全新光電科技股份有限公司
Visual Photonics Epitaxy Co., Ltd.

化合物半導體磊晶片在光電領域上之技術發展

林 昆 泉　　全新光電VPEC

簡 報 內 容

- 化合物半導體特性與產業分工
- 化合物半導體光電產品與技術

化合物半導體半導體特性

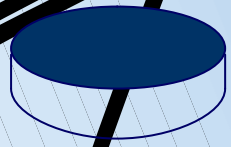
- 直接能隙 ⇒ 發光元件
- 高電子遷移率, 高飽和漂流速度⇒ 高速元件
- 半絕緣性基板(低寄生電容) ⇒ 高速元件
- 較高幅射容忍度 ⇒ 衛星通訊(高速元件)與太陽能電池

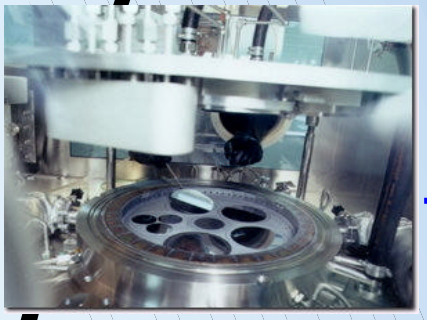
化合物半導體技術所衍生產品市場應用

- 光源：AlGaInP-LEDs, GaN-LEDs
- 光纖通訊：Laser, VCSEL, GaAs ICs
- 光儲存系統：Laser, DVD
- 行動電話：GaAs ICs
- 定點無線微波通訊：GaAs ICs
- 衛星：GaAs ICs, Solar Cells(GaInP/GaAs/Ge)
- 電子收費系統：GaAs ICs
- 汽車雷達：GaAs ICs

化合物半導體產業供應鏈

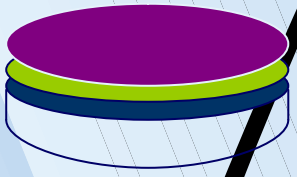
2~6 inch GaAs 基板



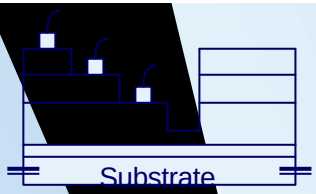


MOCVD磊晶

化合物半導體
磊晶片



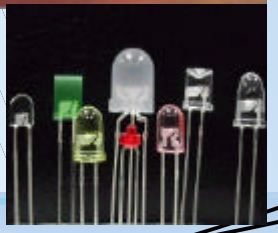
化合物半導體
製程



封裝

IC, Lamp,

TO-can

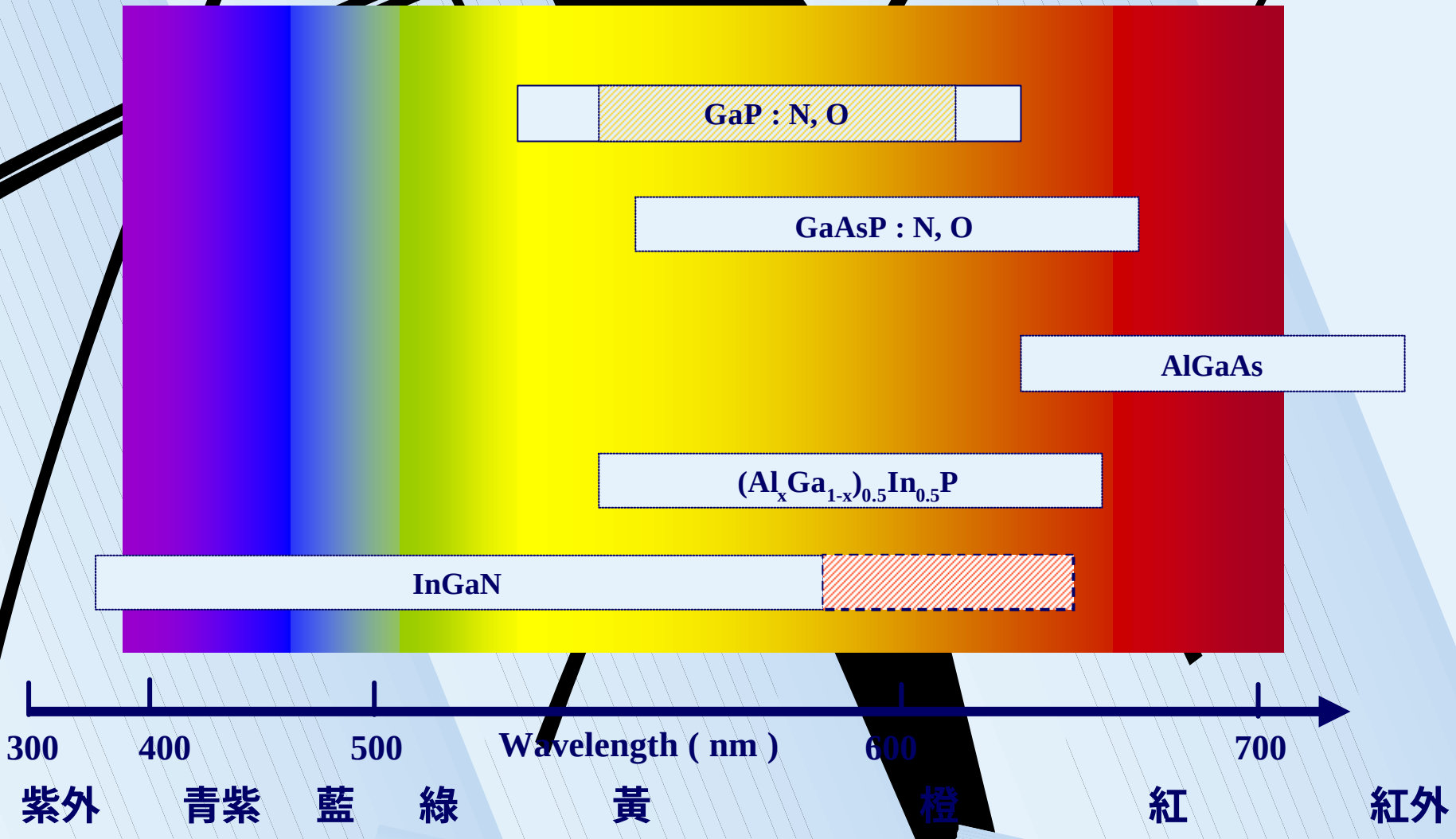


光電及通信應用

光電元件產品與技術

- LED
- LD
- VCSEL
- PIN

半導體材料之發光範圍


GaP : N, O
GaAsP : N, O
AlGaAs
(Al$_x$Ga$_{1-x}$)$_{0.5}$In$_{0.5}$P
InGaN
300
400
500
Wavelength (nm)
600
700
紫外
青紫
藍
綠
黃
橙
紅
紅外

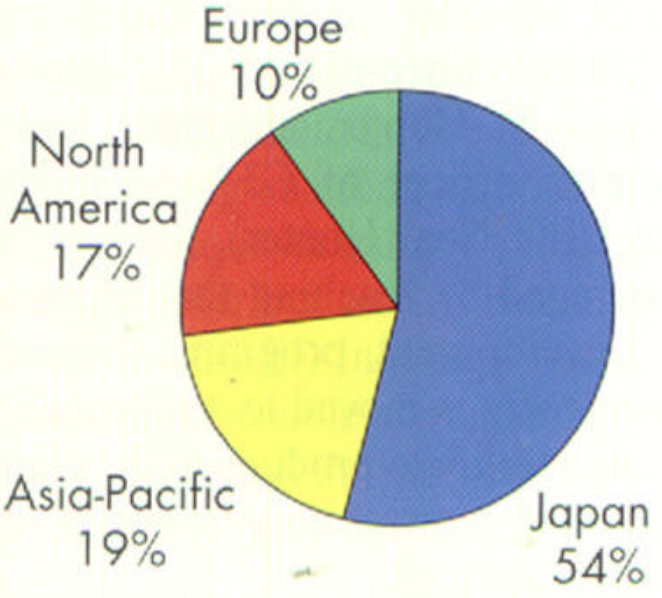
World Wide LED Supplier

Top 10 LED Suppliers

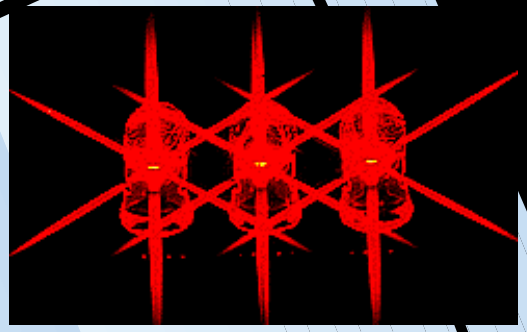
1	Hewlett-Packard	USA
2	Stanley Electric	Japan
3	Siemens	Germany
4	Matsushita Electric	Japan
5	Nichia Chemical	Japan
6	Lite-On Electronics	Taiwan
7	Toshiba	Japan
8	Rohm Co. Ltd.	Japan
9	Sharp	Japan
10	Citizen Electronics	Japan

