



National Changhua University of Education

雷射科技與應用

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大綱

- 雷射原理簡介
- 雷射的類型
- 雷射的應用
- 半導體雷射



簡介-何謂光電

- 光電領域泛指所有應用 **光** → **電** 及 **電** → **光** 轉換的科學與技術
- 雷射是最普遍，典型的光電元件。
- 雷射的原文是Light Amplification by Stimulated Emission of Radiation (LASER)
- 意指”藉由激發性放射幅射的光放大”。
- 大陸翻譯為激光

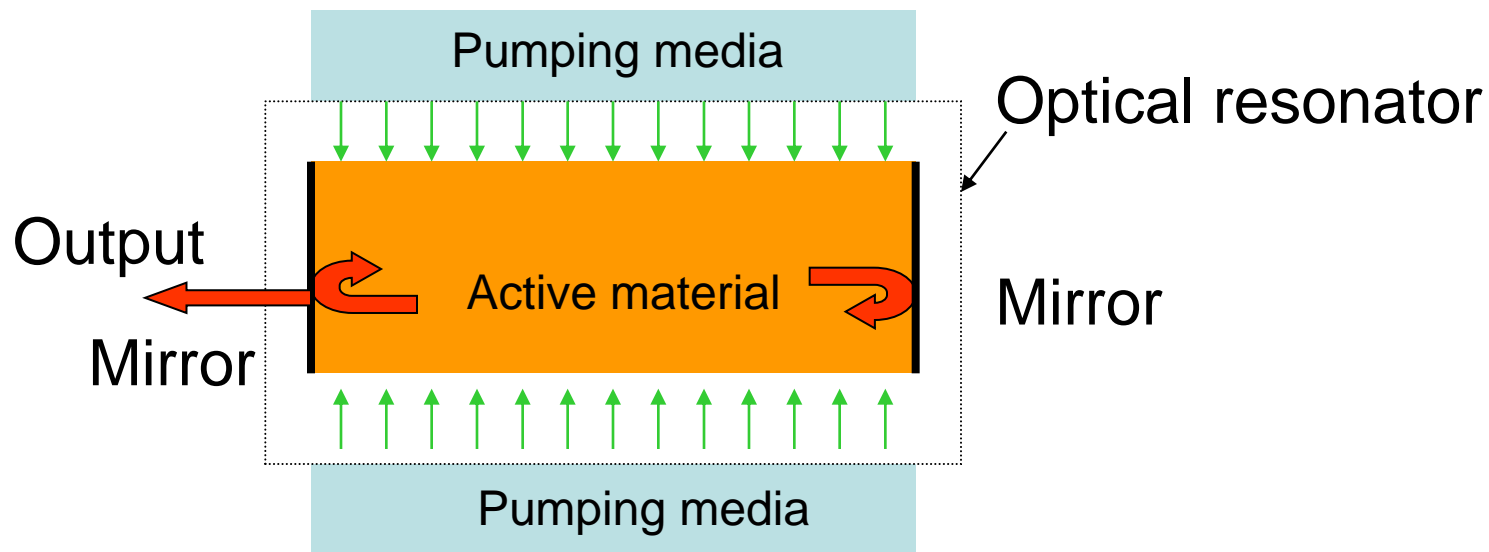


雷射的特性

- 高光功率密度
- 高指向性平行光束
- 高相干性同調光（同相位）
- 單色光



雷射的基本構造





大綱

- 雷射原理簡介
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- 雷射的應用
- 半導體雷射



常見的雷射

相	種類	活性物質	振盪波長	形態	特徵
氣體	He-Ne雷射	Ne	632.8nm	連續	功率雖小但可作同調性佳的穩定輸出、操縱簡單
	氬氣雷射	Ar	488nm 514.5nm	連續	功率大且可作同調性佳的定輸出
	CO2氣體雷射	CO2	10.6nm	連續	高輸出、高效率紅外線
	準分子雷射	ArF、KrF、 XeCl、XeF	193、248、 308、351nm	脈衝	高輸出 紫外線
	金屬蒸汽雷射	Cu、Au	511、578、 628nm	脈衝	高速度往復 平均輸出大
固體	YAG雷射	Nd	1.06mm	脈衝 連續	高能量脈衝、高輸出、高速往復
	半導體雷射	GaAlAs/GaAs InGaAsP/InP InGaN/GaN	0.84nm 1.2~1.6mm 0.3~0.6mm	脈衝 連續	袖珍、可直接調整脈衝



紅寶石雷射

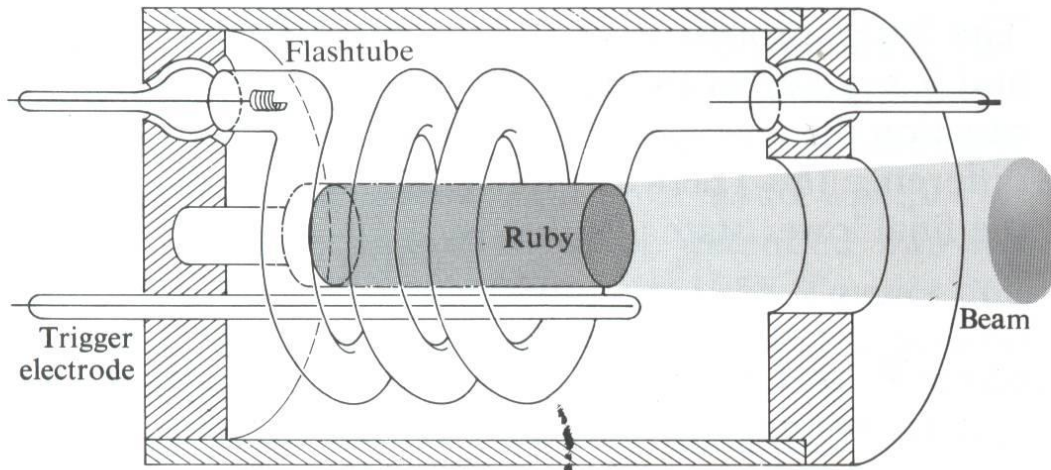


Figure 14.25 The first ruby-laser configuration, just about life-sized.



Flat mirror (Reflectivity = 0.999)

Concave mirror (Reflectivity = 0.985)

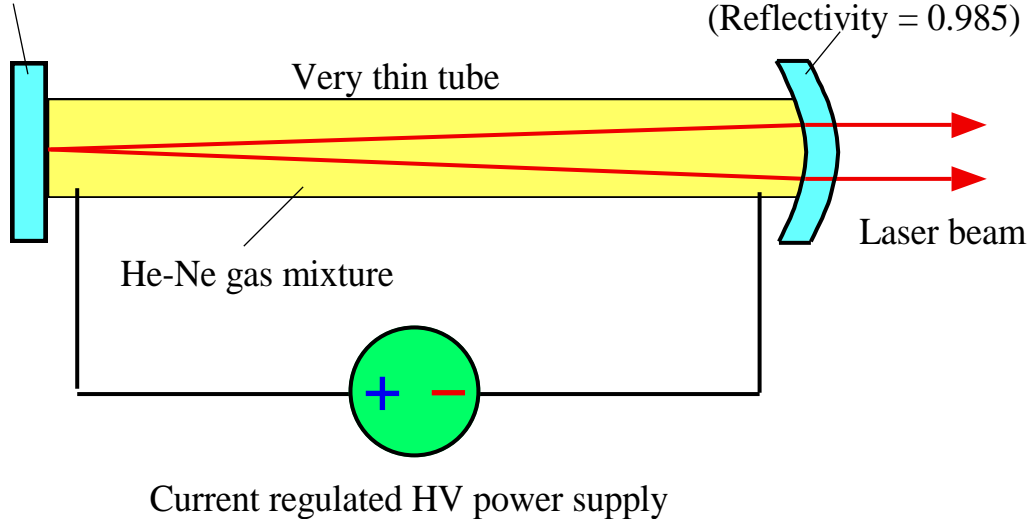


Fig. 3.39: A schematic illustration of the He-Ne laser



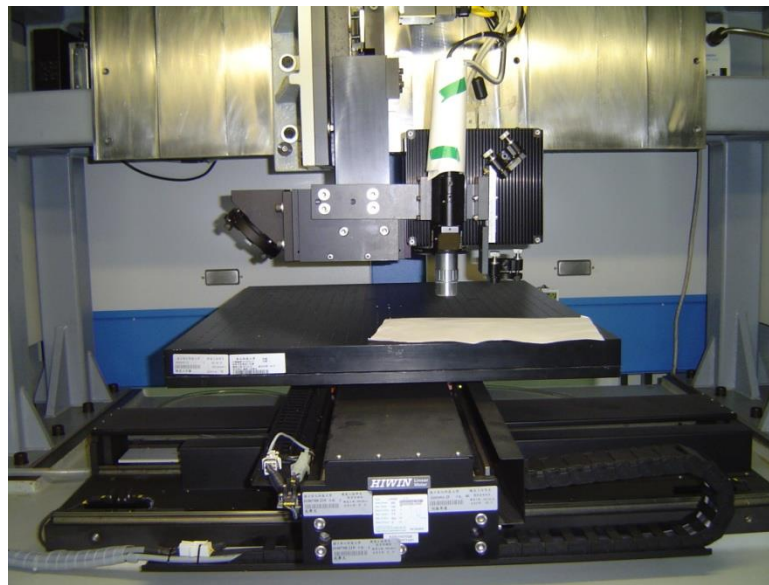
A modern stabilized HeNe laser.



