광통신용 수동부품 및 패키징 기술동향

2002.5.02

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목차

- 개요
- Optical Coupling
- Bonding
- Passive Optical Device
- 결언

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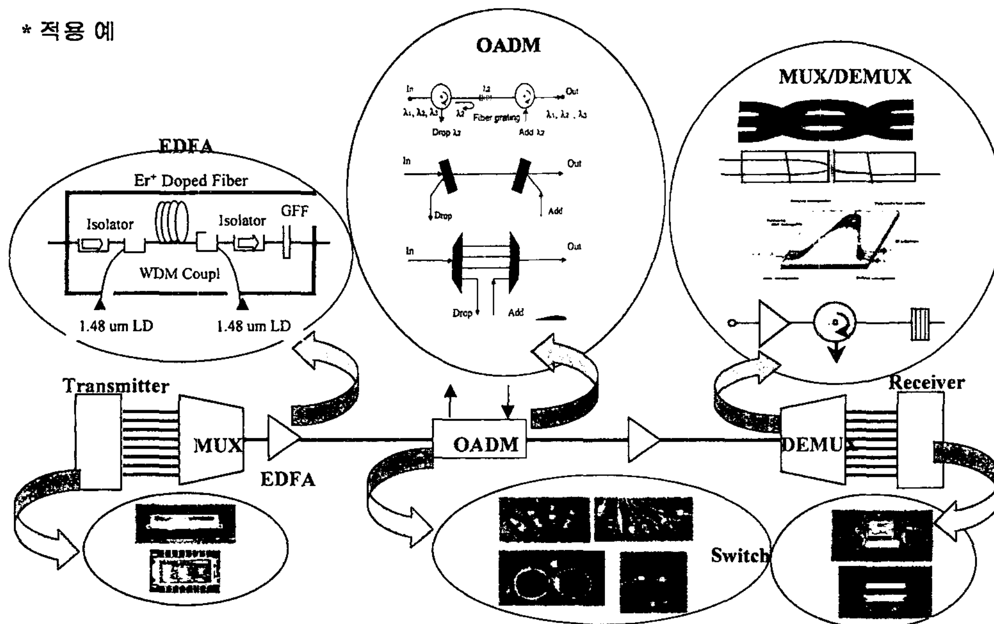
개요

o 현재 인터넷은 사용자의 증가와 사용용량의 증가로 인해 대역확장이 요구되고 있으며 이에 대한 해결방안을 광학(광섬유통신)에서 얻고자 노력하고 있다. 그러나 기존의 구리선에 비해 설치비가 고가이고 다루기가 힘들어 보급되기 힘든 실정이다.

o 광학부품은 크기가 점차 소형화 되는 추세이며, 신뢰성은 더욱 강조되고 있다. 이를 해결하기 위한 방안의 하나가 바로 패키징 기술이다.

WDM 전송시스템에서의 수동광부품

* 적용 예



수동광부품의 기술별 분류

구분	Fiber Optics	Micro Optics	Waveguide Optics
Isolator, Circulator, Collimator		O	
DWDM	O	O	O
OADM	O	O	O
Attenuator	O	O	O
Interleaver	O	O	O
Wavelength Locker	O	O	O
Tunable Filter	O	O	O
Switch		O	O
Power Splitter (Coupler)	O		O
PM Compensator	O		O
Modulator		O	O

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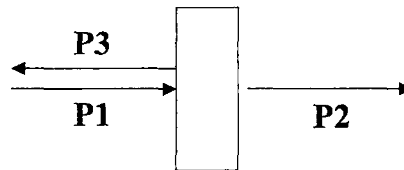
Optical Coupling

<Loss>



- Insertion Loss

  $IL[dB] = -10 \log_{10}(P2/P1)$
- Return Loss

  $RL[dB] = -10 \log_{10}(P3/P1)$

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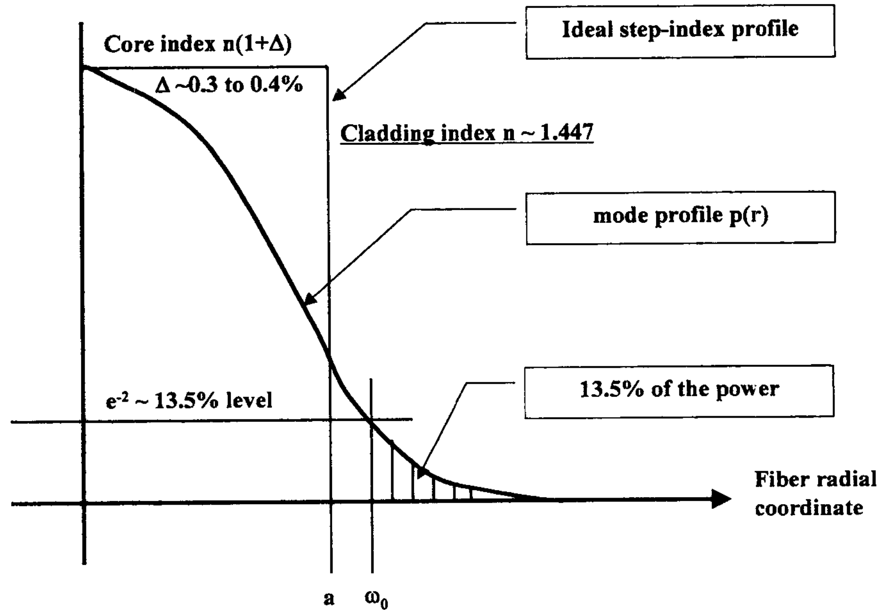
Gaussian Mode Profile



- **Radial power density profile in fibers**

$$p(r) = p(0)\exp\left\{-2\left(\frac{r}{\omega_0}\right)^2\right\}$$

where

$2\omega_0$: mode-field diameter (MFD)
ω_0 : spot-size (SS)

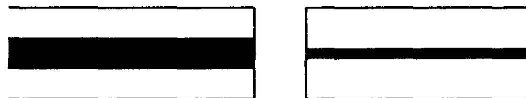
$$\omega_0^2(z) = \left[\omega_0^2 + \left(\frac{z\lambda}{\pi\omega_0}\right)^2\right]$$

