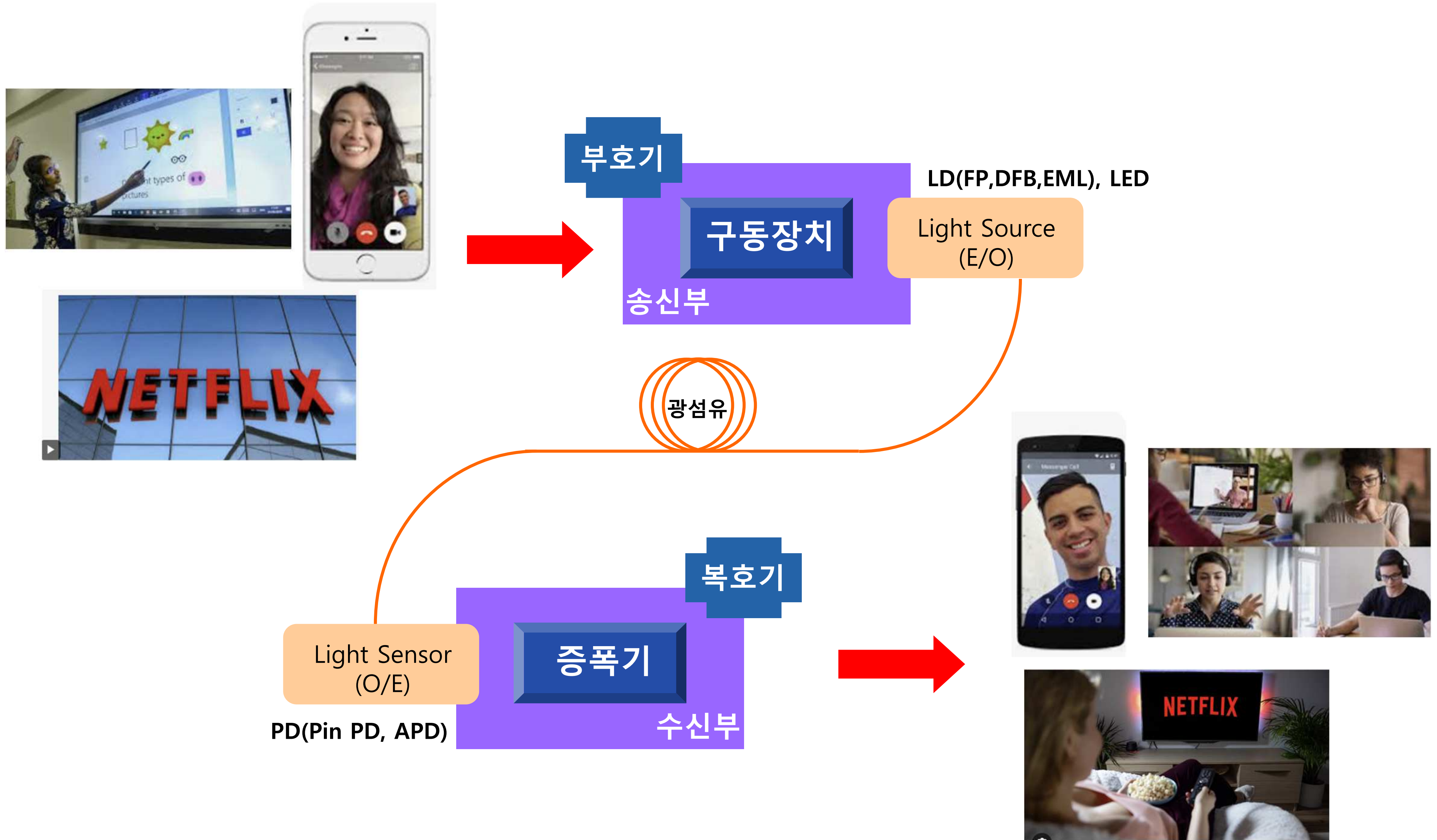
광통신용 반도체 레이저

2024. 5. 27.

OES Chip

광통신 개요



Communication Network

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Long Haul

Metro Core

Metro Edge

Optical wireless

Mobile Access

Gigabit Ethernet

Enterprise Access

Optical Home Network

Residential Access

Gigabit Ethernet

Campus LAN

1000Km

400Km

80Km

20Km

SONET/SDH, Ethernet

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SONET(Synchronous Optical NETwork)

- 미국의 벨코어가 개발하고 미국표준협회(ANSI)가 표준화한 고속 광전송 방식의 표준 규격
- SONET에서 신호의 기본 단위는 810byte 크기를 갖는 구조로서, 51.840Mbps/s의 속도로 전송되는 STS-1

SDH(Synchronous Digital Hierarchy)

- 북미 표준인 SONET을 기초로 하여 동기식 다중화 기술을 바탕으로 개발 된 ITU 국제 표준
- SDH의 기본이 되는 다중화 단위는 동기 전송 모듈(STM)이며 최저 다중화 단계인 STM-1의 전송 속도는 155.520Mbps
- SONET와 호환성이 있는 표준이라는 의미에서 SONET/SDH라고도 부름

Ethernet

일정 구역내의 컴퓨터간의 정보교환 및 장치 공유의 목적으로 개발된 버스 구조 방식의 근거리통신망(LAN: Local Area Network) 분야의 대표적인 기술로서 기본적으로 10Mbps(초당 천만 비트 전송)통신 속도를 제공

Line Rate

OC Level	SONET	SDH	Line Rate (Mbps)
OC 1	STS-1		51.84
OC 3	STS-3	STM-1	155.52
OC 12	STS-12	STM-4	622.08
OC 48	STS-48	STM-16	2,488.32
OC 192	STS-192	STM-64	9,953.28
OC 768	STS-768	STM-256	39,813.12
광 신호	전기 신호	전기 신호	

Ethernet : 10Mbps
Fast Ethernet : 100Mbps
Gigabit Ethernet : 1Gbps
10Gigabit Ethernet :10Gbps

OC(Optical Carrier)
STS(Synchronous Transport Signal)
STM(Synchronous Transport Module)

Wavelength

OE SOLUTIONS

Energy (eV) | Frequency (Hz) | Wavelength (m)

Energy (eV): 10^{9}, 10^{8}, 10^{7}, 10^{6}, 10^{5}, 10^{4}, 10^{3}, 10^{2}, 10^{1}, 10^{0}, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}, 10^{-10}, 10^{-11}, 10^{-12}, 10^{-13}

Frequency (Hz): 10^{23}, 10^{22}, 10^{21}, 10^{20}, 10^{19}, 10^{18}, 10^{17}, 10^{16}, 10^{15}, 10^{14}, 10^{13}, 10^{12}, 10^{11}, 10^{10}, 10^{9}, 10^{8}, 10^{7}, 10^{6}, 10^{5}, 10^{4}, 10^{3}, 10^{2}, 10^{1}

Wavelength (m): 10^{-14}, 10^{-13}, 10^{-12}, 10^{-11}, 10^{-10}, 10^{-9} (1 nm), 10^{-8}, 10^{-7}, 10^{-6} (1 μm), 10^{-5}, 10^{-4}, 10^{-3} (1 mm), 10^{-2} (1 cm), 10^{-1}, 1 (1 m), 10^{1}, 10^{2}, 10^{3} (1 km), 10^{4}, 10^{5}, 10^{6}, 10^{7}

Gamma rays
X-rays
Ultraviolet
VISIBLE
Infrared
Microwaves
Short radio waves
Television and FM radio
AM radio
Long radio waves

400 nm, 450, 500, 550, 600, 650, 700

Optical Communication Wavelengths

감마선 < X선 < 자외선 < 가시광선(보남파초노주빨) < 적외선 < 마이크로파 ....

Optical Spectrum Band

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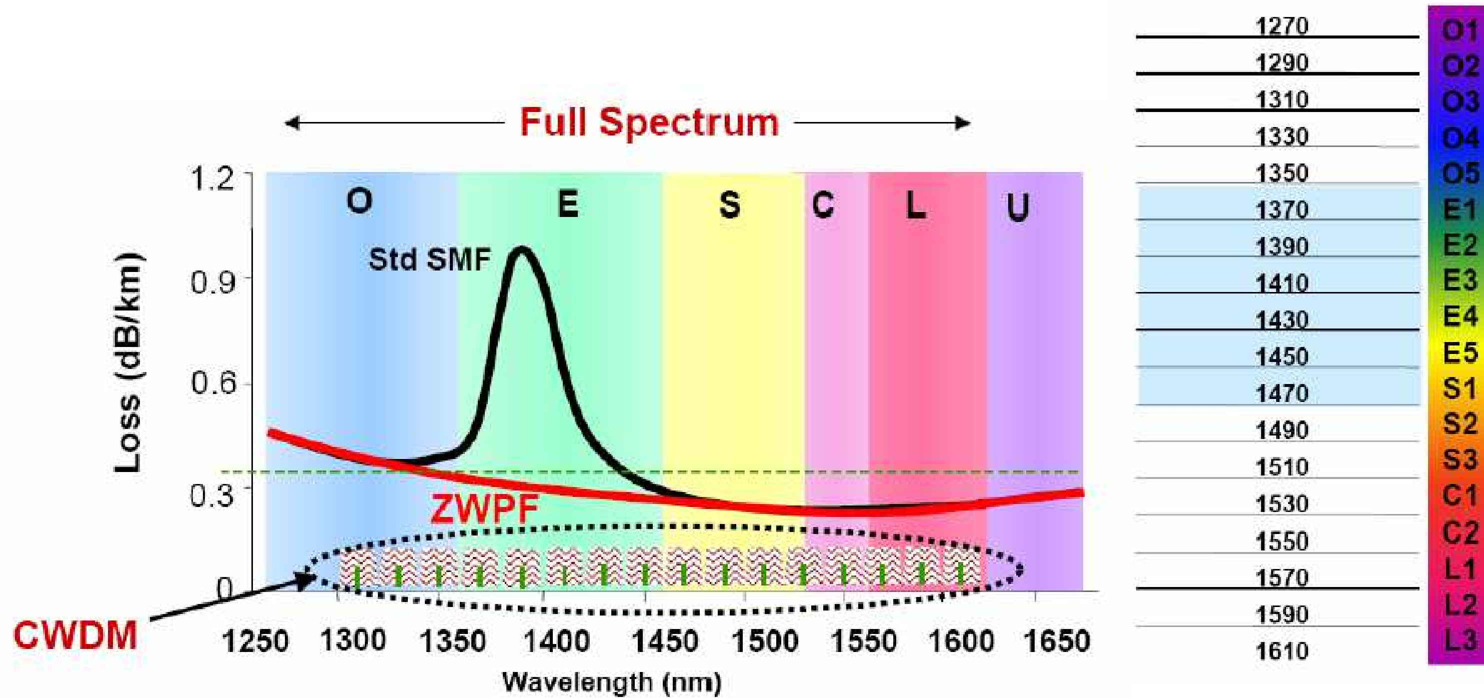
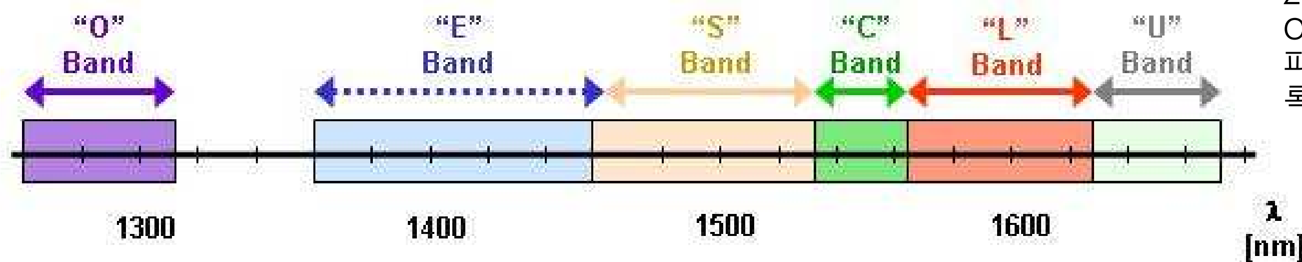


ZWPF(Zero Water Peak Fiber) : OH이온(수분)을 제거해서 특정 파장대역에서 손실을 최소화되도록 제작된 광섬유



Band		WL(nm)
O	Original	1260 ~ 1360
E	Extended	1360 ~ 1460
S	Short	1460 ~ 1530
C	Conventional	1530 ~ 1565
L	Long	1565 ~ 1625
U	Ultra-long	1625 ~ 1675

Optical Loss

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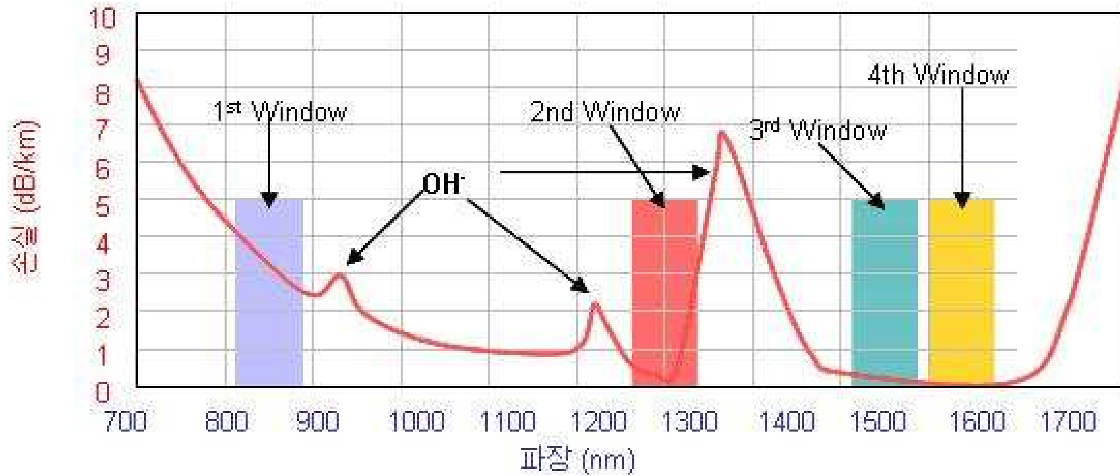
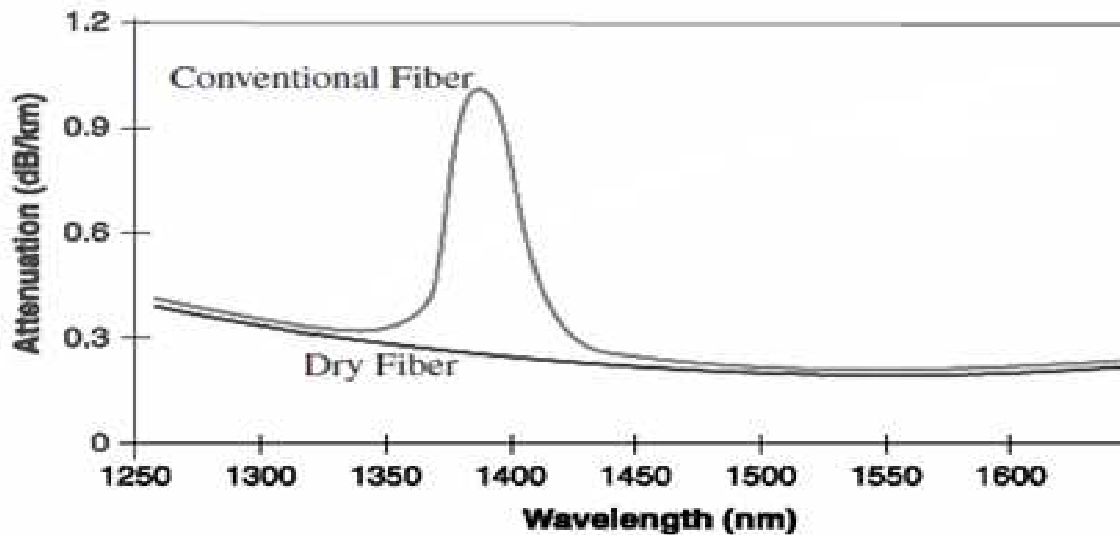




Optical Loss

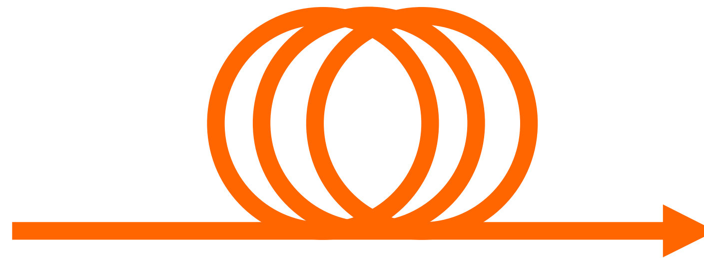
광신호가 광섬유를 진행하면서 산란, 흡수 등의 현상으로 신호 전력이 떨어지는 현상을 말하며 표시단위는 통상 거리에 따른 손실 dB/km을 사용.
1550nm에서 손실이 최저값

Windows

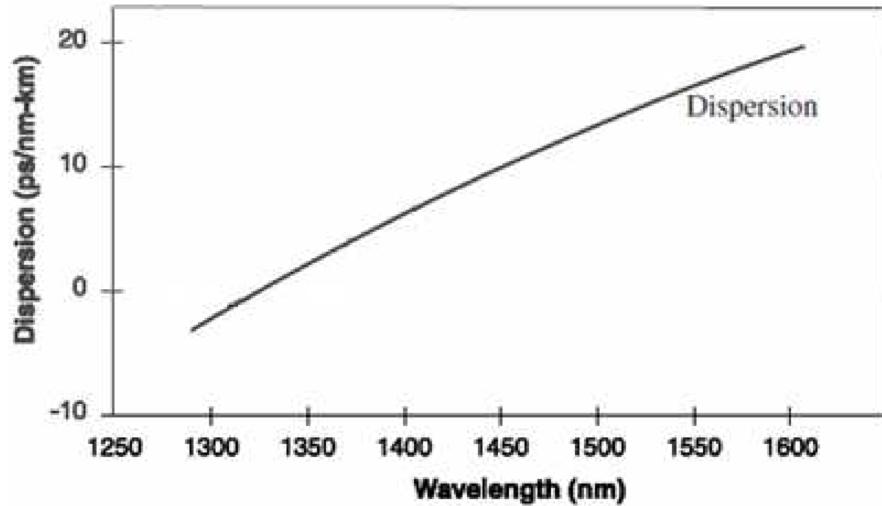
광섬유에서 특정 파장대별에서 손실이 낮아서 굳이 광증폭기 등이 필요없는 파장대역

Optical Loss

Optical Network

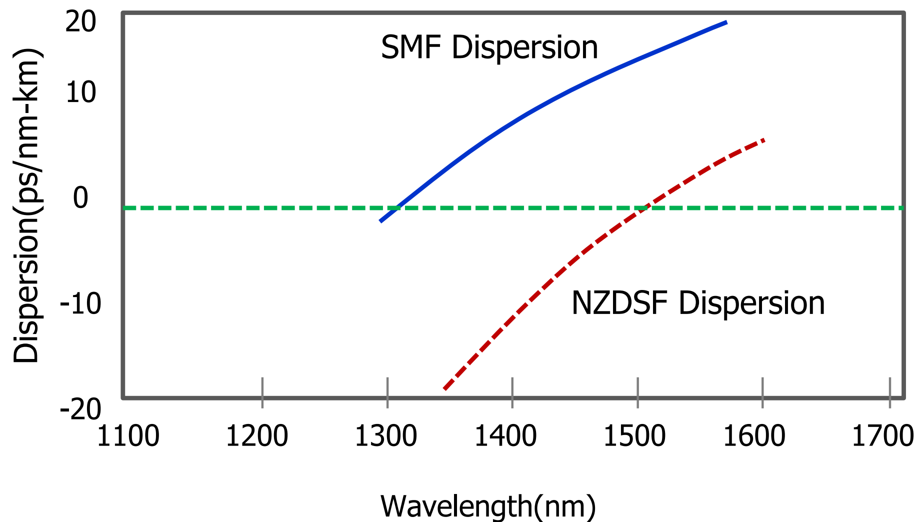


Dispersion



Dispersion

매질 굴절률의 주파수 의존성 등 여러 요인들에 의해 디지털 펄스 신호가 전송매체를 진행하면서 펄스 파형이 퍼지는 현상 즉, 파형이 시간적으로 벌어지는 현상
1310nm에서 분산이 최저값



NZDSF(Non-Zero Dispersion Shifted Fiber)

주요 파장대역(1550nm 부근)에서 나타나는 비선형 효과를 피하기 위해서 해당 파장대에서 분산값이 영(영분산 점) 보다 약간 큰 광섬유

Dispersion

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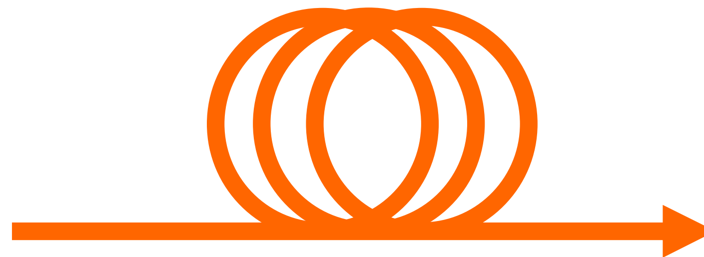
Optical Network