Source: Strategies Unlimited

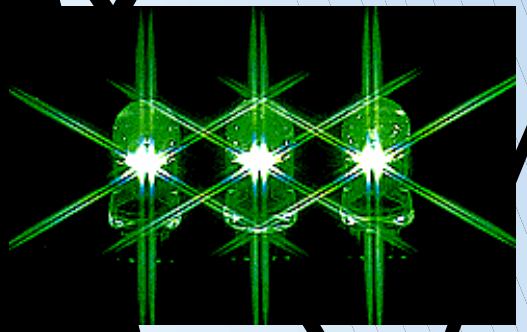
LED Supply by Region



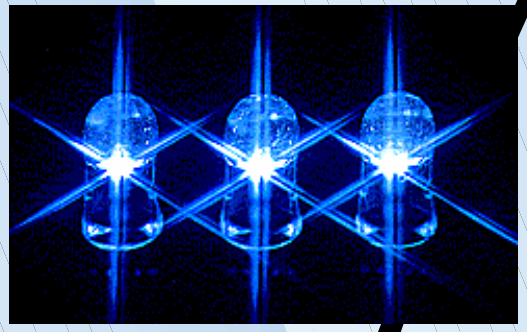
High Brightness LED Lamp



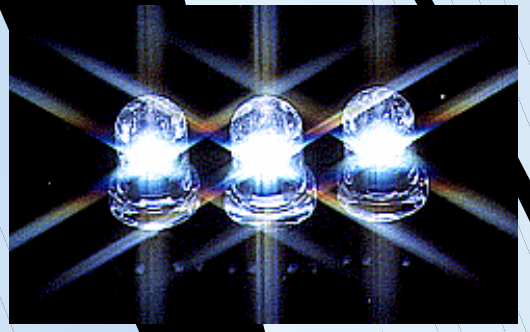
Red HB-LED



en HB-LED



Blue HB-LED



Whi B-LED

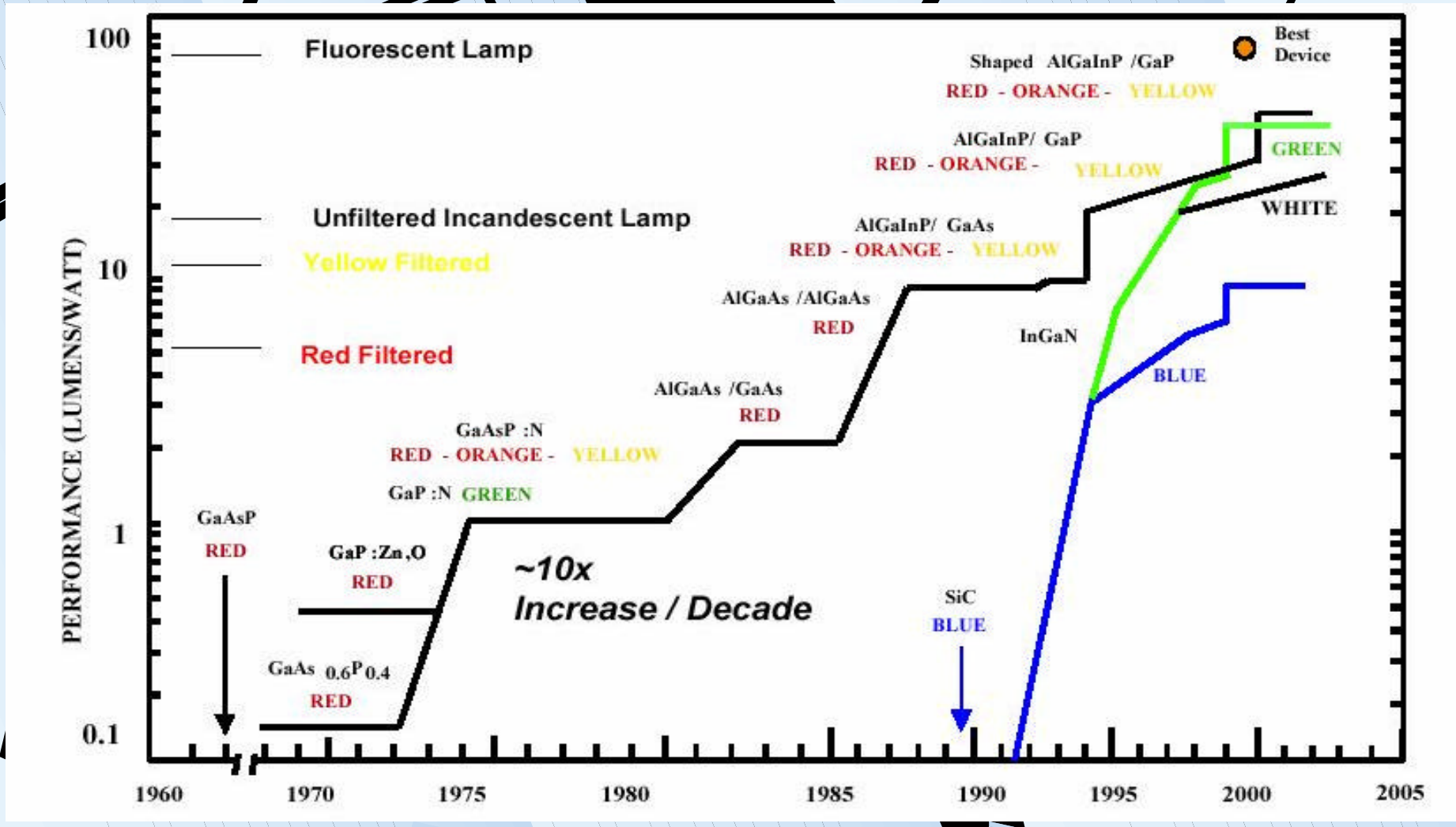
高亮度LED應用

Specification (規格) : □22mm Pitch 25mm 432 dots * 352 dots
Location (地點) : Las Vegas, USA (美國) (Bellagio)

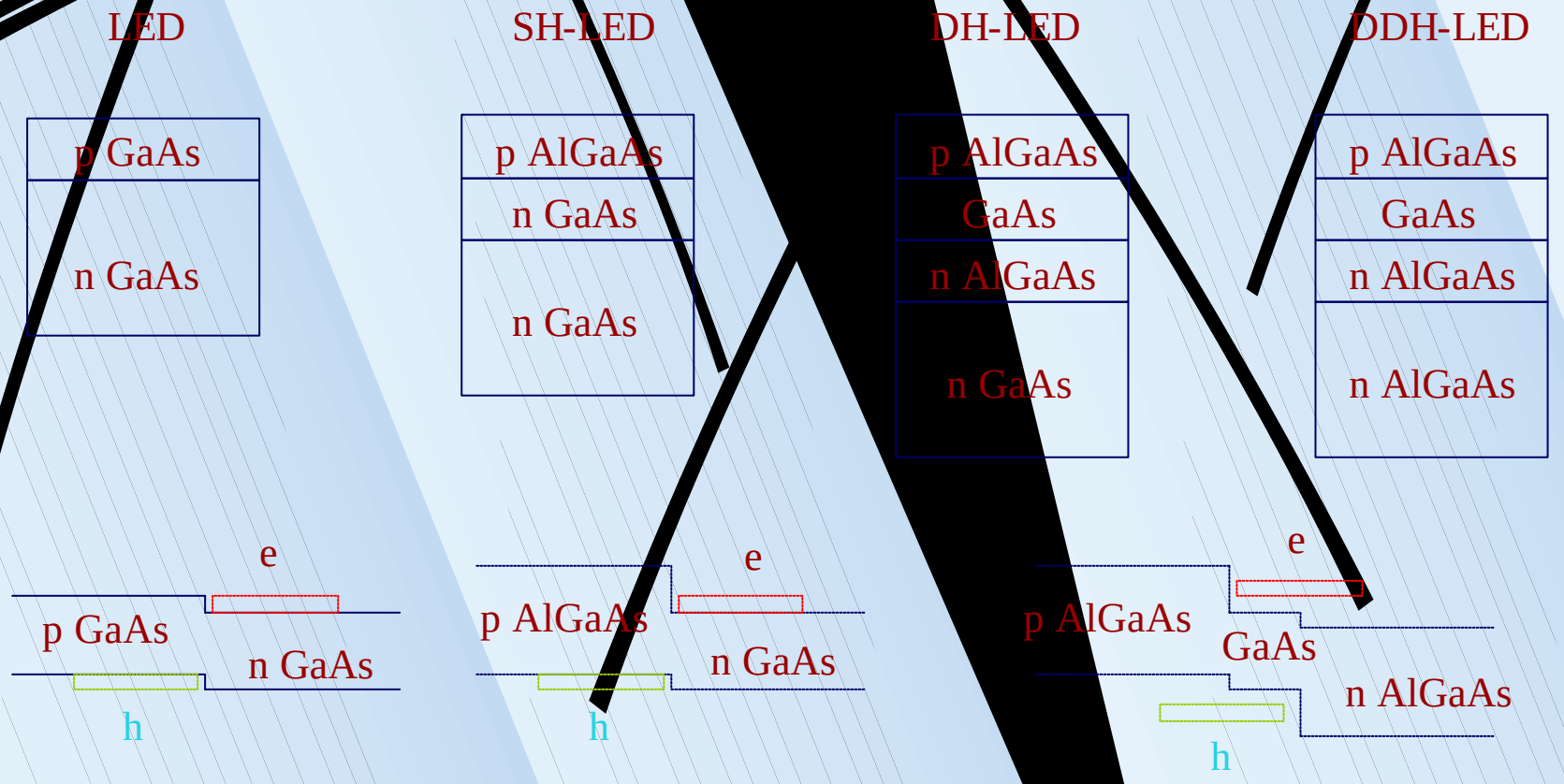
白熱燈與高亮度LED在車燈應用上之比較

Lamp	Advantage	Disadvantages
Incandescent	Low cost Luminous flux Socketed for easy repair Light output independent of temp	Filament shock sensitive MTBF less than vehicle life High heat and power Low reponse time Color determined by exterior leds
LED	Shock resistant MTBF much longer than vehicle life Low heat and power Fast response time Color determined by light source	Higher cost and luminous flux Not repairable Light output varies with temperature