• MFD is about 20% larger than
CD (8.5μm) ≈ 10.25μm

• MFD
- DCF (≅ 8.25μm at 1550nm)
- EDF (≅ 4μm at 1550nm)
- Multi-mode (50~200μm)

• Coupling losses due to MFD mismatches and offsets

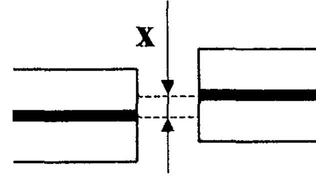
- MFD size mismatch
$L(R) \cong 4.343\ R^2$ in dB



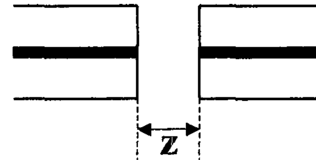
- Offset
  • transverse (x)
  • longitudinal (z)
  • angular (θ)

Offset Loss

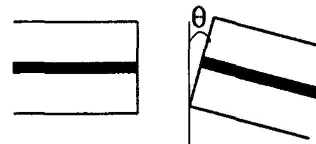
$$L(x) \cong 4.343\left(\frac{x}{\omega_0}\right)^2 \quad \text{in dB}$$



$$L(z) \cong 5.3\left(\frac{\lambda z}{10\omega_0^2}\right)^2 \quad \text{in dB}$$



$$L(\theta) \cong 2.7\left(\frac{\omega_0 \theta}{10\lambda}\right)^2 \quad \text{in dB}$$



<Coupling Errors Corresponding to 0.1dB Loss>

Coupling Error Type	Error Magnitude
MFD mismatch	± 15%
Transverse offset	7.5 % of MFD (0.64μm)
Longitudinal offset[a]	21 μm
Angular offset[a]	0.56°

[a] Assumes a mode-field diameter of 9μm at wavelenth of 1310nm

Laser Diode to Fiber Coupling

- **Bad Coupling : 10~20% coupling (7-10dB)**

  - 주원인 : elliptical emitting

- **해결방안 :**

  - Spherical -> Cylindrical Lens
  - Single Lens -> Double Lens
  - Alignment 최적화
  - 단면 극저 AR Coating (0.1% 이하)
  - Fiber 단면 가공 (lensed or tapered fiber)
  - Mechanical 안정성 확보 (vibration & temperature)

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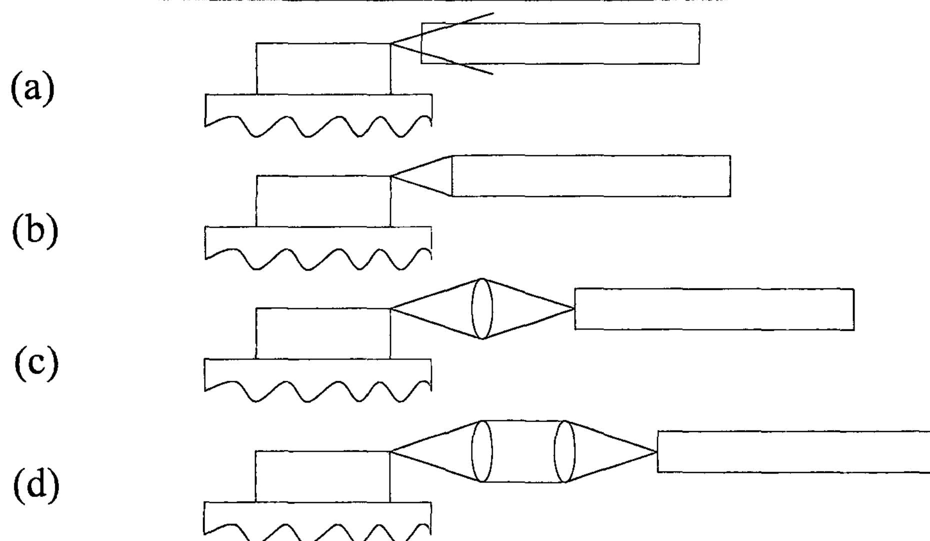

Comparison of four techniques of coupling a laser diode to a fiber : (a) cleaved fiber coupling; (b) coupling with a fiber lenslet; (c) using a single-lens imaging system; and (d) using a double-lens imaging system.

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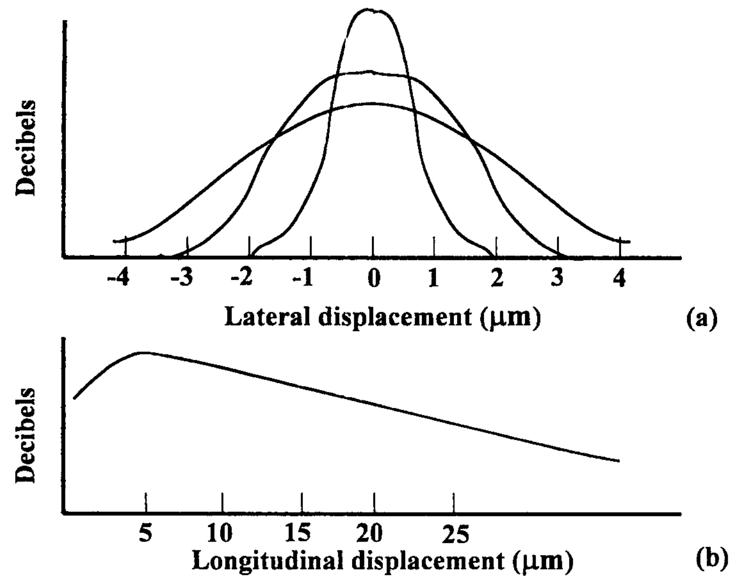


Plots illustrating the sensitivity of laser diode-fiber coupling efficiency to (a) lateral displacement and (b) longitudinal displacement.

