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

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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

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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

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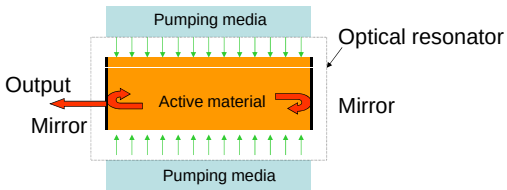
雷射的基本構造



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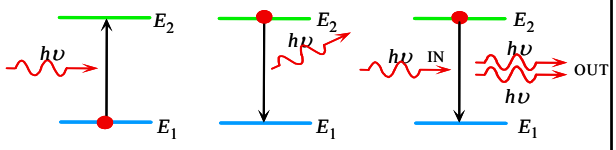
能階概念

- 電子在個別之原子或分子所具有能量（動能＋位能）僅能處於一系列不連續且分立的穩定狀態，其中能量最低的狀態稱為基態（低能狀態）
- 若有能量（熱、光）由外部加入於基態的電子時，電子會被激發，而移至高能量狀態（激態）
- 電子在高能量狀態（激態），也可能躍遷至能量較低的狀態而釋放出熱或光

吸收、自發放射與激發放射

吸收　　發光二極體➔自發放射　雷射➔激發放射



(a) Absorption　(b) Spontaneous emission　(c) Stimulated emission

大綱

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雷射的類型

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
	氮氣雷射	N2	337.1nm	脈衝	短脈衝 近紫外線
	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	紅寶石雷射	Cr	694.3nm	脈衝	高能量脈衝 高功率輸出
	YAG電射	Nd	1.06mm	脈衝 連續	高能量脈衝、高輸出、高速往復
	玻璃雷射	Nd0	1.05mm	脈衝	超高能量單一脈衝
	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

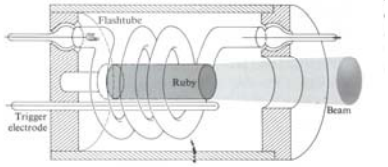


Figure 14.25 The first ruby-laser configuration, just about life-sized.

HELIUM-NEON GAS LASER

Courtesy of Metrologic, Inc.

Laser-Professionals.com

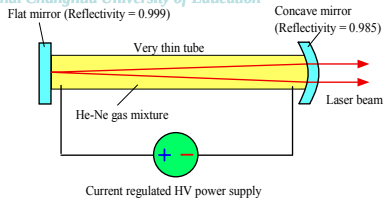
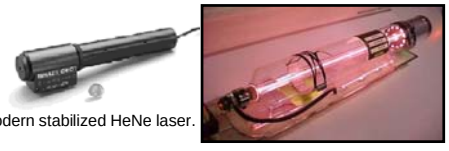


Fig. 3.39: A schematic illustration of the He-Ne laser



A modern stabilized HeNe laser.

|SOURCE: Courtesy of Melles Griot

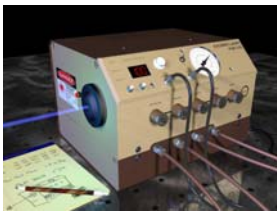
From *Principles of Electronic Materials and Devices, Second Edition*, S.O. Kasap (© McGraw-Hill, 2002)
http://Materials.Usask.Ca

CO_2雷射

脈衝雷射

Nd:YAG

Excimer



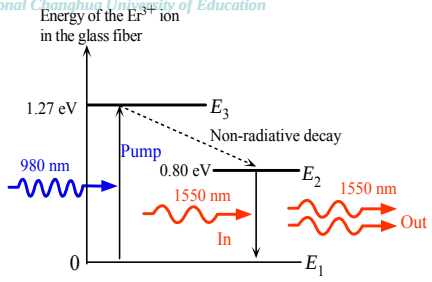


Fig. 3.42: Energy diagram for the Er^{3+} ion in the glass fiber medium and light amplification by stimulated emission from E_2 to E_1. Dashed arrows indicate radiationless transitions (energy emission by lattice vibrations)

From *Principles of Electronic Materials and Devices, Second Edition*, S.O. Kasap (© McGraw-Hill, 2002)
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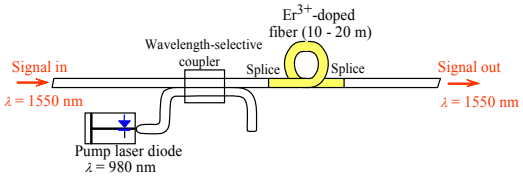

Fig. 3.43: A simplified schematic illustration of an EDFA (optical amplifier). The erbium-ion doped fiber is pumped by feeding the light from a laser pump diode, through a coupler, into the erbium ion doped fiber.