[SOURCE: Courtesy of Melles Griot



CO₂雷射



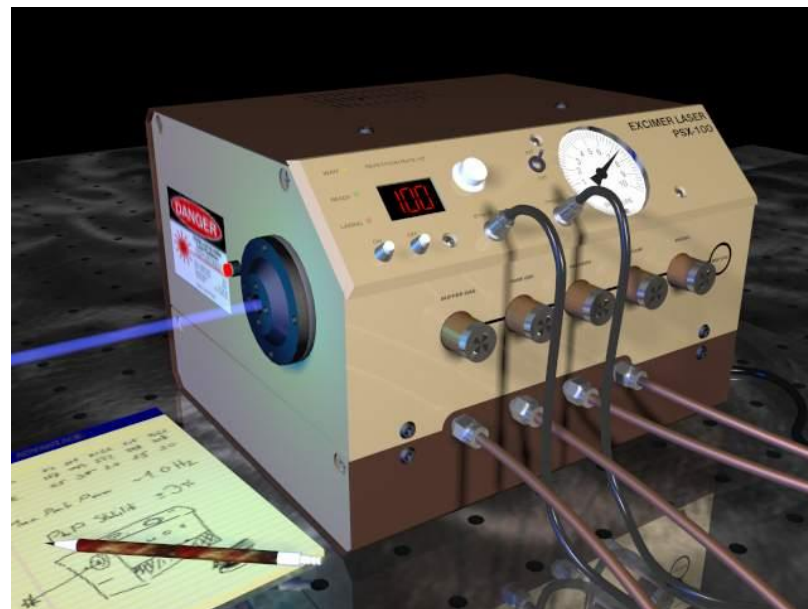


脈衝雷射

Nd:YAG



Excimer





半導體雷射

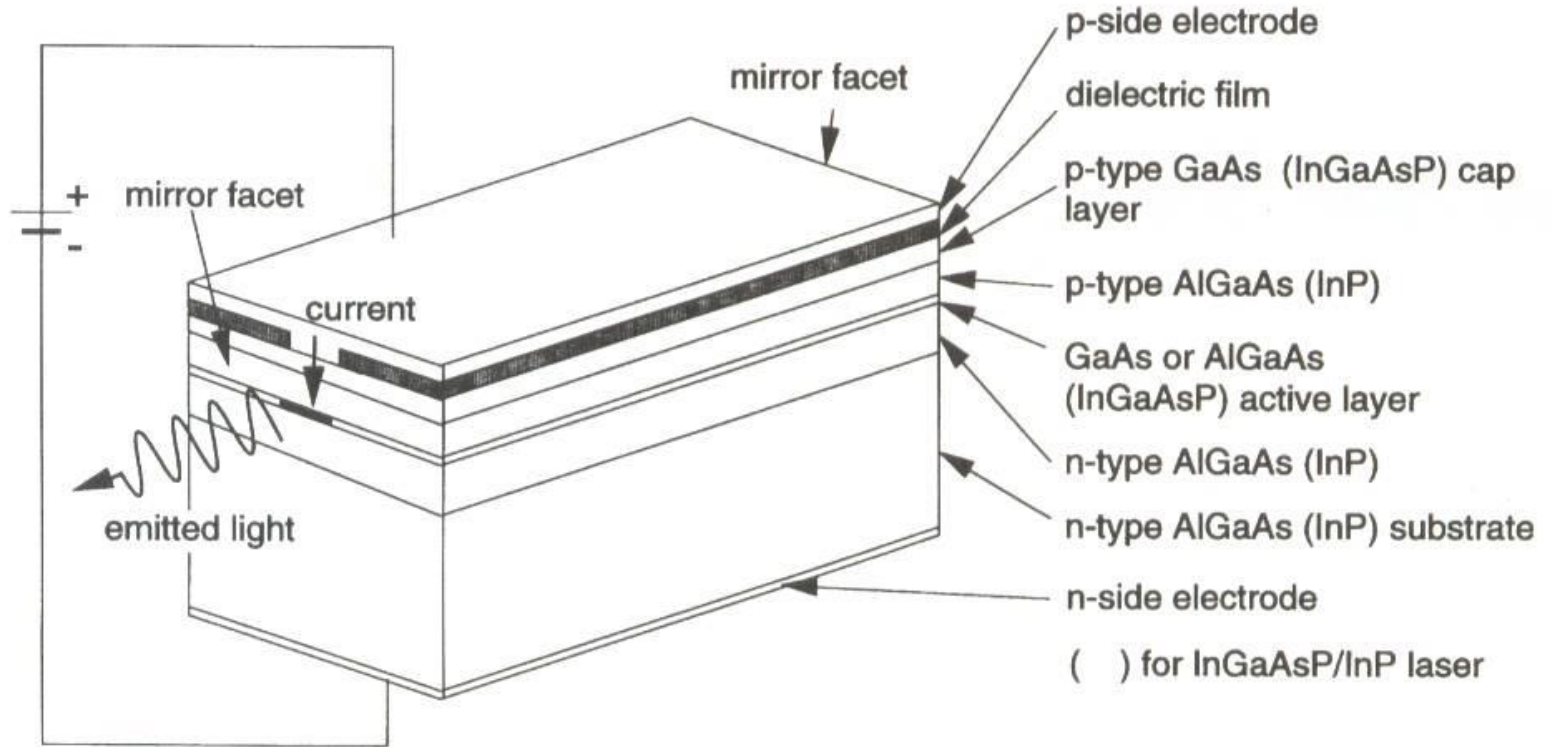


FIGURE 3.1 Basic structure of a Fabry-Perot laser diode.



大綱

- 雷射原理簡介
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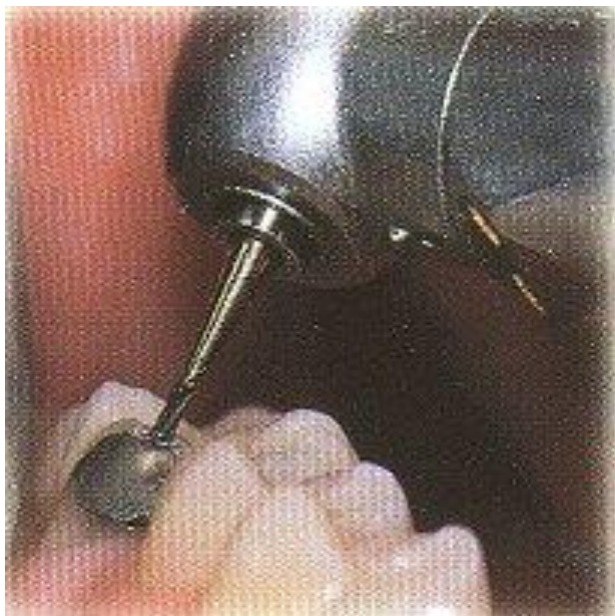


醫學(皮膚治療)

- 脈衝染料雷射也可以被用來有效地治療許多其他不同的血管疾病，包括臉上破裂的血管，胎記，血管瘤，不同類型的疤，甚至是疣。
- 治療皮膚的色素性疾病。這種雷射釋放出的光波長，可以讓皮膚上的色素吸收較好。這使得它可以用來治療各種皮膚表面或是較深部的色素性病灶。現在已經有許多種雷射被核准可以用來治療老人斑，太陽斑（雀斑），咖啡色胎記，以及刺青等等。



醫學(牙齒治療)

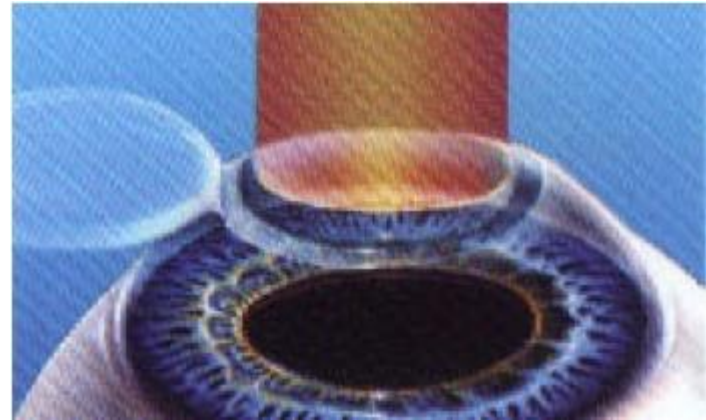
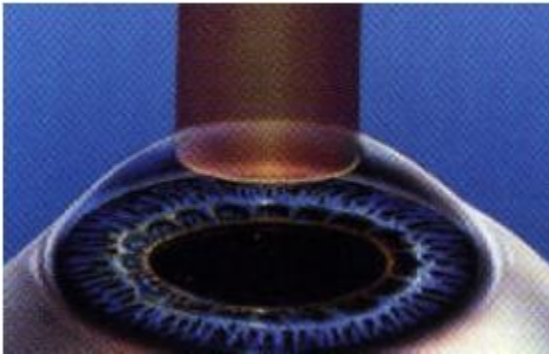


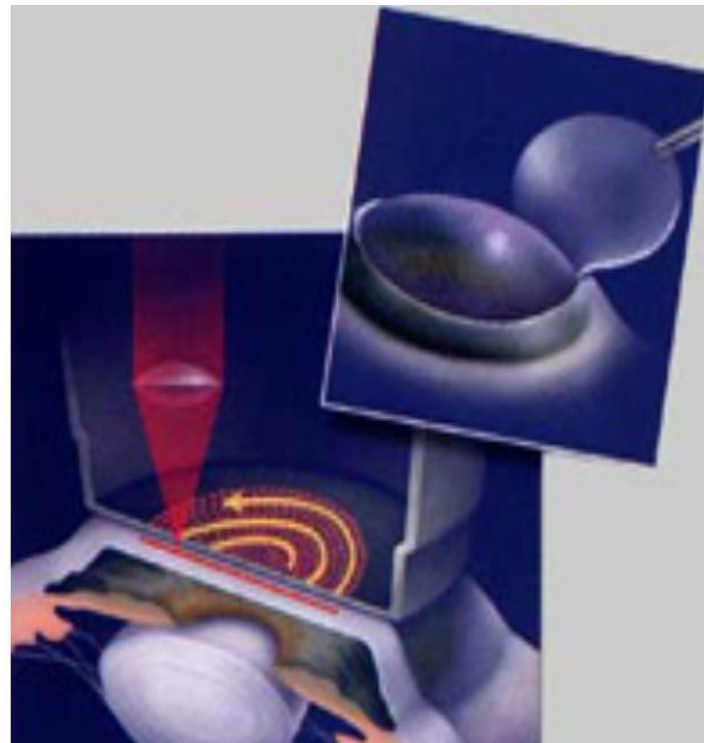
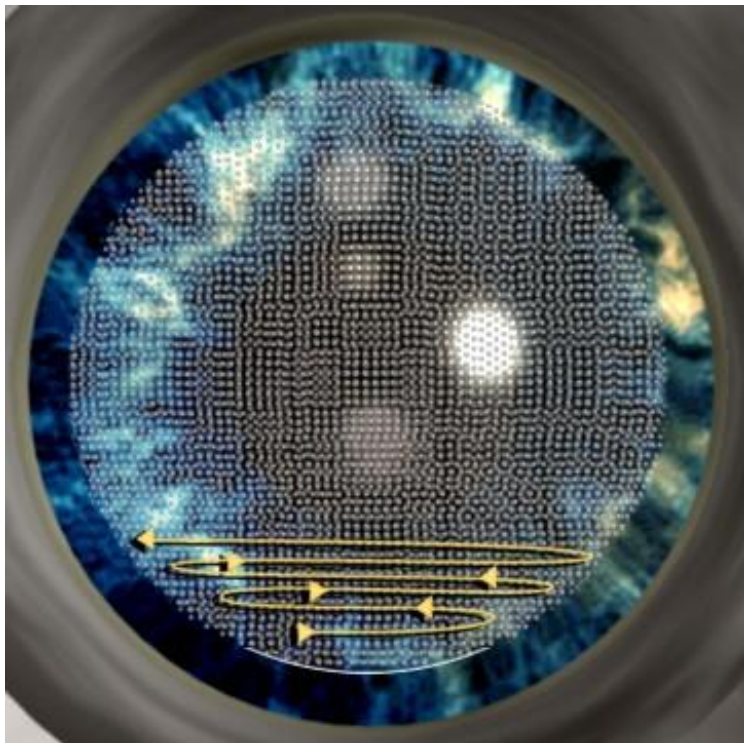


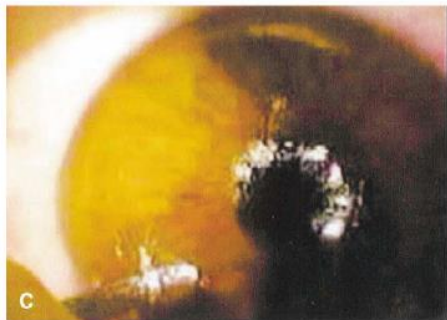
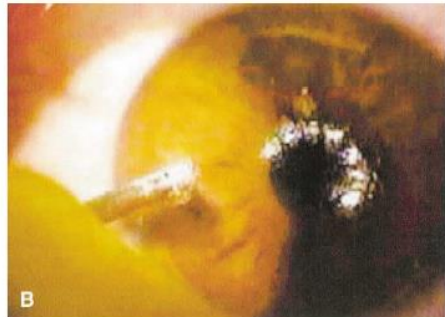
準分子雷射近視手術又主要分為雷射屈光角膜切除術(photorefractive keratectomy, PRK)和雷射原位層狀角膜成塑形(Laser in-situ keratomileusis, LASIK)兩種。

PRK 手術的方式(圖一)是把角膜上皮細胞刮除後，以準分子雷射來進行預先設定的角膜厚度切除，達到削平角膜而減低近視和散光度數，度數越深切除越厚。一般雷射照射的時間約30 秒至一分鐘間，術後會給予抗生素眼藥水和戴隱形眼鏡，約3 至10 天上皮細胞才會癒合。

LASIK 手術(圖二)是以層狀角膜切割刀切開約130 - 160um厚角膜瓣後，再以準分子雷射來進行角膜切除，之後再回復原角膜瓣至原來位置，其視力復原較PRK 快且術後疼痛程度較少也較短，大多數隔天視力就恢復至相當好而且也不痛了，較不影響日常生活。

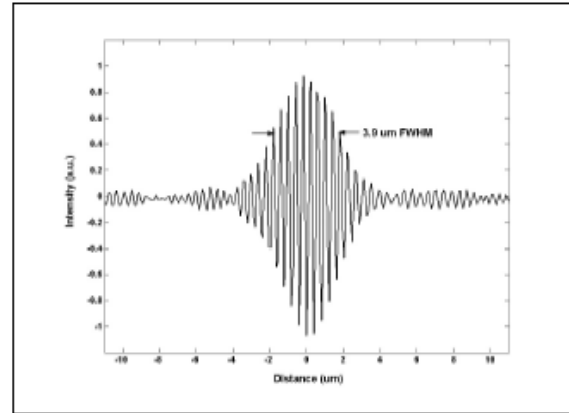
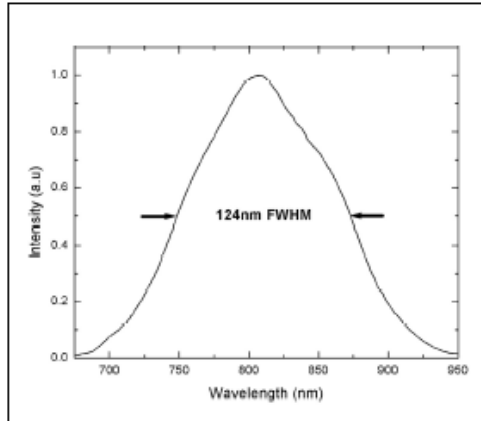