LED技術演進

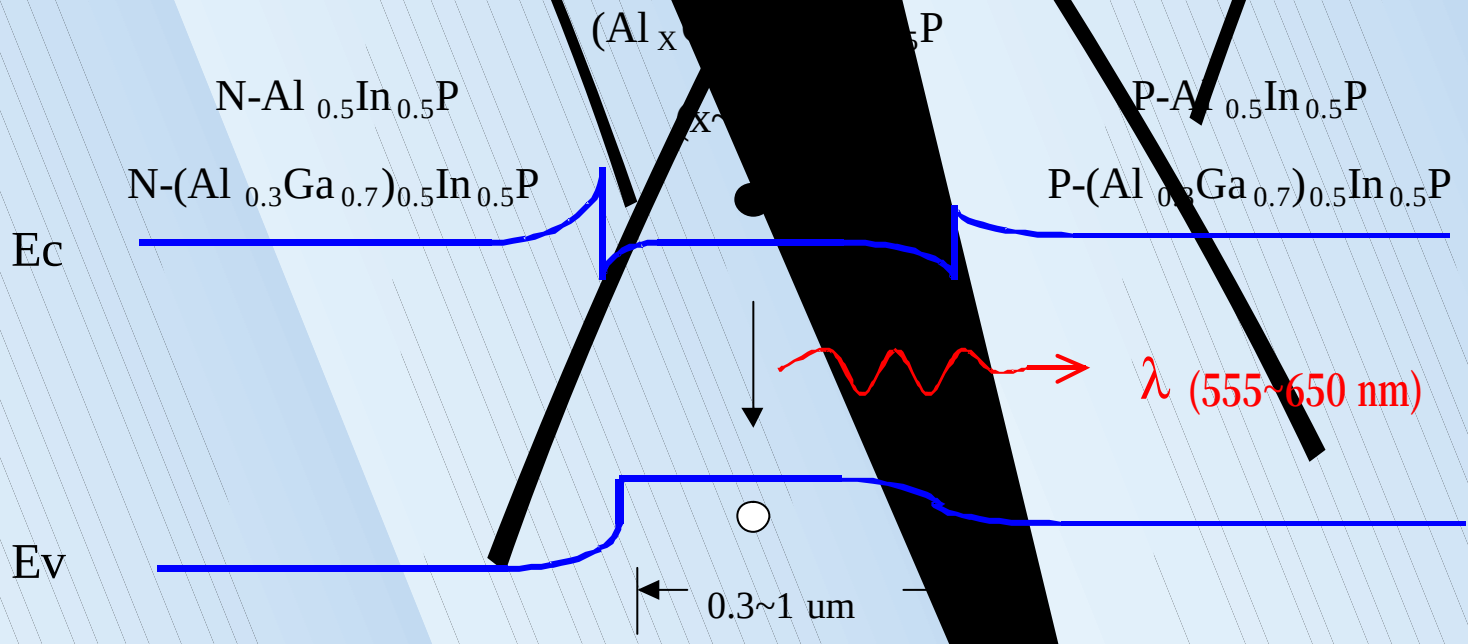

PERFORMANCE (LUMENS/WATT)
100
10
1
0.1
1960
1970
1975
1980
1985
1990
1995
2000
2005
Fluorescent Lamp
Unfiltered Incandescent Lamp
Yellow Filtered
Red Filtered
Best Device
Shaped AlGaInP /GaP
RED - ORANGE - YELLOW
AlGaInP/ GaP
RED - ORANGE - YELLOW
GREEN
WHITE
AlGaInP/ GaAs
RED - ORANGE - YELLOW
AlGaAs /AlGaAs
RED
InGaN
BLUE
AlGaAs /GaAs
RED
GaAsP :N
RED - ORANGE - YELLOW
GaP :N GREEN
GaAsP
RED
GaP :Zn,O
RED
~10x
Increase / Decade
SiC
BLUE
GaAs 0.6P0.4
RED

LED結構演進歷史1


LED
p GaAs
n GaAs
SH-LED
p AlGaAs
n GaAs
n GaAs
DH-LED
p AlGaAs
GaAs
n AlGaAs
n GaAs
DDH-LED
p AlGaAs
GaAs
n AlGaAs
n AlGaAs
e
p GaAs
n GaAs
h
e
p AlGaAs
n GaAs
h
e
p AlGaAs
GaAs
n AlGaAs
h

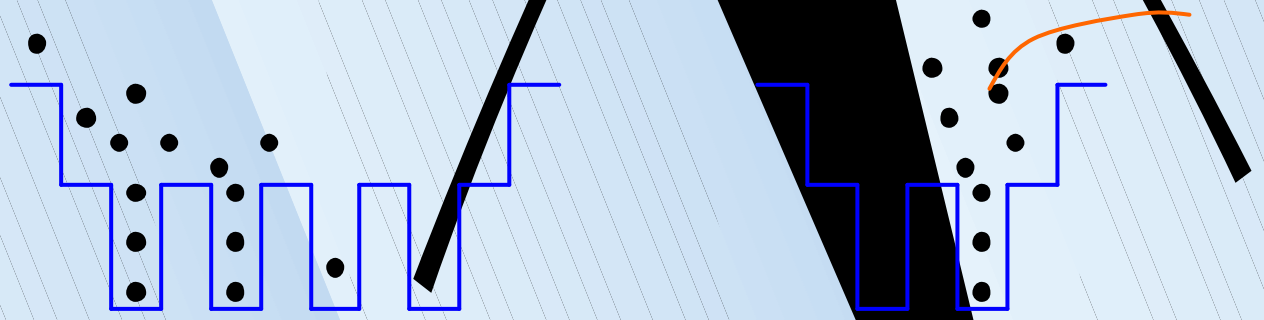
Double Heterostructure

1. Enhanced injection efficiency of electrons and holes.
2. Transparent windows for [illegible] light extraction.

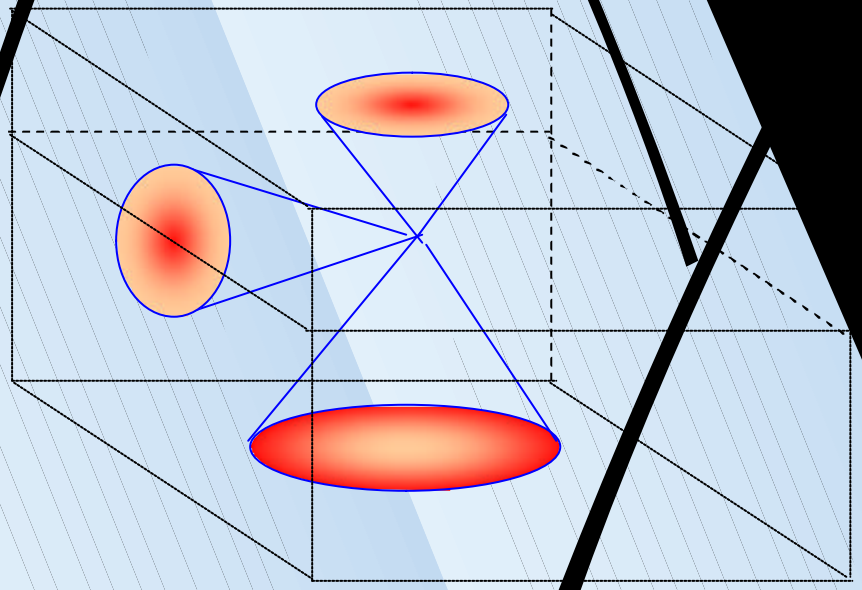


Quantum Well Devices

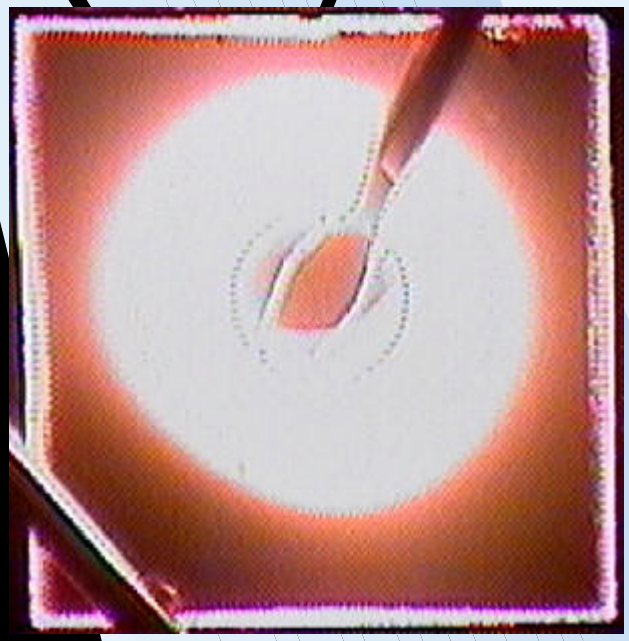
1. Quantum size effects (QSE) can shorten wavelength .
2. Reduced self-absorption in a thin active layer.
3. Increased power conversion efficiencies.
4. Increased operating temperatures.