Loss와 Dispersion 동시 발생

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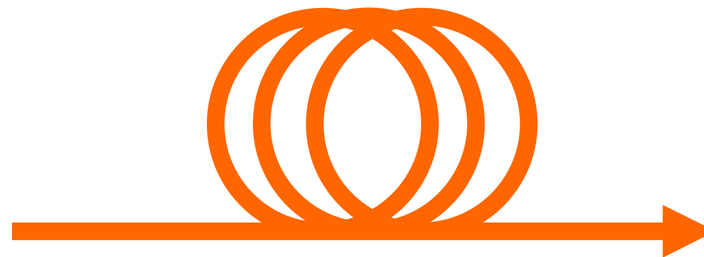
Optical Network



Optical Network

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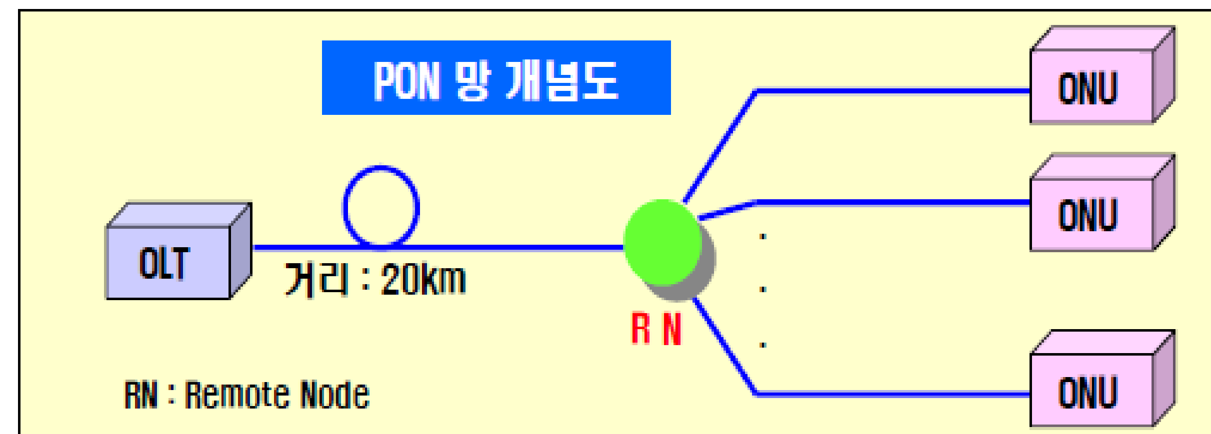
AON : Active Optical Network

전력공급이 필요한 능동형 소자가 사용됨

PON : Passive Optical Network

별도의 전원공급이 불필요한 광수동소자만으로 구성



PON System

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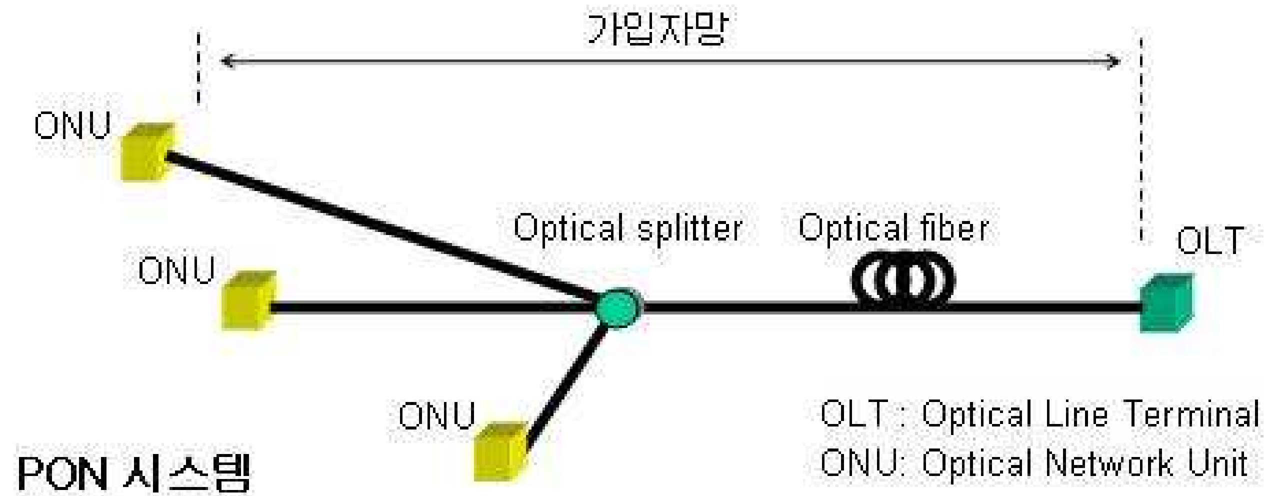

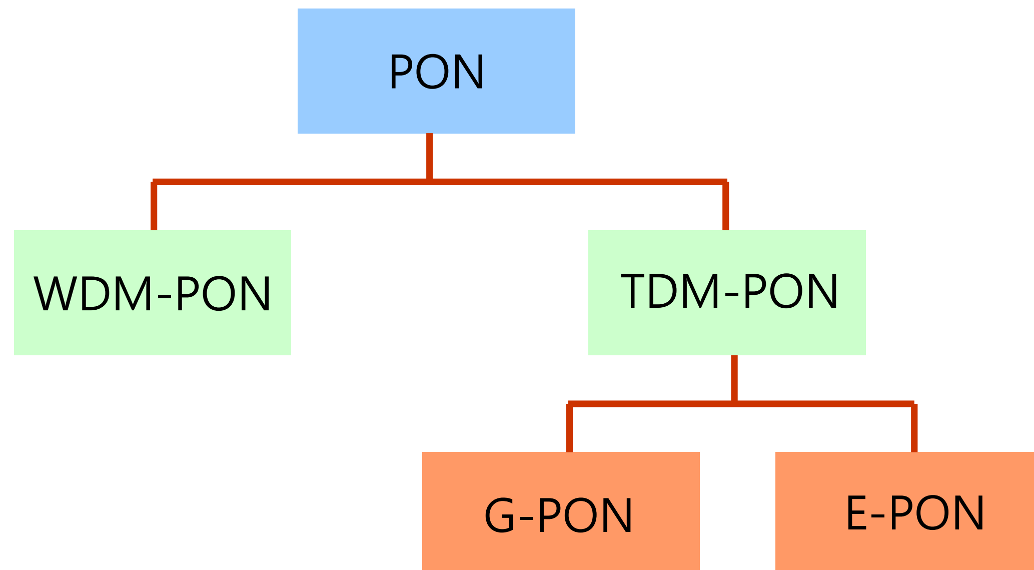

TDM vs WDM

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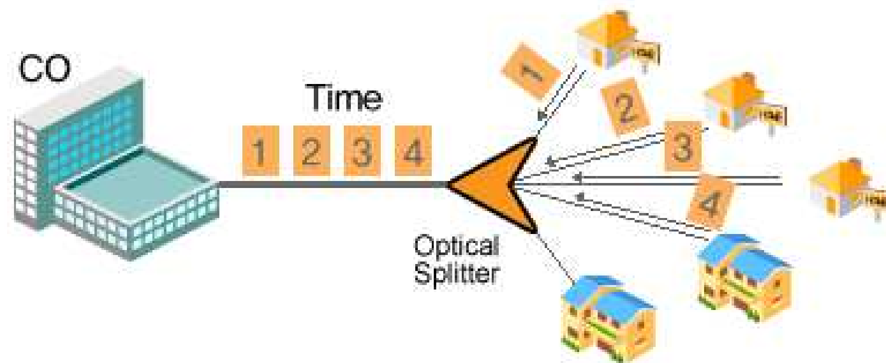
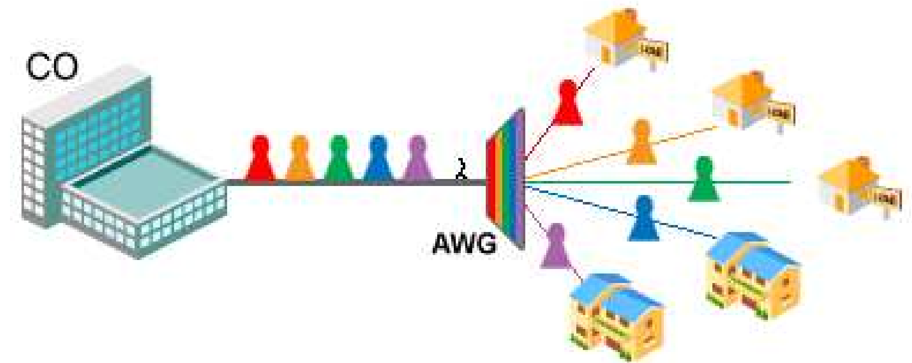
TDM PON

WDM PON





CO : Central Office
AWG : Arrayed Waveguide Grating

- 시분할에 의해 가입자별로 할당된 시간에 필요한 데이터의 송수신을 수행하는 방식

- CO에서 하나의 광원으로 여러 가입자를 수용할 수 있음
- 기존 전달망에서 많은 성숙된 표준 및 기술, 비용 우위를 가지고 있음
- 시간 분할에 의해 가능한 대역폭을 최대로 활용할 수 없음
- 중앙집중국에서 모든 가입자에게 정보가 분산되므로 보안성이 약함

- 가입자 또는 서비스 별로 파장을 다중화하여 다수의 ONU가 하나의 광섬유에 여러 개의 광 링크를 수용하여 경제적으로 광가입자망을 구축하는 기술

- 전송 프로토콜에 관계없이 전송이 가능
- 전용선 수준의 대역폭 제공
- 전송속도의 제한이 없으며, 서비스 품질을 보장하고
- 보안성이 뛰어남
- CO에 가입자 수만큼 광송수신기 필요

CWDM vs DWDM

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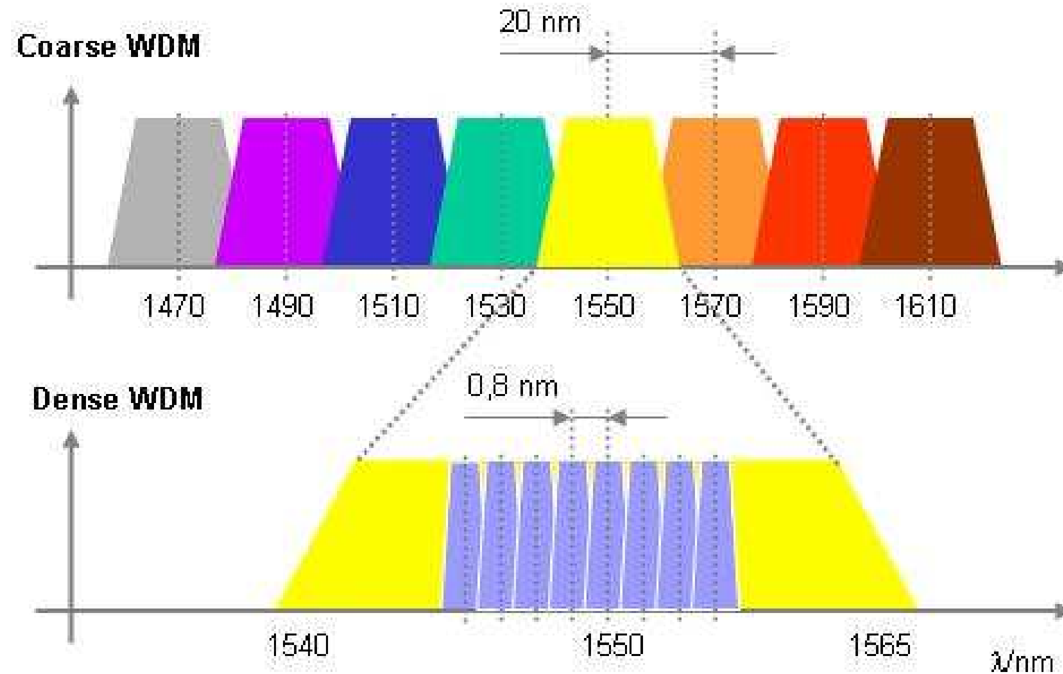

CWDM(Coarse WDM)

. 파장 간격이 수 20 nm(10 nm ~ 이상), 간격이 넓음
. 사용 파장의 수가 적고(8개 정도) 가격이 저렴한 편, 허용 오차가 약 ±3 nm 정도
. 엑세스망을 주대상으로 함, 단거리 전송 위주 (50km 이하)
. 통상 2.5Gbps 전송속도 단위로 최대 18개 채널 정도 구현

DWDM(Dense WDM)

. 파장대 : 1550nm (C 밴드)
. 파장 간격이 수 0.1~수nm
. 64~160개 이상의 조밀한 채널 간격
. 10Gbps 전송속도 단위로 최대 160 채널 정도 구현
. 최근에는 S Band 사용으로 40Gbps 전송속도 단위의 전송 구현

LD 일반

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Periodic Table(원소주기율표)

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
*Lanthanoids			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
**Actinoids			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

Ex) InP, GaAs, GaN, InGaAs, InGaN, InGaAsP, AlGaInAs, etc

LASER

OE SOLUTIONS

LASER란?

Light Amplification by Stimulated Emission of Radiation
(유도방출에 의한 광증폭)

LASER의 종류

- Semiconductor Laser : LD
- Solid State Laser : YAG(1.064um), Ruby
- Gas Laser : He-Ne(632.8nm), Co2(10.6um),
  Ar(488, 514nm), Excimer(UV)
- Liquid Laser(0.57~0.65um)

LASER Application

- Optical fiber communications
- Laser disk : CD, DVD
- Electro-optic equipment
  : Laser printer, Bar code reader
- Laser display
- Medical applications
- Energy development
- Light-wave sensing

LED vs LD

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공통점

Semiconductor PN junction에 의해 생성되어
Current injection시 Electron과 Hole의
Recombination에 의해 빛이 방출

차이점

	LED	LD
발광방식	자연방출	유도방출
결합효율	낮음	높음
유효수명	길다	짧다
용도	저속, 단거리	고속, 장거리
온도의존	다소 둔감	민감
스펙트럼 폭	~40nm	1~2nm

LED의 응용

- IRED(Infrared Emitting Diode)
  TV 리모컨, 광학스위치, IR LAN, 무선 디지털 데이터 통신용 모듈등의 광원

- VLED(Visible Light Emitting Diode)
  휴대폰의 Back light, 전자제품의 표시나 신호등 및 전광판등의 광원

LD의 응용

- Short wavelength LD
  Laser pointer, Optical mouse, Laser printer, ODD pick-up

- Long wavelength LD
  Optical communication

자연방출 vs 유도방출

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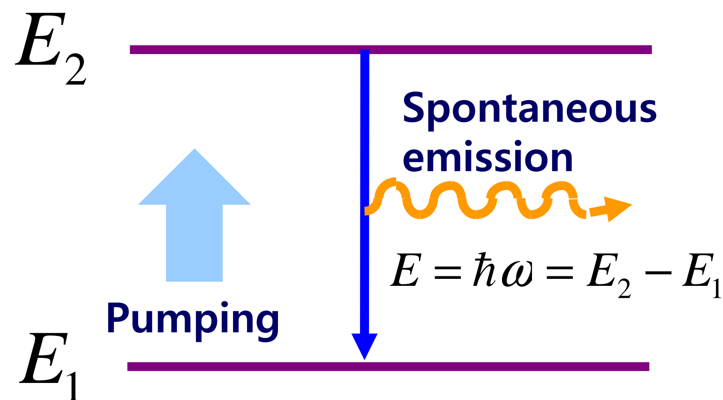
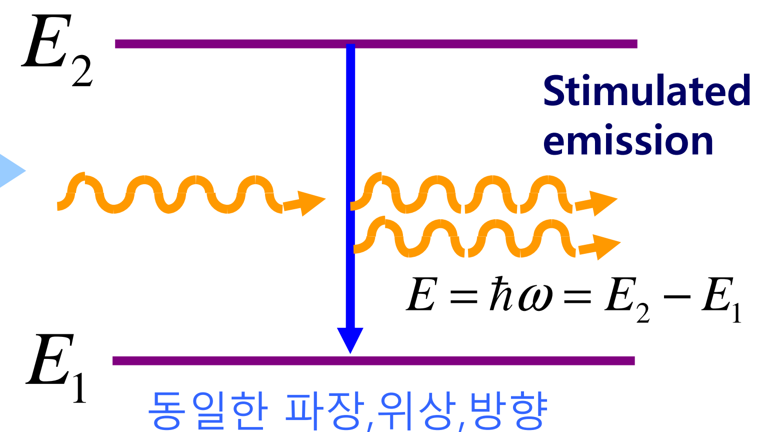
자연방출 (Spontaneous Emission)

Valence band에 있던 Electron이 Conduction band로 올라 가서 다시 Valence band로 떨어지면서 에너지 차이에 해당하는 빛을 방출

유도방출 (Stimulated Emission)

전자가 높은 에너지 상태에서 비교적 오래 머물게 되고 외부에 Photon이 존재하는 경우에는 Photon에 의해 자극을 받아 원래의 Photon과 동일한 파장, 위상, 방향을 갖는 빛을 방출





동일한 파장,위상,방향

I-L & Spectral Width

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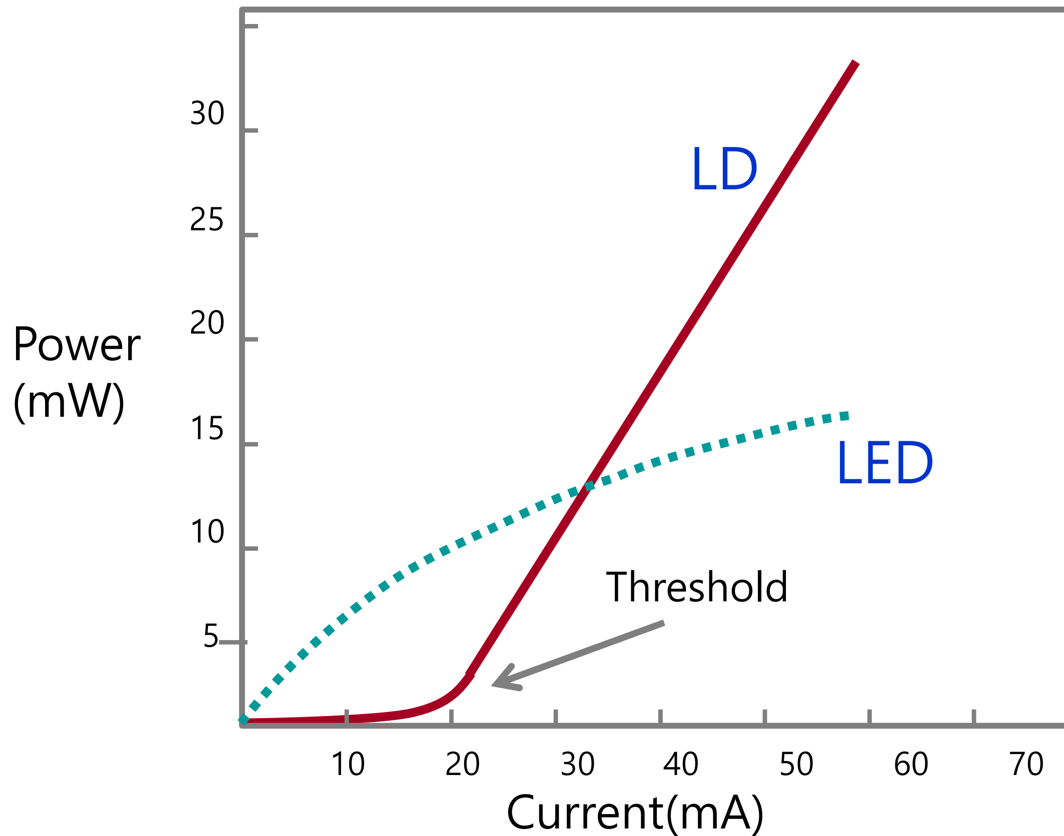