Optical Coherence Tomography (OCT)



視網膜

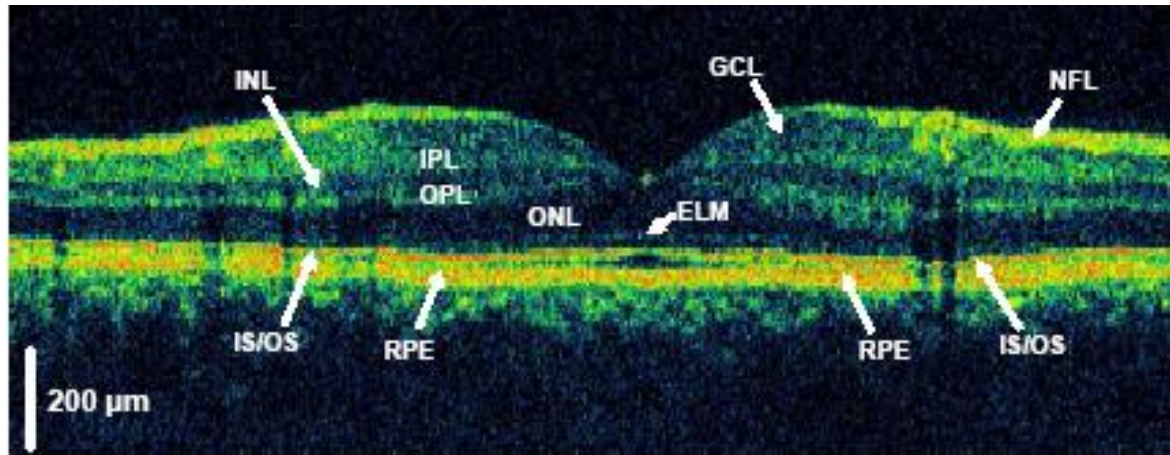
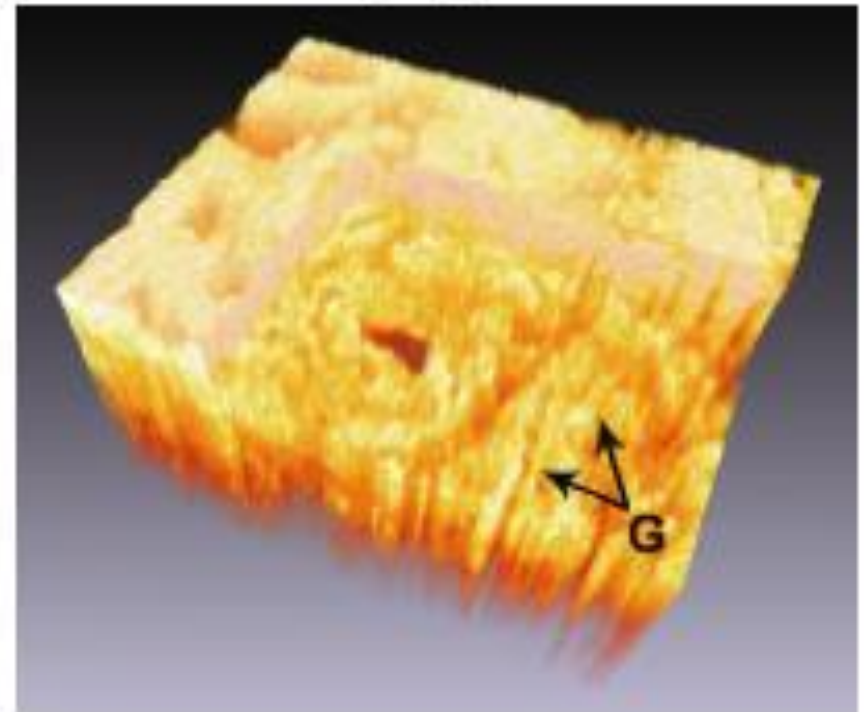
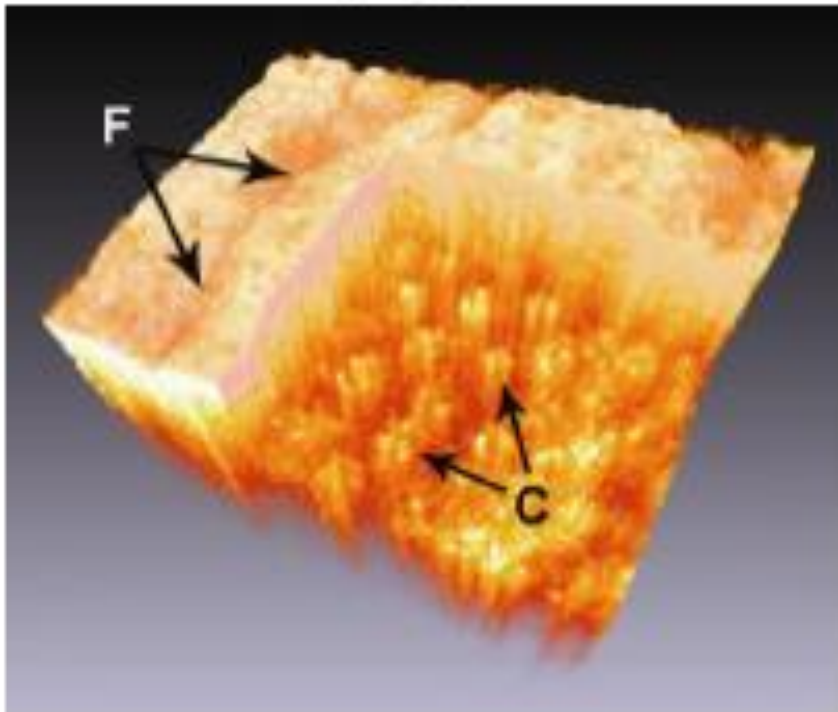


Figure 4. *In vivo* ultrahigh resolution OCT image of the human retina taken with a broadband SLD light source. Image axial resolution in the retina was about 3.2 μm and transverse resolution was about 15-20 μm. All the major intraretinal layers can be clearly seen in this ultrahigh resolution OCT image.



醫學診斷

結腸



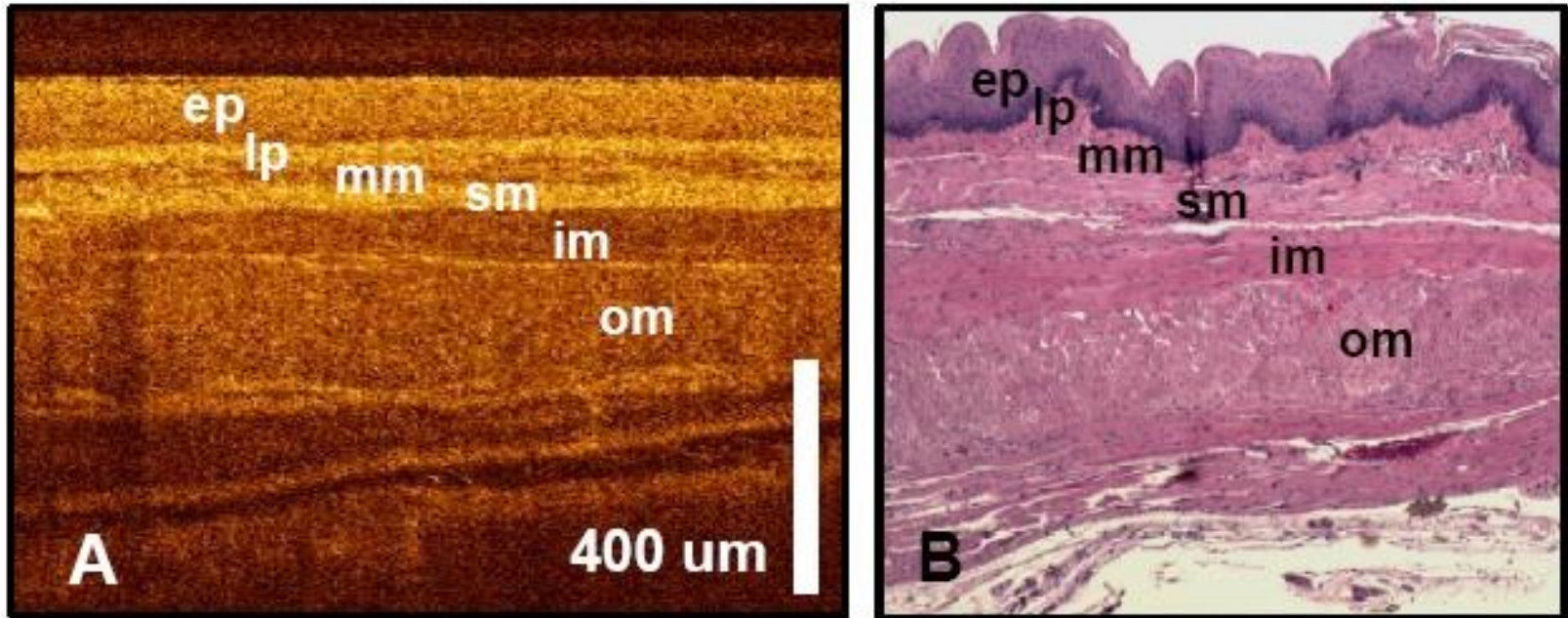


Figure 3. (A) *In vivo* endoscopic OCT image of rabbit esophagus with corresponding histology (B). Good correlation is seen between the OCT and histological cross sections for epithelium (ep), lamina propria (lp), muscularis mucosa (mm), submucosa (sm), and inner (im) and outer muscular (om) layers.



機械加工

- 切割1, 切割2
- 雕刻1, 雕刻2
- 焊接



其他應用

- 測距(測速)
- 光鉗(奈米操弄)
- 雷射印表機
- Laser TV
- 光儲存(CD,DVD)
- Pointer
- 雷射水平垂直儀
- Science research
- Toxic gas detection
- Sensors
- 熱處理

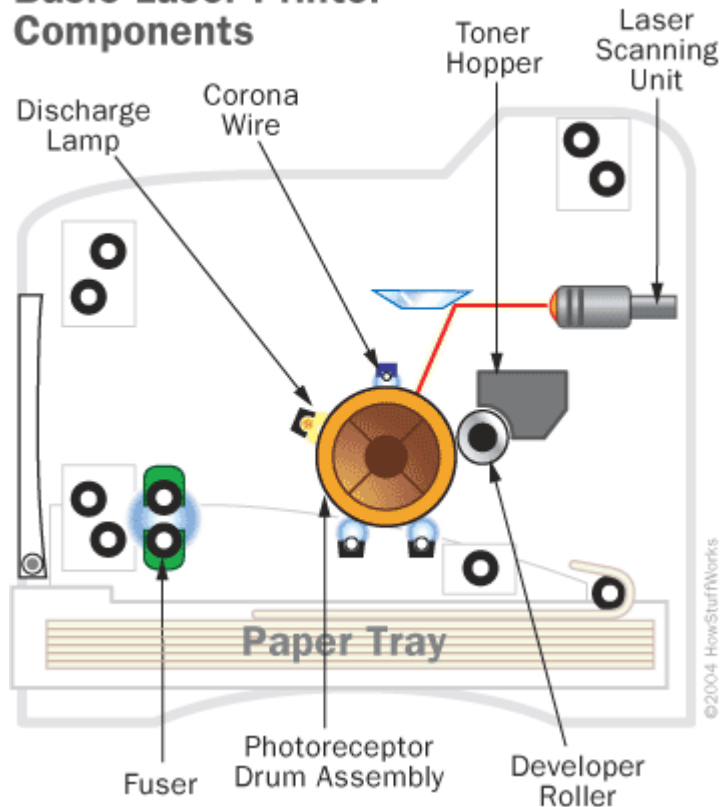


- 量子保密通信(密碼傳輸)
- Surgery knife
- Bar-code scanner
- 武器
- 光通訊



雷射印表機原理

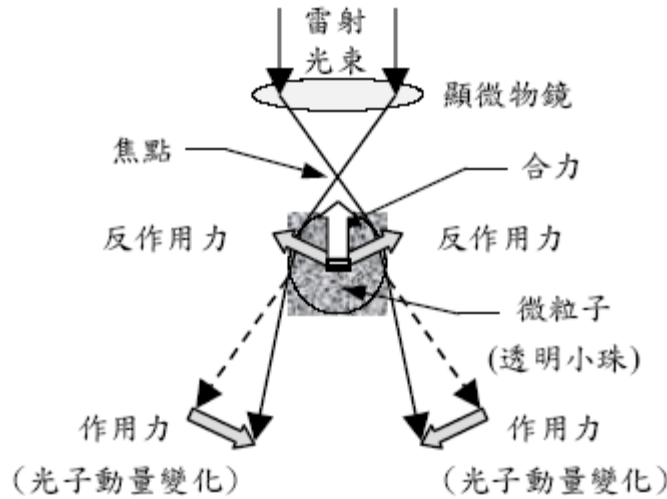
Basic Laser Printer Components



1. Charging (usually negative)
2. Exposure (laser scanning to remove charge)
3. Developing (adding carbon powder to the drum)
4. Transferring (print powder to paper)
5. Fusing
6. Clean