Fiber to Planar Waveguide Coupling

- **Butt joint coupling**

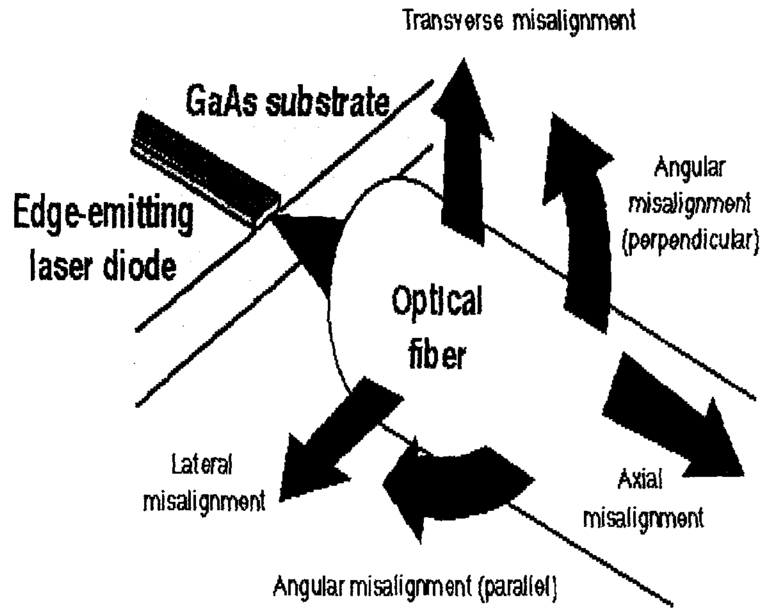
- **MFD matching 필요**
  - **Polymer & 반도체 waveguide의 경우**
    - **⇒ Lensed Fiber, Spot Size Converting 기술 필요**

- **정밀 Align 기술**
  - **V-groove**
  - **Epoxy adhesives**
  - **Weld bonding**

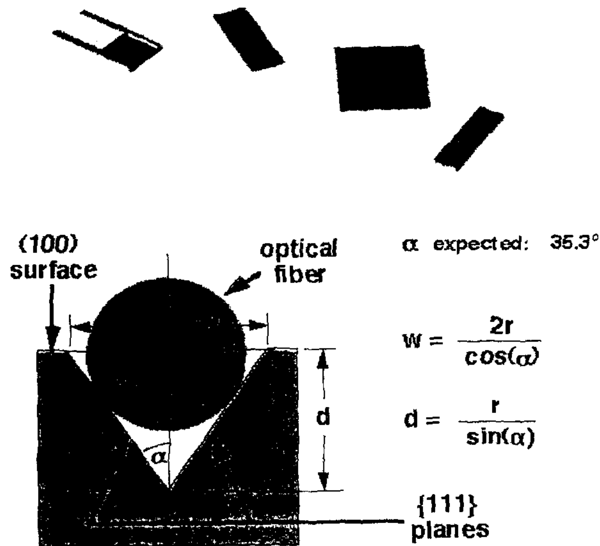
- **취약점 : Relaxation & Moisture**

- **개선방안 : Metal bonding & Welding**

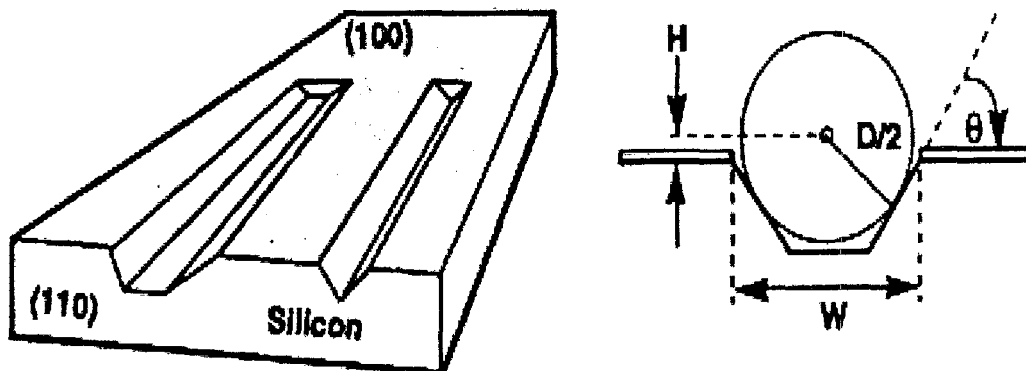
Fiber to waveguide coupling



Si v-groove



Fiber block Design



Array V-groove의 단면도와 V-groove의 기하학적 구조
(H:Bond Height/2 ,D:Radius of cladding ,W:Opening window)

Fiber to Fiber Coupling

- **Fusion 방식 : 0.05dB 이하**
- **Connector 방식 : 0.2dB 이하**
  - **1μm 이하의 Alignment 가능 (정밀 Ferrule 사용)**
  - **Air Gap에 의한 interference 발생**
    ⇒Insertion Loss(0~0.6dB) &
    Return Loss(~9dB)에 영향
  - **PC (physical contact)**
  - **APC (angled PC)**
- **Mechanical Splicing**
  - **index matching material 사용**

Bonding

패키징 방식	특 징
Epoxy	Long time for curing Large shift after curing
Soldering	Relative short time Large shift due to thermal process
Laser Welding	High speed welding process Very small welding point(~300μm) Very small size of thermal affected area Very small post weld shift (PWS) Weldable between various different materials Very rigid and reliable joining Prone to bulky