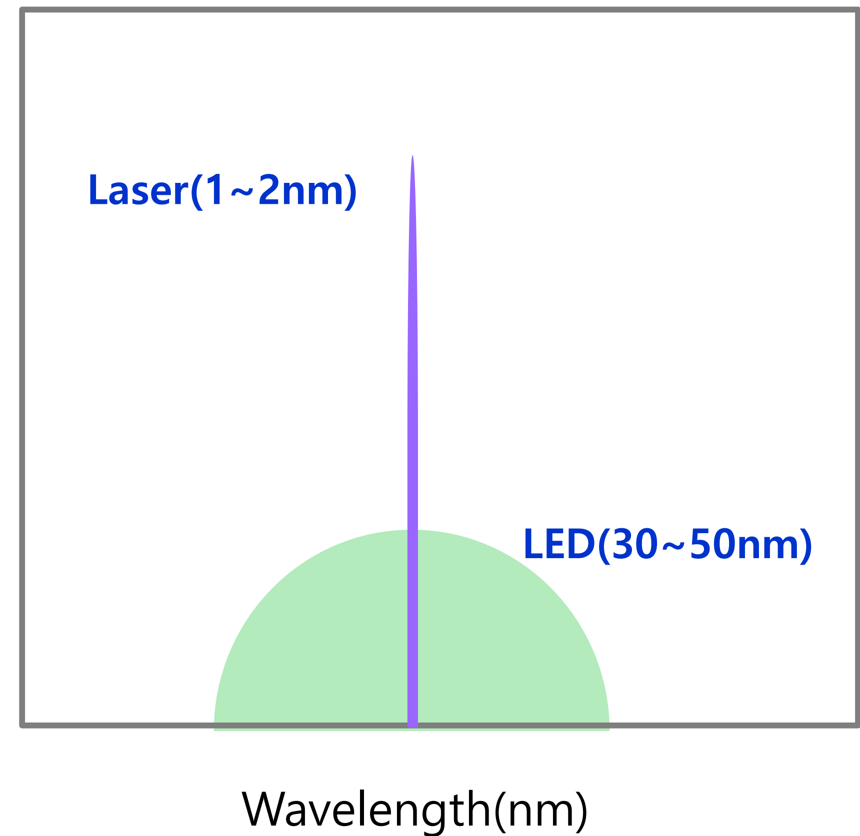

Laser Diode의 분류

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파장에 따라
- Long
- Short

Emitting 방식에 따라
- Edge
- Surface

Lasing Mode에 따라
- FP
- DFB

Modulation에 따라
- DML
- EML

LD 구조에 따라
- BH
- RWG

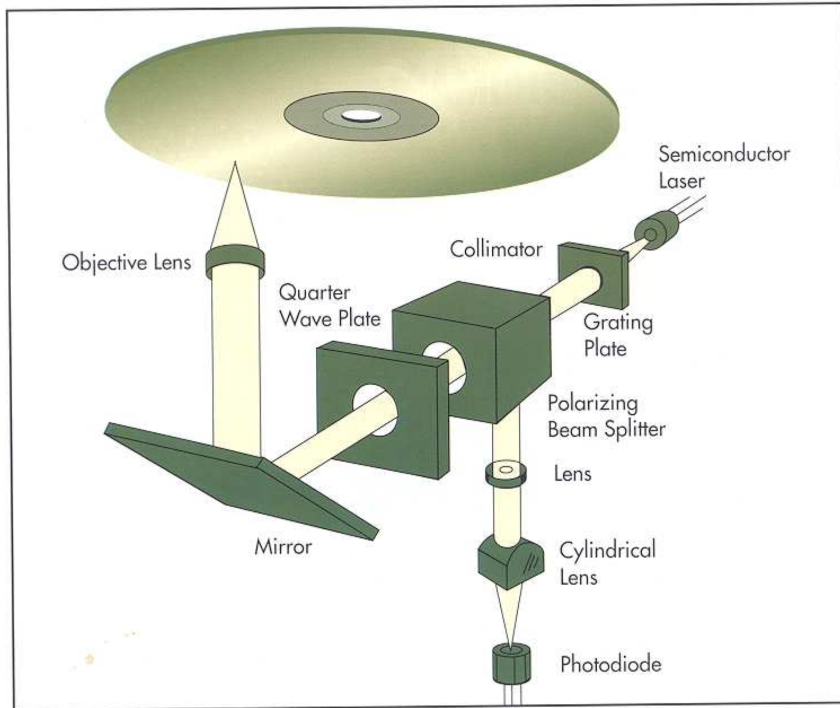
Wavelength에 따라

OE SOLUTIONS

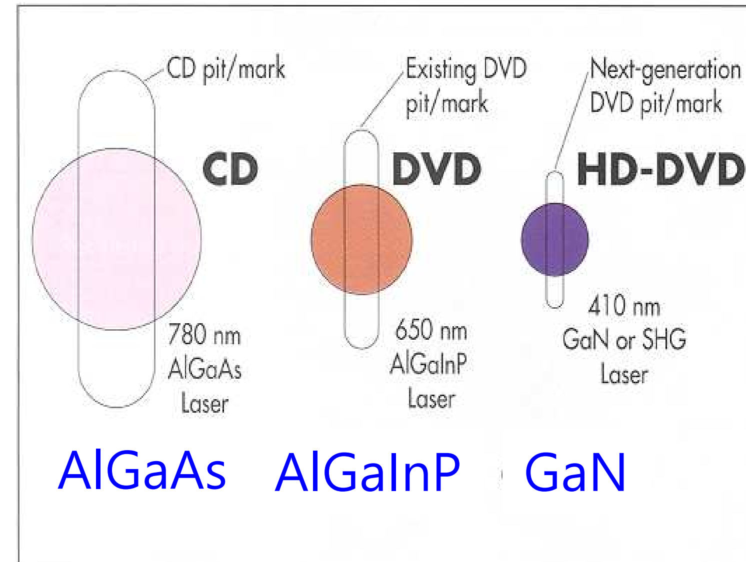
Wavelength (nm)	Material	용 도
410	GaN	Blue Ray Disc
445	InGaN	High Bright Projcector
532	AlGaAs	Green Laser Pointer
635	AlGaInP	Red Laser Pointer
657	AlGaInP	DVD Disc
760	AlGaInP	O2 Gas Sensing
785	AlGaAs	CD Disc
980	InGaAs	Yb:YAG DPSS Laser
1310	InGaAsP	Fiber Optic Communication
1550	InGaAsP	Fiber Optic Communication
1654	InGaAsP	CH4 Gas Sensing
1877	GaSbAs	H2O Gas Sensing
2680	GaSbAs	CO2 Gas Sensing

CD vs DVD and BD

OE SOLUTIONS

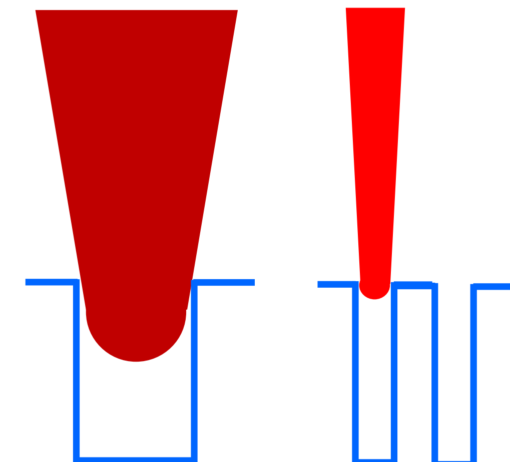


Relative Sizes of Laser Spots



세대	1세대(CD)	2세대(DVD)	3세대(BD)
용량	0.7GB	4.7GB	25GB/50GB
Laser 파장	780nm(IR)	650nm(Red)	405nm(B-V)
Application	CD-Audio, PC	DVD-Video,PC	HD-DVD, PC
Logo	COMPACT disc	DVD	Blu-ray Disc

7배 6배



Emitting 방식에 따라

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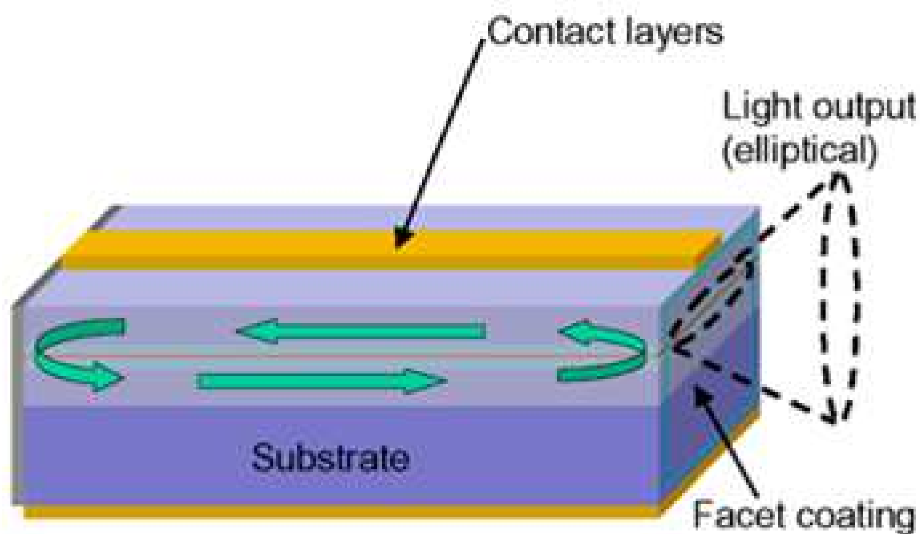
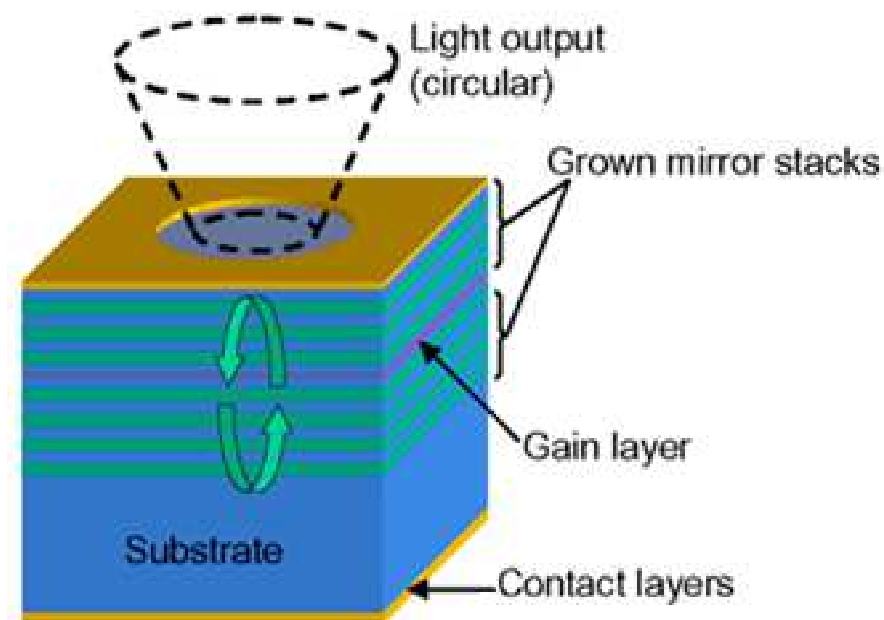
Edge Emitting



- Cleaved Facets
- Asymmetric Far Field
- High Output Power
- High Current Operation
- Simple Epi Structure

Vertical Emitting



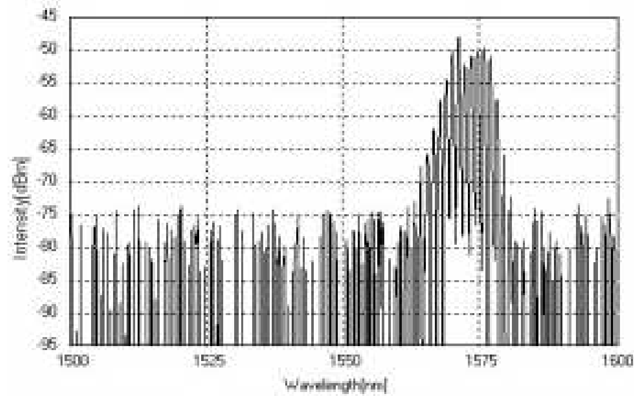
- Cleaved Facets
- LED like Manufacturing
- Low Output Power
- Low Current Operation
- Complex Epi Structure

Lasing Mode에 따라

OE SOLUTIONS

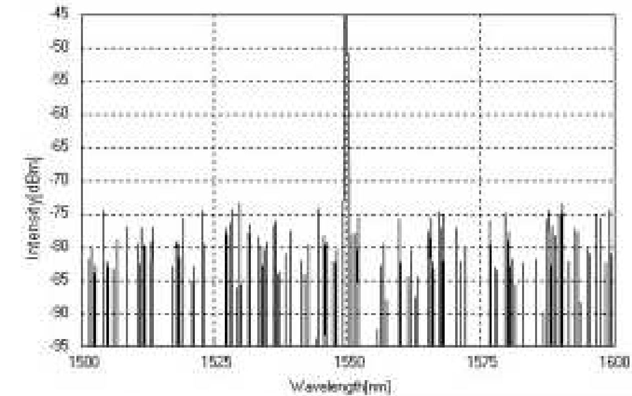
FP(Fabry Perot)

소자의 양단에 한 쌍의 거울이 있고 거울 사이의 거리가 반 파장의 정수배가 되는 모드만 살아남아 증폭됨

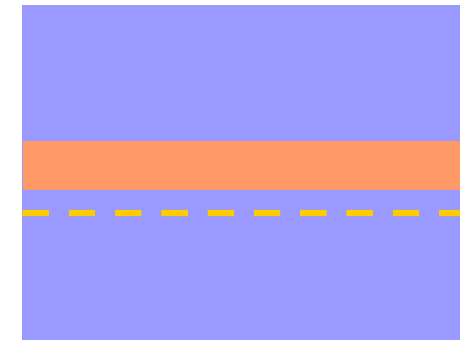


DFB(Distributed FeedBack)

소자 양단의 거울 사이에서 Grating이 길이 방향으로 굴절률의 주기적인 변화를 주어 선택된 파장의 빛만 보강 간섭에 의해 증폭됨



	FP	DFB
선폭	넓음	좁음
광출력	낮음	높음
응답속도	느림	빠름
가격	저가	고가
잡음	고잡음	저잡음
Mode	Multi	Single



Fabry Perot (FP)

OE SOLUTIONS

Charles Fabry (1867-1945)

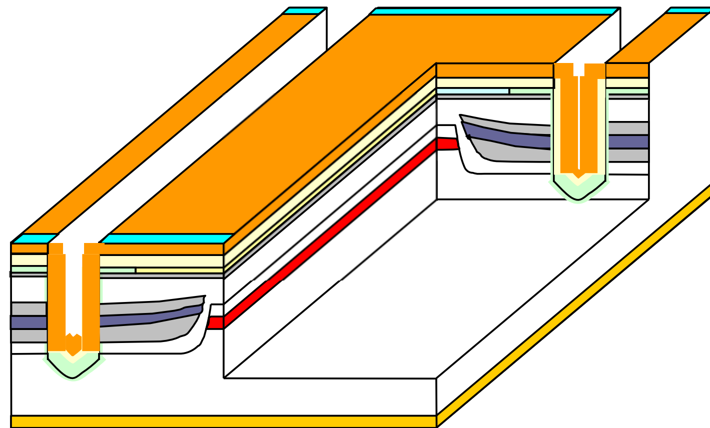
Alfred Perot (1863-1925)

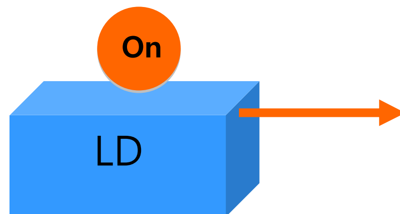
French Physicists

Modulation 방식에 따라

DML(Directly Modulated Laser)

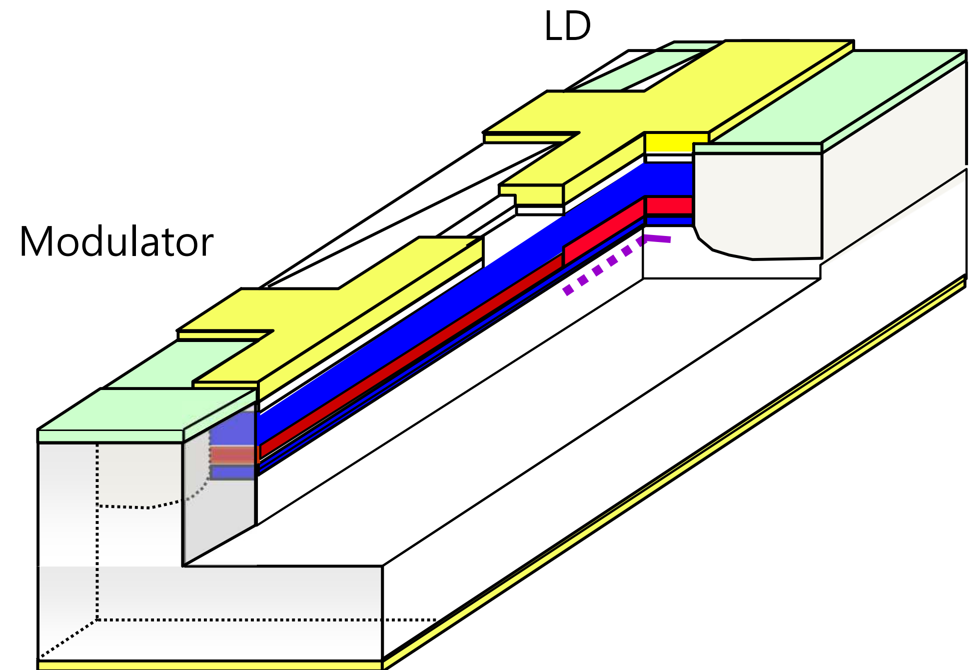
Laser 를 직접 Modulation 함

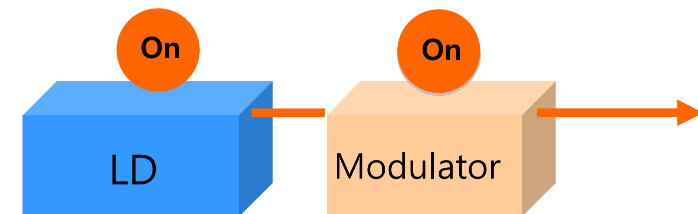




EML(Electroabsorption Modulator)

Modulator를 이용하여 Modulation 함

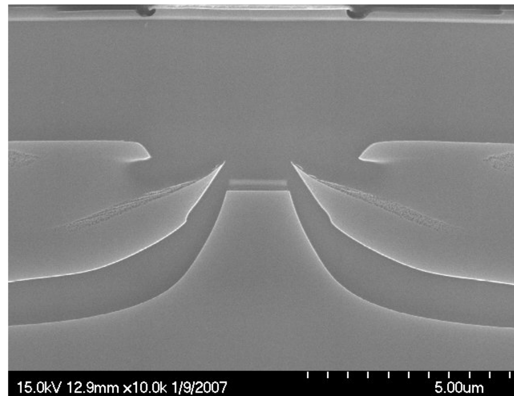


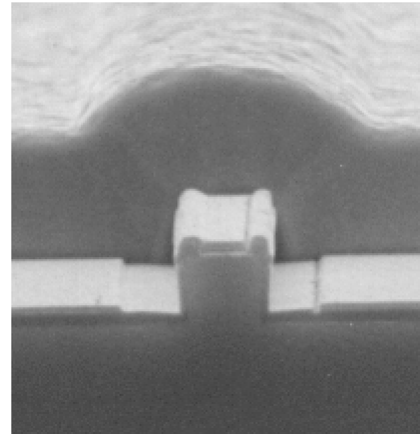


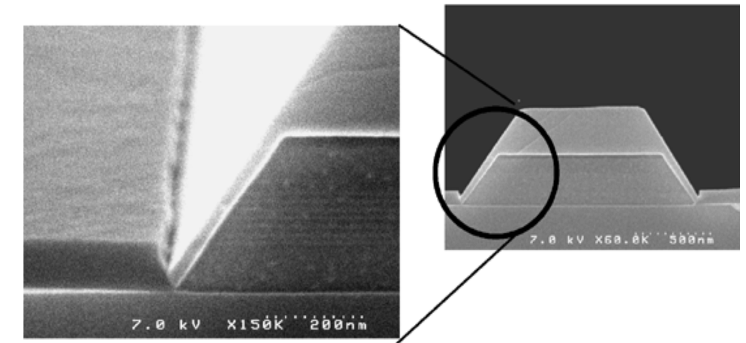
LD 구조에 따라

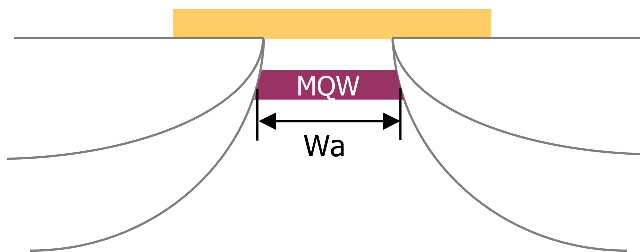
OE SOLUTIONS

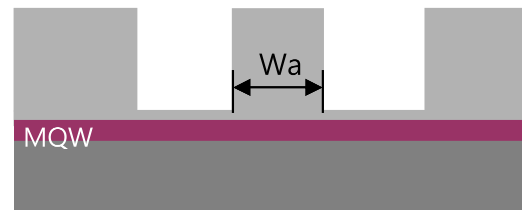
BH (Buried Heterostructure)	RWG (Ridge WaveGuide)	SAG (Selective Area Growth)