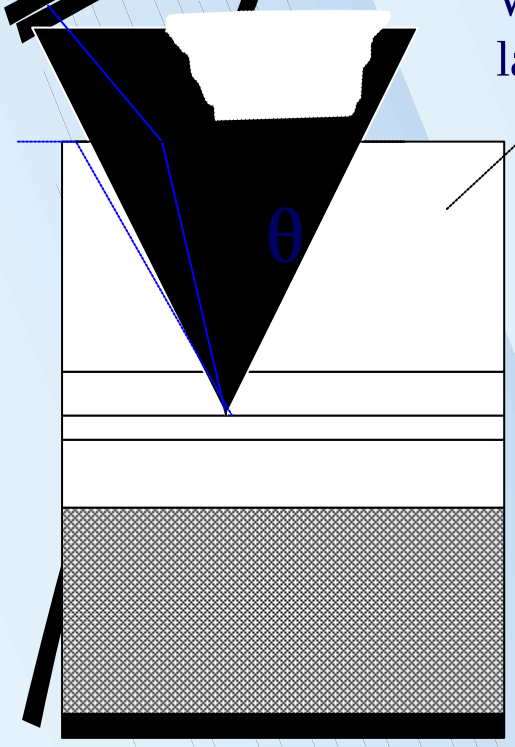
Light Extraction



Light extraction properties



Window Layers



Window layer

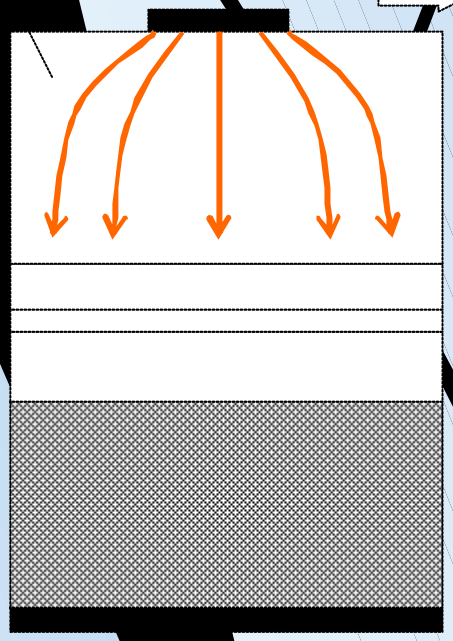
transparent
AlGaAs > 580nm
GaP > 565nm

$N_{air} \sim 1$

$N_{chip} \sim 3.4$

$\theta = \sin^{-1}(n1/n2)$

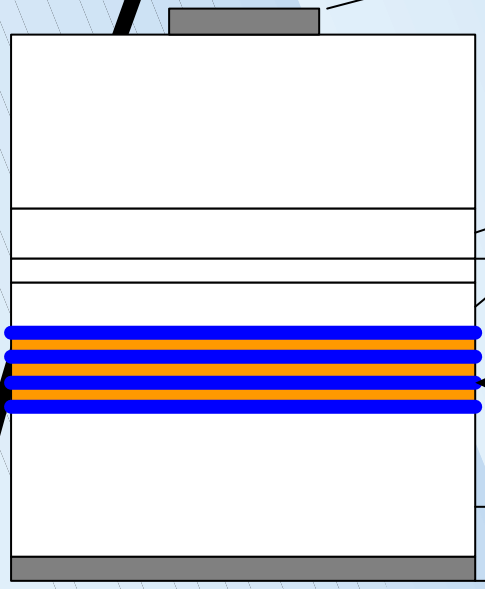
$= 17°$



Window layer

Window layer doping ↑
Conductivity ↑
Current-spreading ↑

Distributed Bragg Reflector



p- metal

Window layer

Cladding layer

Active layer

DBR

Substrate

n- metal

N-pairs

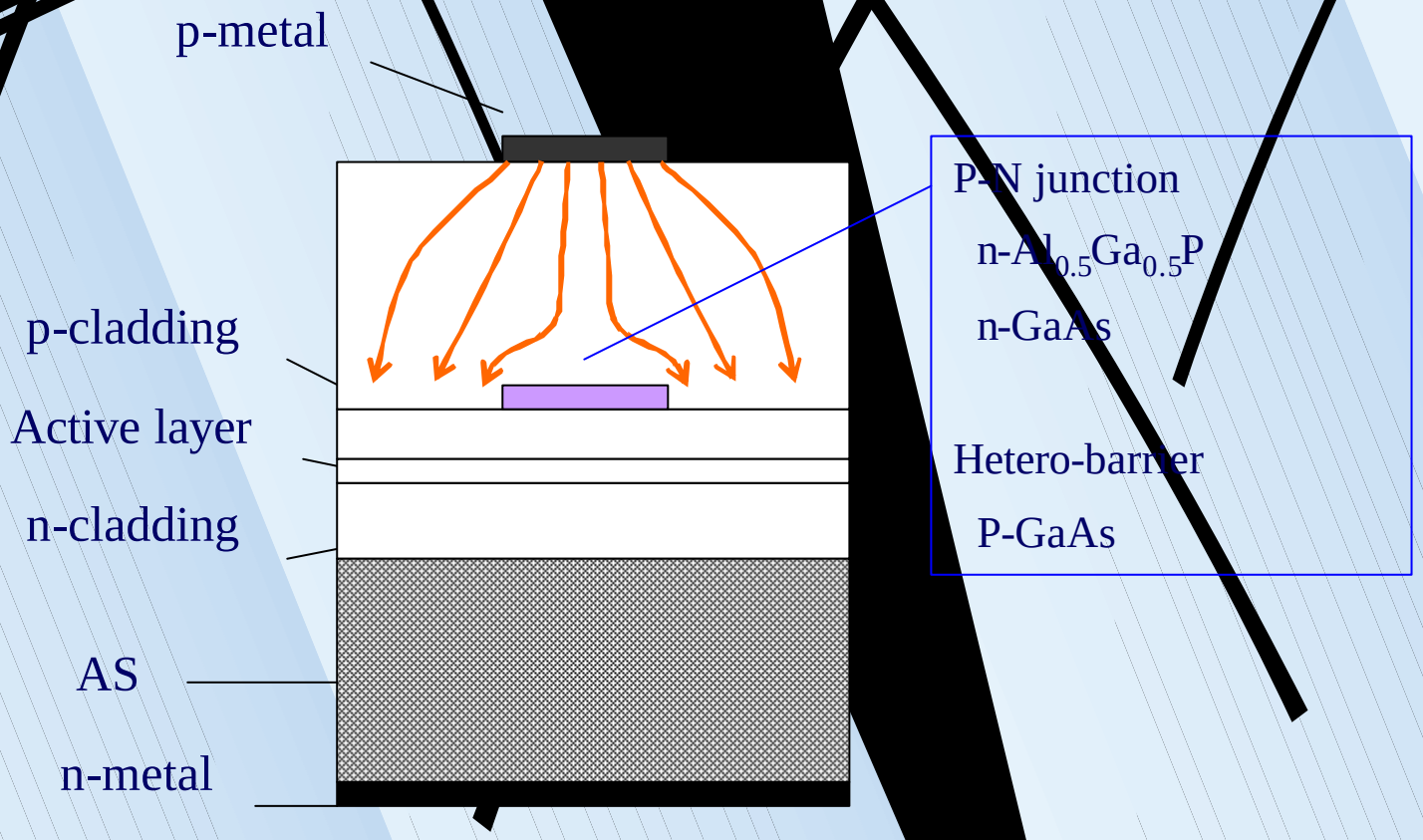
GaAs $\lambda/4n_{GaAs}$

AlGaAs $\lambda/4n_{AlGaAs}$

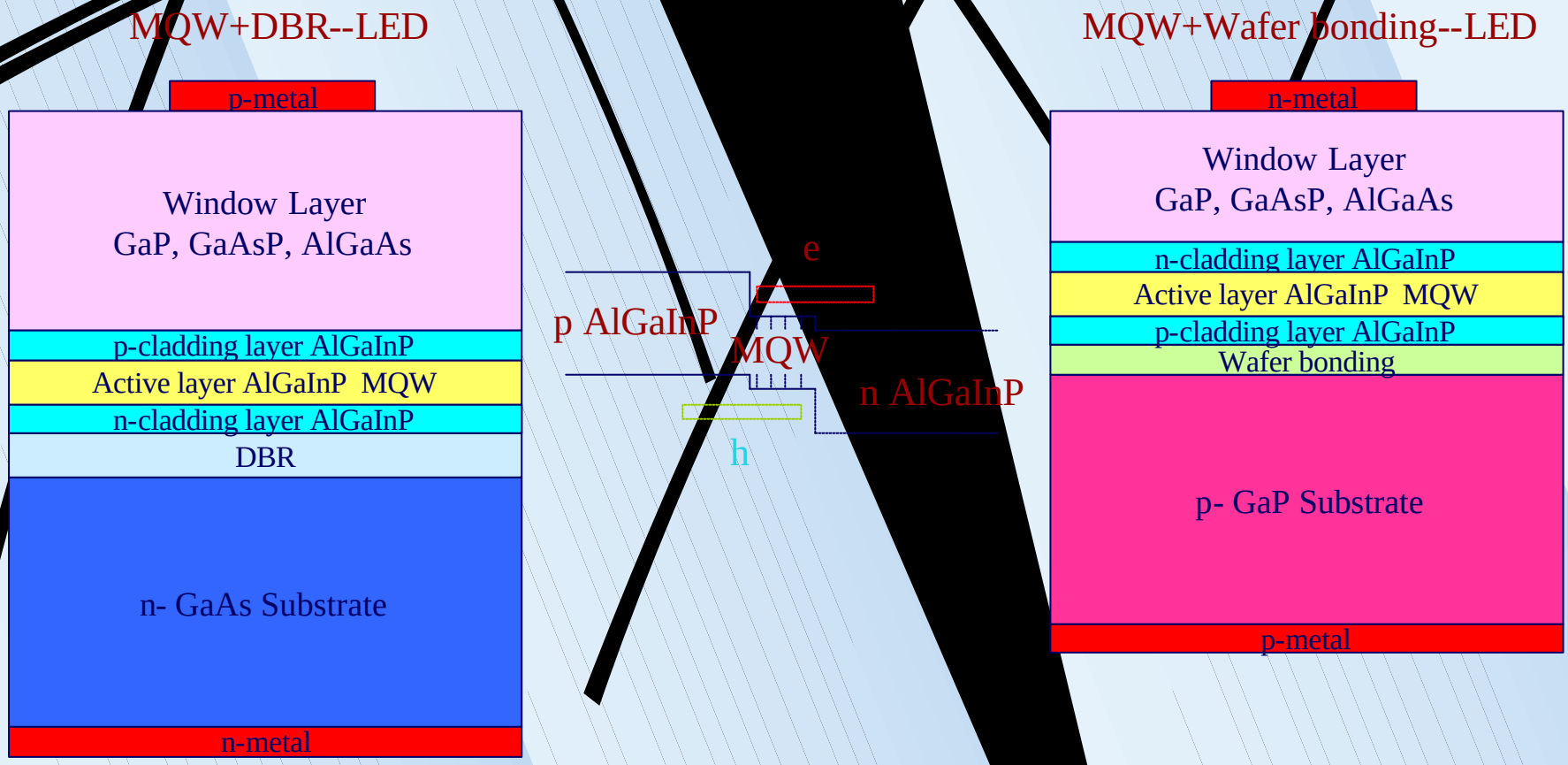
Properties of Semico… …ted Bragg Reflector (DBR) Mirror Utilized in (A… …P Light Emitting Diodes

DBR Materials	D… …at Des… …gth	Mirror Type
$Al_{0.5}In_{0.5}P$—GaAs	0.85(	Lossy
$Al_{0.5}In_{0.5}P$—$Ga_{0.5}In_{0.5}P$	0.61(590	Lossy
$Al_{0.5}In_{0.5}P$—$(Al_{0.3}Ga_{0.7})_{0.5}In_{0.5}P$	0.37(615nm)	Transparent(λ>592nm)
$Al_{0.5}In_{0.5}P$—$(Al_{0.4}Ga_{0.6})_{0.5}In_{0.5}P$	0.35(590nm)	Transparent(λ>576nm)
SiO_2———Si	1.95(1550nm)	Transparent(λ>1500nm)
AlxOy——GaAs	1.95(850nm)	Transparent(λ>800nm)