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

半導體雷射

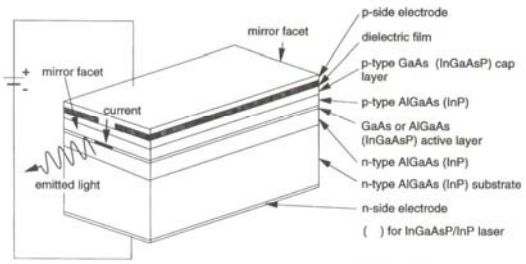

FIGURE 3.1 Basic structure of a Fabry–Perot laser diode.

大綱

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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。

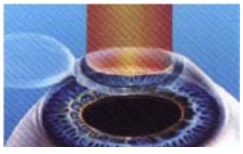
●治療皮膚的色素性疾病。這種雷射釋放出的光波長，可以讓皮膚上的色素吸收較好。這使得它可以用來治療各種皮膚表面或是較深部的色素性病灶。現在已經有許多種雷射被核准可以用來治療老人斑，太陽斑（雀斑），咖啡色胎記，以及刺青等等。

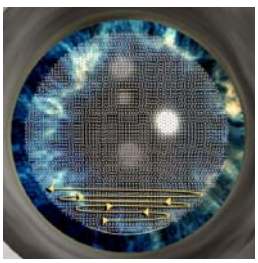
醫學(牙齒治療)

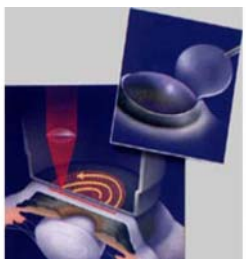
準分子雷射近視手術又主要分為雷射屈光角膜切除術(photorefractive keratectomy, PRK)和雷射原位層狀角膜成塑形(Laser in-situ keratomileusis, LASIK)兩種。

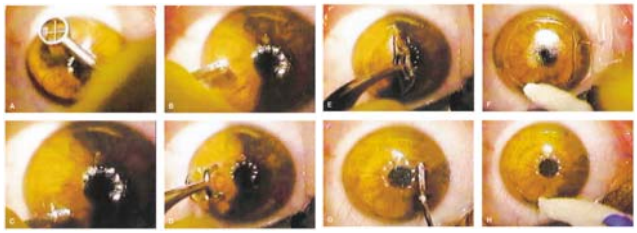
PRK 手術的方式(圖一)是把角膜上皮細胞刮除後，以準分子雷射來進行預先設定的角膜厚度切除，達到削平角膜而減低近視和散光度數，度數越深切除越厚。一般雷射照射的時間約30 秒至一分鐘間，術後會給予抗生素眼藥水和戴隱形眼鏡，約3 至10 天上皮細胞才會癒合。

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。

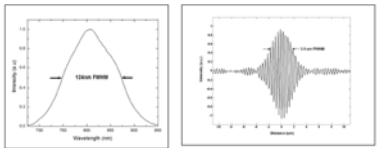








光學同調斷層掃瞄
Optical Coherence Tomography (OCT)



視網膜

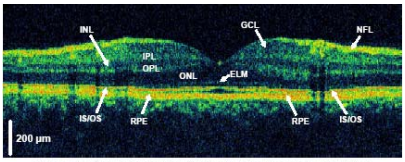
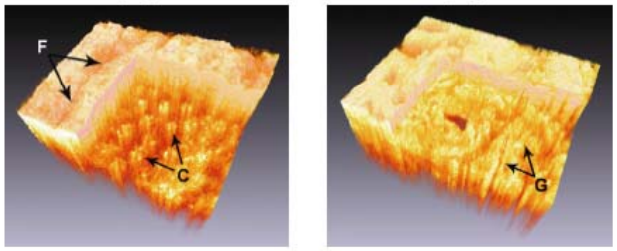


Figure 4. *In vivo* ultrahigh resolution OCT image of the human retina taken with a broadband SLD light source. Image axial resolution in the retina was about 3.2 μm and transverse resolution was about 15-20 μm. All the major intraretinal layers can be clearly seen in this ultrahigh resolution OCT image.