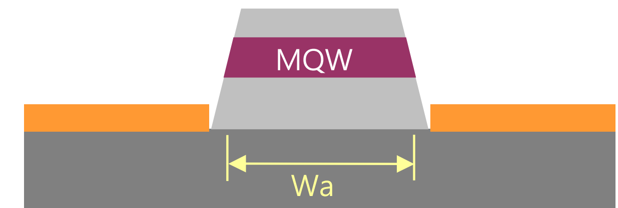










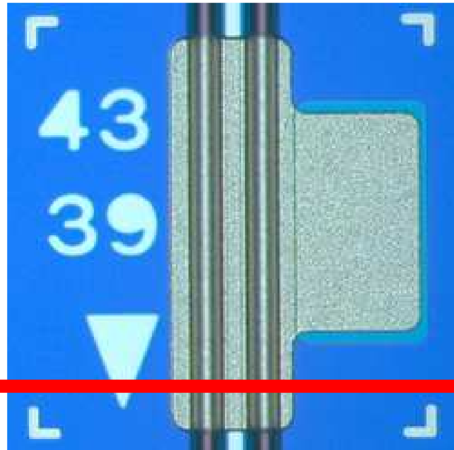


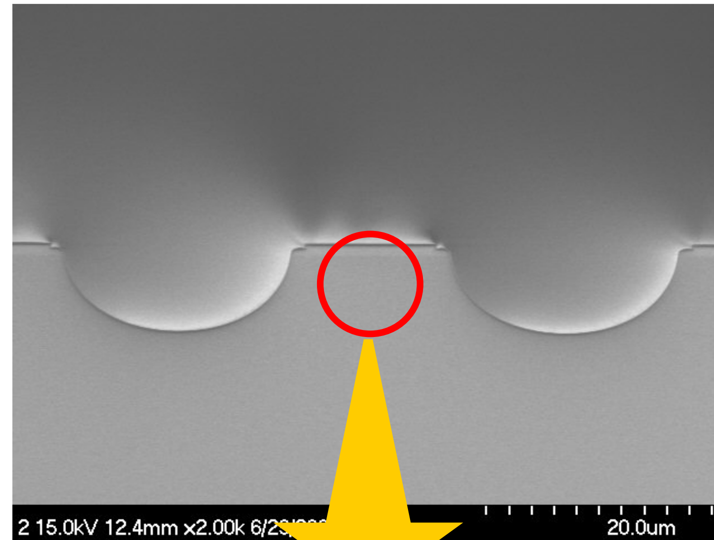
OE SOLUTIONS

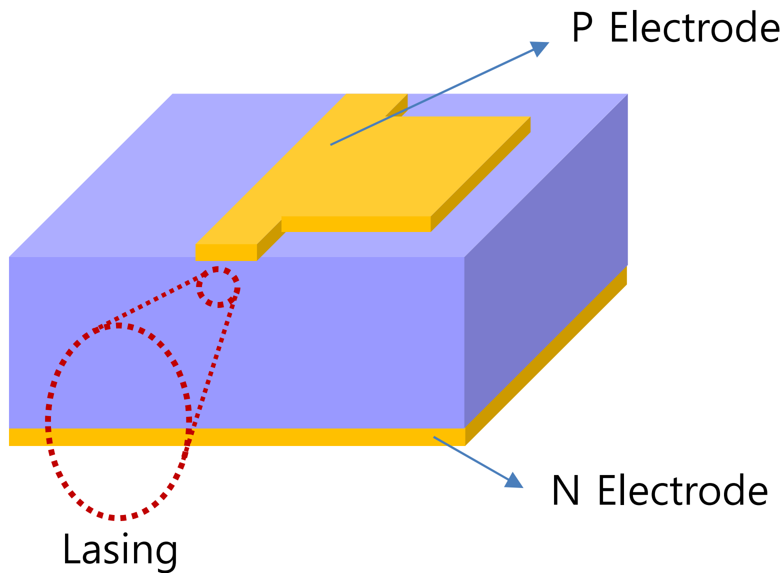
Chip Process

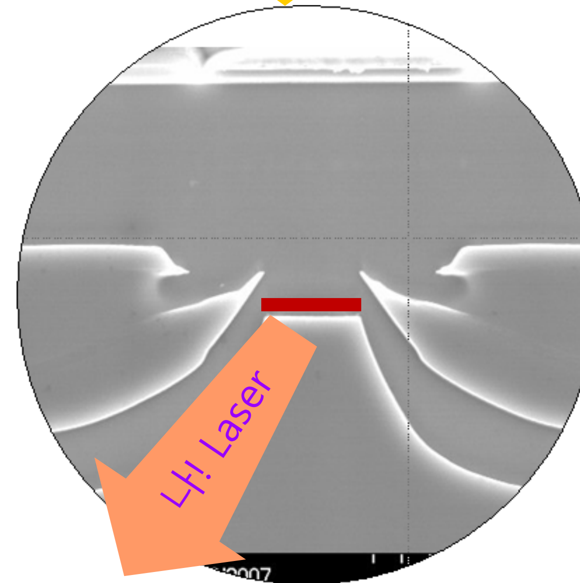
Chip Cross Section

OE SOLUTIONS









Run

- 약 200 Step
- 약 3~4주 소요

Chip Process

OE SOLUTIONS

Epi

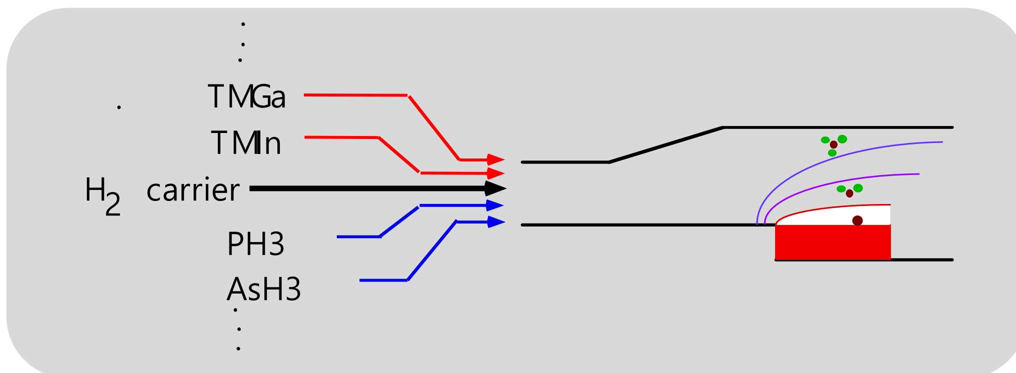
Photo

Thin Film

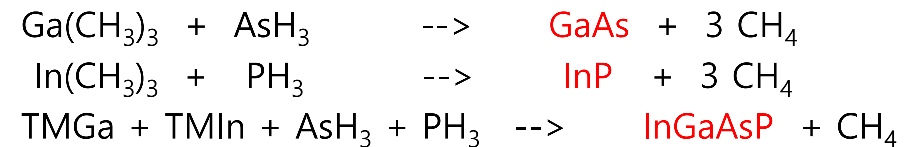
Bar Chip

Epi Process

OE SOLUTIONS



Horizontal Type



$Ga(CH_3)_3$ + AsH_3 --> GaAs + 3 CH_4

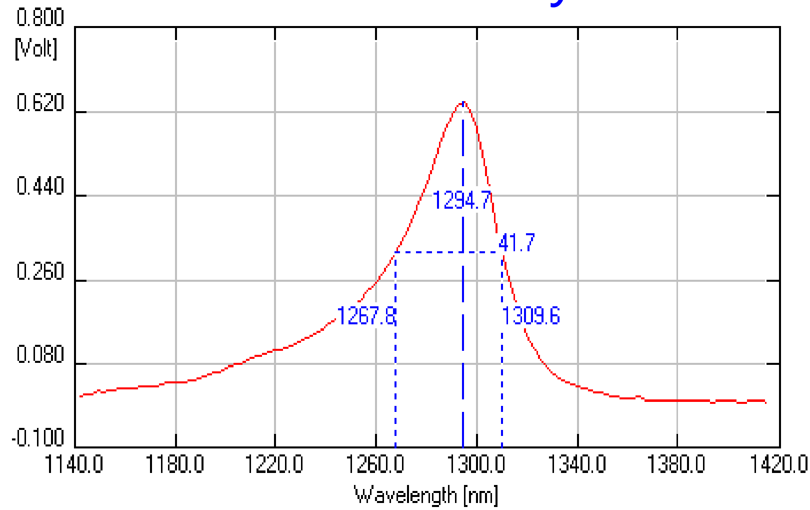
$In(CH_3)_3$ + PH_3 --> InP + 3 CH_4

TMGa + TMIn + AsH_3 + PH_3 --> InGaAsP + CH_4

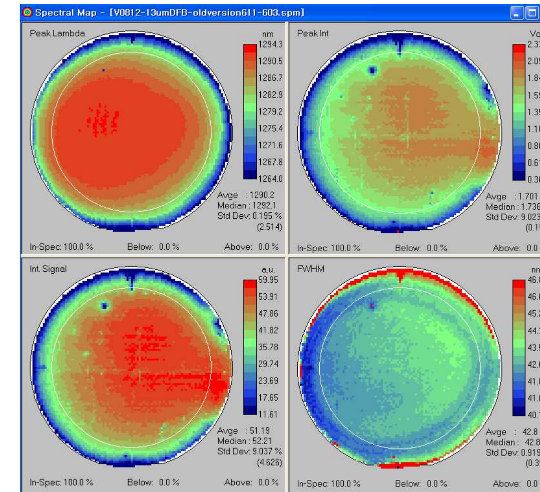
Epi Measurement

OE SOLUTIONS

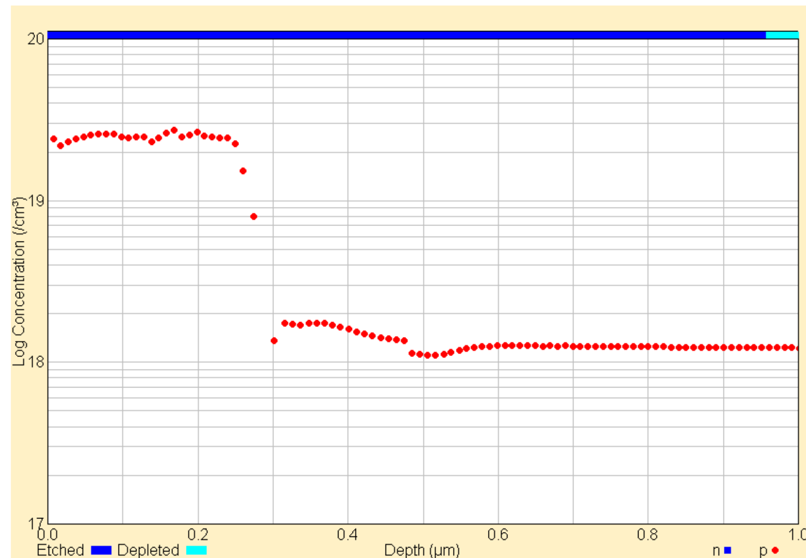
PL Intensity



PL Uniformity



Doping



X-ray

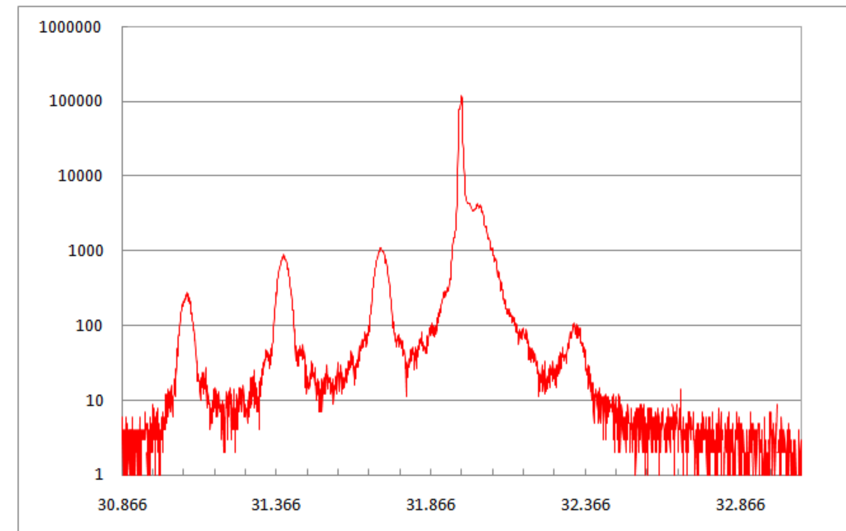
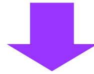


Photo Process

OE SOLUTIONS

Dehydration Bake

전 공정에서 생긴 수분을 제거하기 위해 Bake 한다.



P/R Coating

Spin 방식에 의해 P/R을 균일하게 도포한다.

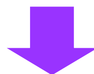
RPM(Revolutions Per Minute)

Soft Bake

P/R내에 존재하는 약 80~90%의 Solvent를 열에너지에 의하여 증발시켜 고형의 필름상태로 만든다.

Alignment & Exposure

원하는 Pattern의 Mask를 사용하여 Wafer와 Mask를 Align하고 정해진 시간동안 Exposure 한다.

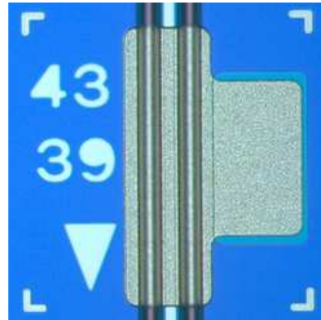


Development

알칼리 용액(Developer)을 사용하여 노광 지역과 비노광지역간의 용해도 차이에 의한 화학반응을 이용하여 최적으로 Pattern 형상을 재현한다.

Photo Mask

OE SOLUTIONS



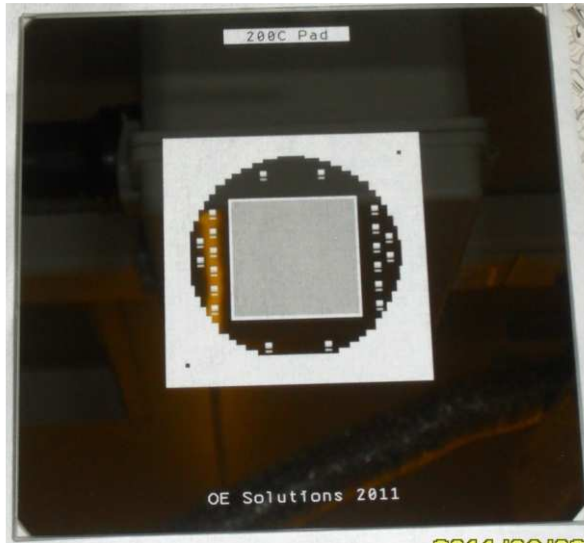
Mesa	Trench	Extra	P-Ohmic	Pad
4.8um	10um, 28um		5um	
Posi P/R	Nega P/R	Posi P/R	Nega P/R	Nega P/R

P/R

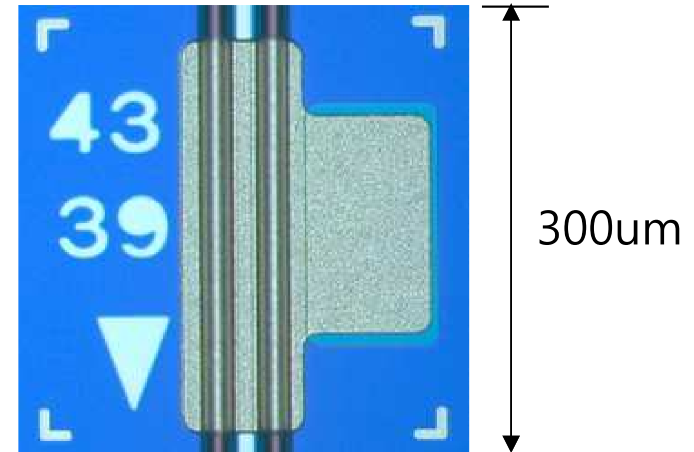
Wafer

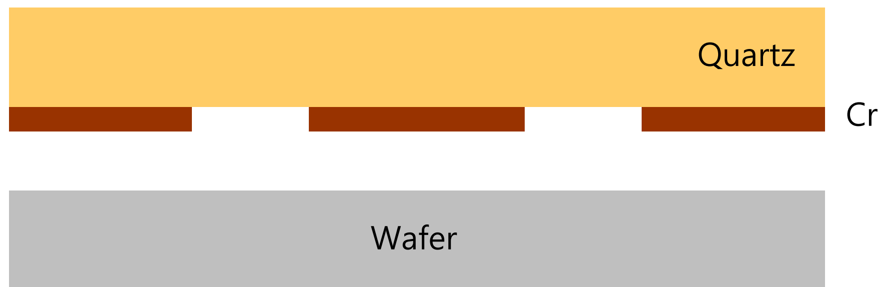
Photo Mask

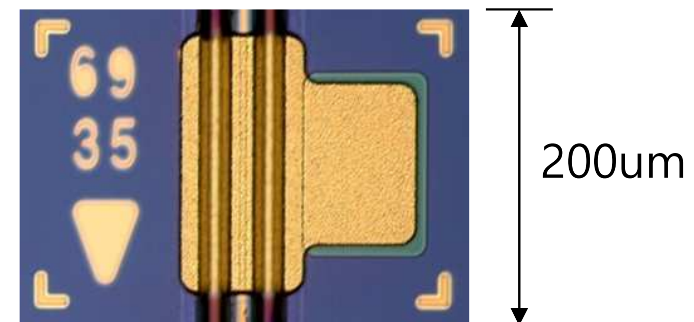
OE SOLUTIONS



Cavity Length

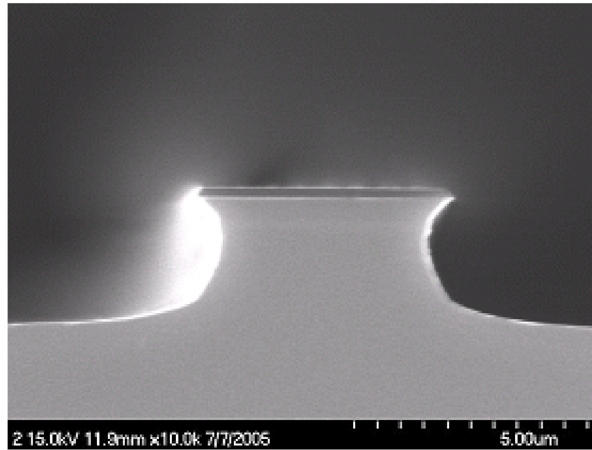




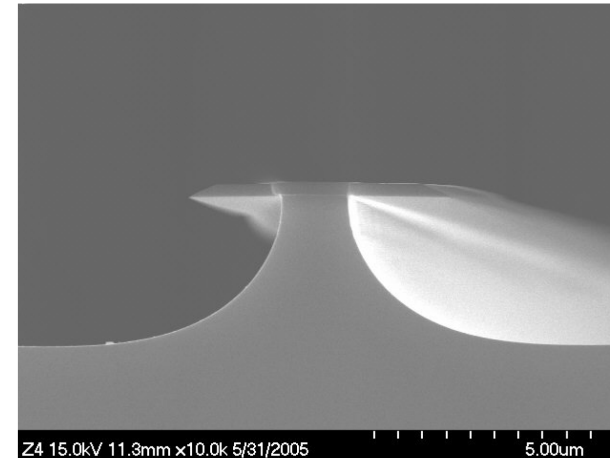


Thin Film Process-Etch

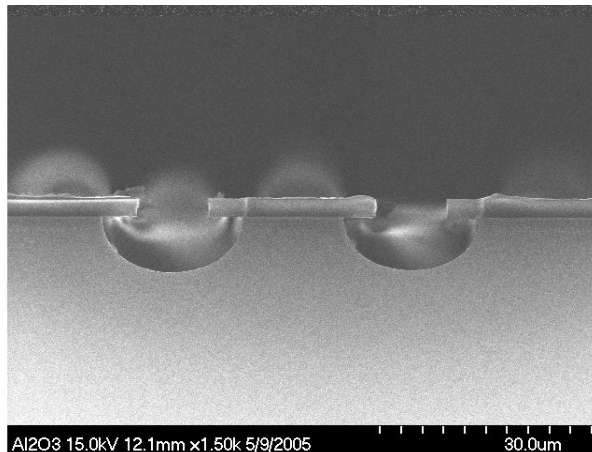
OE SOLUTIONS



Dry Etch



Wet Etch



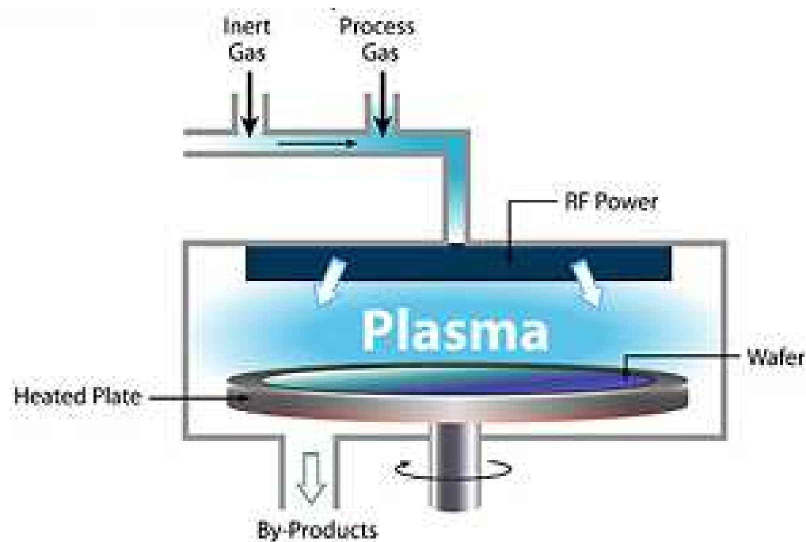
Trench Etch

Backside Etch

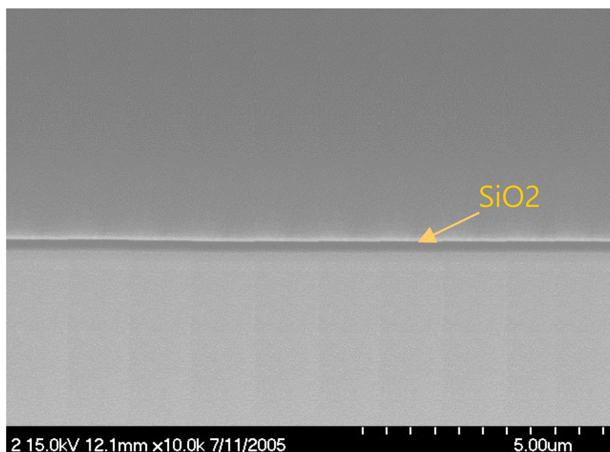
Thin Film Process-SiO_2

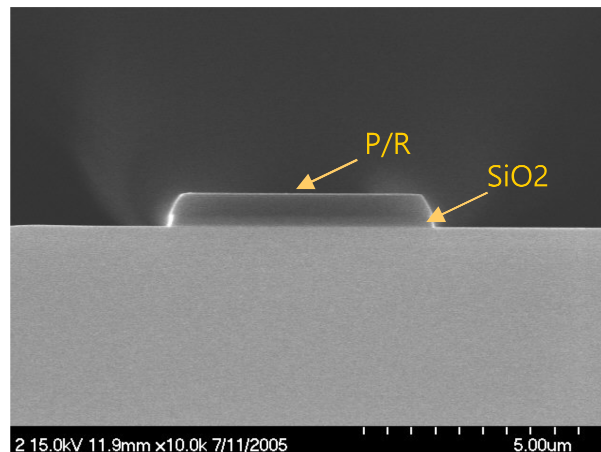
OE SOLUTIONS

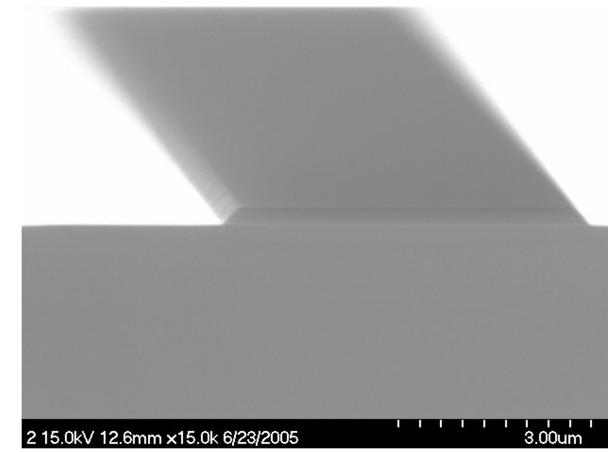
PECVD (Plasma Enhanced Chemical Vapor Deposition)