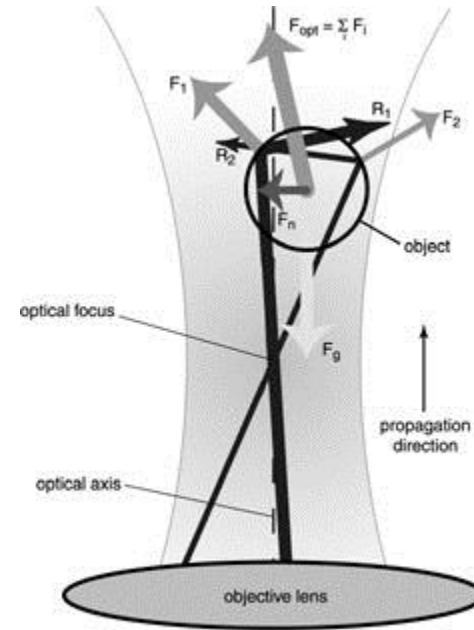


Optical Tweezer



圖二. 雷射鐮夾的工作機制

物理雙月刊 (廿二卷五期) 2000 年 10 月



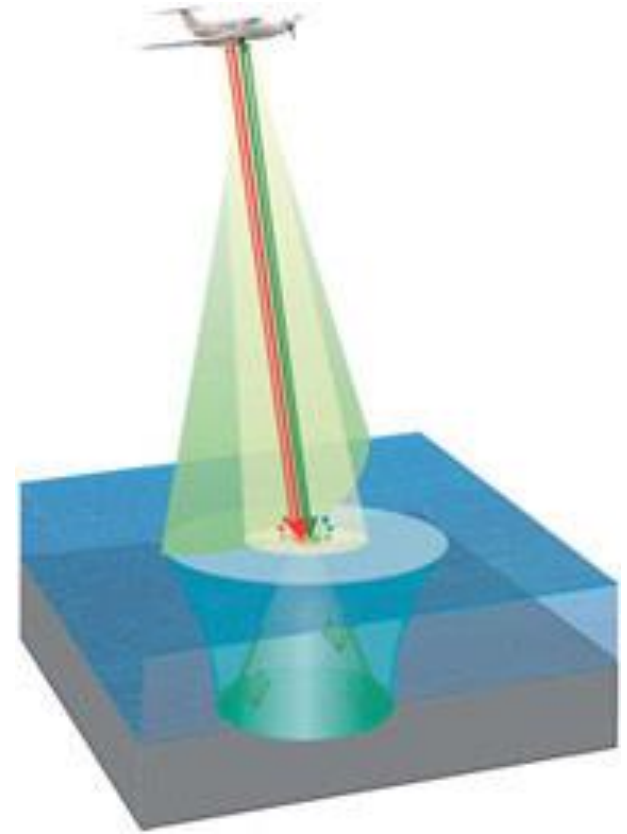
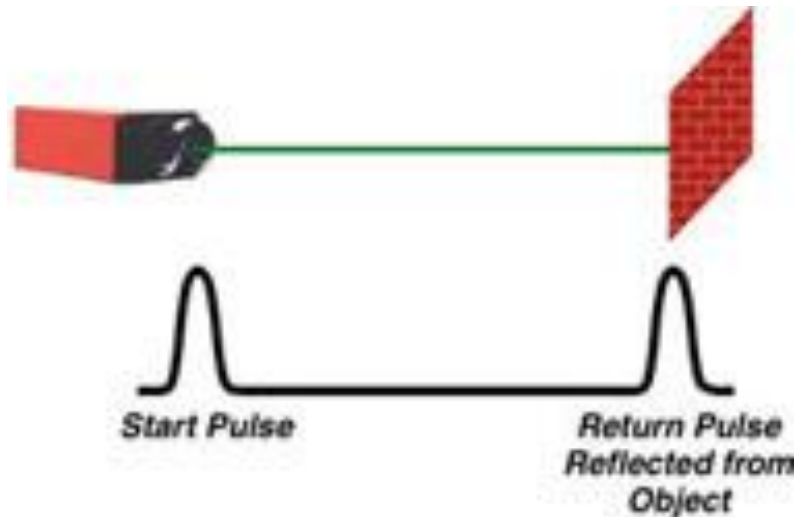
http://photoms.ym.edu.tw/PHOTOMS_C/Research.htm

Ag nano particle Particle manipulation



Lidar

$$\text{Distance} = (\text{Speed of Light} \times \text{Time of Flight}) / 2$$





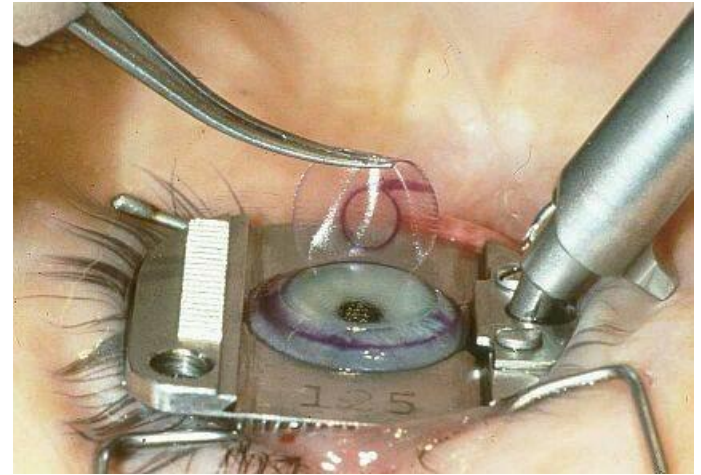
雷射測距儀





雷射水平垂直儀







Natio





Nanjing University of Aeronautics and Astronautics





Optical Storage

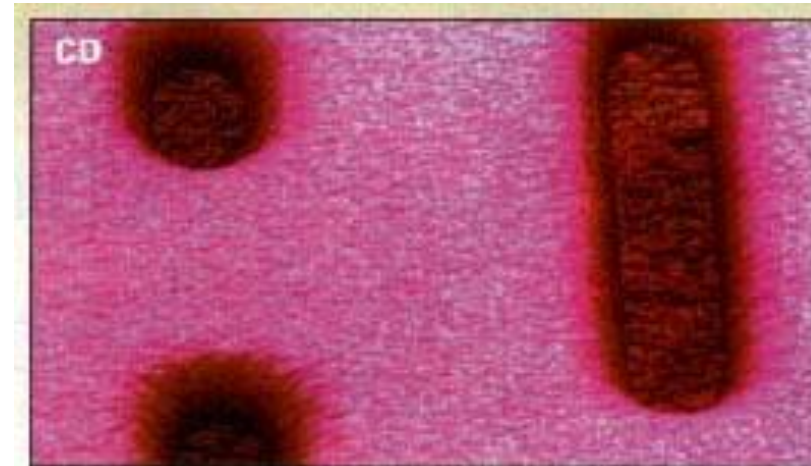
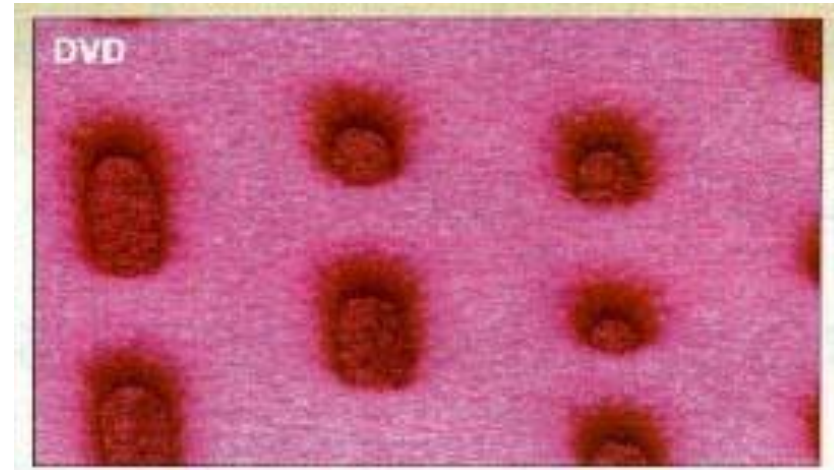
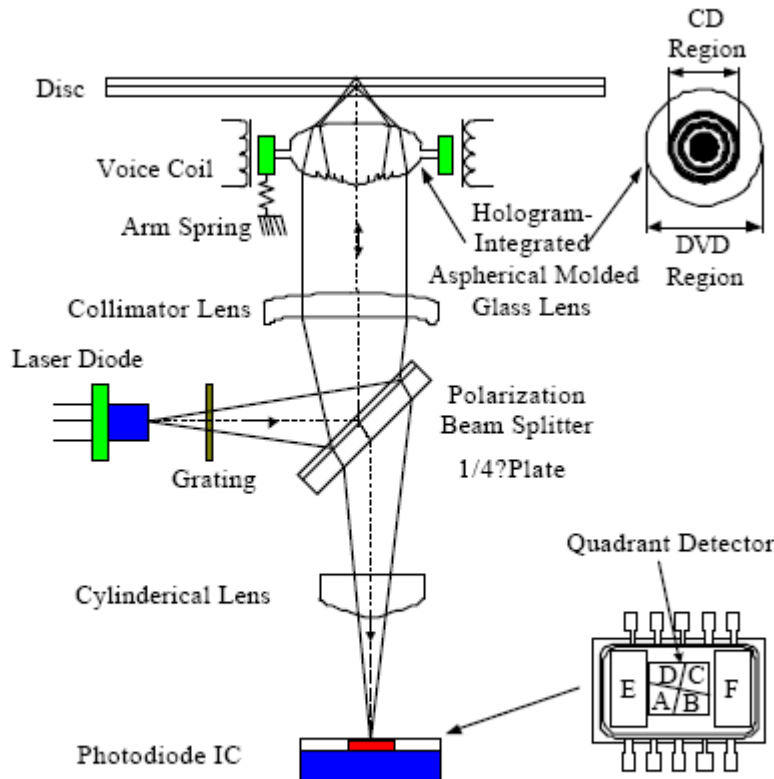


圖 2-1 DVD 光學讀取頭的內部結構示意圖



大綱

- 雷射原理簡介
- 雷射的類型
- 雷射的應用
- 半導體雷射



如何選擇適當半導體材料？

- 基板的限制 → 原子晶格大小須與基板一致
- 波長的限制 → 能隙大小須與所需波長吻合
- 材料特性 → 能隙必須是直接能隙才能發光



常見的光電半導體材料

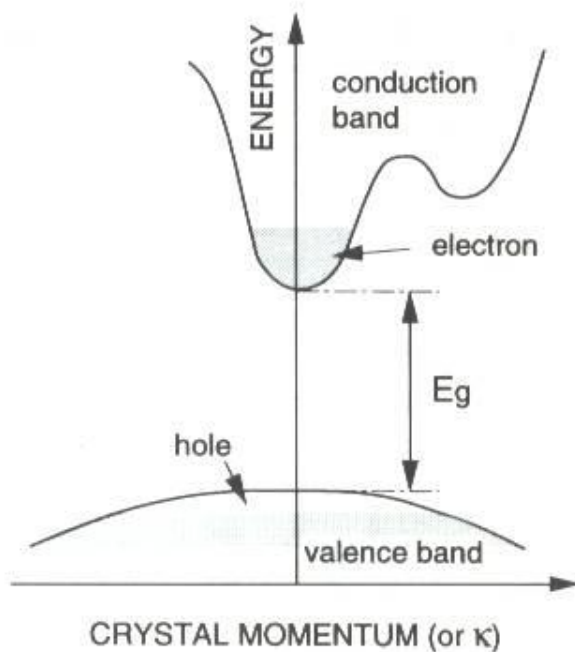
- GaN based 可發藍光或紫外光用於全彩顯示面板
- InP based 可發綠光紅光及紅外光
- GaAs based 可發紅外光用於光通訊
- Si, Ge, InGaAs 可用於製造太陽電池或檢光器
- Si可用於製造太陽電池
- 多晶矽及有機化合物可用於製造發光二極體