醫學診斷

結腸



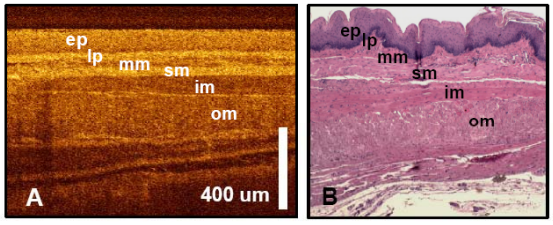


Figure 3. (A) *In* vivo endoscopic OCT image of rabbit esophagus with corresponding histology (B). Good correlation is seen between the OCT and histological cross sections for epithelium (ep), lamina propria (lp), muscularis mucosa (mm), submucosa (sm), and inner (im) and outer muscular (om) layers.

機械加工

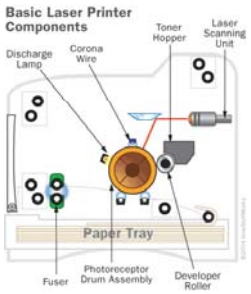
- 切割1,切割2
- 雕刻1,雕刻2
- 焊接

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

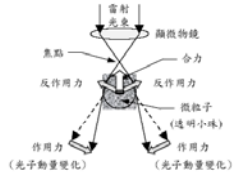
雷射印表機原理



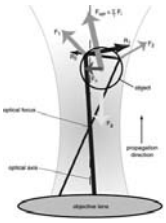
1. Charging (usually negative)
2. Exposure (laser scanning to remove charge)
3. Developing (adding carbon powder to the drum)
4. Transferring (print powder to paper)
5. Fusing
6. Clean

http://computer.howstuffworks.com/laser-printer2.htm

Optical Tweezer



圖二、雷射鑷夾的工作機制
物理雙月刊（廿二卷五期）2000年10月

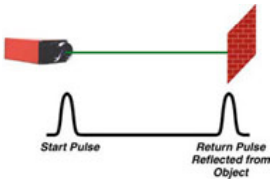


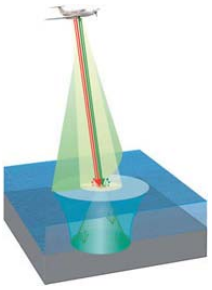
http://photoms.ym.edu.tw/PHOTOMS_C/Research.htm

Ag nano particle
Particle manupulation

Lidar

Distance = (Speed of Light x Time of Flight) / 2





Optical Storage

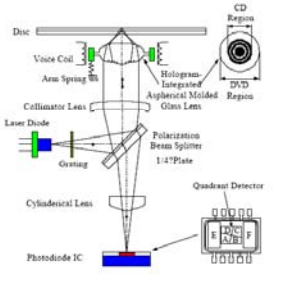
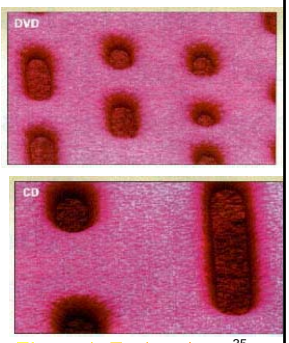


圖 2-1 DVD 光學讀取頭的內部結構示意圖



http://www.youtube.com/watch?v=DS6wsJRGqnQ

http://www.hsienfa.com.tw/pls-all.html

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?