- Mesa SiO_2
- Extra SiO_2
- P-Ohmic SiO_2



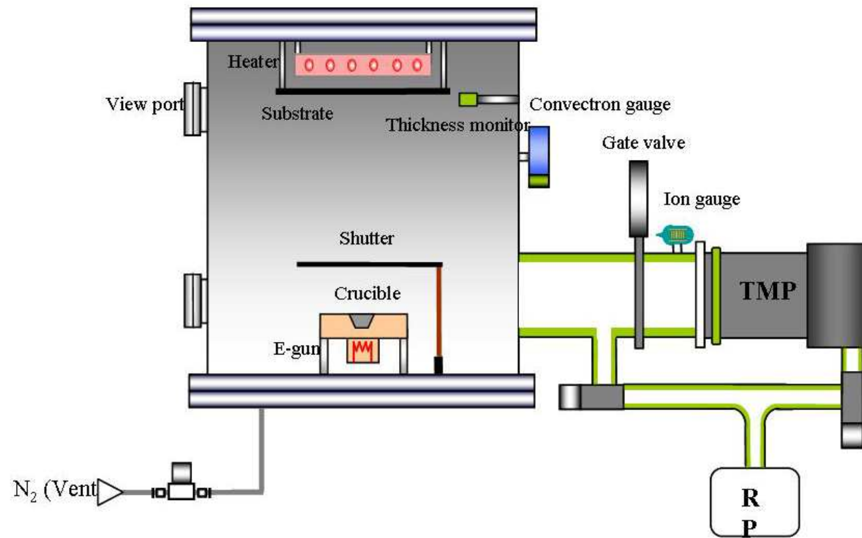


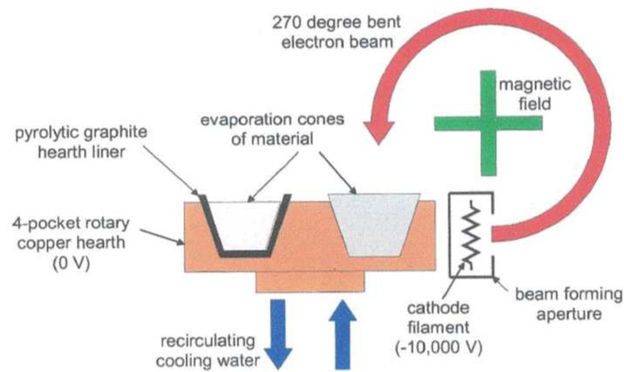


Thin Film Process-Metal

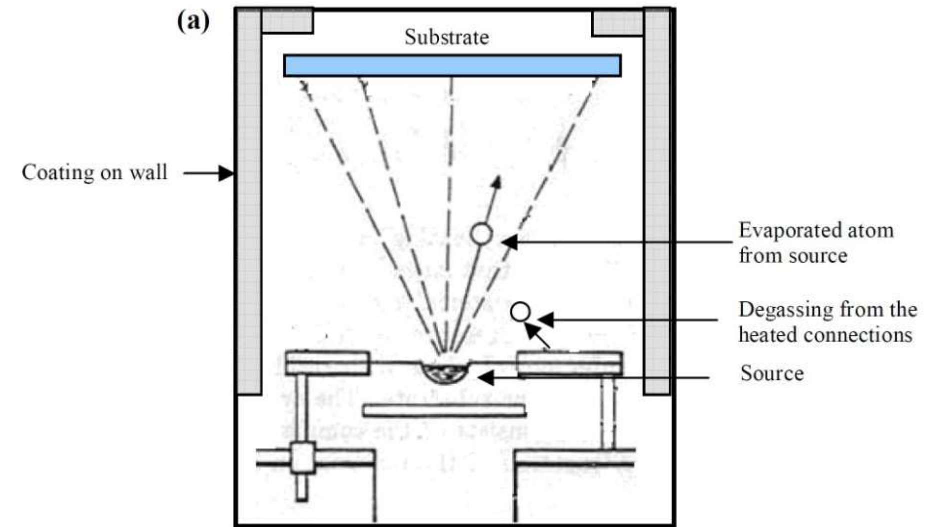
OE SOLUTIONS

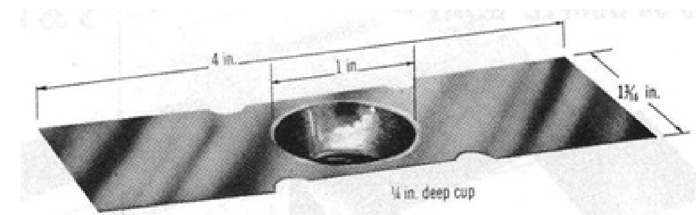
E-Beam Evaporation

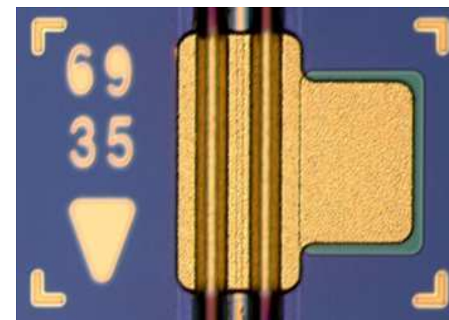




Thermal Evaporation



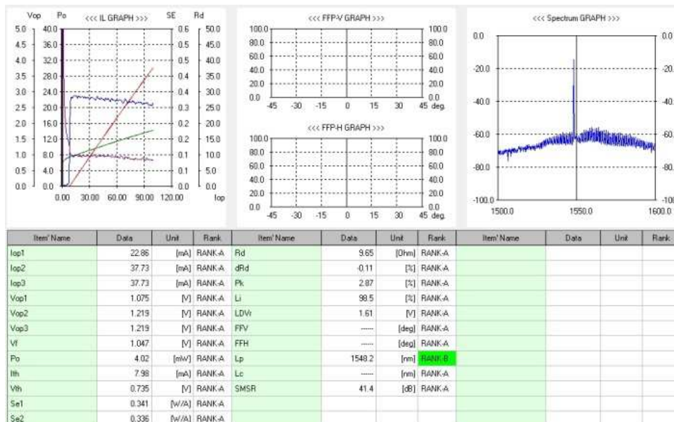




- P Metal
- Pad Metal
- N Metal

BarChip Process

W/F Fab Out



Item' Name	Data	Unit	Rank	Item' Name	Data	Unit	Rank	Item' Name	Data	Unit	Rank
Iop1	22.86	[mA]	RANK-A	Rd	9.65	[Ohm]	RANK-A				
Iop2	37.73	[mA]	RANK-A	dRd	-0.11	[%]	RANK-A				
Iop3	37.73	[mA]	RANK-A	Pk	2.87	[%]	RANK-A				
Vop1	1.075	[V]	RANK-A	Li	98.5	[%]	RANK-A				
Vop2	1.219	[V]	RANK-A	LDVr	1.61	[V]	RANK-A				
Vop3	1.219	[V]	RANK-A	FFV	------	[deg]	RANK-A				
Vf	1.047	[V]	RANK-A	FFH	------	[deg]	RANK-A				
Po	4.02	[mW]	RANK-A	Lp	1548.2	[nm]	RANK-B				
Ith	7.98	[mA]	RANK-A	Lc	------	[nm]	RANK-A				
Vth	0.735	[V]	RANK-A	SMSR	41.4	[dB]	RANK-A				
Se1	0.341	[W/A]	RANK-A								
Se2	0.336	[W/A]	RANK-A								

Chip Test

Packing

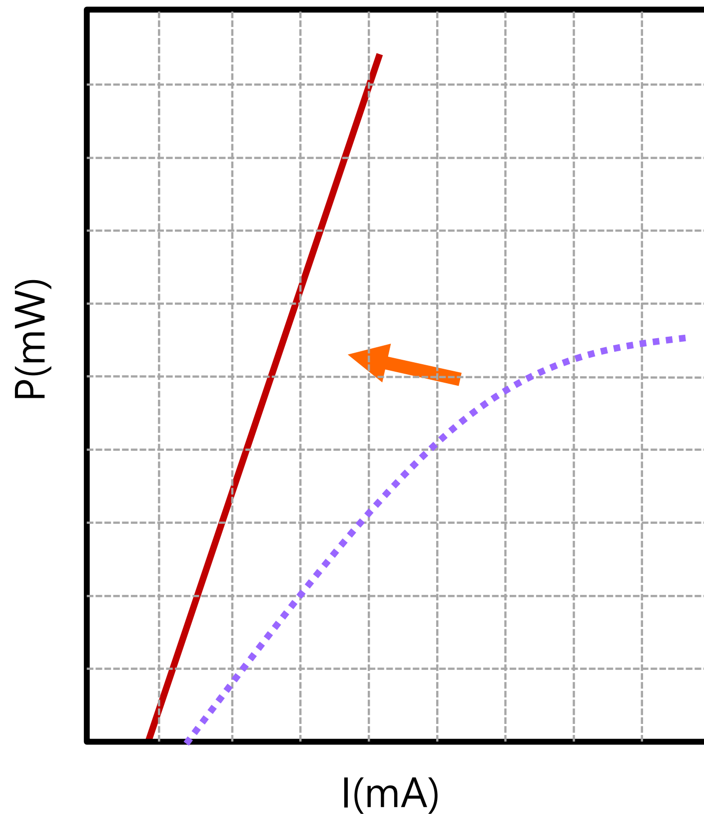
DFB/FP LD Fabrication

Laser Diode Target

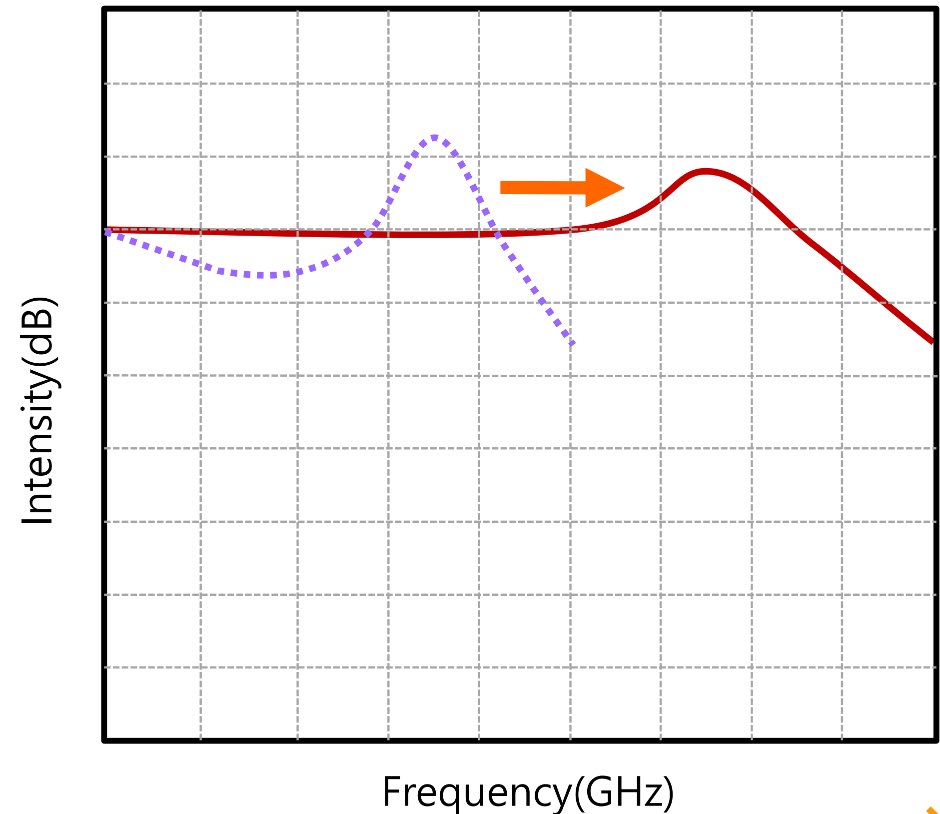
OE SOLUTIONS

- High(Low) Temperature
  Low Ith, Low Ith Rate, High SE, High SE Rate
- High Speed (@High Temp.)
- High Yield

I-L



S21



High Temperature

OE SOLUTIONS

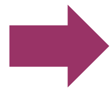
T_0 : Characteristic temperature

η_i : Internal quantum efficiency
α_{int} : Internal loss

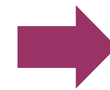
$$I_{th}(T) = I_0 \exp(\frac{T}{T_0})$$

$$\eta_d = \frac{2q}{h\nu}\frac{dP_{out}}{dI}$$

$$\eta_d = \eta_i \left[1 + \frac{\alpha_{int} L}{\ln\left(\frac{1}{R_m}\right)} \right]^{-1}$$



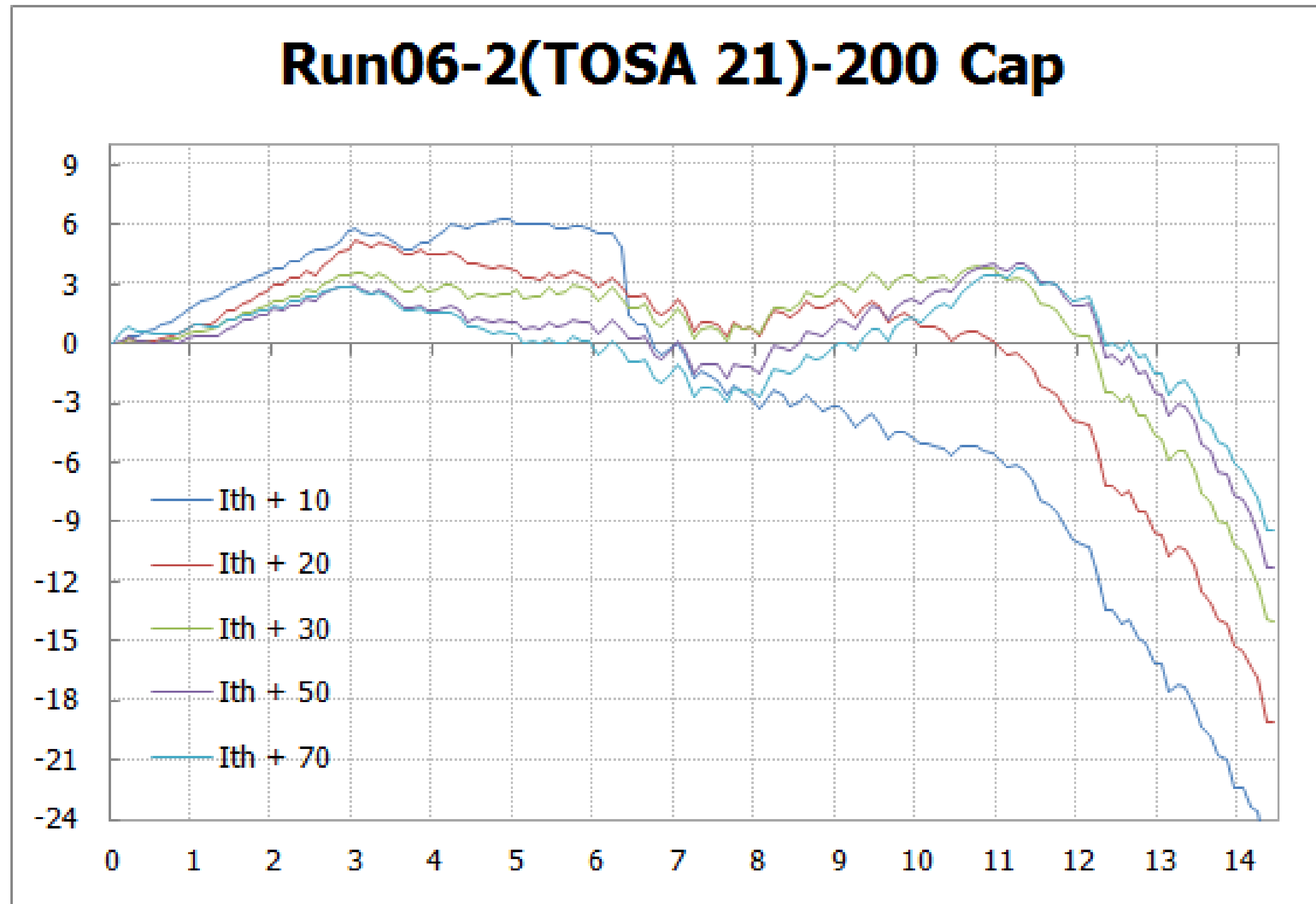
T_0



η_i , α_{int}

Bandwidth Measurement

OE SOLUTIONS



OE SOLUTIONS

$$H(f)=\frac{f_r^4}{(f^2-f_r^2)^2+f^2\gamma^2/(2\pi^2)}\cdot\frac{1}{1+(2\pi fRC)^2}$$

- Resonance frequency(fr) 증가

$$f_{3dB}(f_r)\cong 1.55 f_r \qquad f_r=\frac{1}{2\pi}\sqrt{\frac{S_0 v_g (dG/dN)}{\tau_p}}$$

- Damping rate(γ) 감소

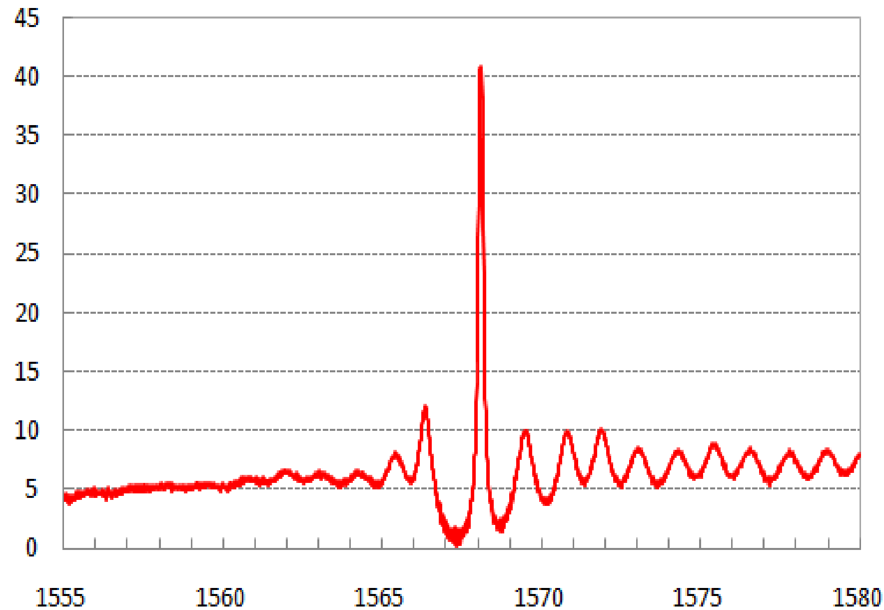
$$f_{3dB}(K)=\frac{2\sqrt{2}\pi}{K} \qquad K=\frac{(2\pi)^2}{v_g}\left[\frac{\varepsilon}{dg/dN}+\frac{1}{\alpha_m+\alpha_i}\right]$$