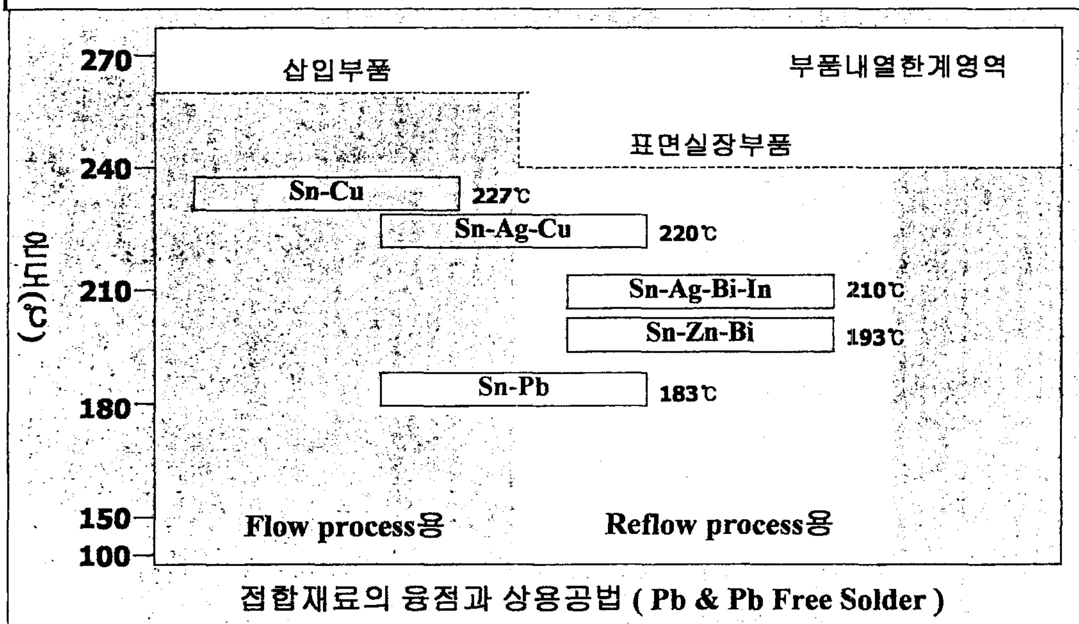
Major Issues in Joining of Packages

- **Bond Strength**
  - **atomic bonding(primary or secondary)**
  - **reaction at the interface**
- **Precision of bonding**
  - **errors should be a few micrometer or less**
- **Distortion or stress at joint**
  - **thermal stress should be minimized**
- **Robust process**
  - **reproducible**
  - **low cost**
  - **high yield**

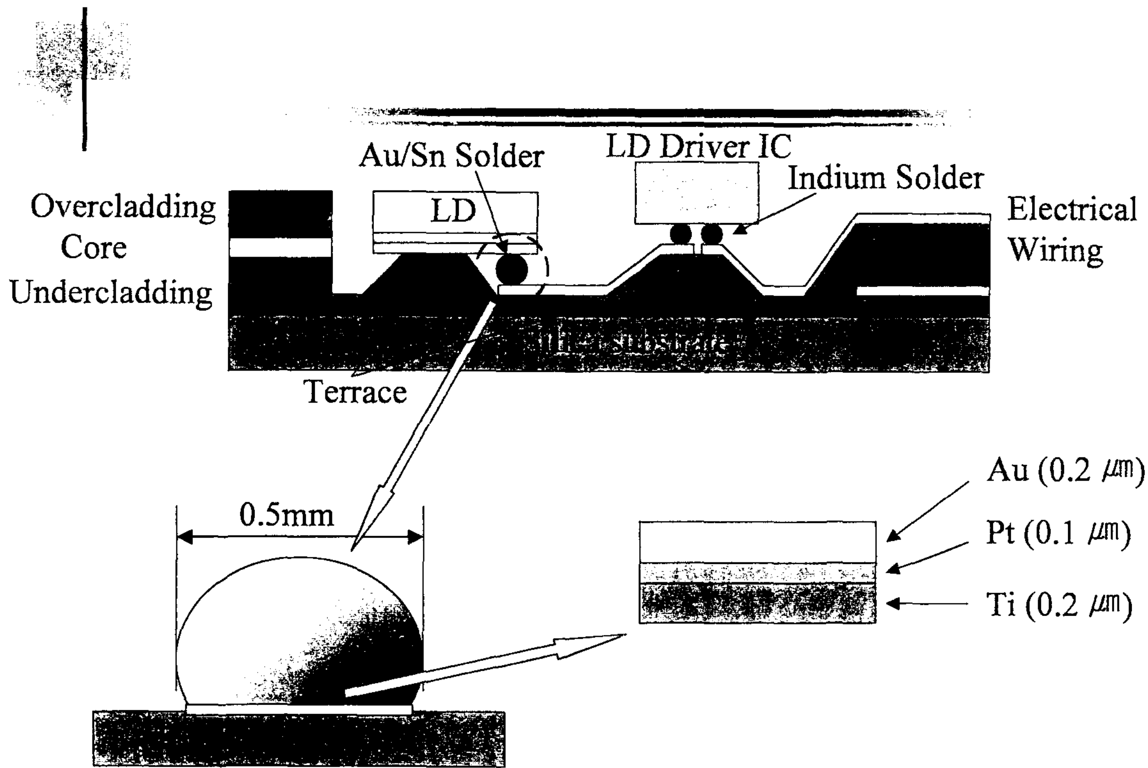
- **Adhesion bonding**
  - low cost
  - reliability

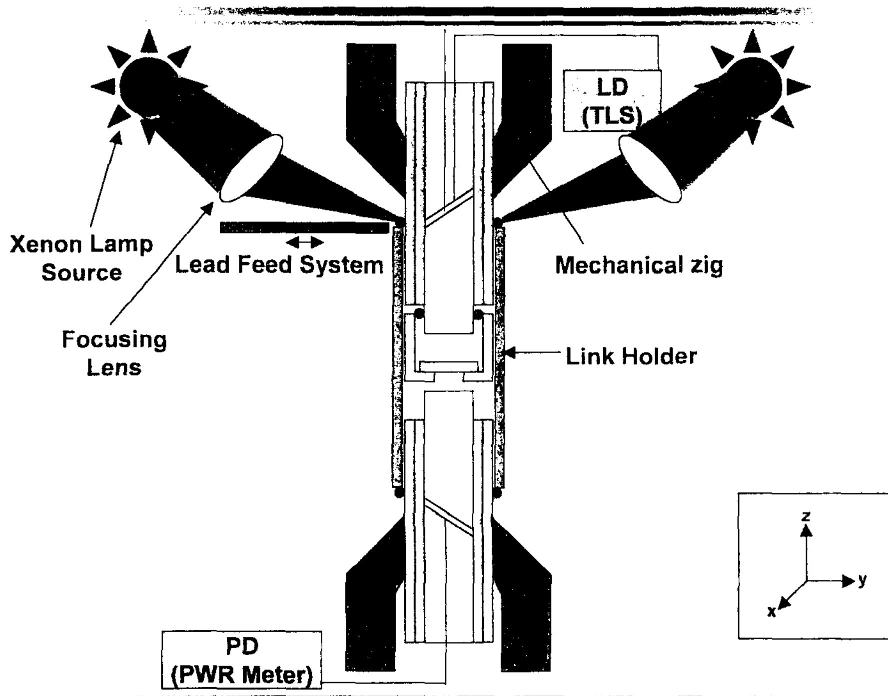
- **Soldering and Brazing :**
  - primary bonding
  - reaction at the interface
  - low strength(creep deformation)