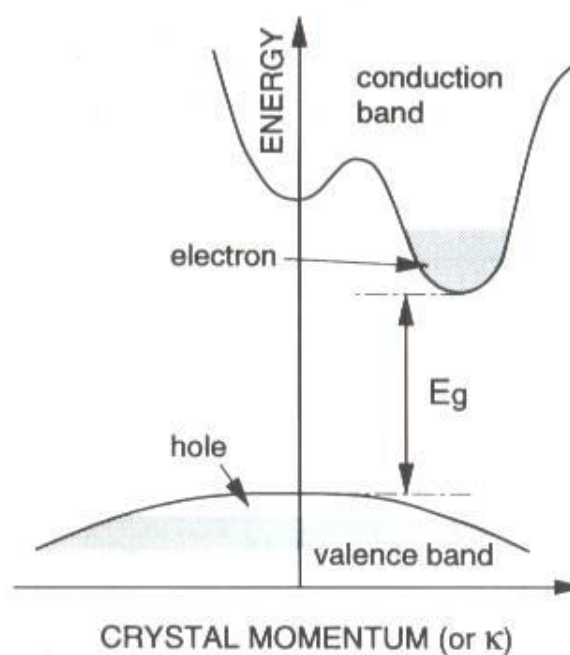
半導體材料的能帶特性

直接能隙 (GaAs)

間接能隙 (Si)



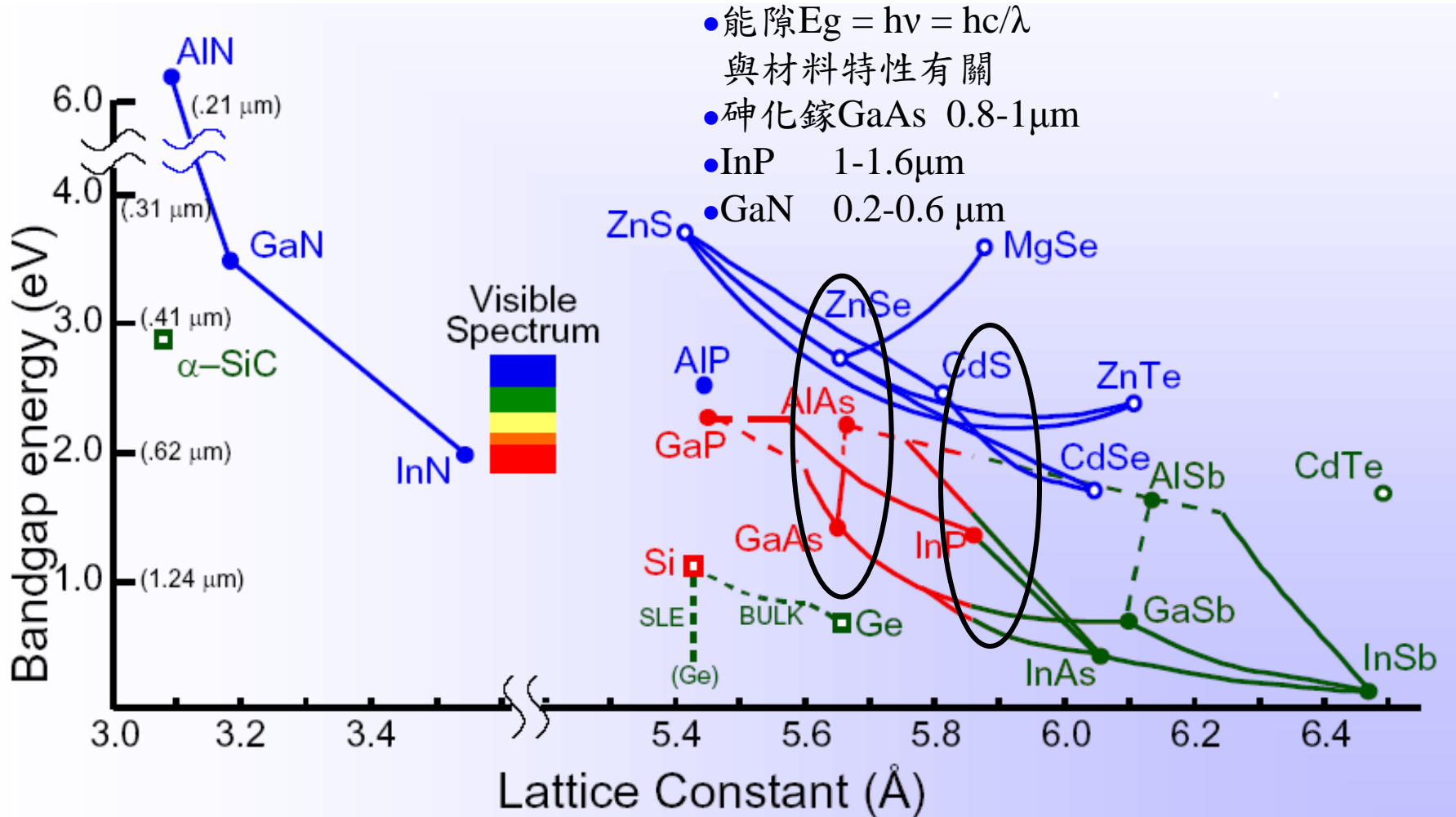
(a) direct-gap



(b) indirect-gap



光電半導體的晶格-能隙相圖



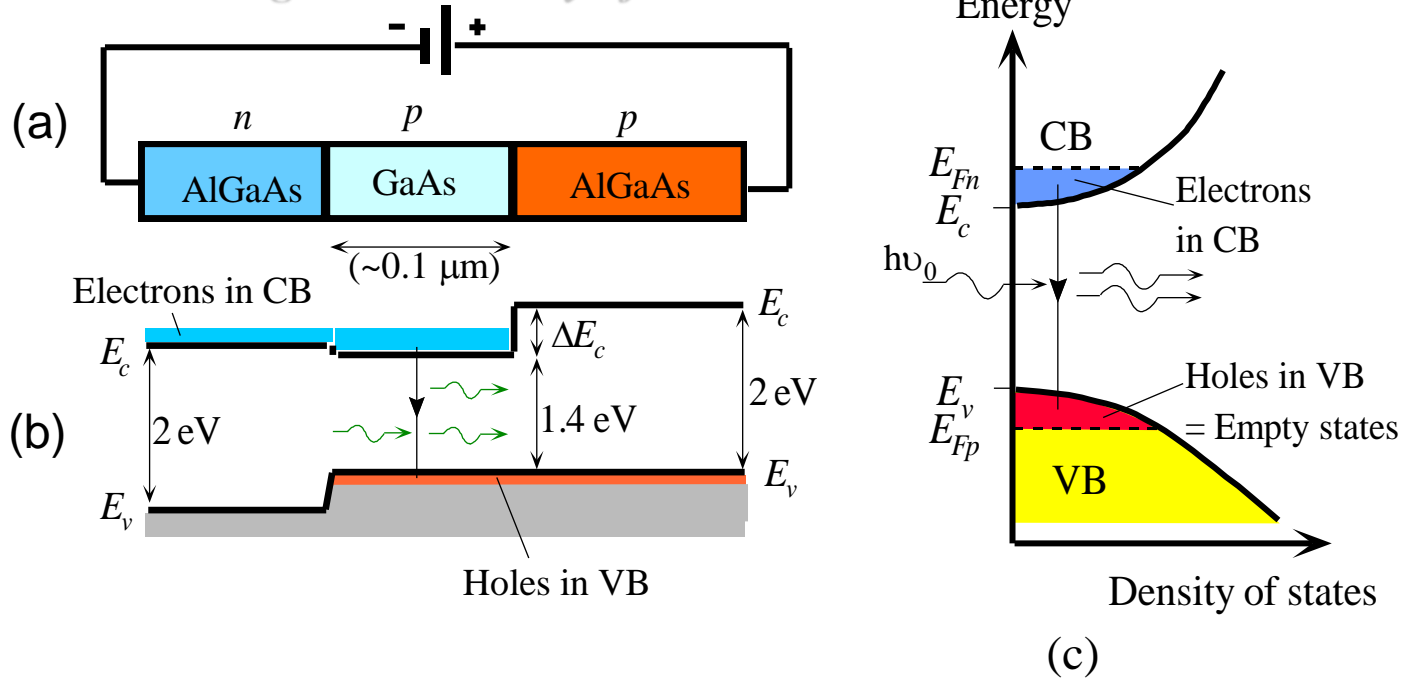


Fig. 6.55: (a) A double heterostructure diode has two junctions which are between two different bandgap semiconductors (GaAs and AlGaAs). (b) Simplified energy band diagram under a large forward bias. Lasing recombination takes place in the p-GaAs layer, the *active layer*. (c) The density of states and energy distribution of electrons and holes in the conduction and valence bands in the active layer.

From *Principles of Electronic Materials and Devices, Second Edition*, S.O. Kasap (© McGraw-Hill, 2002)
<http://Materials.USask.ca>

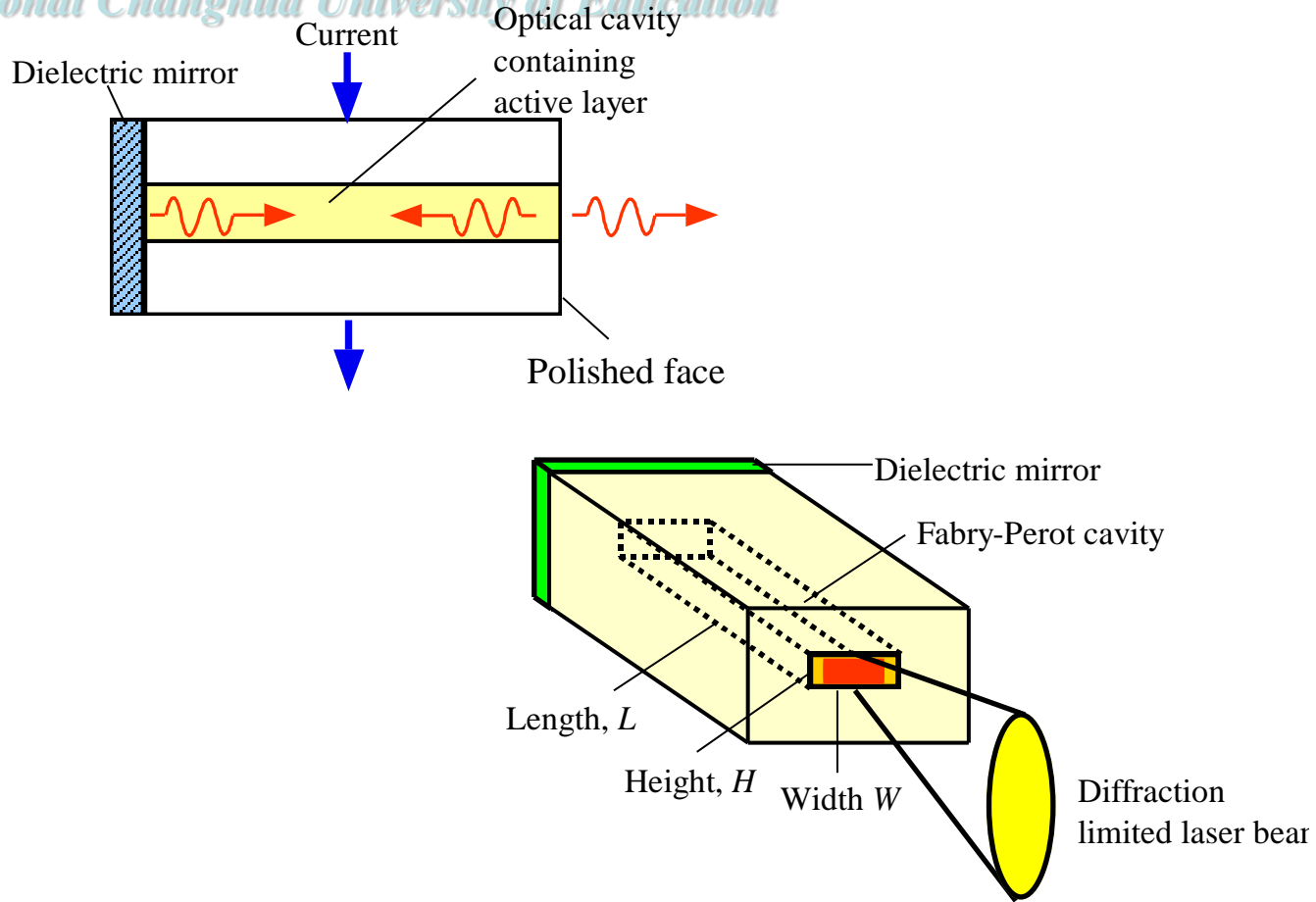


Fig. 6.56: A semiconductor lasers have an optical cavity to build-up the required electromagnetic oscillations.