Current Blocking Structures



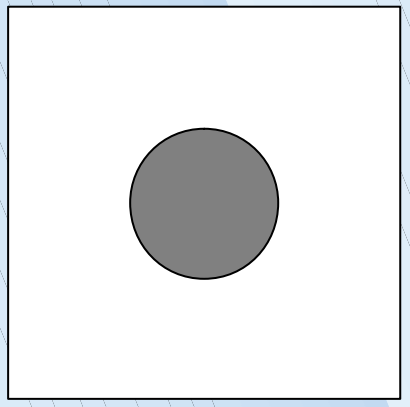
LED結構演進歷史2


MQW+DBR--LED
p-metal
Window Layer
GaP, GaAsP, AlGaAs
p-cladding layer AlGaInP
Active layer AlGaInP MQW
n-cladding layer AlGaInP
DBR
n- GaAs Substrate
n-metal
e
p AlGaInP
MQW
n AlGaInP
h
MQW+Wafer bonding--LED
n-metal
Window Layer
GaP, GaAsP, AlGaAs
n-cladding layer AlGaInP
Active layer AlGaInP MQW
p-cladding layer AlGaInP
Wafer bonding
p- GaP Substrate
p-metal

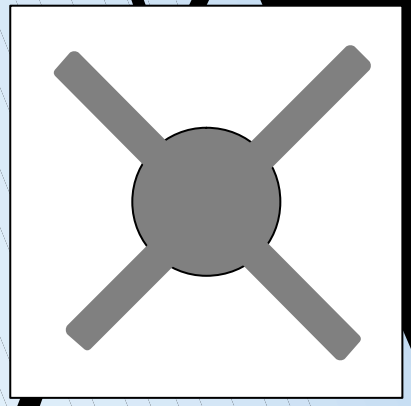
Ohmic Contact Modification

1. Most of the light blocked by the contact metal.
2. Most of the area nonradiation.

400mlm/W

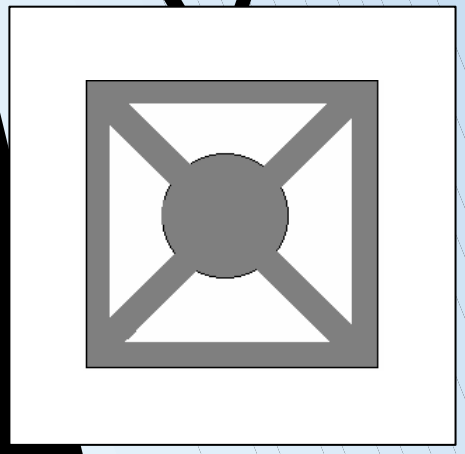


250umX250um



250umX250um

1000mlm/W

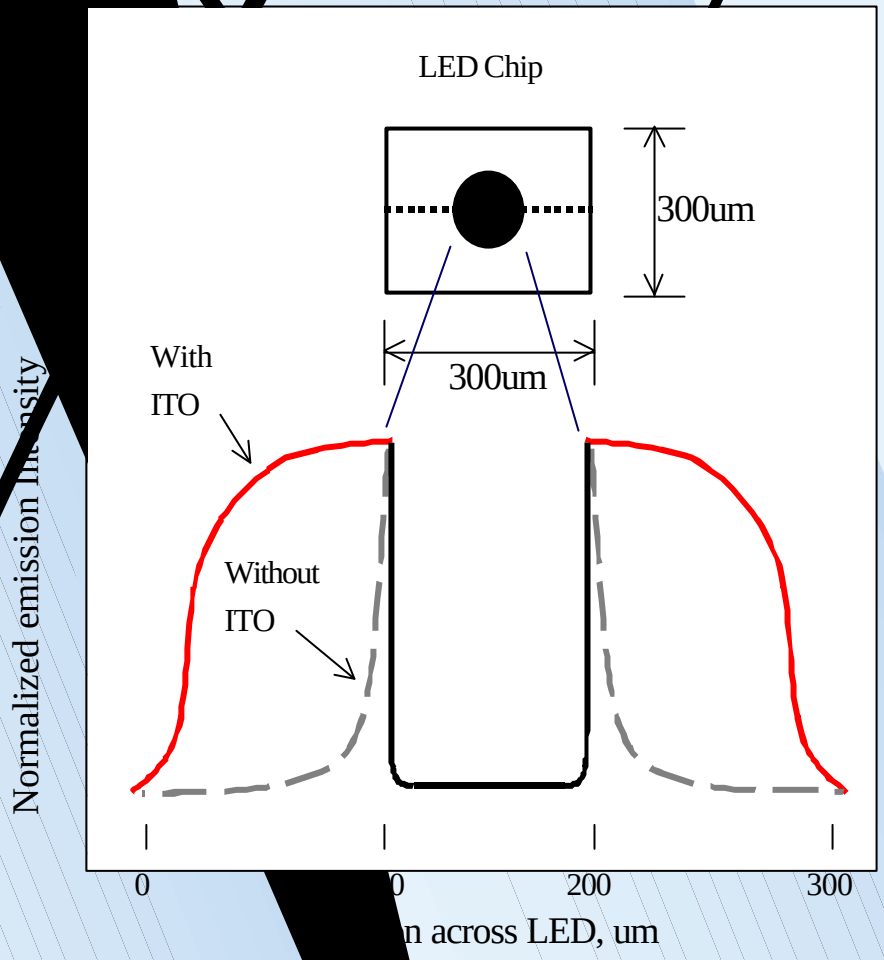


350umX350um

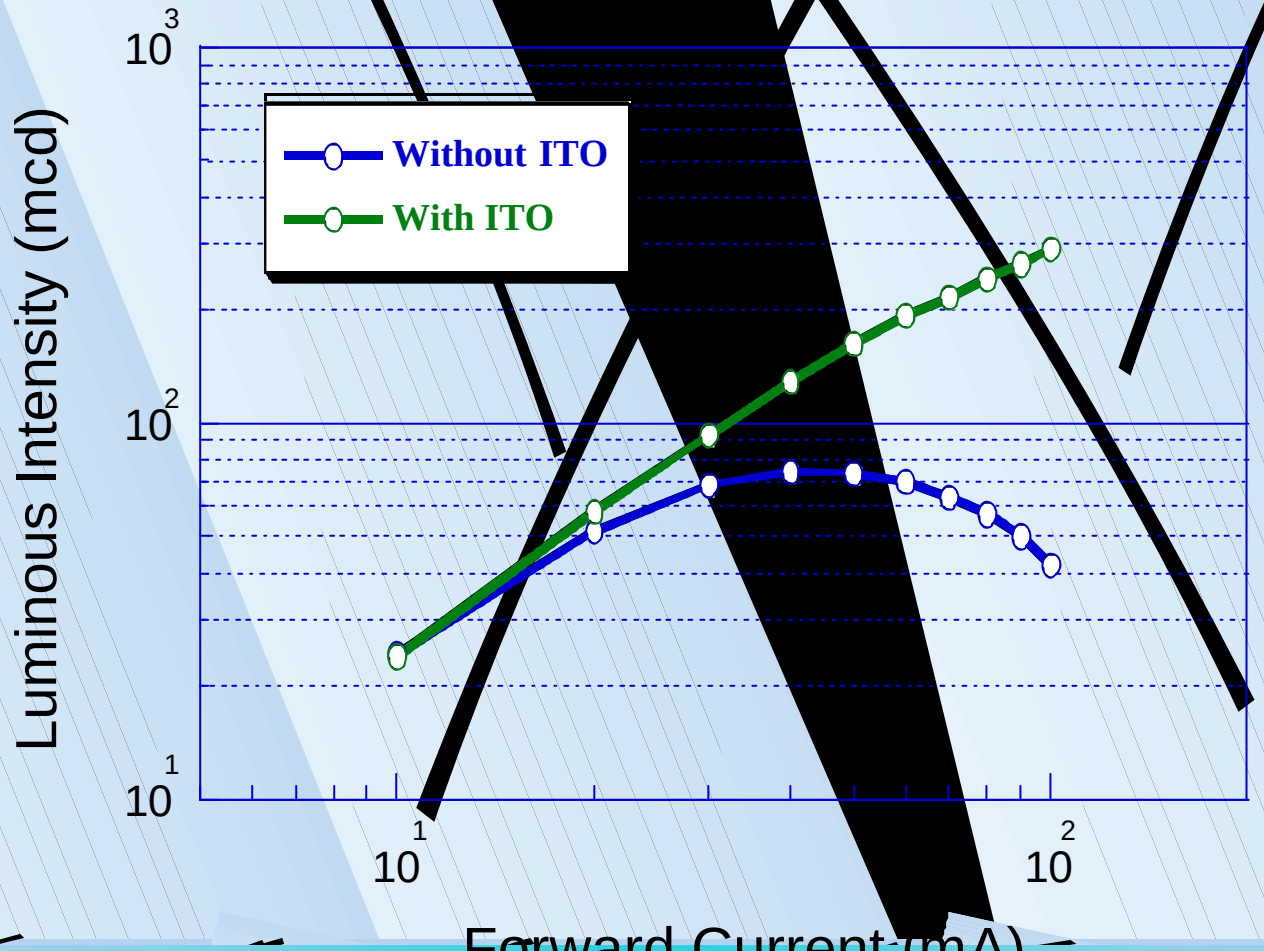
Indium Tin Oxide

600Å ITO
500Å p-GaAs Contact Layer
GaInP Transition Layer
p-Cladding Layer
Active Layer
n-Cladding Layer
DBR
n-GaAs Buffer Layer
n-GaAs substrate

ITO/AlGaInP LED Structure



Intensity Comparison for Samples with/without ITO



LED Wafer Bonding Technique
Motivation

- GaAs substrate is absorbing
- DBR reflects only the light at normal direction

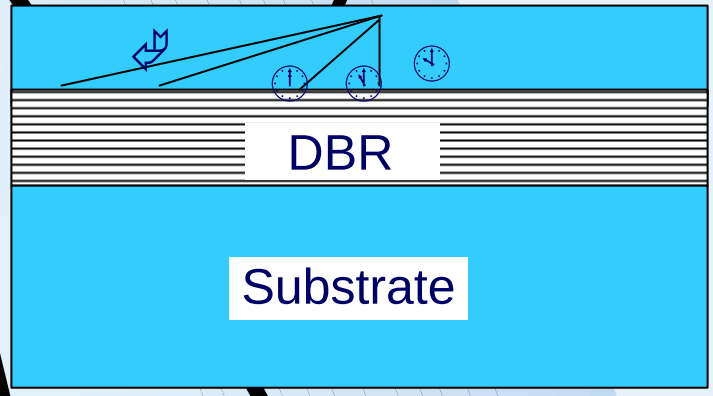
⇒ AlGaInP LED bonded to **mir** **bstrates** at a **low temperature** process