- **Welding**
  - primary bonding
  - large welding stress due to solidification process



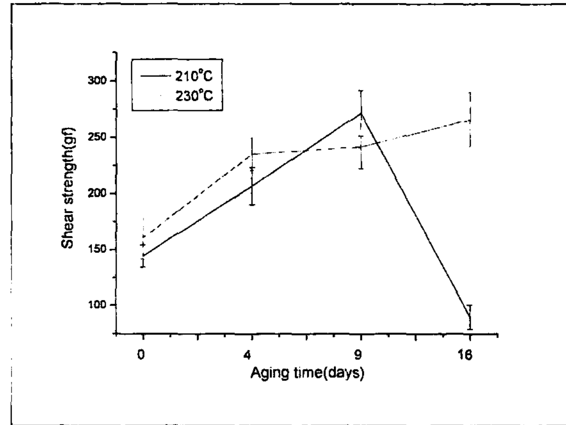
접합재료의 융점과 상용공법 (Pb & Pb Free Solder)


Au/Sn Solder
LD Driver IC
Indium Solder
Overcladding
Core
Undercladding
LD
Electrical
Wiring
Terrace
0.5mm
Au (0.2 ㎛)
Pt (0.1 ㎛)
Ti (0.2 ㎛)

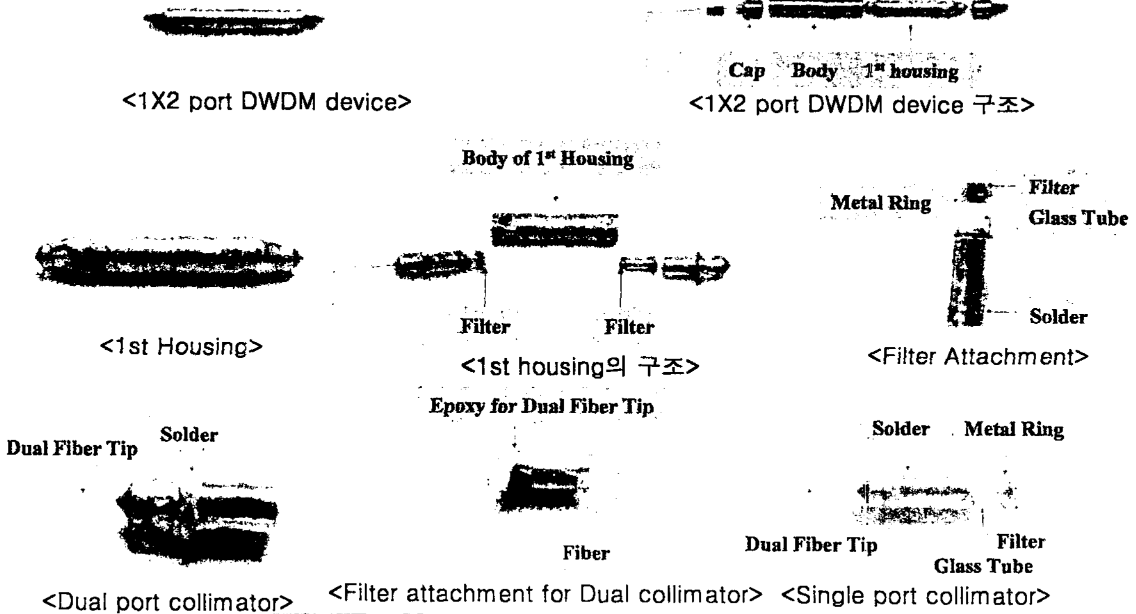

LD
(TLS)
Xenon Lamp
Source
Lead Feed System
Mechanical zig
Focusing
Lens
Link Holder
z
y
x
PD
(PWR Meter)

0.5mm Sn/Pb solder on Si wafer

시효조건 110°C 0일~16일



Sn63/Pb37

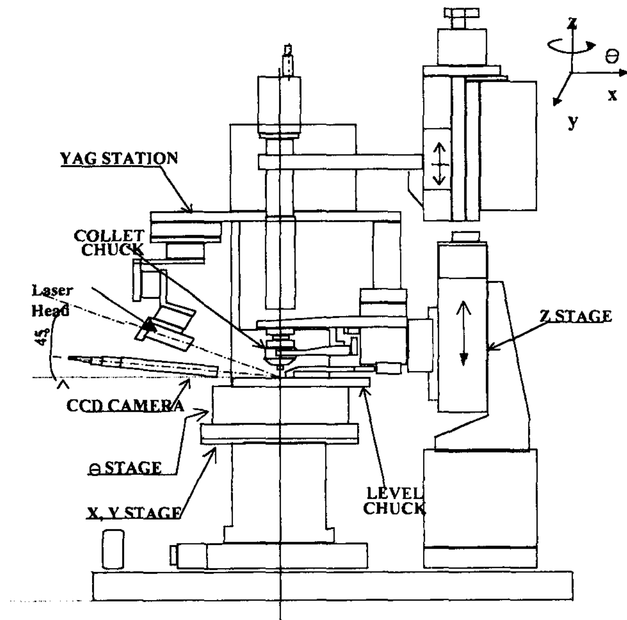


<1X2 port DWDM device> <1X2 port DWDM device 구조>

<1st Housing> <1st housing의 구조> <Filter Attachment>

<Dual port collimator> <Filter attachment for Dual collimator> <Single port collimator>

Laser Welding



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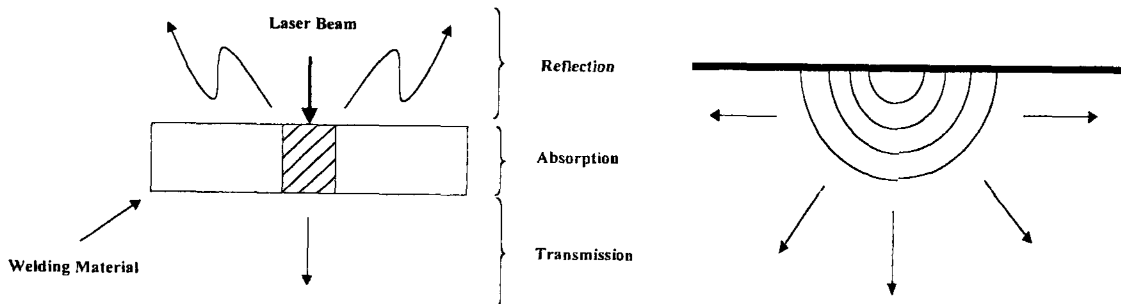
용접원리



