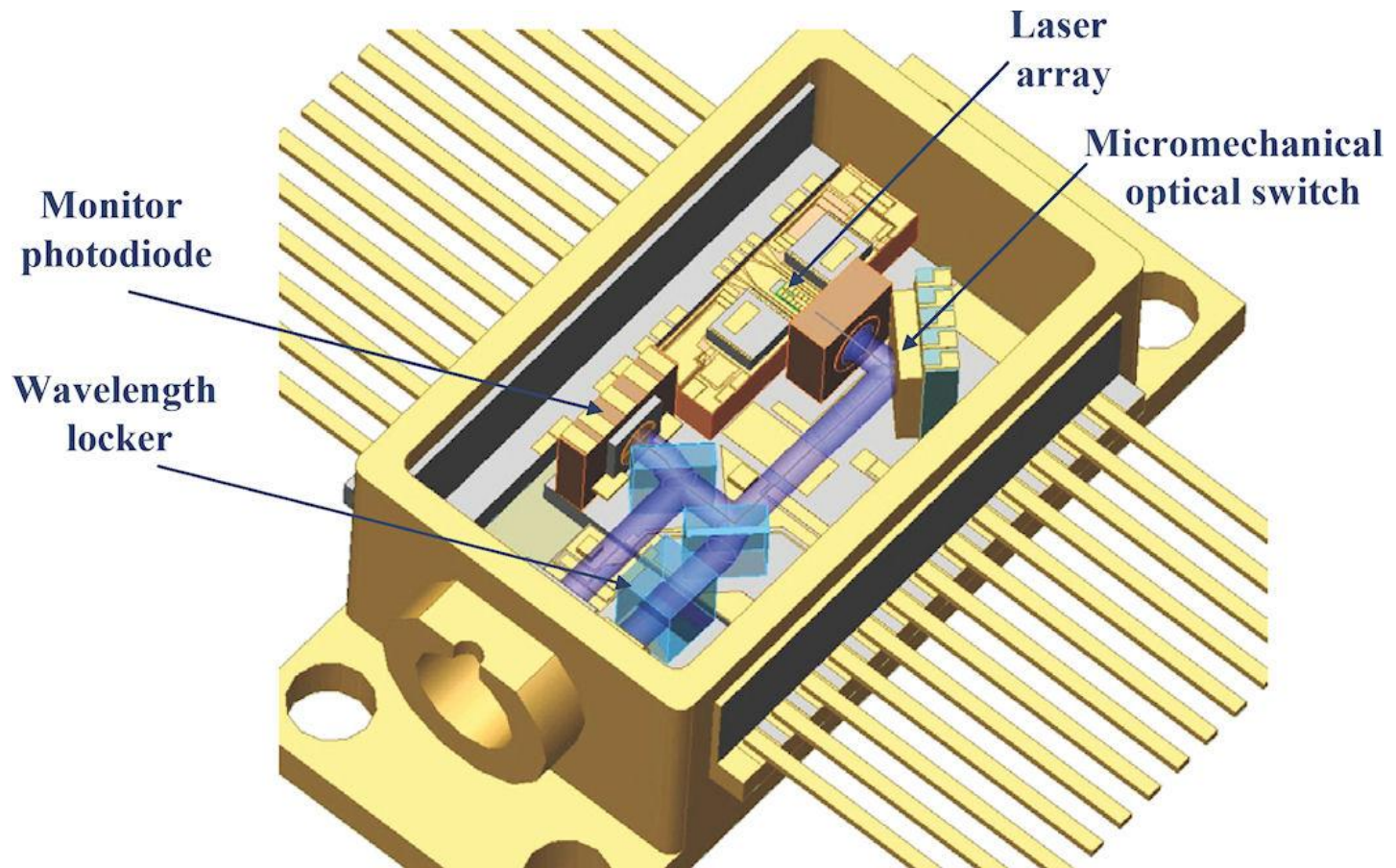
Perpendicular

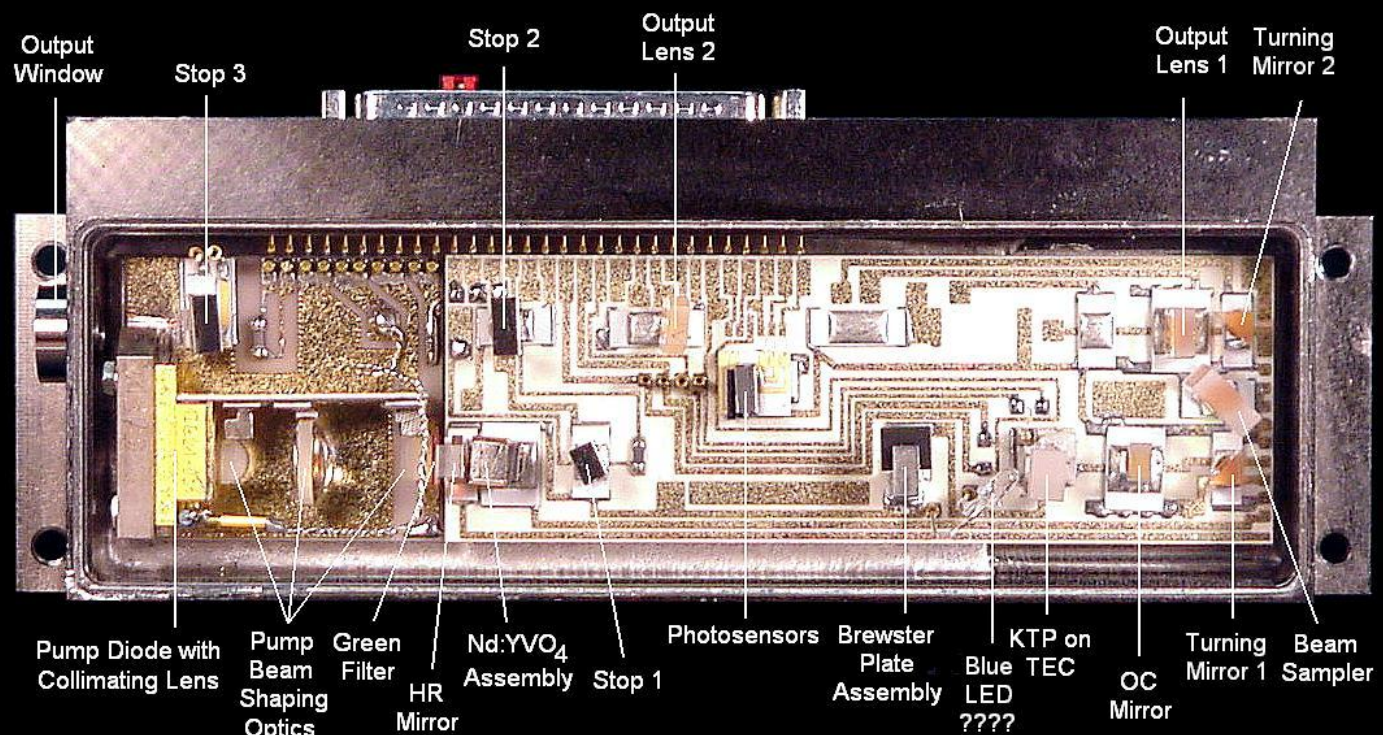


CW Laser, 650 nm

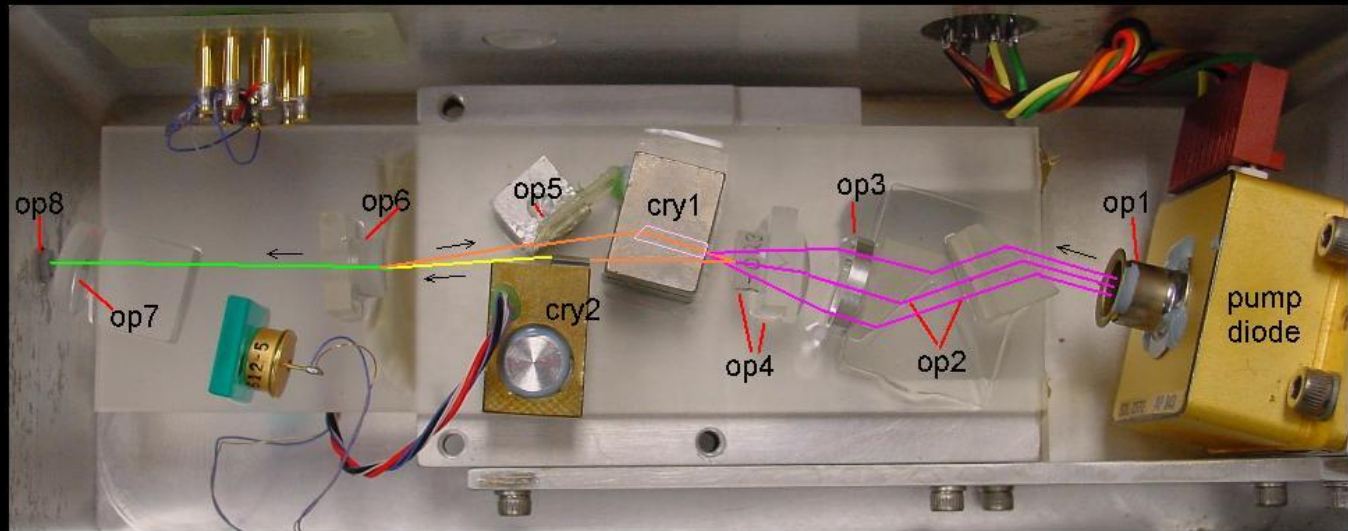


Tunable Laser Diode Chip





Coherent 415M Cavity Components and Output Optics



Beam Paths: 808 nm — 1064 nm — 1064+532 nm — 532 nm —

Legend: op1-op3: Pump beam shaping, op4: HR@1064nm, cry1: YAG crystal assembly, cry2: KTP SHG crystal, op5: Angled plate, op6: HR@1064nm;HT@532nm/beam expander, op7: collimator, op8: IR filter/polarization rotator.

Coherent 532-200 Cavity Components and Output Optics

Contact

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