From *Principles of Electronic Materials and Devices, Second Edition*, S.O. Kasap (© McGraw-Hill, 2002)
<http://Materials.Usask.Ca>



The following threshold condition must be satisfied to make a laser lase.

$$R_1 R_2 e^{2(g-\alpha_i)L} = 1$$

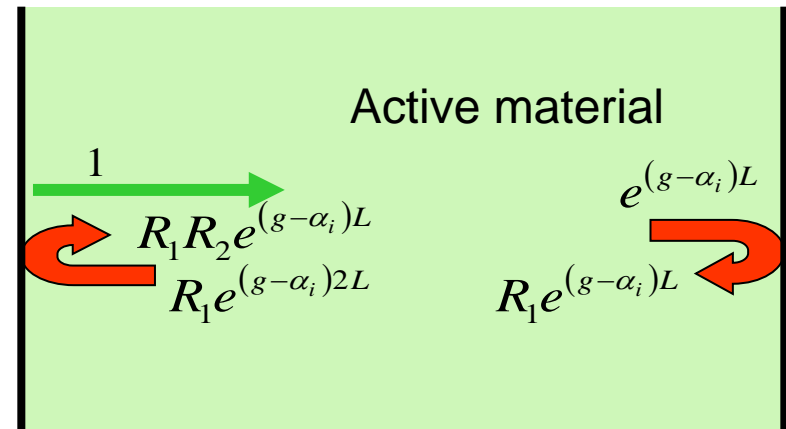
$$\Rightarrow g = \alpha_i + \frac{1}{2L} \ln \left(\frac{1}{R_1 R_2} \right)$$

R : the mirror reflectance

g : material gain (optical gain)

α_i : internal optical loss

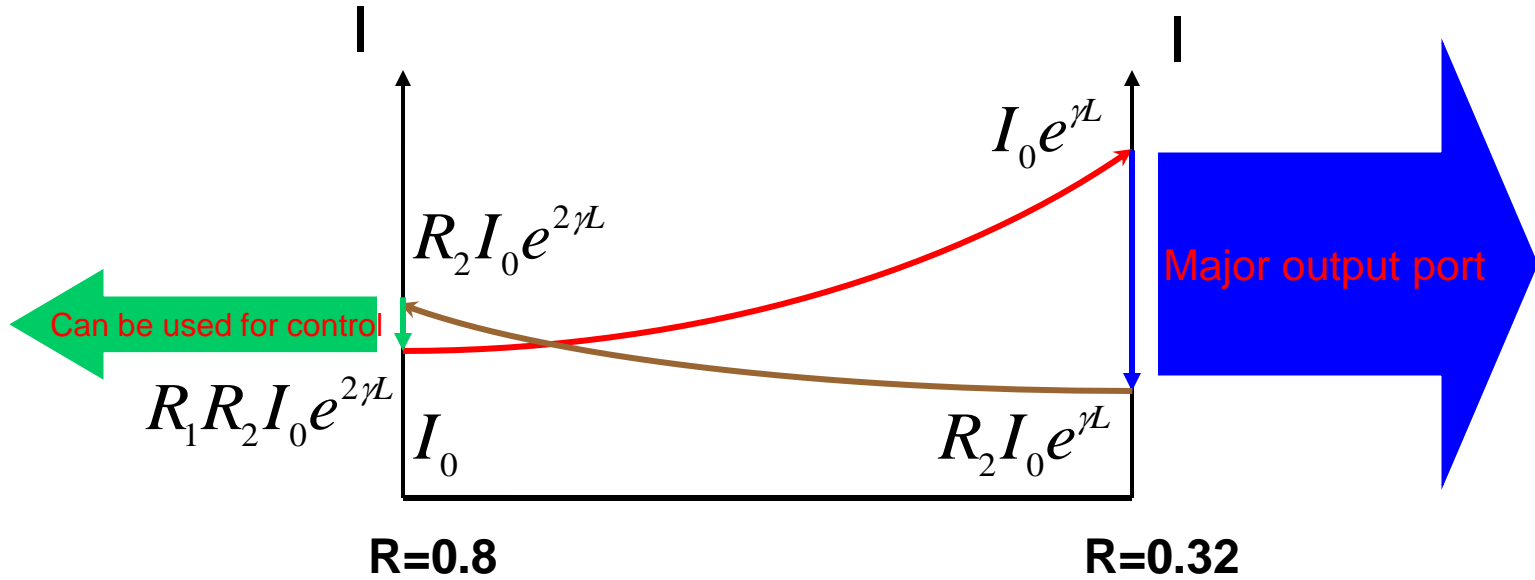
L : cavity length



When the round trip gain is larger than 1, the light intensity will keep increasing until its maximum limit which is set by the pumping system.



Laser Threshold Condition



After one trip, the photon density increases

⇒ Positive gain ⇒ Lasing

The threshold condition is :

$$I_0 = R_1 R_2 I_0 e^{2\gamma L} \text{ or } R_1 R_2 e^{2\gamma L} = 1$$

$$\gamma = g - \alpha_i = \frac{1}{2L} \ln \left(\frac{1}{R_1 R_2} \right)$$



光學共振腔

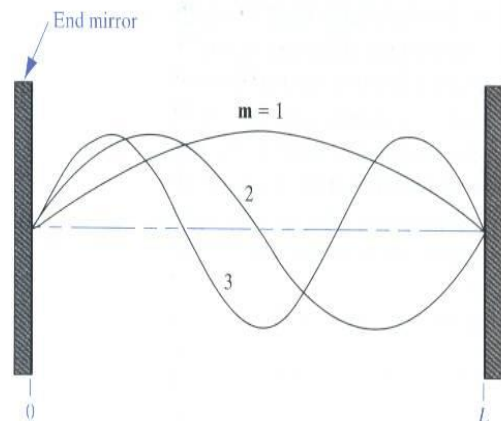


Figure 8-17
Resonant modes
within a laser
cavity.

The purpose of the resonance cavity is to elongate the photon lifetime in the cavity in order to increase gain.

駐波條件 $L = m\lambda / 2$
提供光學回授



Gain Profile and Longitudinal Modes

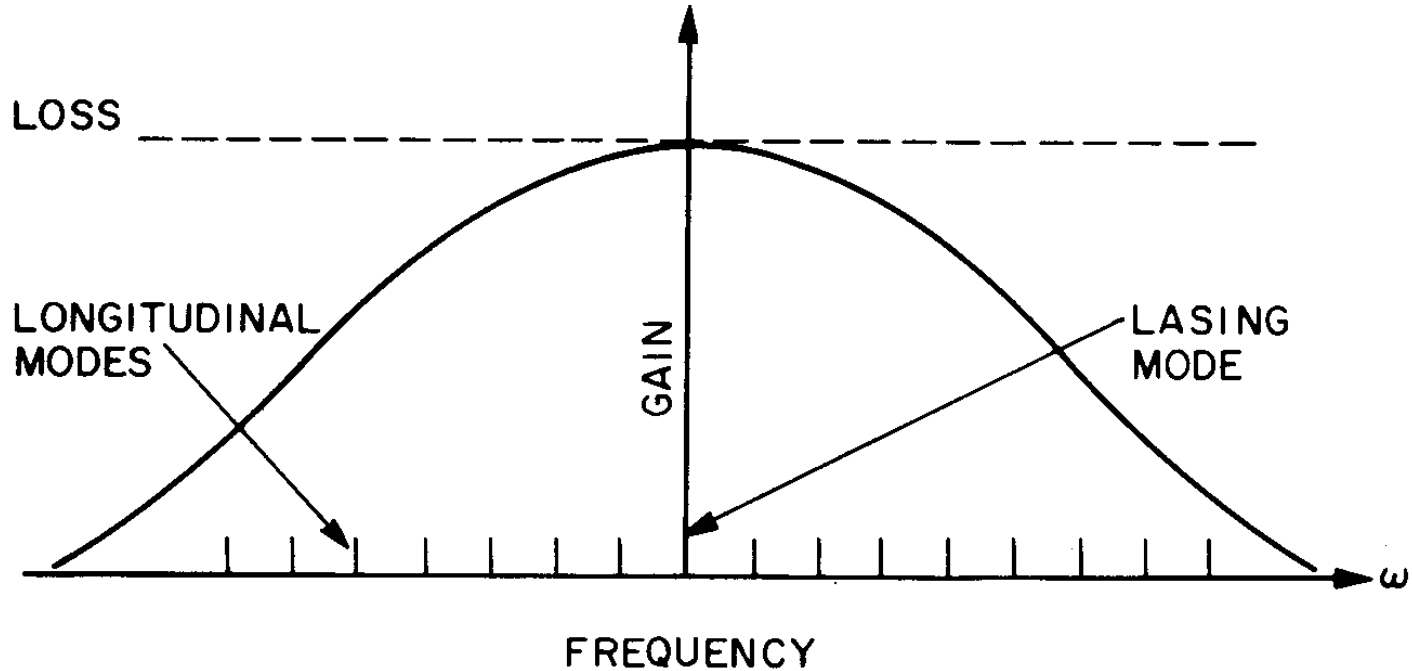
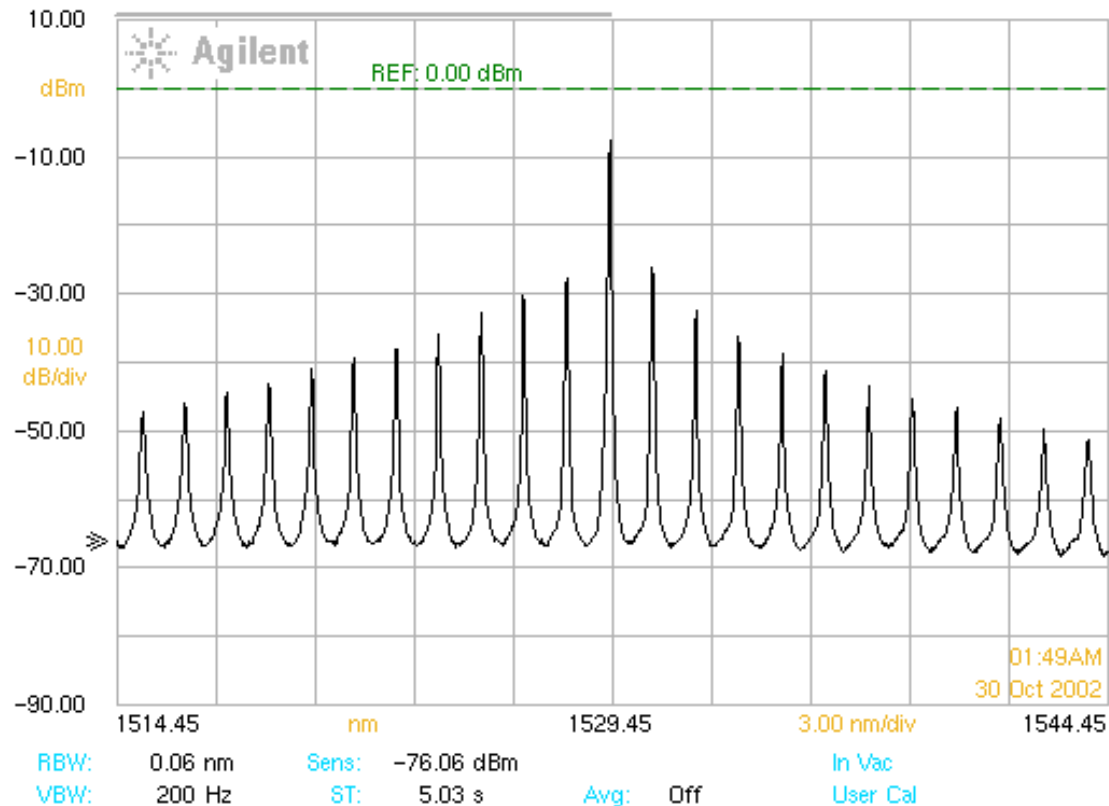


Fig. 2.2 Schematic illustration of the gain profile and longitudinal modes of a semiconductor laser. For the lasing mode in the vicinity of the gain peak, the threshold is reached when gain equals loss.