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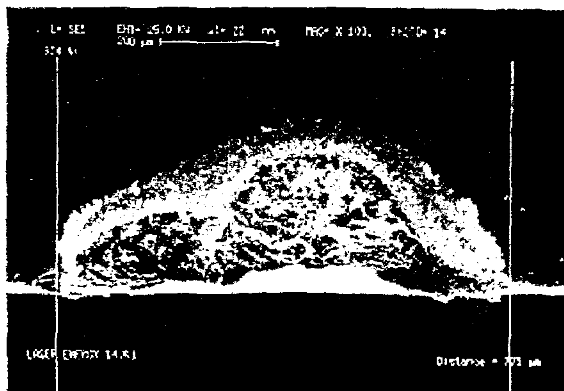
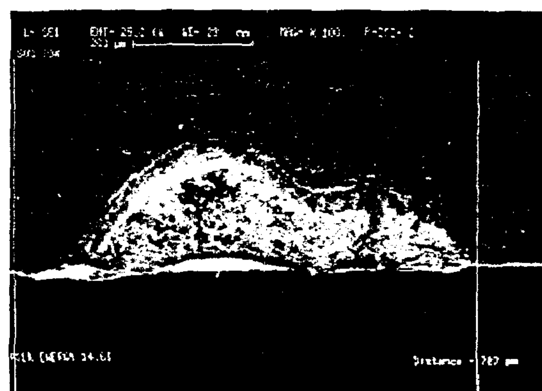
금속재질의 특성비교

	흡수율(%)	용점(℃)	비점(℃)	비고
SPPC(연철)	35	1533	2750	용접성양호
Zn(아연)	49	420	906	연철의 표면보호를 위해 사용, 융점이 낮아 레이저용접시 금속내부에 기포발생
Ni(니켈)	28	1450	2730	자체의 용접성 우수, 철에 도금된 형태에서는 레이저 용접시 crack 발생
Cu(구리)	9	1083	2595	반사율과 열확산율이 높음
Ag(은)	3	961	2212	최대반사율, 레이저 mirror로 사용
Stainless	- SUS 303 : 절삭성 향상, burr 형성 - SUS 440C : 내마모성 향상, 경질 - SUS 316 : 탄력성 향상, 경질 - SUS 304 : 압연성 향상			

Laser 용접부

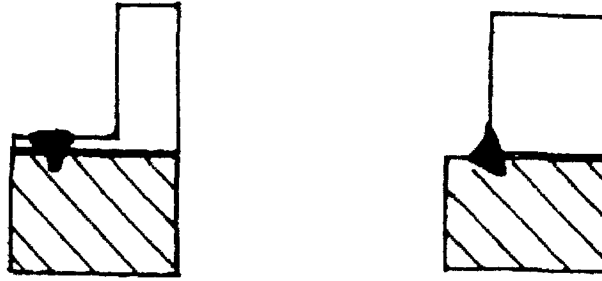


Ideal Case



Bubble & Crack

Laser 용접부



Lap weld　　Fillet weld

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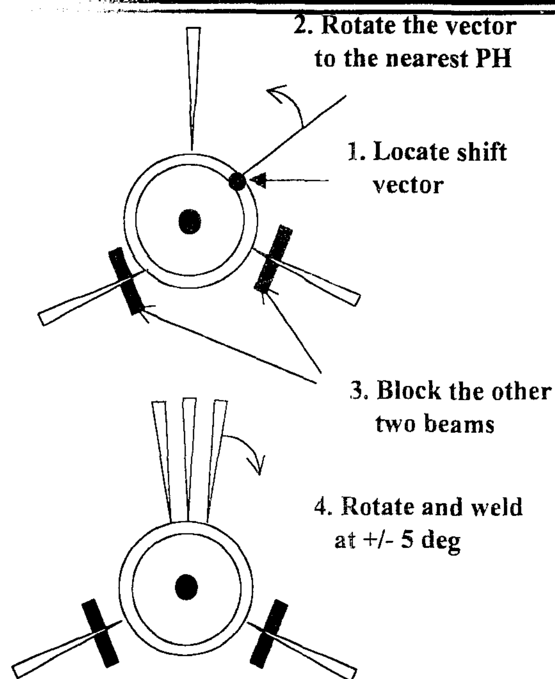
Laser Hammering