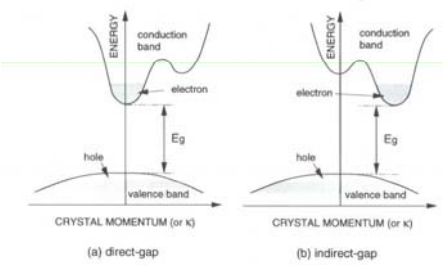
- 基板的限制➔原子晶格大小須與基板一致
- 波長的限制➔能隙大小須與所需波長吻合
- 材料特性➔能隙必須是直接能隙才能發光

常見的光電半導體材料

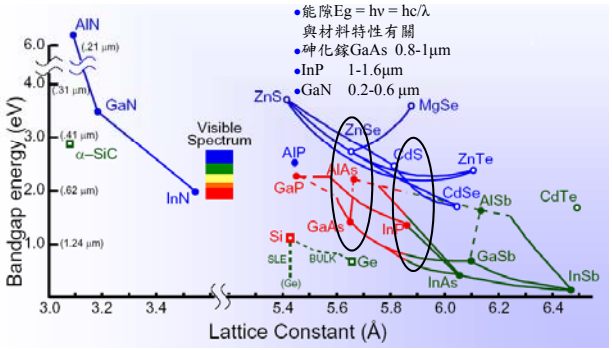
- GaN based 可發藍光或紫外光用於全彩顯示面板
- InP based 可發綠光紅光及紅外光
- GaAs based 可發紅外光用於光通訊
- Si, Ge, InGaAs 可用於製造太陽電池或檢光器
- Si可用於製造太陽電池
- 多晶矽及有機化合物可用於製造發光二極體

半導體材料的能帶特性

直接能隙 (GaAs)　　間接能隙(Si)



光電半導體的晶格-能隙相圖



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

$R_1R_2e^{2(g-\alpha_i)L}=1$

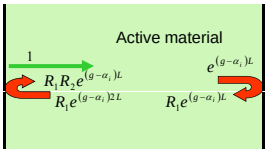
$\Rightarrow g=\alpha_i+\frac{1}{2L}\ln\left(\frac{1}{R_1R_2}\right)$

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 maximun limit which is set by the pumping system.

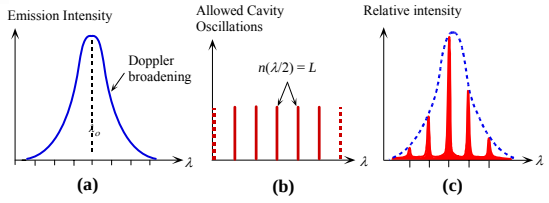


Fig. 3.41: (a) Doppler broadened emission vs. wavelength characteristics of the lasing medium. (b) Allowed oscillations and their wavelengths within the optical cavity. (c) The output spectrum is determined by satisfying (a) and (b) simultaneously.

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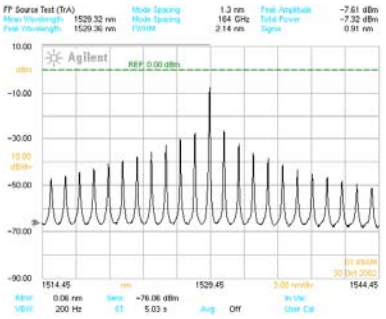
雷射頻譜



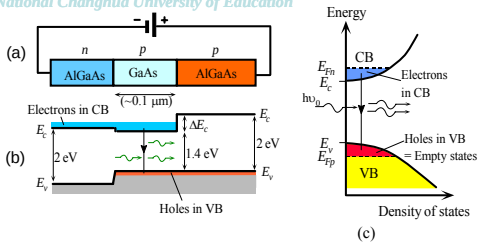


Fig. 6.55: (a) A double heterostructure diode has two junctions which are between two different bandgap semiconductors (GaAs and AlGaAs). (b) Simplified energy band diagram under a large forward bias. Lasing recombination takes place in the *p*-GaAs layer, the *active layer*. (c) The density of states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

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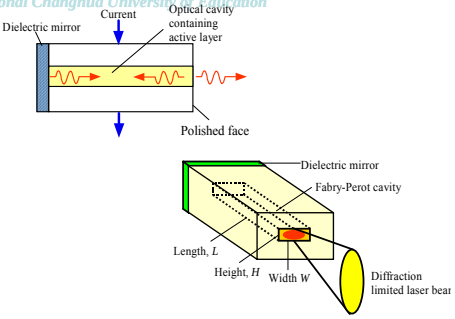

Fig. 6.56: A semiconductor lasers have an optical cavity to build-up the required electromagnetic oscillations.