雷射頻譜

FP Source Test (TrA)	Mode Spacing	1.3 nm	Peak Amplitude	-7.61 dBm	
Mean Wavelength	1529.32 nm	Mode Spacing	164 GHz	Total Power	-7.32 dBm
Peak Wavelength	1529.36 nm	FWHM	2.14 nm	Sigma	0.91 nm





半導體雷射的電流-發光特性

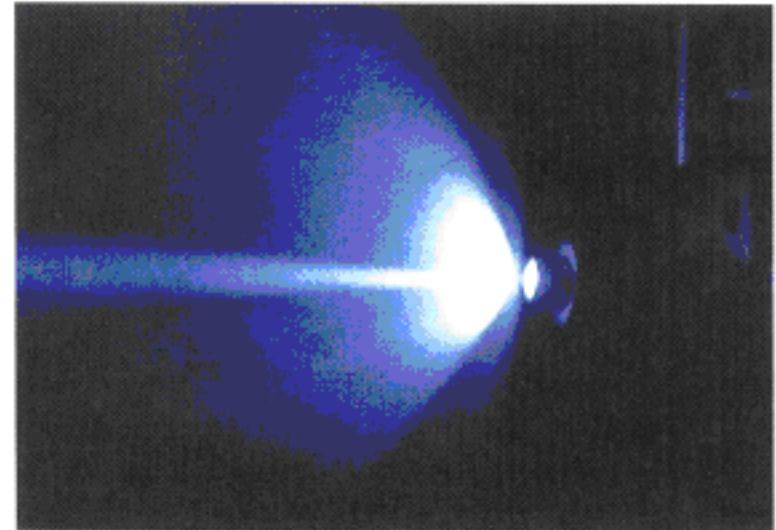
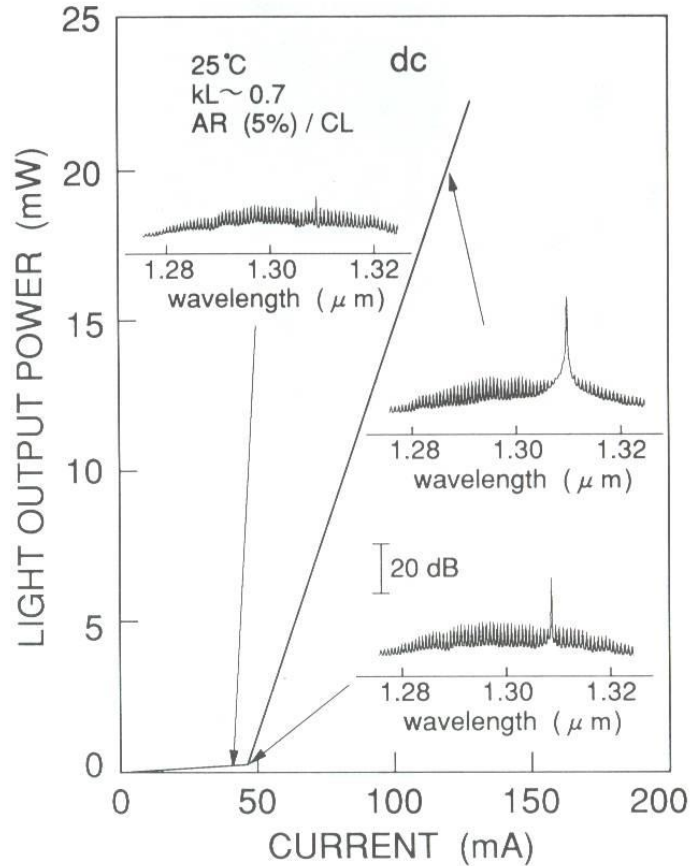
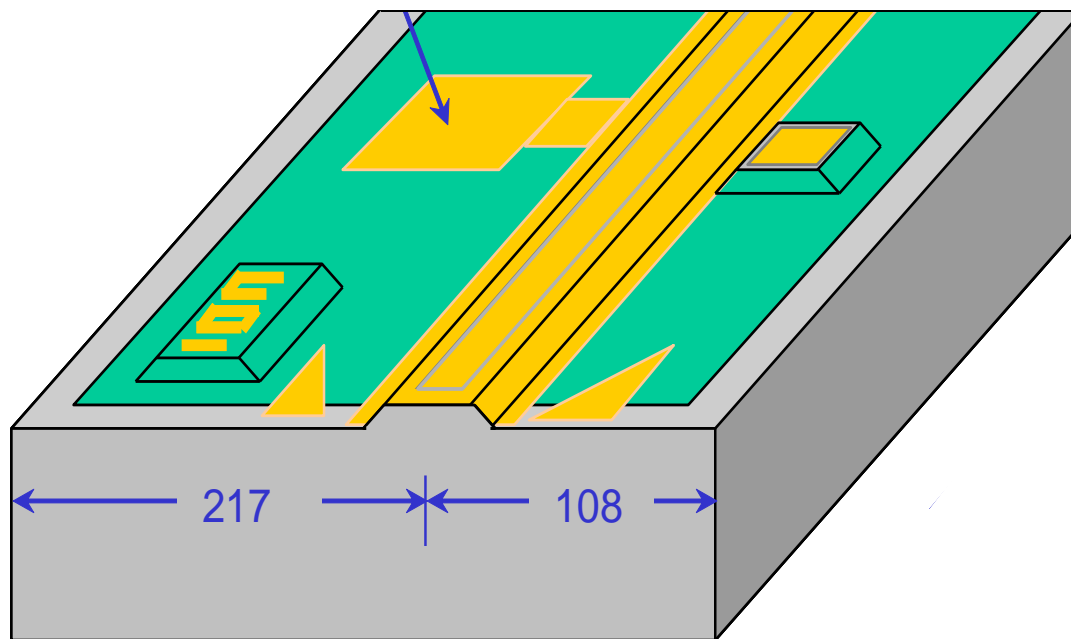


Figure 2.46 Change in emission spectra before and after lasing in a DFB laser.



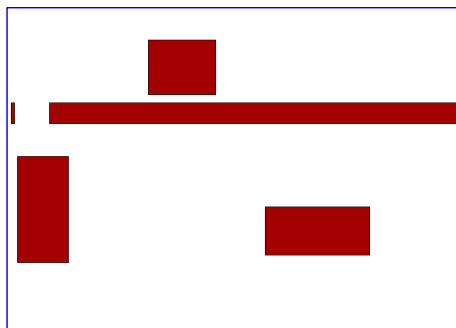
半導體雷射製程



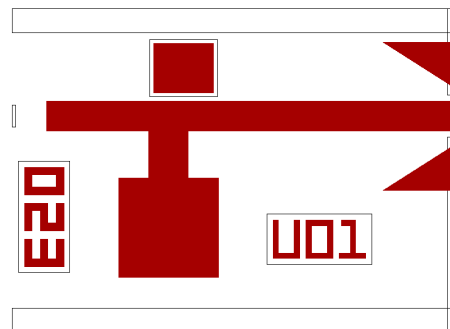


光罩設計

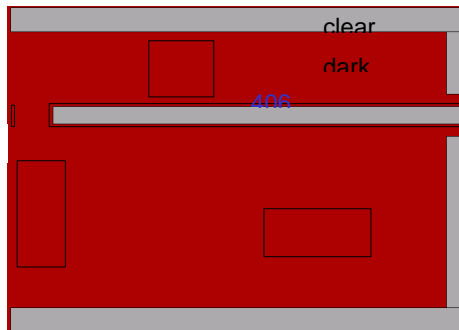
Mask 1: Ridge Etch



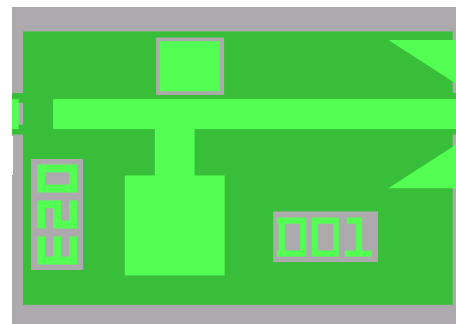
Mask 3: Metalization



Mask 2: Nitride Etch

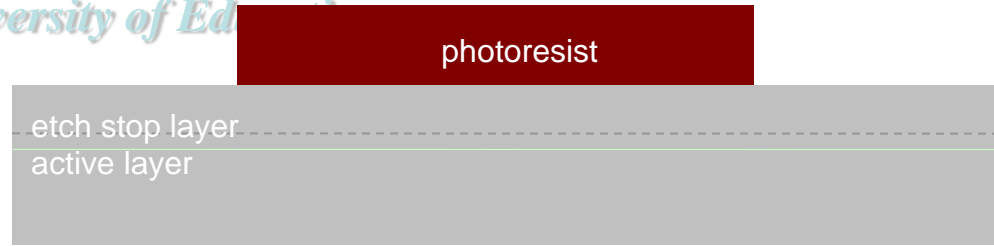
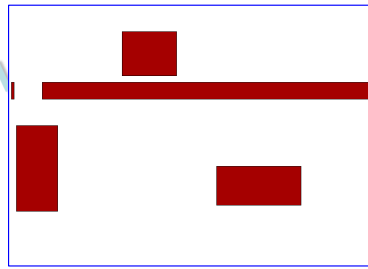


Mask 1, 2, and 3

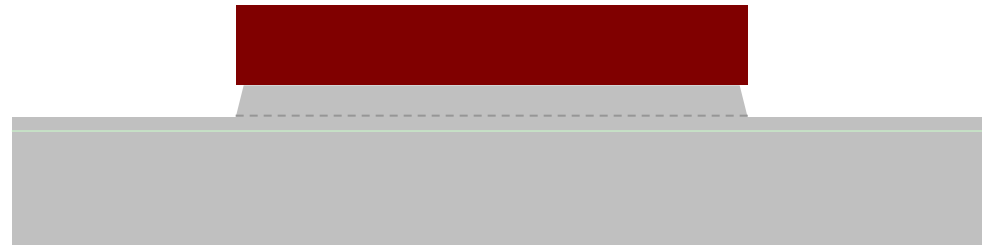




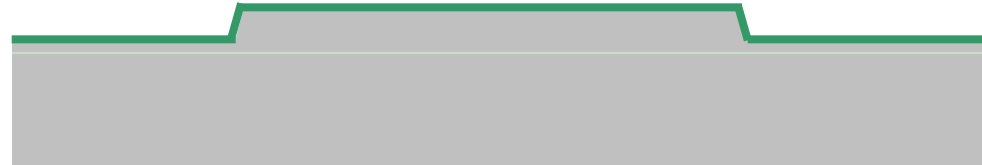
1. Ridge photo (mask 1)



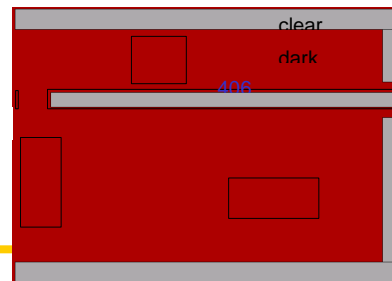
2. Ridge Wet Etch

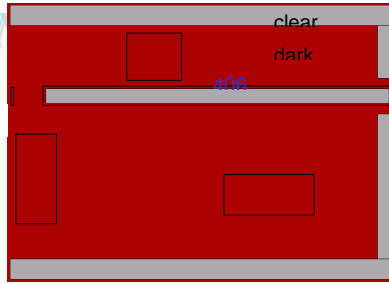


3. Si3N4 Deposit



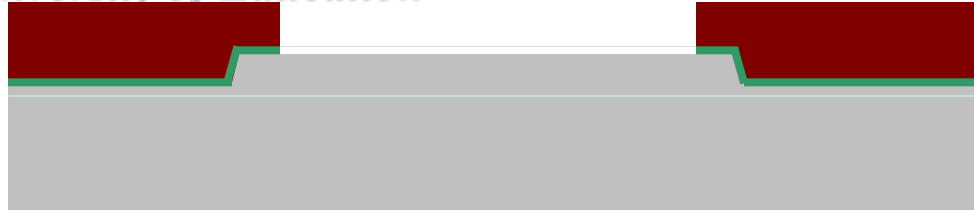
4. Via photo (mask 2)