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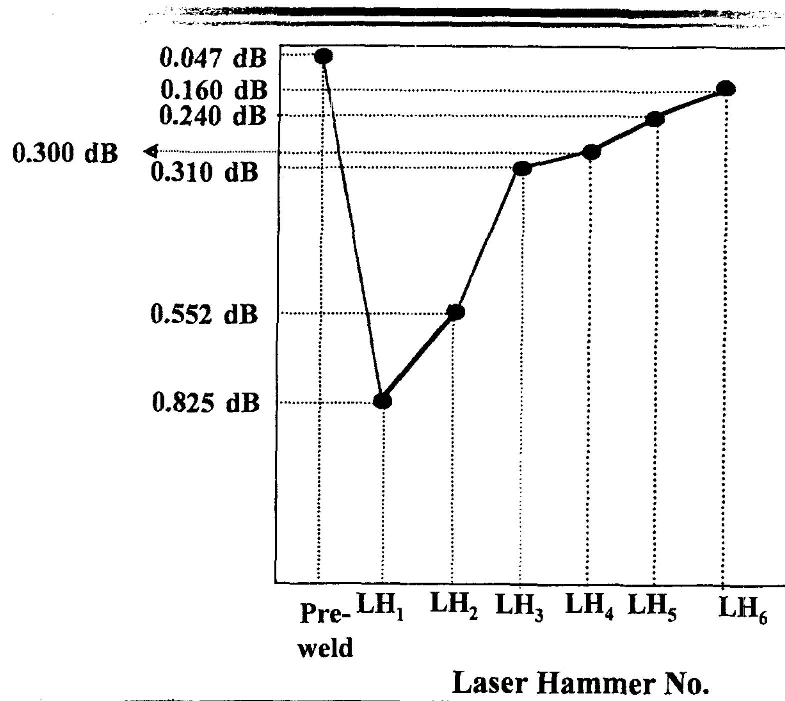
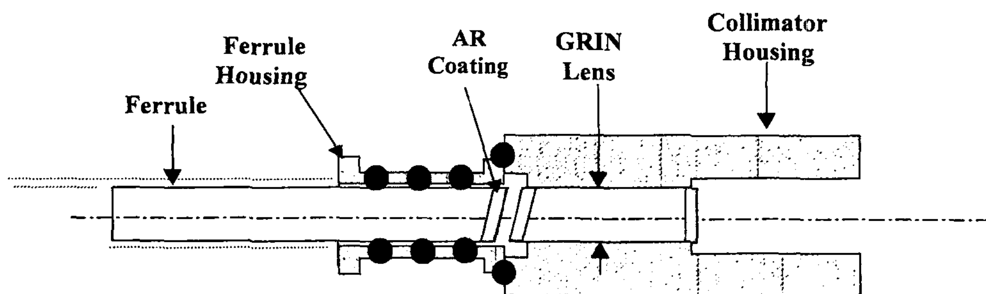
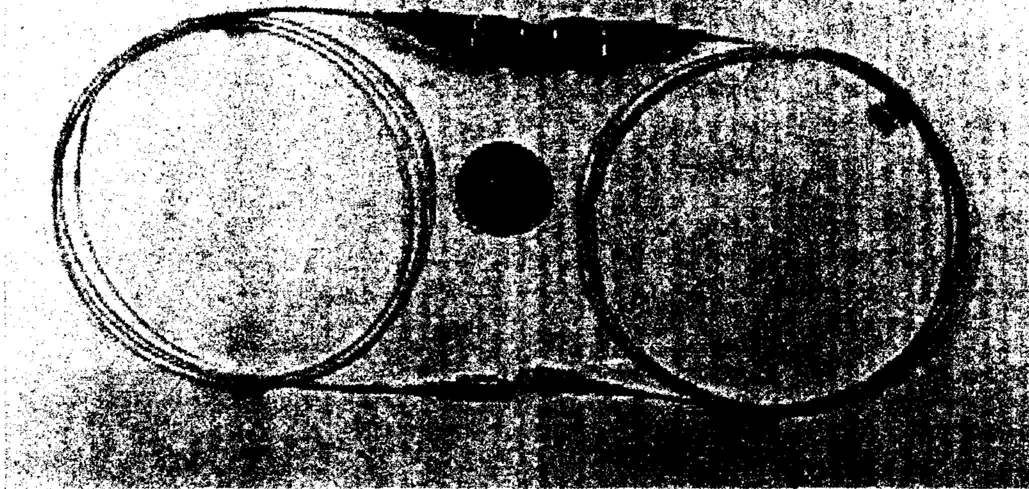
Laser Hammering에 따른 광결합 효율의 변화



Optical Collimator



Optical Collimator



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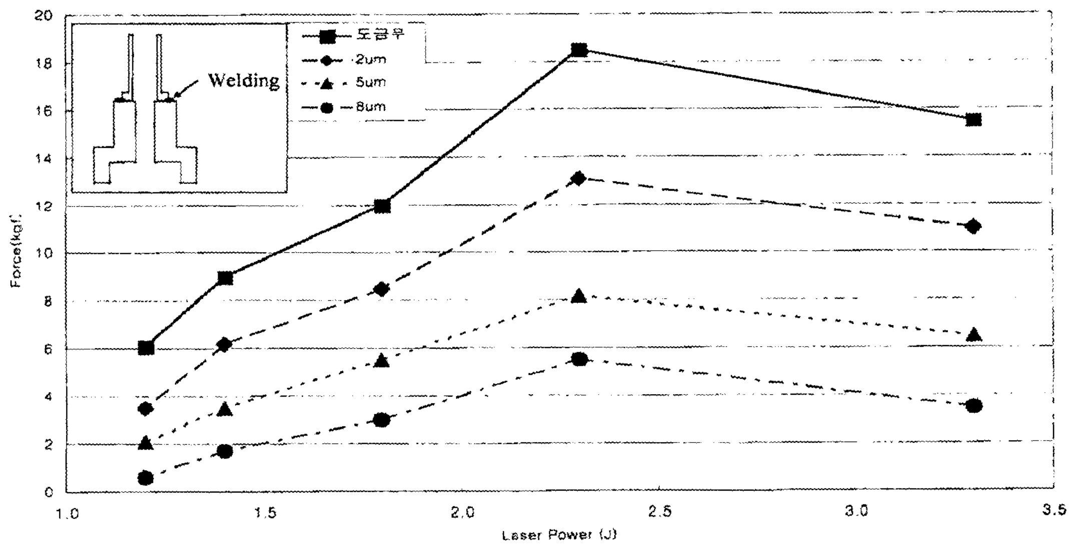
Shear Strength



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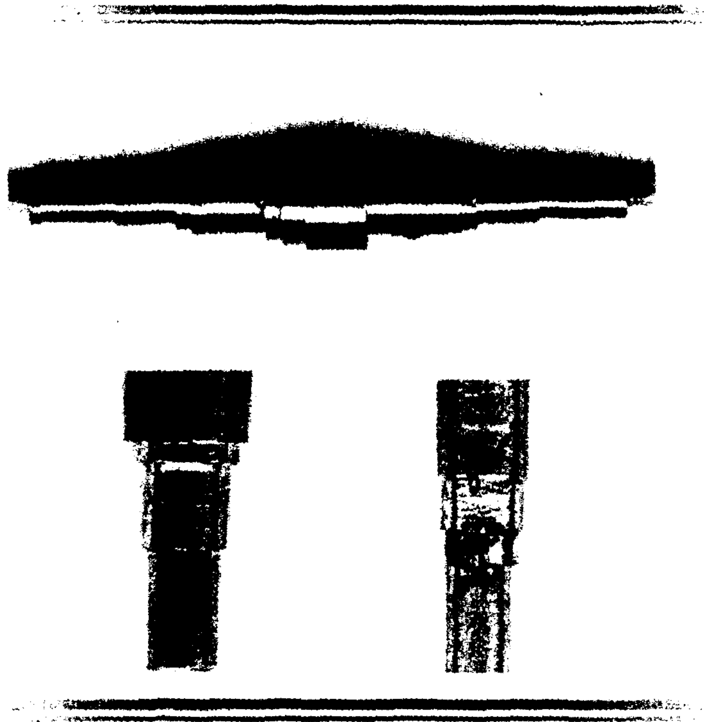
Optical Isolator