- Parasitic capacitance 감소

$$f_{3dB}(C)=\frac{1}{(2\pi RC)}$$

High Yield

OE SOLUTIONS



- Kink Fail (Mode Change) 방지
- SMSR Fail 방지
- Ith, SE 특성 유지

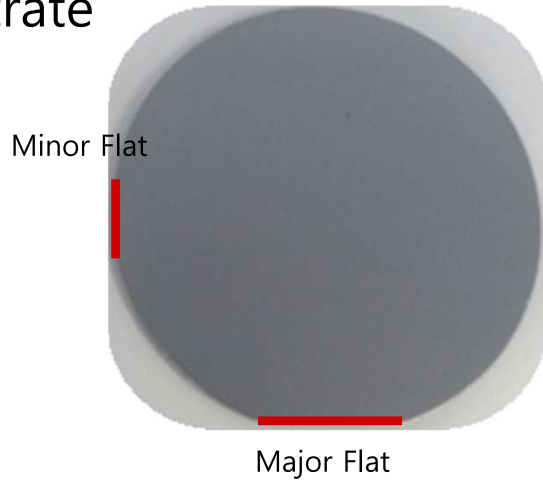
➔ Right peak 발진 또는 Left/Right 유지

➔ kL, Tapered Stripe, Partial Grating, Sampled Grating, Top Grating, λ/4 Shift Grating

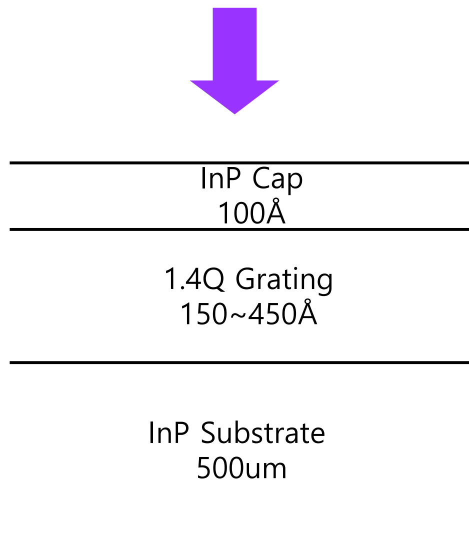
0th Epi & Grating

- 0th Epi는 Grating layer로 사용할 Layer를 성장하는 공정
- Grating은 DFB Single mode를 위해 Corrugation을 형성하는 공정

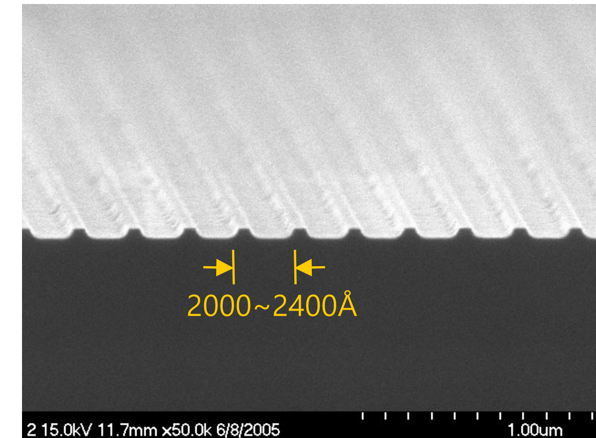
Substrate

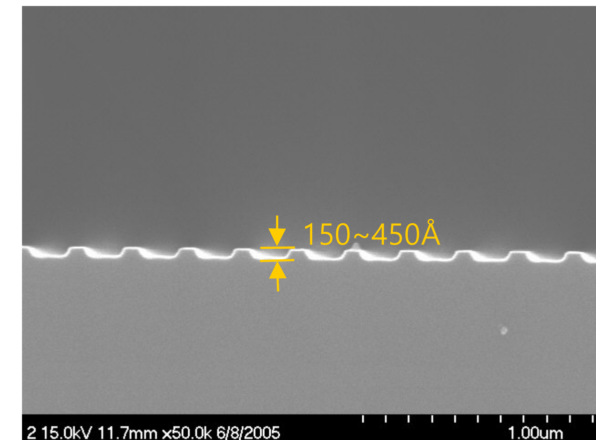


0th Epi



Grating

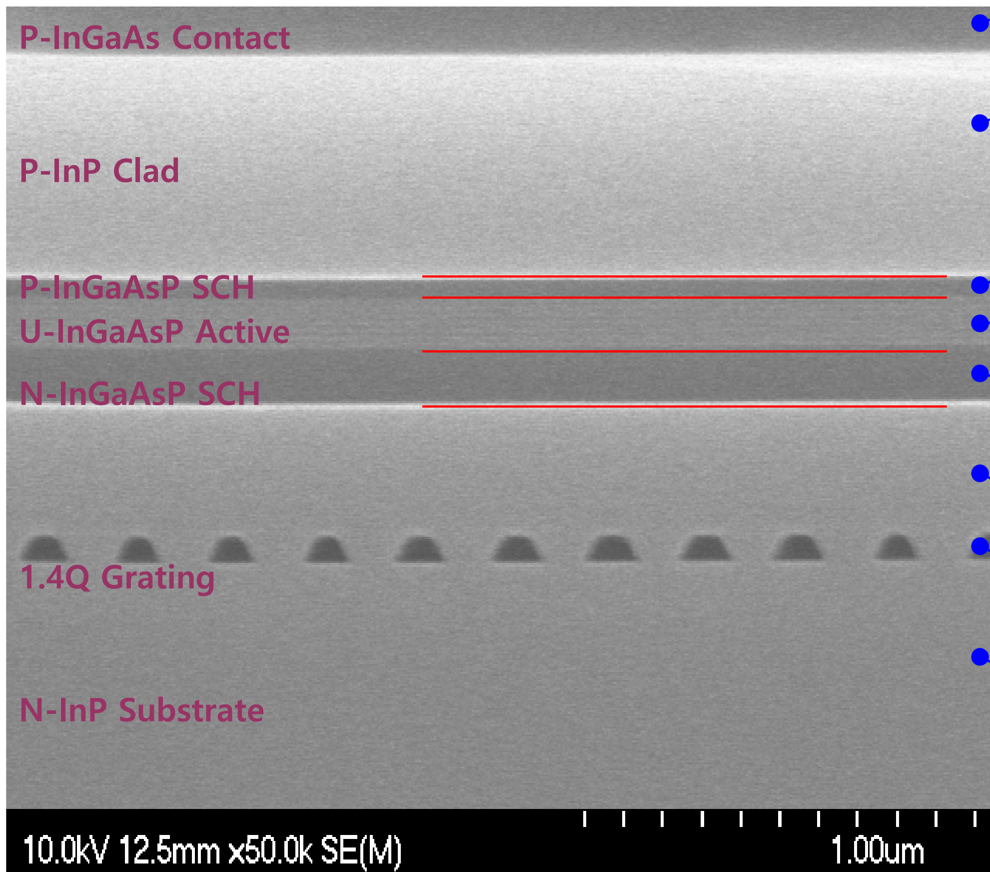


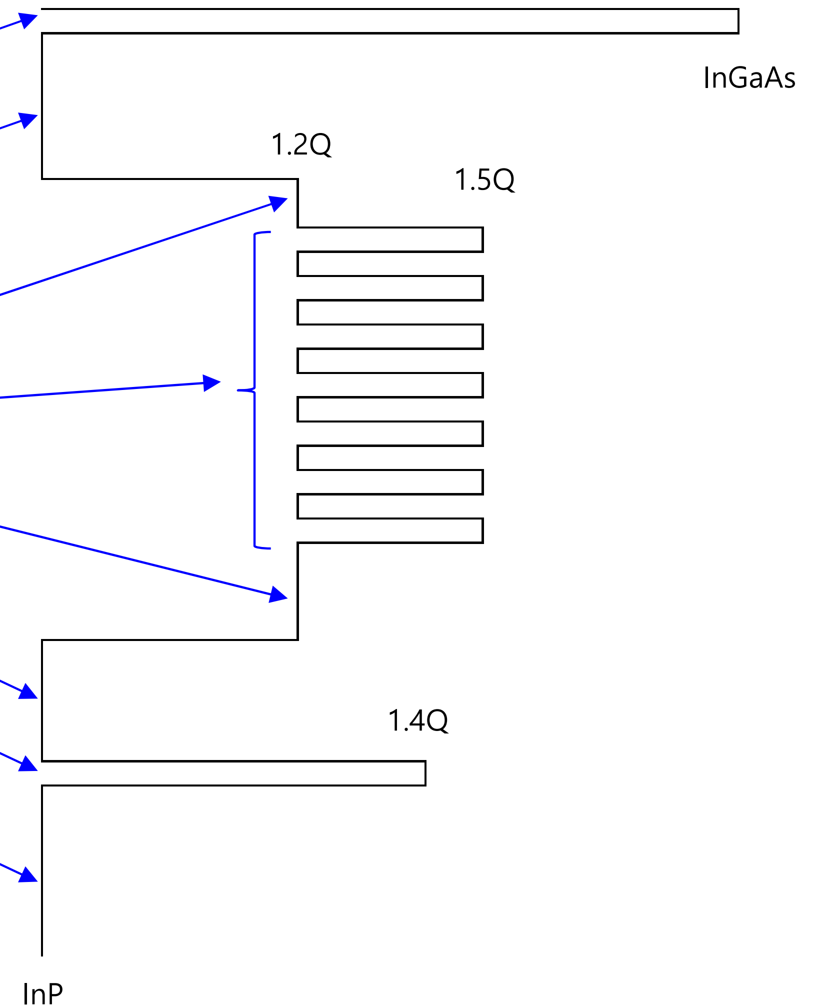


Base Epi

OE SOLUTIONS

- Base Epi는 Lasing을 위한 기본구조형성 공정(Clad/SCH/MQW/SCH/Clad)

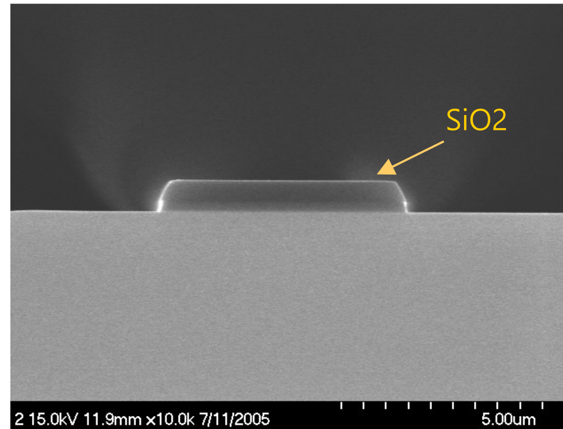




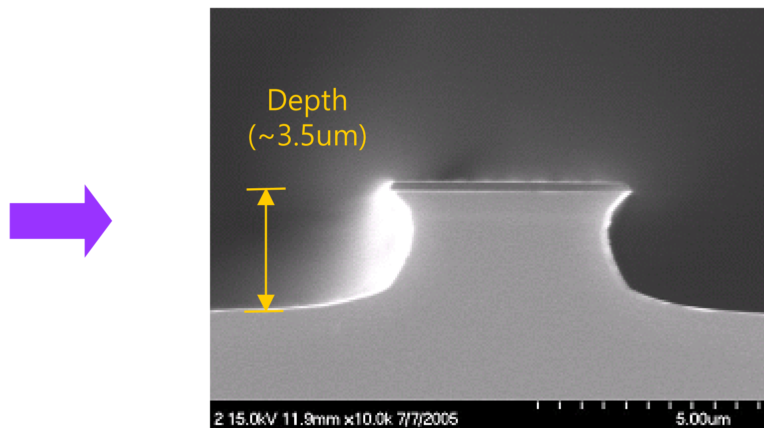
Mesa Etch

OE SOLUTIONS

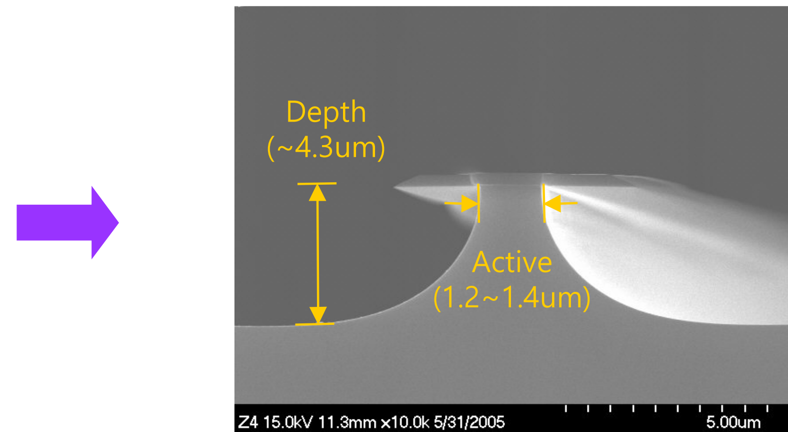
- Mesa는 Lasing할 부분(Active)만 남기고 나머지 부분을 선택적으로 제거하는 공정



SiO2 Pattern



Dry Etch

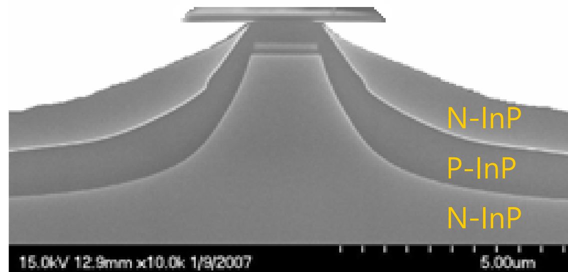


Wet Etch

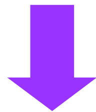
Regrowth

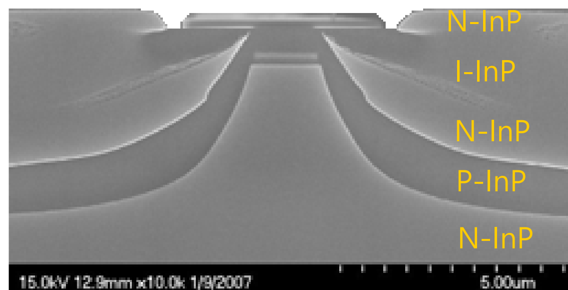
OE SOLUTIONS

- Regrowth는 Active 이외의 부분으로 Current가 새지 않게 Blocking하는 공정

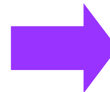


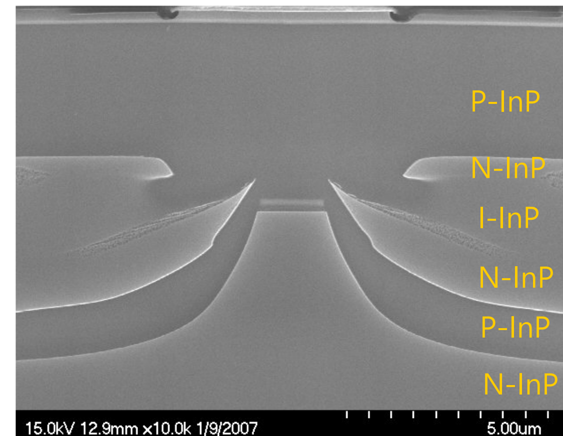
1st Regrowth





2nd Regrowh



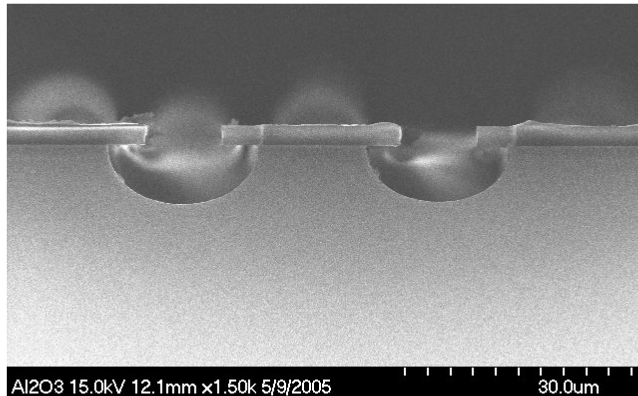


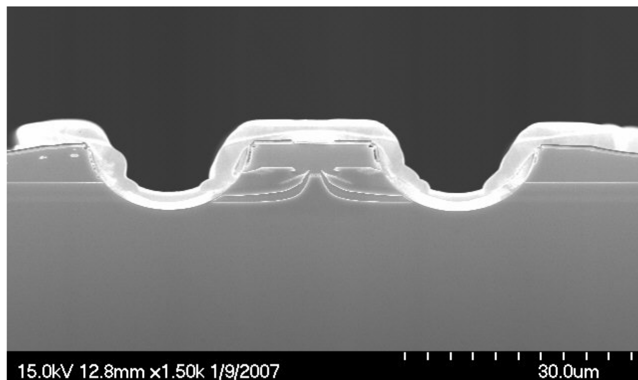
3rd Regrowh

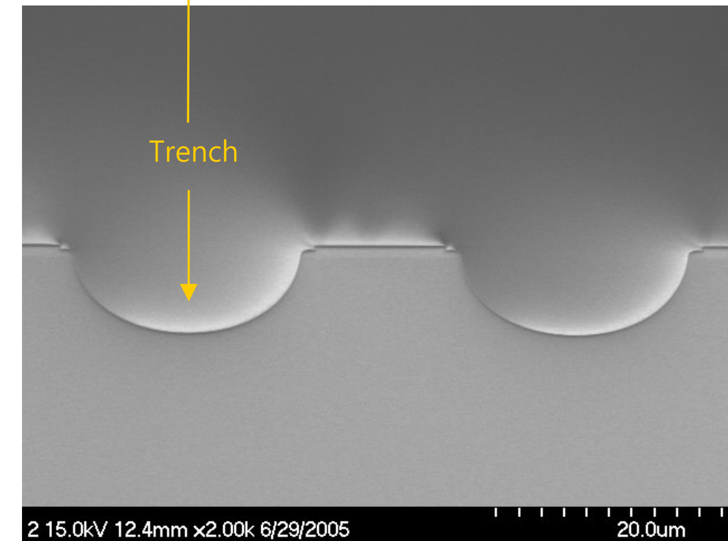
Trench

OE SOLUTIONS

-Trench는 P/N Junction의 면적을 줄이기 위해 Active 양쪽 옆을 깍는 공정





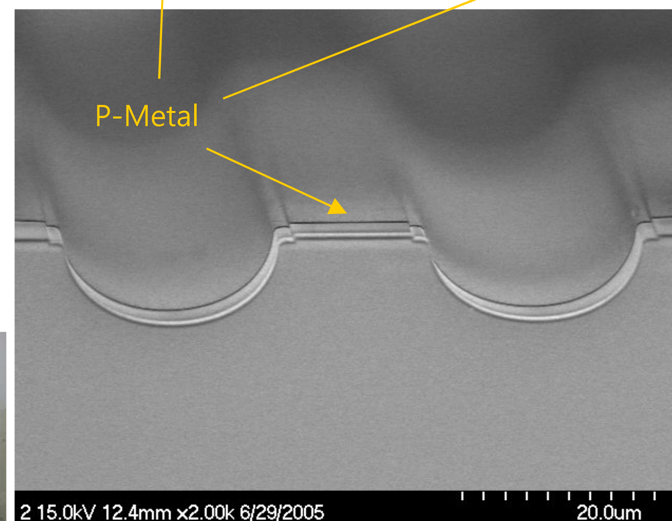


Extra SiO2 & P-Metal

OE SOLUTIONS

Extra SiO2

- Extra는 Pad 밑부분에 SiO2를 두껍게 형성하는 공정
- P Metal은 Laser Diode의 P 전극을 형성하는 공정



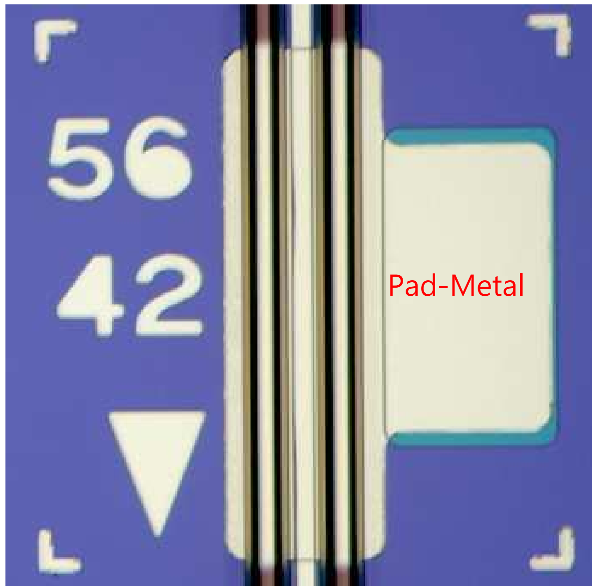
P Metal

Pad Metal & Au Plating

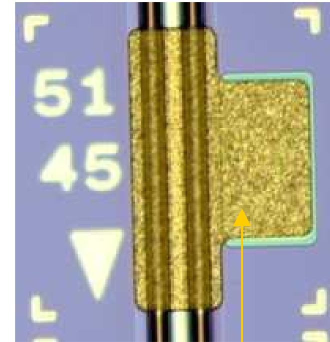
OE SOLUTIONS

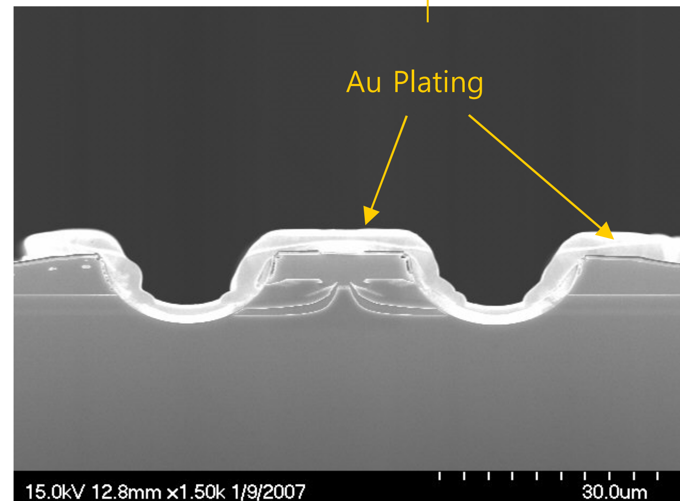
- Pad Metal은 Bonding pad를 형성하는 공정

- Plating은 Bonding을 원활하게 하기 위해 Au를 두껍게 입히는 공정
- Alloy는 Metal과 반도체사이에 최저 저항을 형성하기 위한 공정