Wafer Bonding (mirror substrates)

Traditional Methods to Improve LEDs efficiency

- DBR (Distributed Bragg Reflector) structure

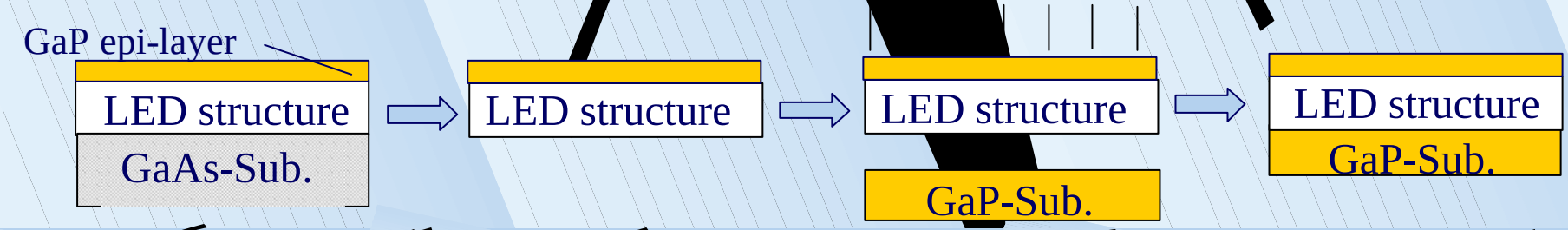
  disadvantage:DBR only reflects the near normal incident light.



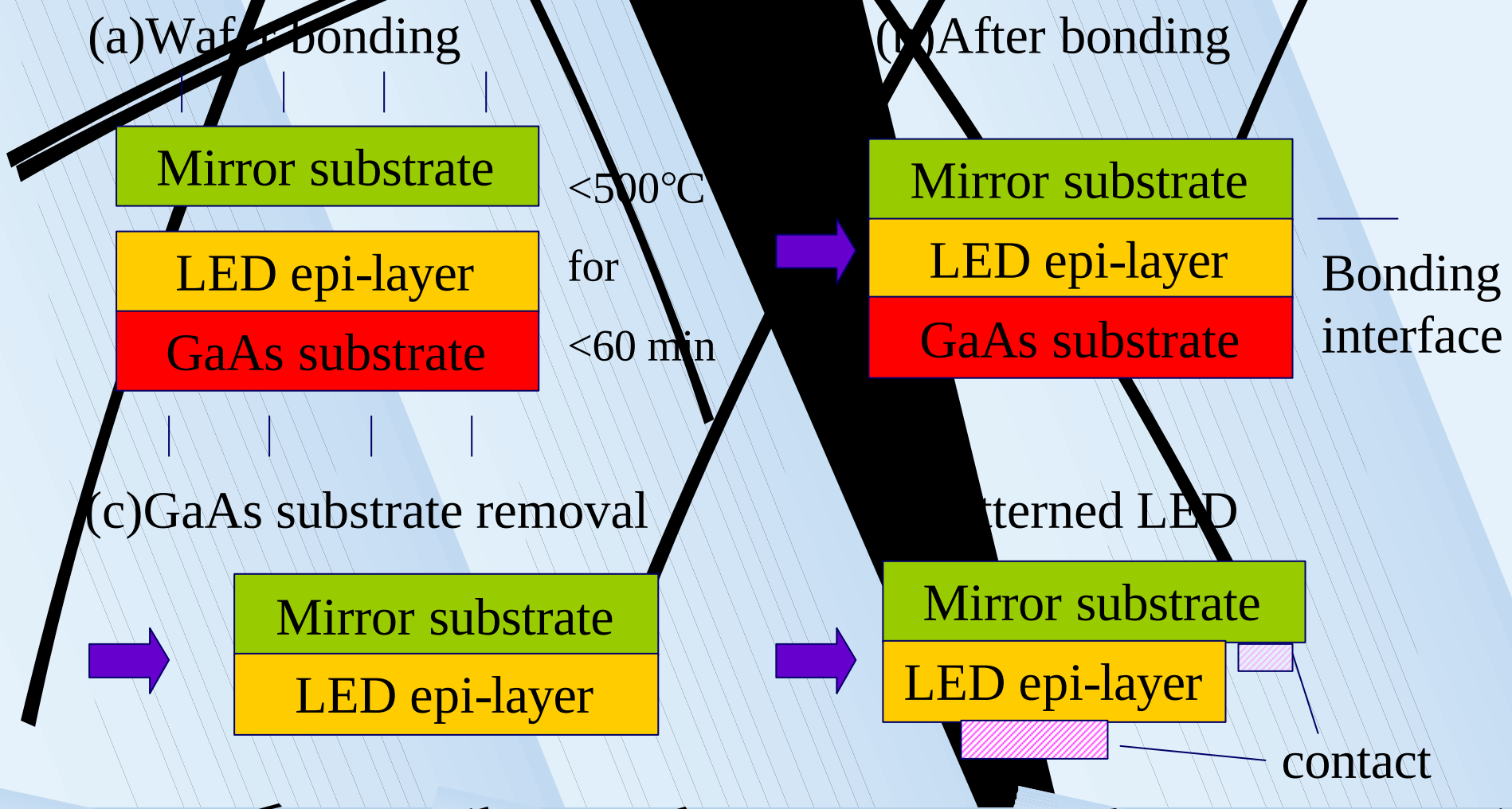
- GaP wafer bonding (by HP)

  disadvantages:

  - Need handle thin epi-layer
  - High treatment temperature (> 600°C)
  - Long duration time (> 1 hour)⇒might destroy LED



Wafer Bonding Procedure



RESULTS / DISCUSSION

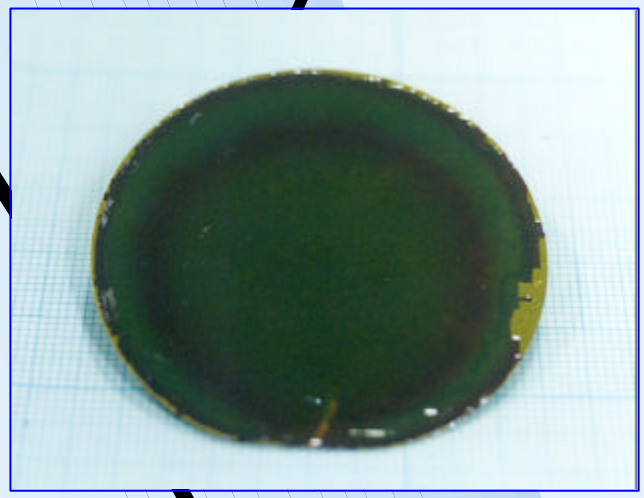
Absorbing substrate: GaAs

Luminous intensity : 13 mcd

M[illegible]e: Si

Luminous intens[illegible]cd

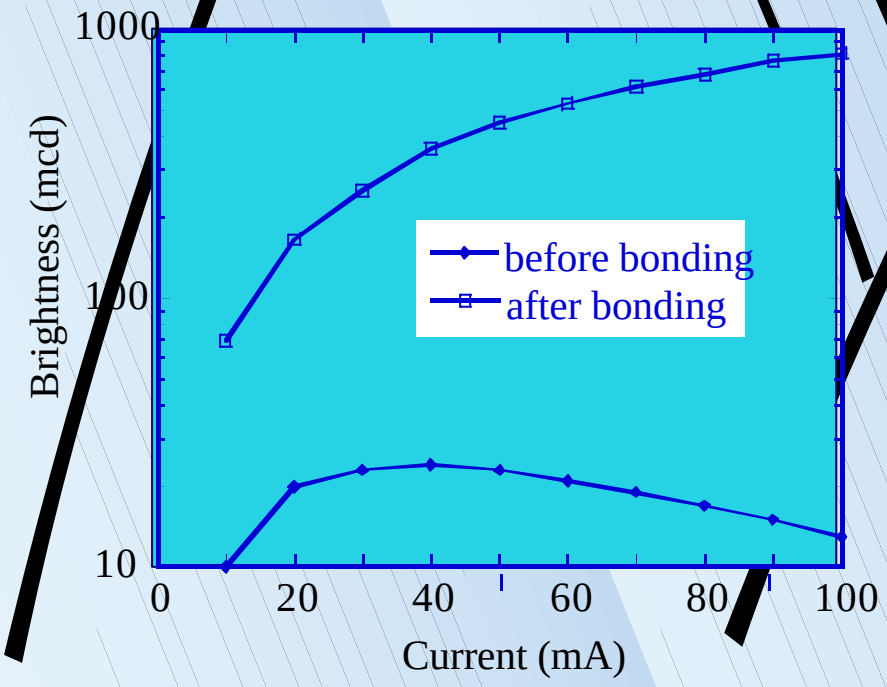
2” LED/metal/SiO_2/Si wafer



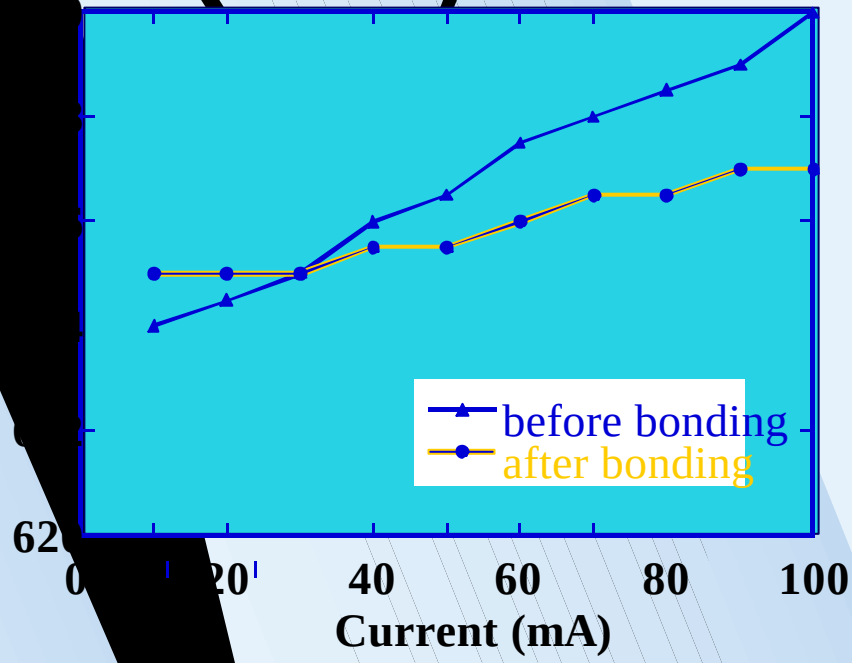
- The metal mirror can reflect both l[illegible]hat is emitted and internally reflected downwardly to [illegible] the mirror .
- Elimination of bulk absorption substa[illegible]lly improves the LED efficiency.