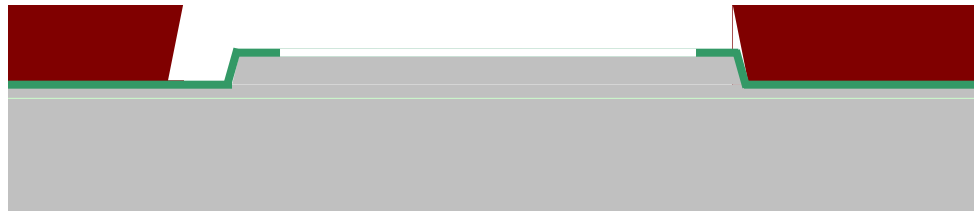
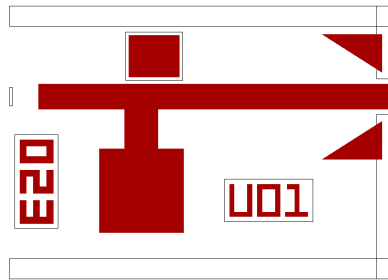


5. Nitride etch

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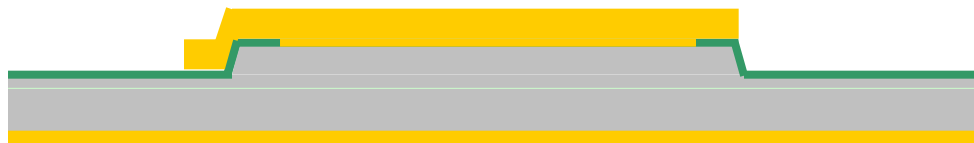
6. Metal photo (mask 3)



7. Metal Deposition & liftoff

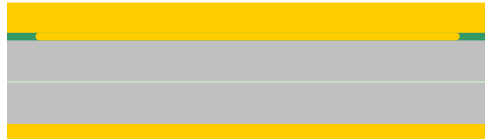


8. Backside lapping & metalization

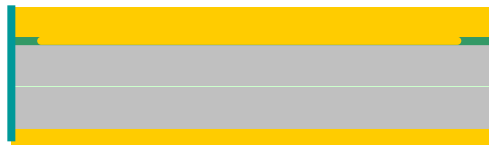




9. Bar cleaving

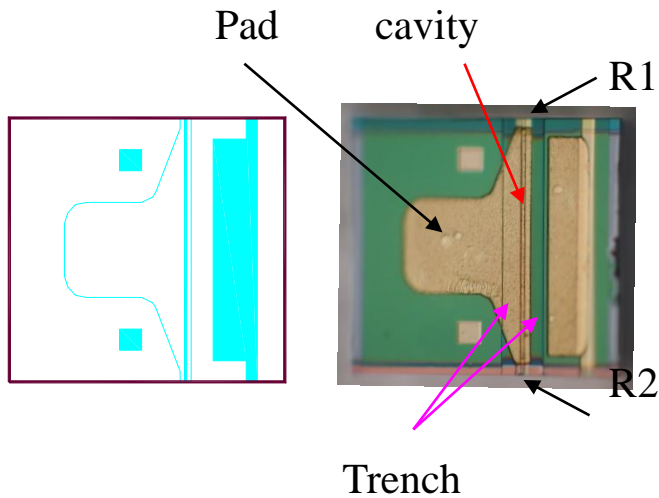
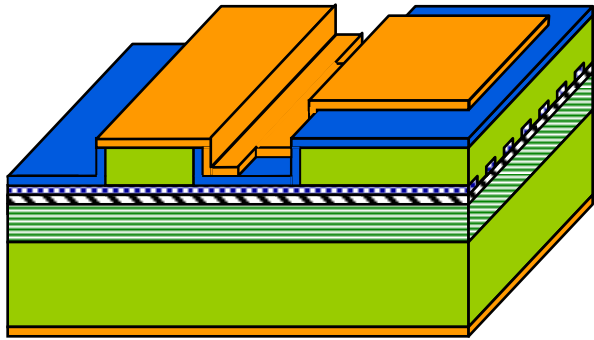


10. HR/AR coating

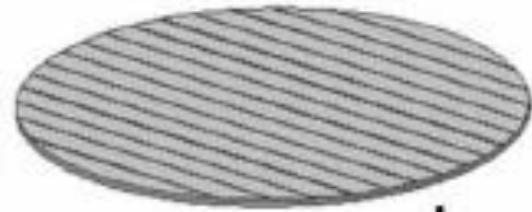




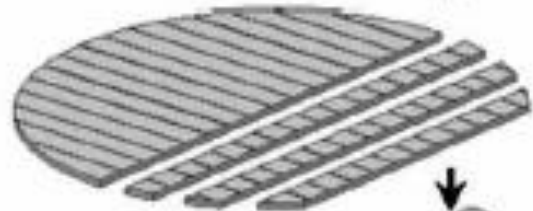
Conventional laser process



- Waveguide Formation
- Contacts



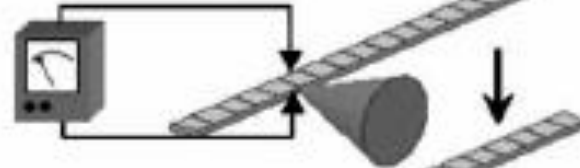
- Cleave to Form Mirrors



- Stack & Coat Mirrors



- Test



- Singulate



- Package





Side view

100um



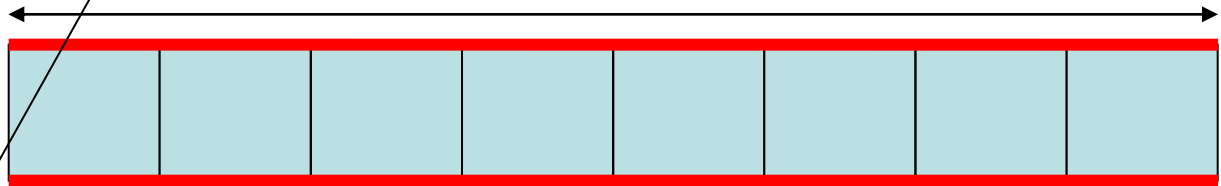
AR coating

Laser bar

Top view

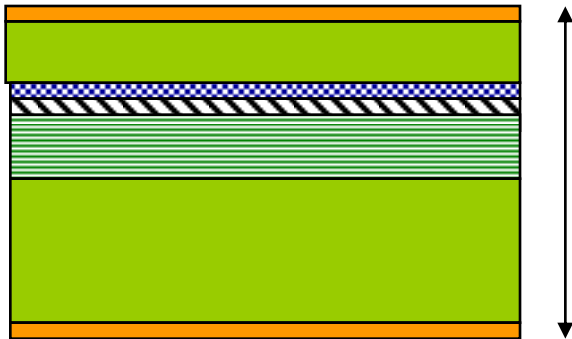
~2cm

250um



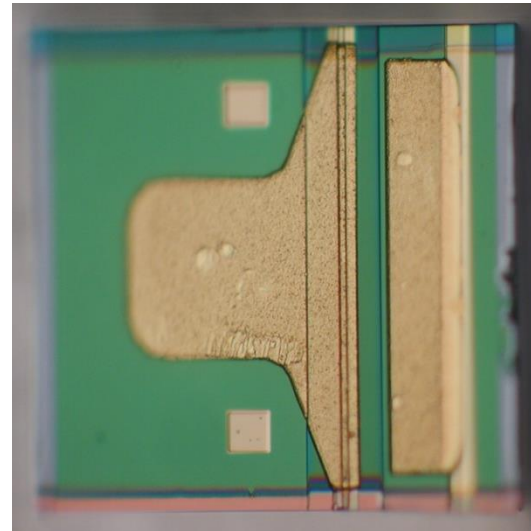
AR coating

Crosssectional view



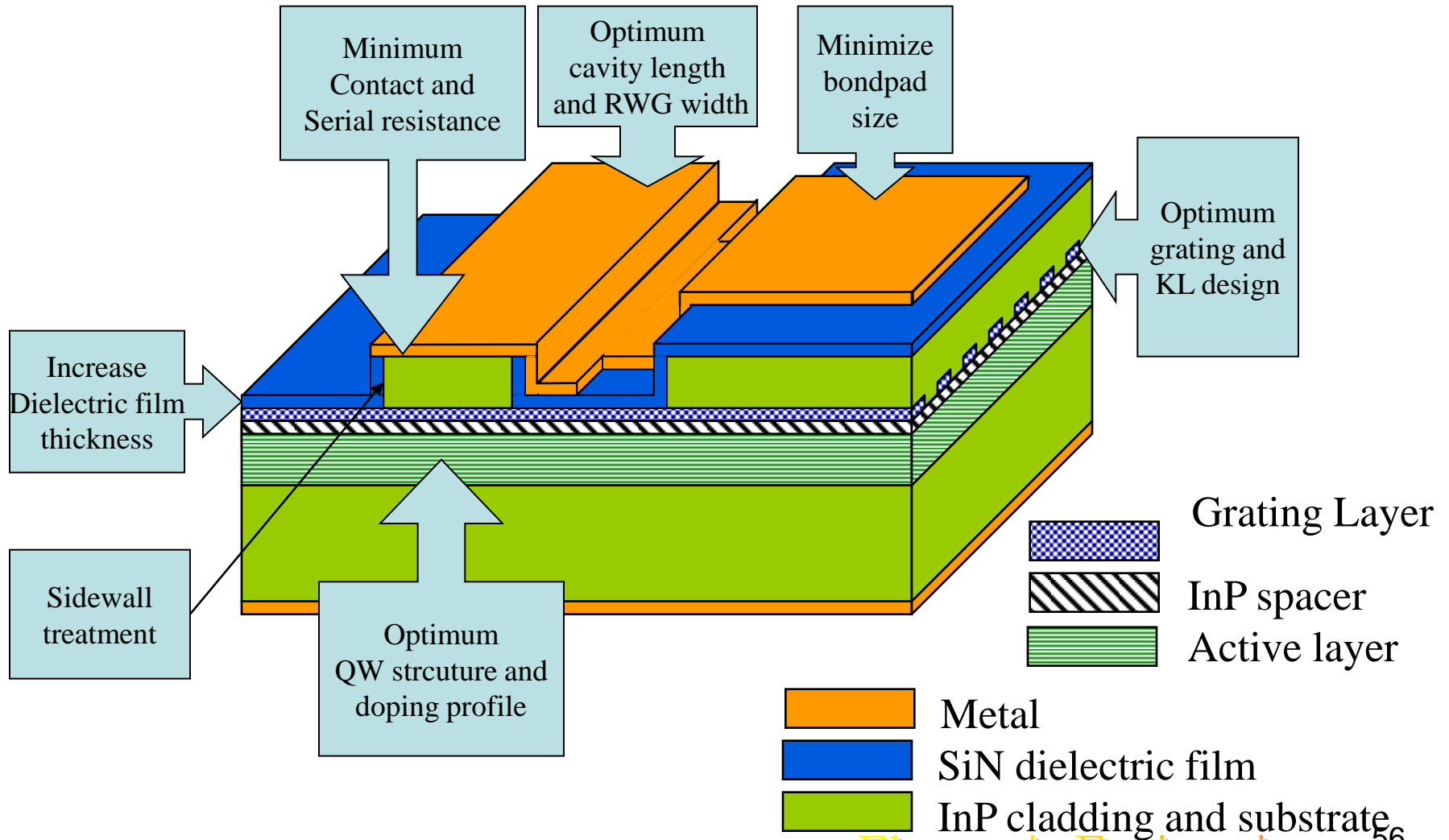
100um

Multilayer structure





Laser設計考量







Laser Chip Side View