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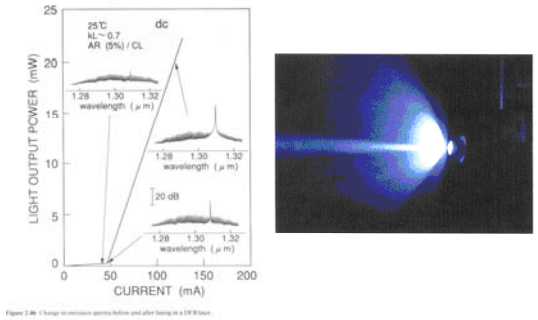
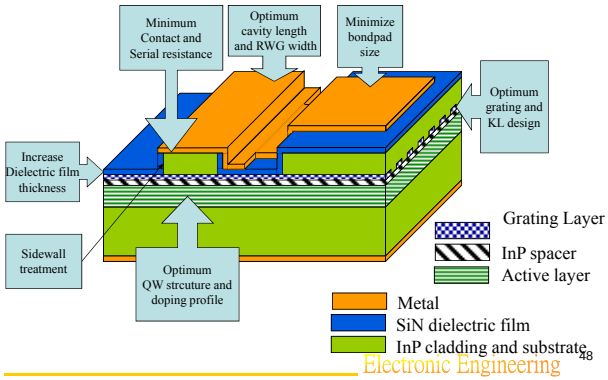
http://Materials.Usask.Ca

半導體雷射的電流-發光特性

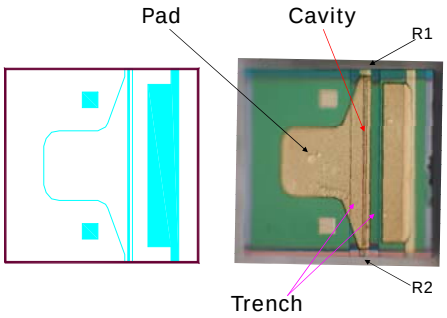


Laser設計考量

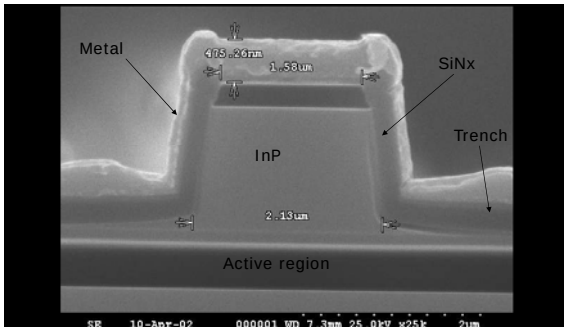


生產線概觀 - CHIP

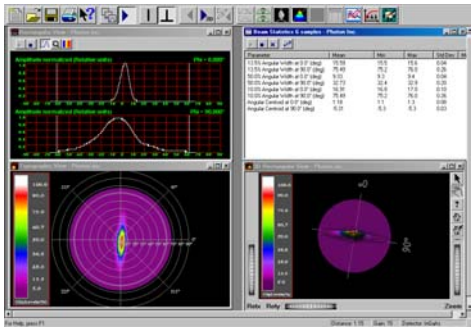
Laser Chip Top View



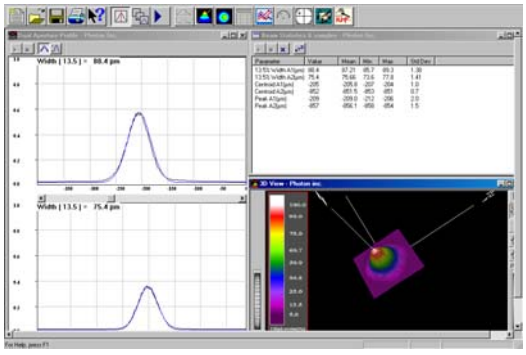
Laser Chip Side View



FP Laser Far Field Pattern



VCSEL Far Field Pattern



Why VCSEL?

- Vertical output light
- Excellent performance
- Lower fabrication cost
- On-wafer testing
- High coupling efficiency to fiber

For a laser

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

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

For semiconductor lasers, usually L=200~1000um and R=0.15~0.9
For VCSEL, usually L=0.5~3um and R~0.99