RESULTS / DISCUSSION

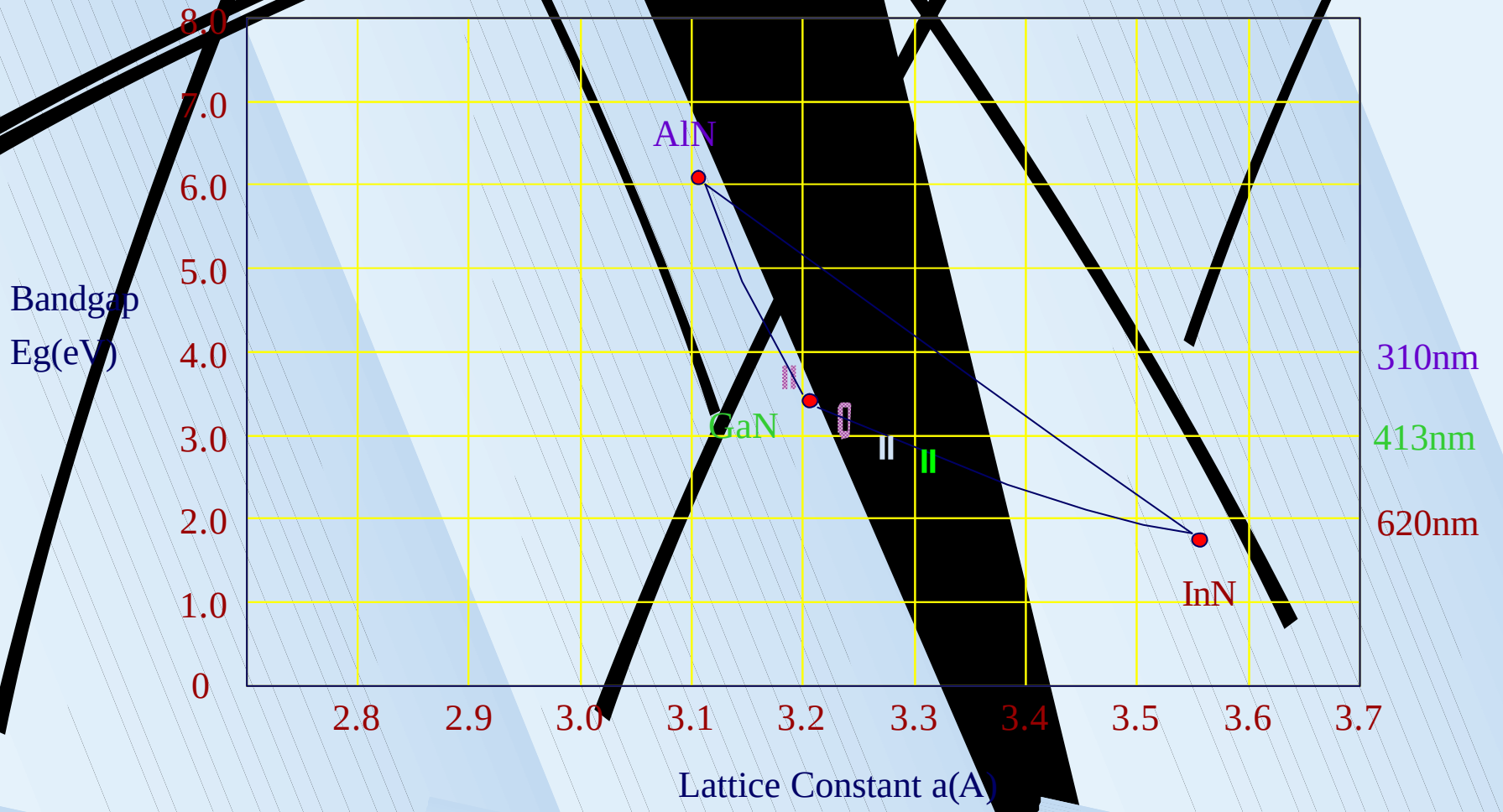
625 nm 12-mil LED L-I Curve



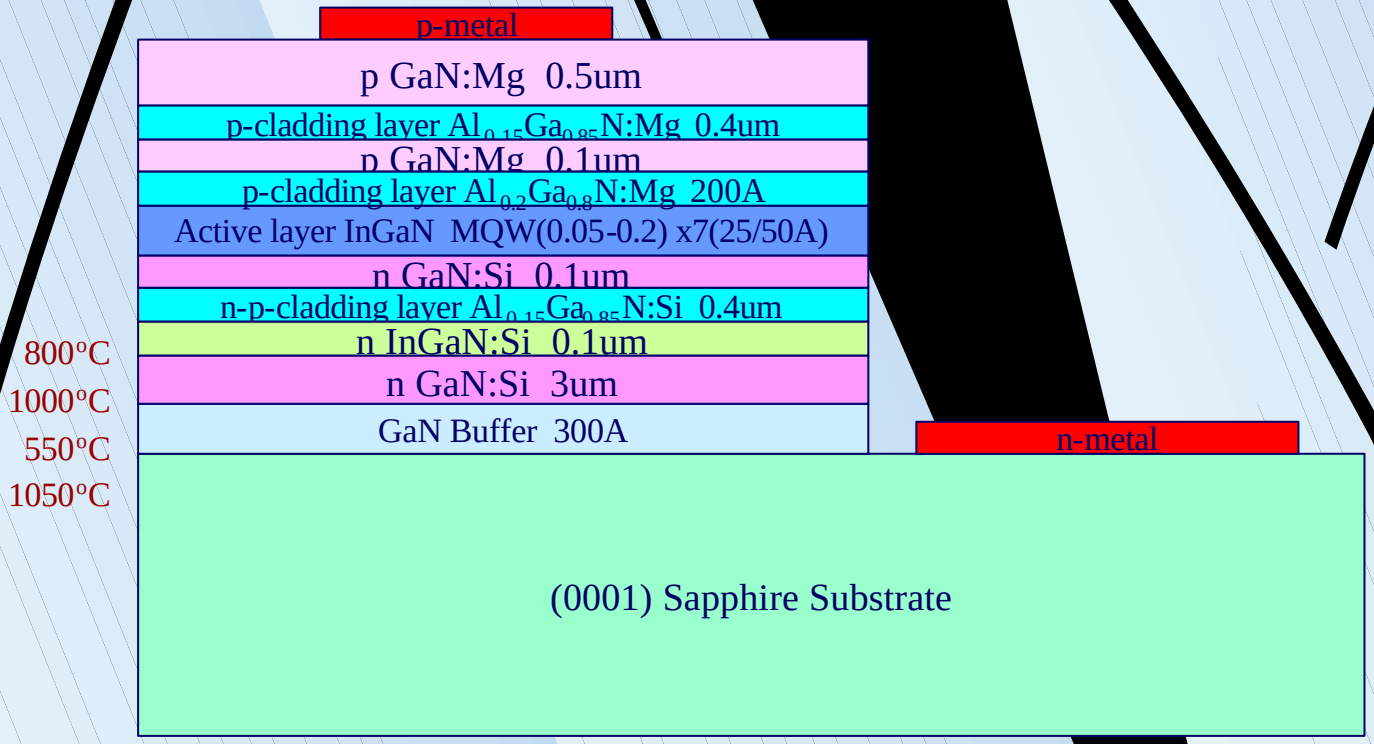
Wavelength v.s. Current



Energy Bandgap and Lattice Constant



GaN LED


p-metal
p GaN:Mg 0.5um
p-cladding layer Al0.15Ga0.85N:Mg 0.4um
p GaN:Mg 0.1um
p-cladding layer Al0.2Ga0.8N:Mg 200A
Active layer InGaN MQW(0.05-0.2) x7(25/50A)
n GaN:Si 0.1um
n-p-cladding layer Al0.15Ga0.85N:Si 0.4um
n InGaN:Si 0.1um
n GaN:Si 3um
GaN Buffer 300A
n-metal
(0001) Sapphire Substrate
800°C
1000°C
550°C
1050°C

GaN LED 專利說明

Assignee	Patent No.	Date of Patent	m	Material
Nichia	5290393	Mar. 1, 1994	AlGaN buffer	AlGaN x=0-1
Nichia	5306662	Apr. 26, 1994	p-GaN activation	AlGaN, InGaN , >400C
Nichia	5334277	Aug. 2, 1994	M	GaN, Two Flow Reactor
Nichia	5433169	Jul. 18, 1995	MO	AlGaInN, Two Flow
Nichia	5468678	Nov. 21, 1995	P type III-V, II-IV	AlGaInN, ZnSe
Nichia	5563422	Oct. 8, 1996	Contact + Anneal	III-V
Nichia	5578839	Nov. 26, 1996	DH + I	AlGaN, GaN
M. A. Tischler	5585648	Dec. 17, 1996	SiC	GaN, AlGaInN

結論:現有廠商的潛在風險，後續發展值得觀察

照明設備製造廠商之動作

- GE + EMCORE Þ GELcore
- Philips + HP Þ LumiLeds
- OSRAM + SIEMES Þ OSRAM Opto Semiconductors