Pad Metal





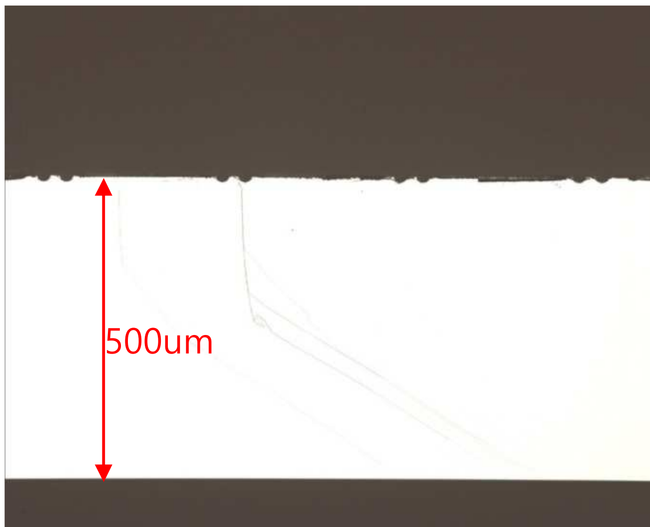
Au Plating

Lapping & N Metal

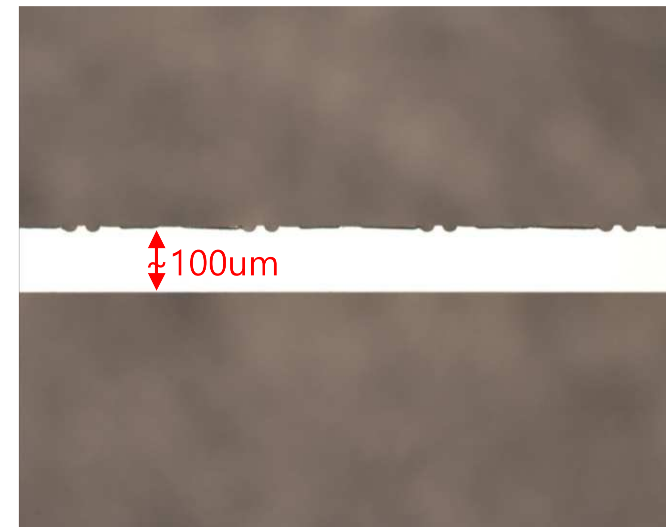
OE SOLUTIONS

- Lapping은 열특성과 Cleaving을 위해 Wafer를 얇게 갈아내는 공정
- Polishing은 Lapping으로 인한 표면손상을 없애기 위한 공정

- N Metal은 Laser Diode의 N 전극을 형성하는 공정
- Alloy는 Metal과 반도체사이에 최저 저항을 형성하기 위한 공정



Lapping 전 (x100)

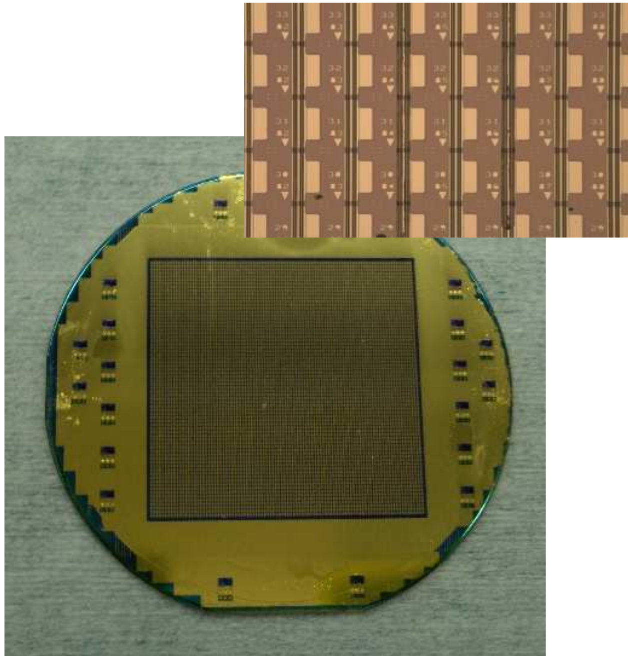


Lapping 후 (x100)

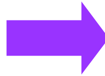
Bar Scribing & Breaking

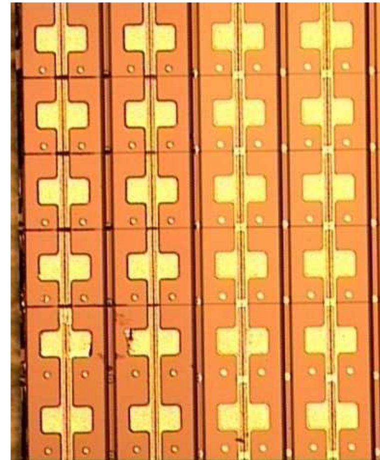
OE SOLUTIONS

- Bar cleaving은 AR/HR Coating을 하기 위해 Wafer를 Bar 형태로 자르는 공정

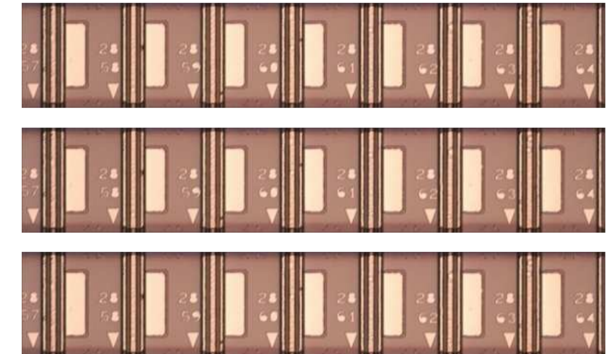


W/F Fab Out





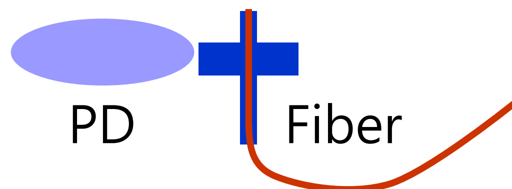
Bar Scribing

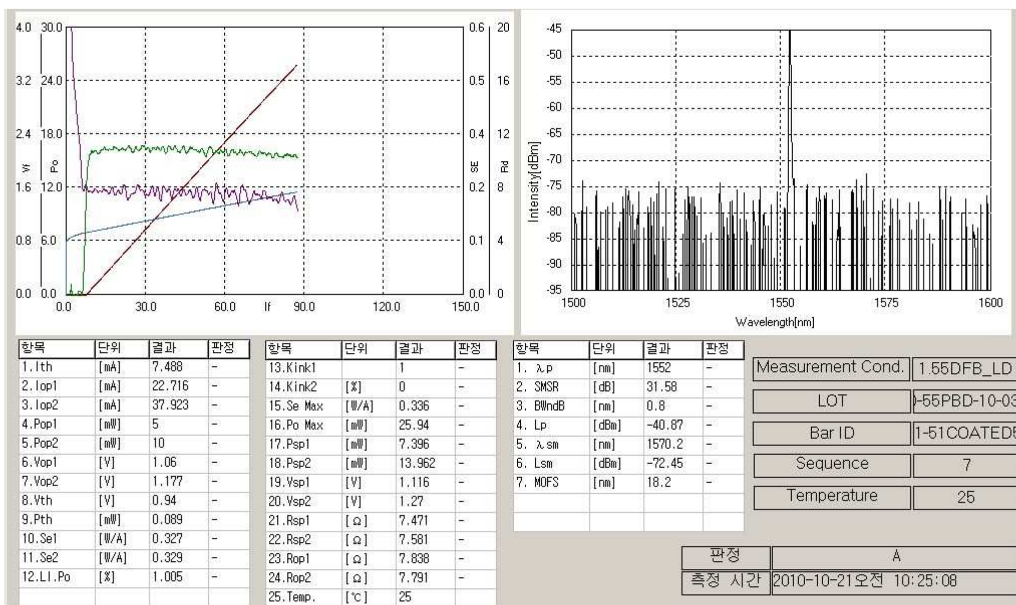


Bar Breaking

Bar Test

- Bar test는 Coating전후의 Bar 상태에서 Chip특성을 평가하는 공정





항목	단위	결과	판정
1.Ith	[mA]	7.488	-
2.Iop1	[mA]	22.716	-
3.Iop2	[mA]	37.923	-
4.Pop1	[mW]	5	-
5.Pop2	[mW]	10	-
6.Vop1	[V]	1.06	-
7.Vop2	[V]	1.177	-
8.Vth	[V]	0.94	-
9.Pth	[mW]	0.089	-
10.Se1	[W/A]	0.327	-
11.Se2	[W/A]	0.329	-
12.LI.Po	[%]	1.005	-

항목	단위	결과	판정
13.Kink1		1	-
14.Kink2	[%]	0	-
15.Se Max	[W/A]	0.336	-
16.Po Max	[mW]	25.94	-
17.Psp1	[mW]	7.396	-
18.Psp2	[mW]	13.962	-
19.Vsp1	[V]	1.116	-
20.Vsp2	[V]	1.27	-
21.Rsp1	[Ω]	7.471	-
22.Rsp2	[Ω]	7.581	-
23.Rop1	[Ω]	7.838	-
24.Rop2	[Ω]	7.791	-
25.Temp.	[℃]	25	

항목	단위	결과	판정
1. λp	[nm]	1552	-
2. SMSR	[dB]	31.58	-
3. BWndB	[nm]	0.8	-
4. Lp	[dBm]	-40.87	-
5. λsm	[nm]	1570.2	-
6. Lsm	[dBm]	-72.45	-
7. MOFS	[nm]	18.2	-

Measurement Cond.	1.55DFB_LD
LOT	)-55PBD-10-03
Bar ID	1-51COATED5
Sequence	7
Temperature	25

판정	A
측정 시간	2010-10-21오전 10:25:08

Threshold Condition

OE SOLUTIONS

Pump Current

Leakage Current

Spontaneous Emission

Laser Output

Laser Threshold

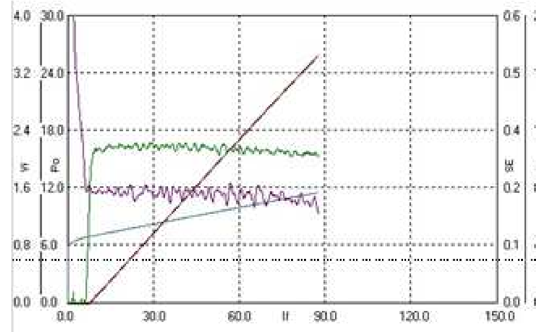
Internal Optical Loss

Non-radiative Recombination

I-L & I-V Graph

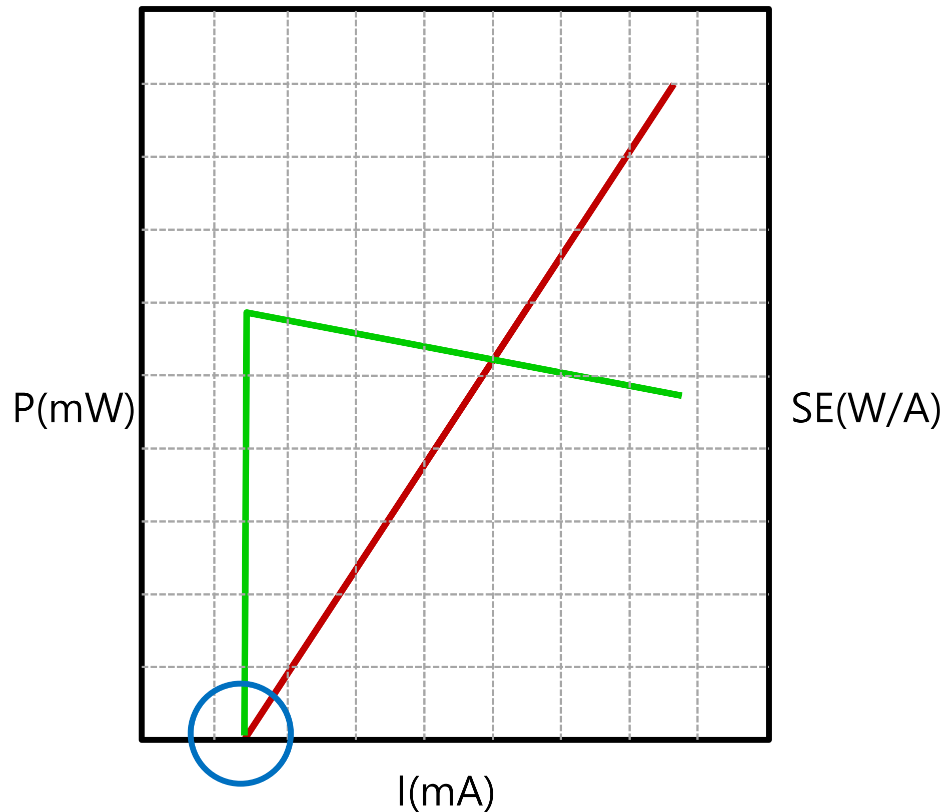
OE SOLUTIONS

- Ith(Threshold Current)
- SE(Slope Efficiency)
- Po(Output Power)
- Kink

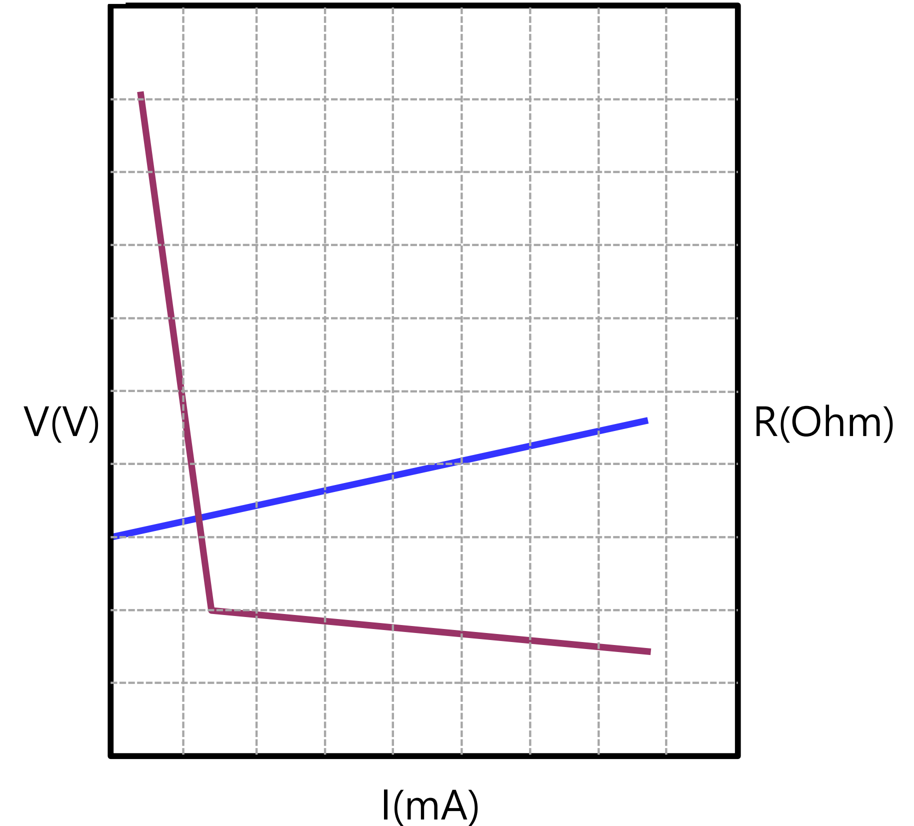


- Vop(Operation Voltage)
- Rop(Operation Resist)

I-L

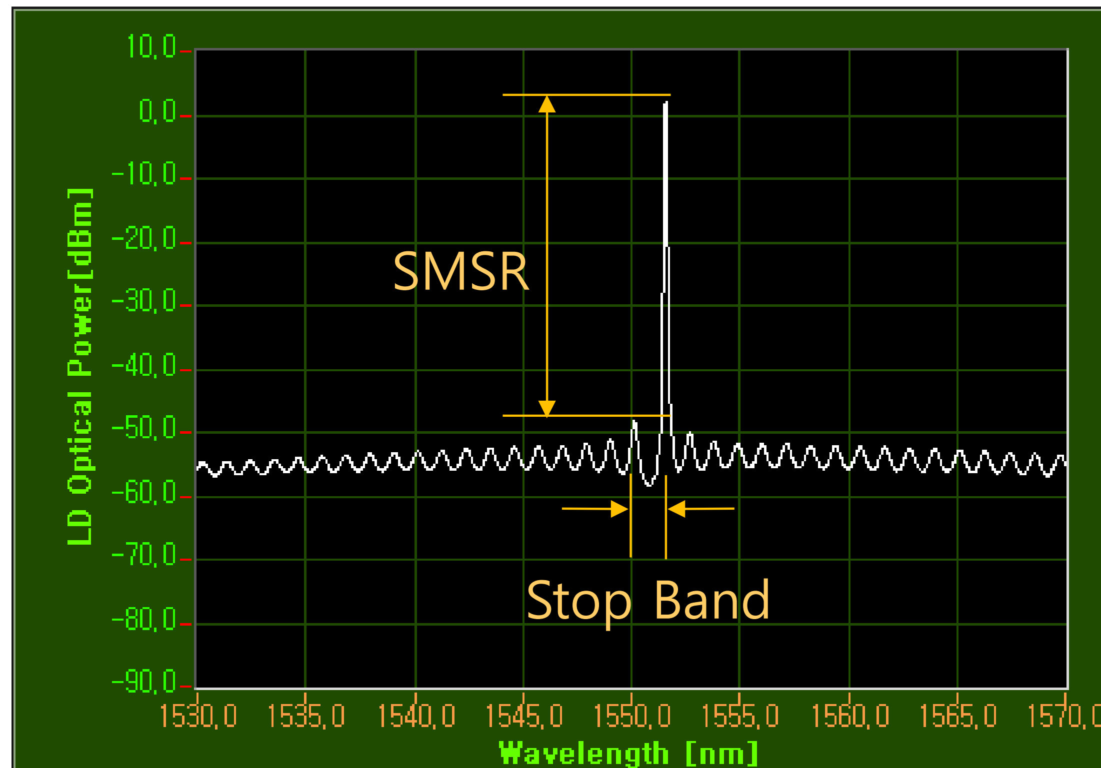


I-V



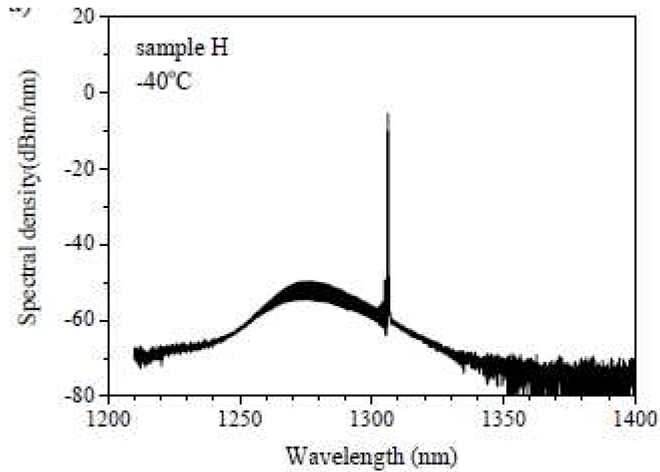
Spectrum

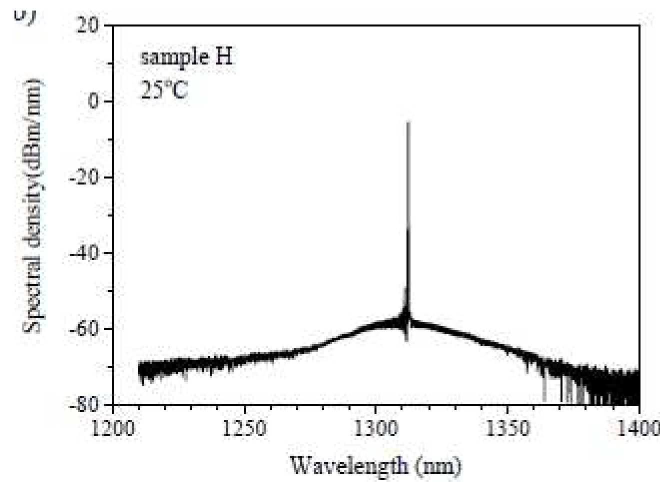
- Wavelength
- SMSR(Side Mode Suppression Ratio)
- Stop Band