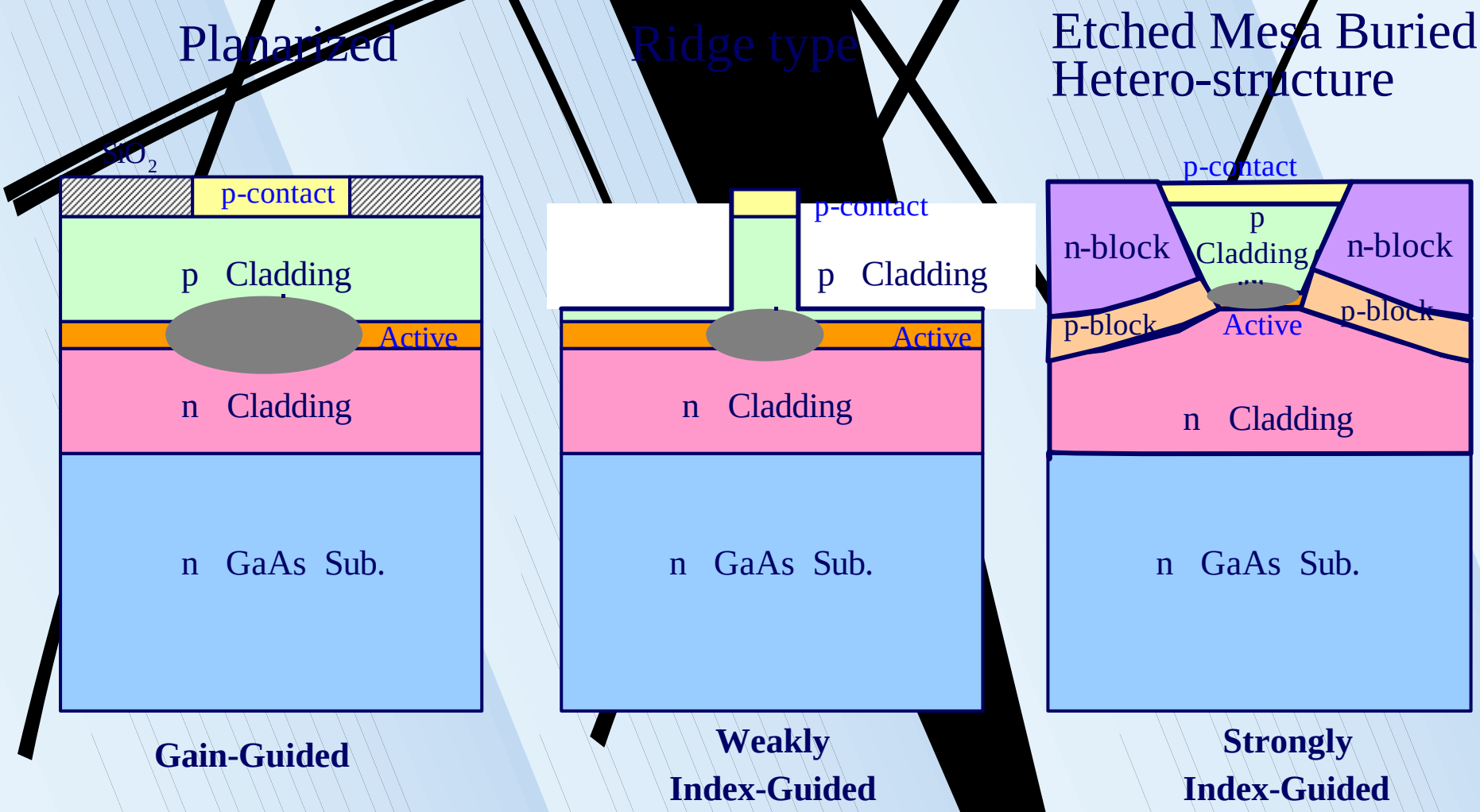
LD Applications:

650 / 780 nm: Barcode scanning, Laser printer scanning,
DVD, CD-ROM, CD-RW (Optical Storage)
8倍速50mW=➔48倍速260mW
(AlGaInP/InGaP,AlGaAs/GaAs)

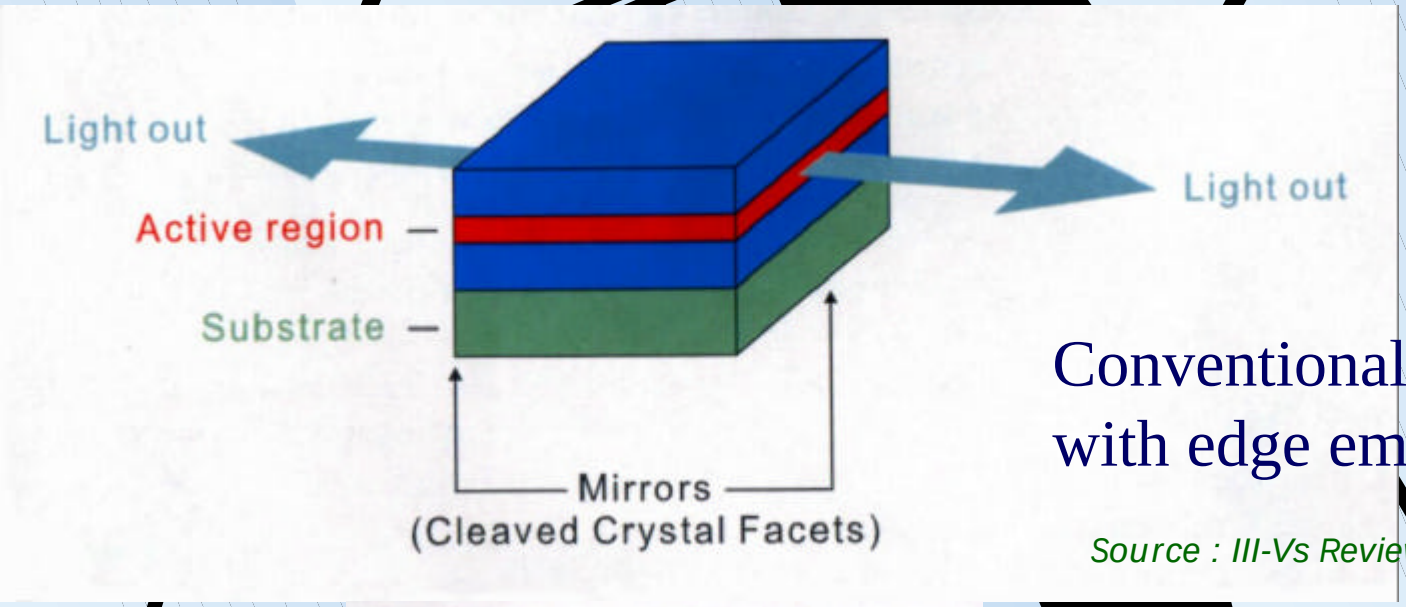
980 /1480 nm: Pump Laser(EPFA)
(InGaAs/GaAs, InGaAs/InP)

1310/1550 nm: Optical fiber communication
(AlGaInAs/InP, InGaAs/InP)

Various Laser Structures

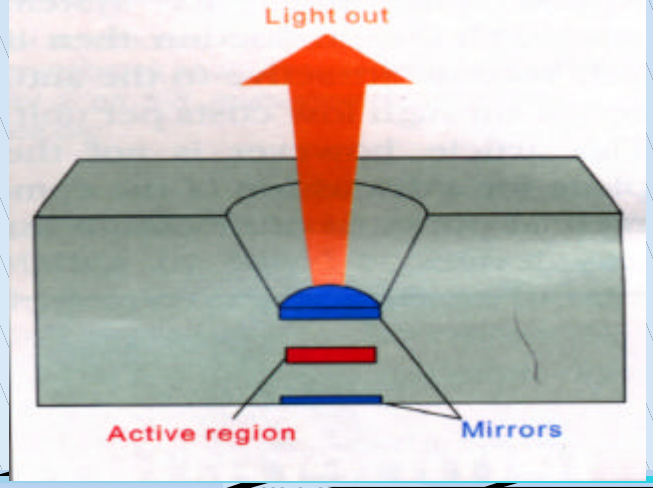


Semiconductor laser



Conventional Semiconductor laser with edge emission

Source : III-Vs Review • Vol. 13 No.1 2000



Vertical-cavity surface-emitting laser (VCSEL)

Source : III-Vs Review • Vol. 13 No.1 2000

Advantages of VCSEL

(1) Circular light pattern, easily coupled to fiber

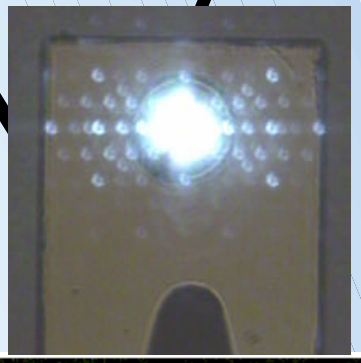
(2) Low operation current, Good temperature stability

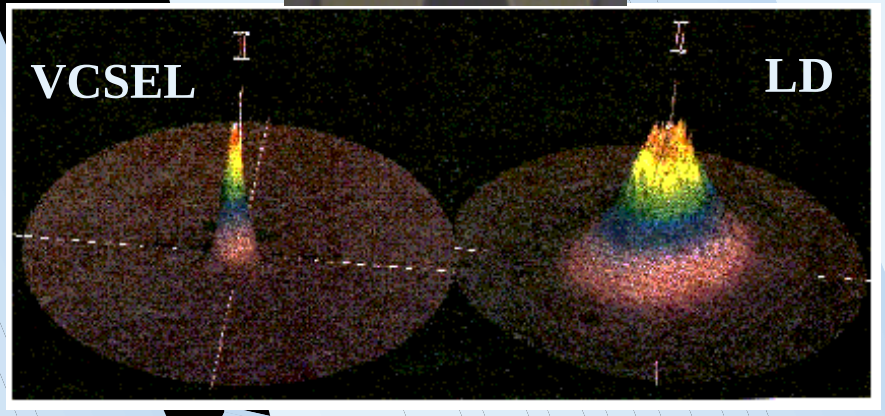
(3) High frequency modulation

(4) Direct on-wafer probing

(5) Easy packaging,Cost reduction

(6) Suitable for Array bar/ 2-D matrix





❖**Application**

----- For low-cost, mass production datacom

----- For CD/DVD、Bar-code reader及Printer

Important Characteristics of PIN Diode

1. Dark Current
2. Capacitance
3. Responsivity

Planar-Type PIN Process