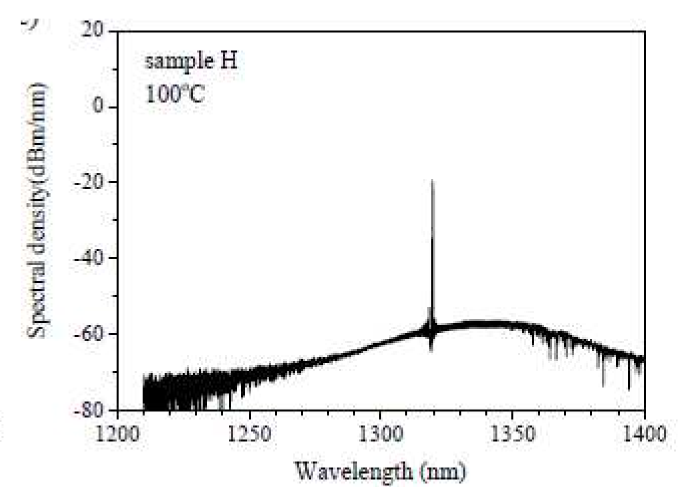


Detuning

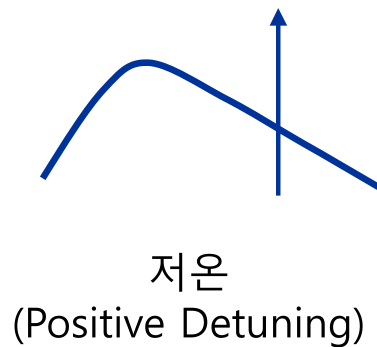
OE SOLUTIONS



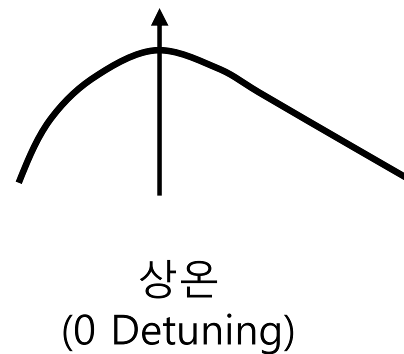




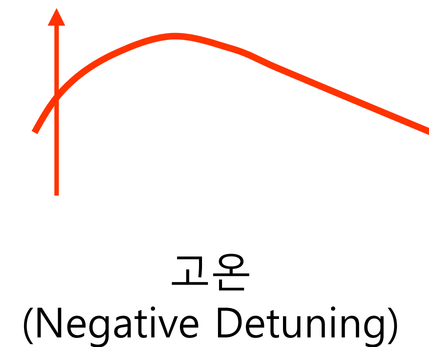
DFB



저온
(Positive Detuning)



상온
(0 Detuning)



고온
(Negative Detuning)

Bar Setting

OE SOLUTIONS

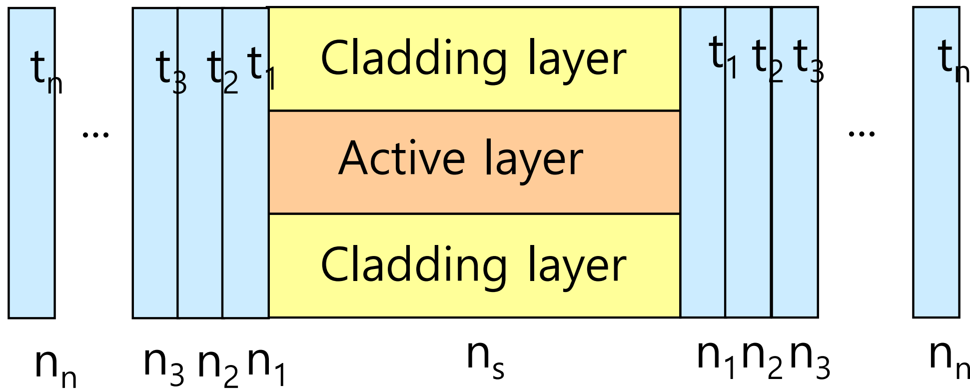
지지 Bar

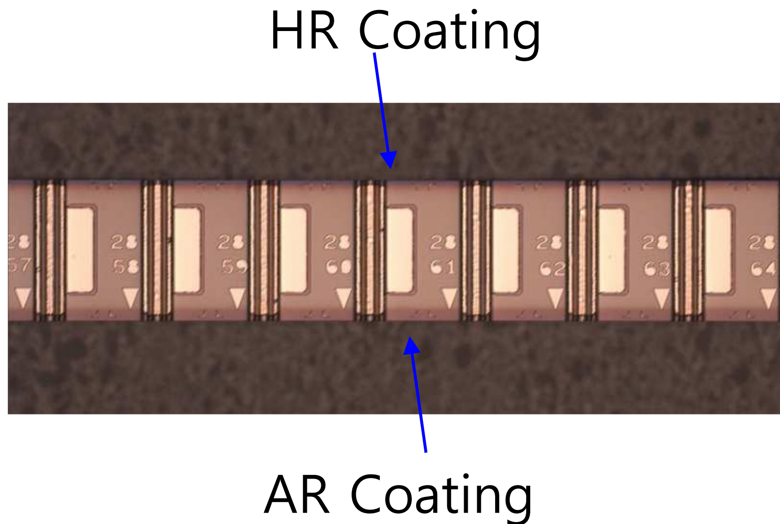
Bar

AR/HR Coating

OE SOLUTIONS

- AR Coating은 DFB 수율을 높이고 효율을 좋게 하기 위해 앞면에 박막을 입히는 공정
- HR Coating은 효율을 좋게 하기 위해 뒷면에 박막을 입히는 공정





Coating Simulation

OE SOLUTIONS

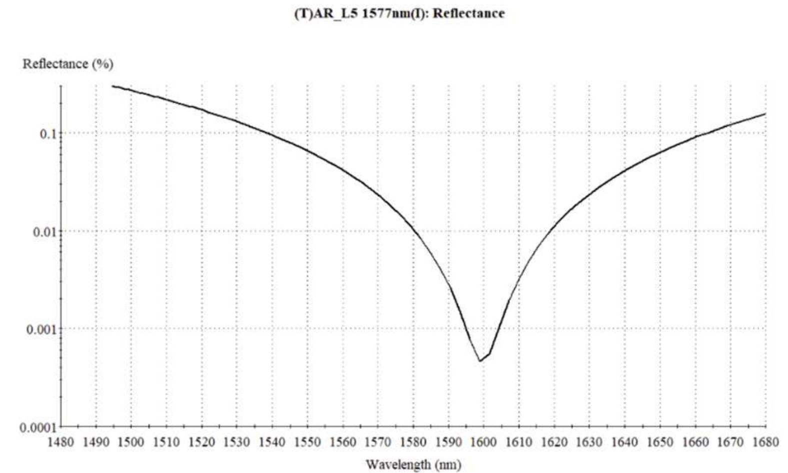
디자인

Design | Context | Notes

Incident Angle (deg)	0.00
Reference Wavelength (nm)	510.00

Layer	Material	Refractive Index	Extinction Coefficient	Optical Thickness (FWOT)	Physical Thickness (nm)	Lock
Medium	Air	1.00000	0.00000			
1	MgF2	1.38542	0.00000	0.24160637	88.94	No
2	ZnO:Al	2.04081	0.00958	1.80071811	450.00	d, n
3	ZnO	2.03718	0.00000	0.79889372	200.00	d, n
4	CdS(1)	2.68800	0.68400	0.63247059	120.00	d, n
5	CZTS	3.19893	1.02398	9.40862094	1500.00	d, n
6	Mo	3.51667	3.76406	6.89542521	1000.00	d, n
Substrate	Glass	1.52083	0.00000			
				19.77773495	3358.94	

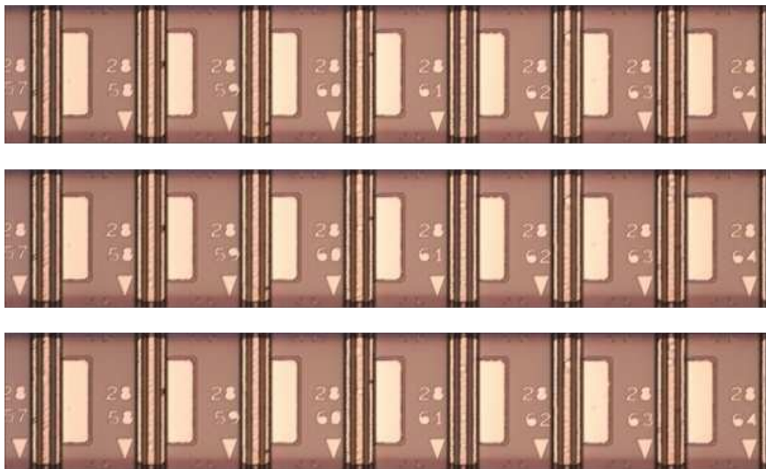
반사율 Simulation

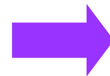


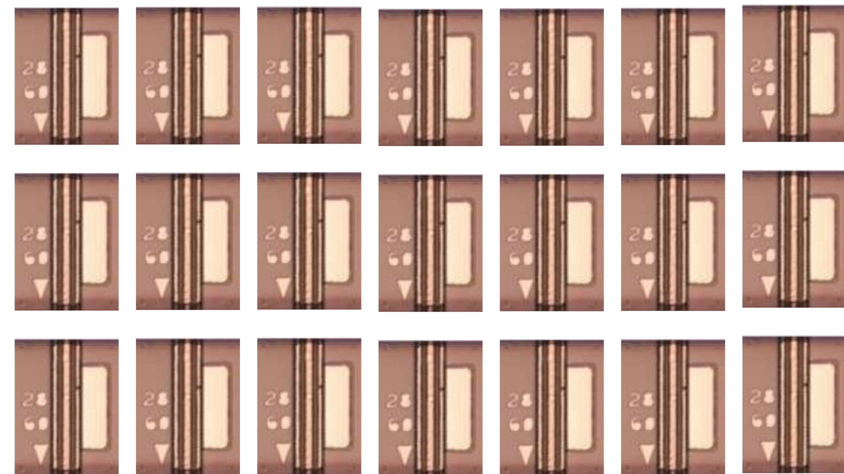
Chip Scribing & Breaking

OE SOLUTIONS

- Chip cleaving은 Chip Test를 하기 위해 Bar를 Chip형태로 자르는 공정



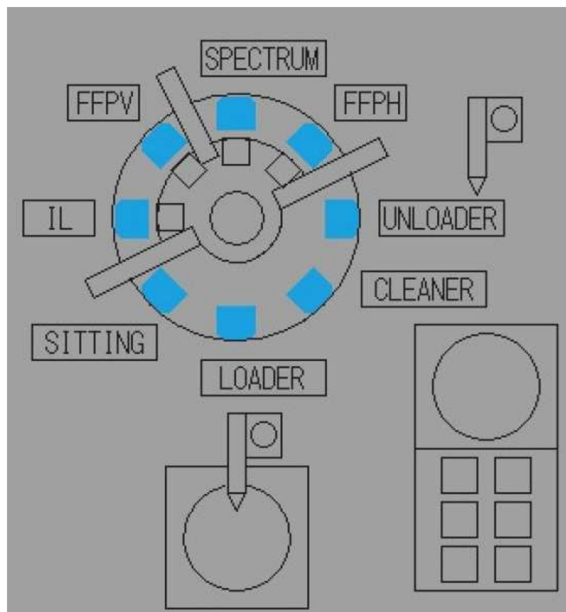


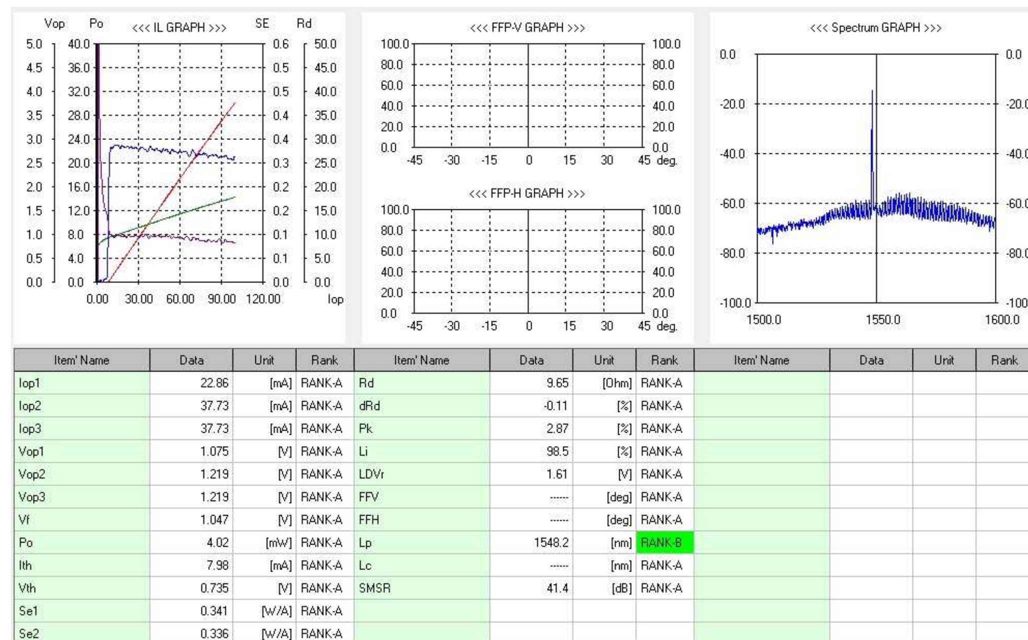


Chip Cleaving

Chip Test

-Chip test는 각각의 Chip을 평가하여 양/불을 판별하는 공정

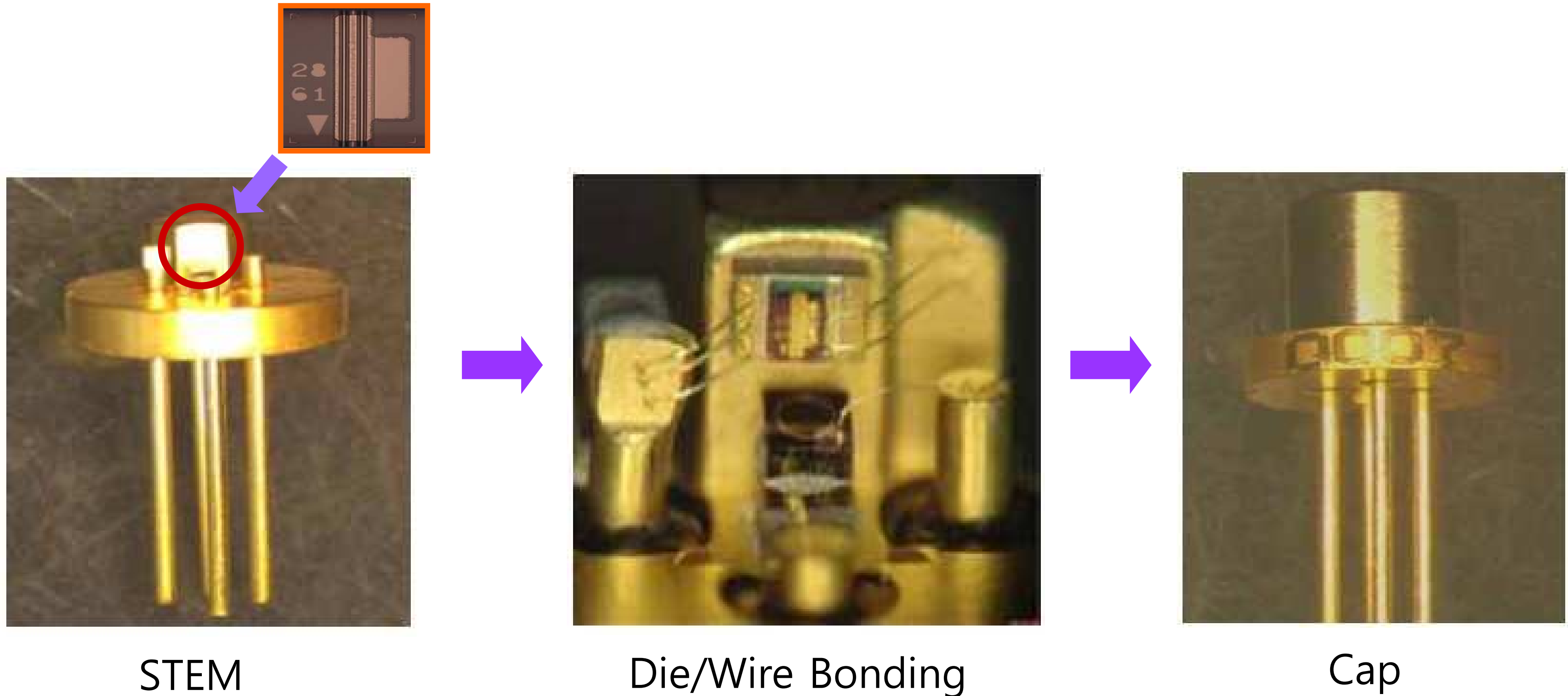




Item' Name	Data	Unit	Rank	Item' Name	Data	Unit	Rank	Item' Name	Data	Unit	Rank
Iop1	22.86	[mA]	RANK-A	Rd	9.65	[Ohm]	RANK-A				
Iop2	37.73	[mA]	RANK-A	dRd	-0.11	[%]	RANK-A				
Iop3	37.73	[mA]	RANK-A	Pk	2.87	[%]	RANK-A				
Vop1	1.075	[V]	RANK-A	Li	98.5	[%]	RANK-A				
Vop2	1.219	[V]	RANK-A	LDVr	1.61	[V]	RANK-A				
Vop3	1.219	[V]	RANK-A	FFV	------	[deg]	RANK-A				
Vf	1.047	[V]	RANK-A	FFH	------	[deg]	RANK-A				
Po	4.02	[mW]	RANK-A	Lp	1548.2	[nm]	RANK-B				
Ith	7.98	[mA]	RANK-A	Lc	------	[nm]	RANK-A				
Vth	0.735	[V]	RANK-A	SMSR	41.4	[dB]	RANK-A				
Se1	0.341	[W/A]	RANK-A								
Se2	0.336	[W/A]	RANK-A								

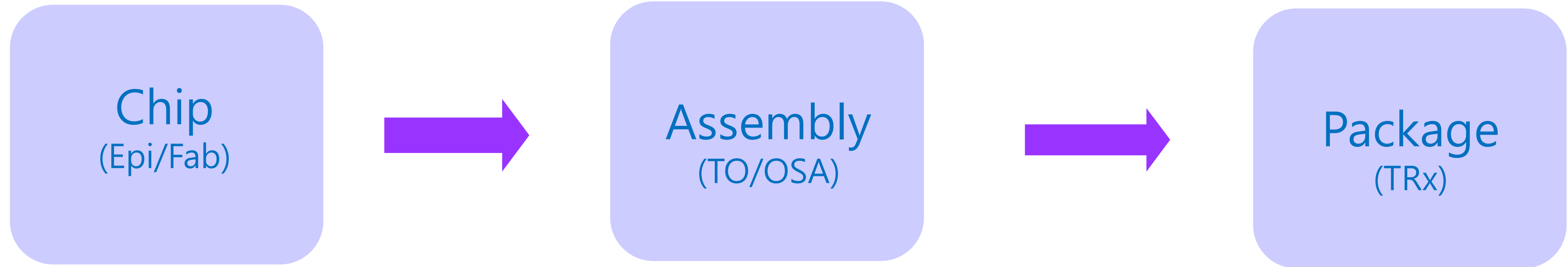
TO Process

OE SOLUTIONS

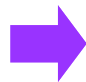


Module Process

OE SOLUTIONS

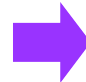


LD Chip

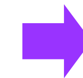


TO PD

TO LD



ONU BOSA



TRx(ONU Bidi SFF)