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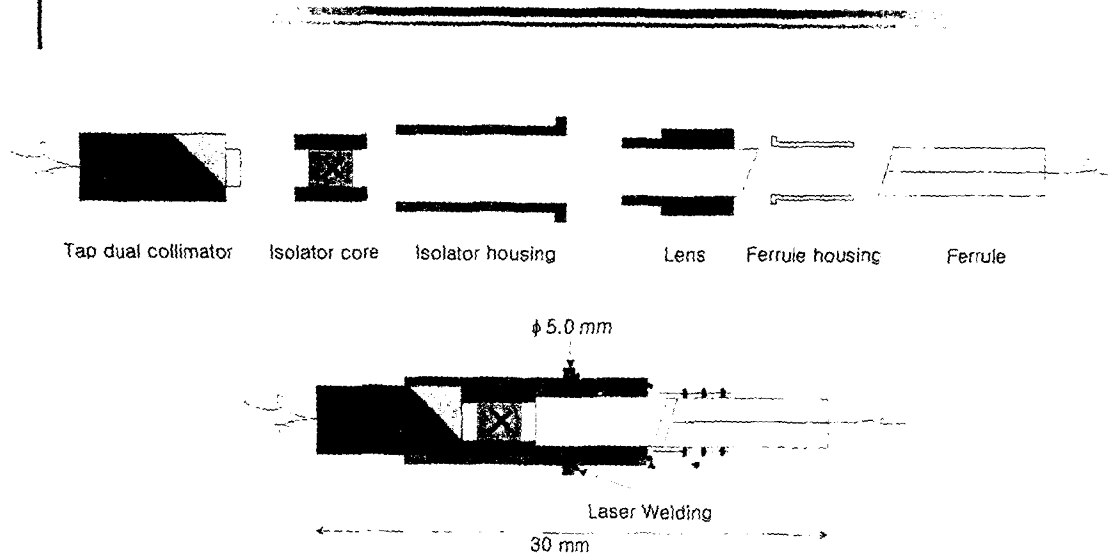
Hybrid Isolator Packaging



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Reliability

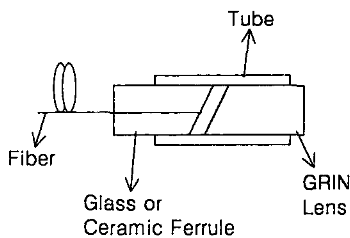
Device	신뢰성 시험	Insertion Loss [dB]	Isolation [dB]	Return Loss [dB]	Tap Ratio [dB]
광콜리메이터	시험 전	0.25	-	50	-
	시험 후	0.30	-	51	-
광아이솔레이터	시험 전	0.5	41	53	-
	시험 후	0.6	42	53	-
하이브리드 광아이솔레이터	시험 전	0.54	42.73	58	14.23
	시험 후	0.74	41.51	56	14.43

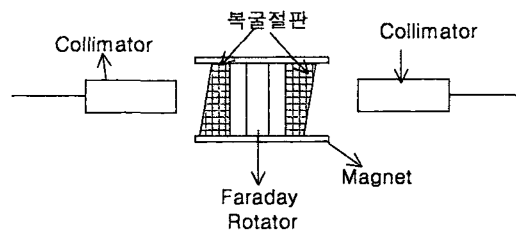
시험조건: 70 ℃, 96시간

Collimator & Isolator

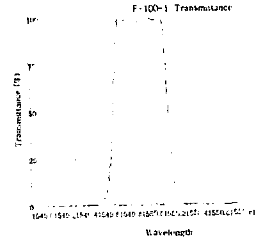
* 광섬유에서 나온 광을 평행광으로 만들거나 평행광으로 입사한 빛을 광섬유로 집속 시키는 광부품으로 광감쇠기, 광아이솔레이터, 광서큘레이터등의 광섬유 소자의 핵심부품
* 대표기업 -국내:삼성 SCM, 한요 텔레콤
  -국외: Casix

* 광전송시스템의 각종부품 및 경계면에서 반사되어 전송 광신호와 간섭을 유발 시킴 으로서 광전송시스템 전체의 성능을 저하시키는 역반사 잡음 광신호를 제거하기 위한 소자
* 대표기업 -국내:삼성 SCM, 한국단자
  -국외: JDS uniphase, FDK, Oyokoden



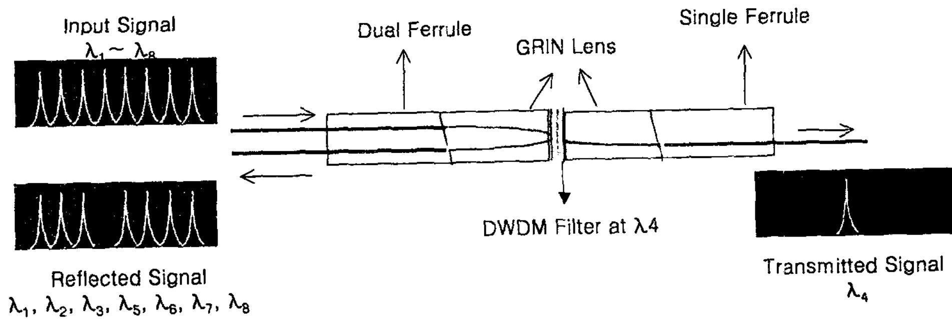


박막간섭형 Dense WDM 광필터



- 유리 기판 위에 박막 간섭형 필터를 형성하여 특수 파장은 통과시키고 나머지 파장은 반사 시키는 기능 소자

- 삽입손실이 큼



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결 언

- 수동 광부품의 경우 JDS uniphase 등이 독주
- Low cost 패키징 기술 확보를 위한 자동화 설비 개발 필요.
- 기술 Infra 구축 필요(소재, 부품, 모듈, 시스템 연계 강화)
- 기술 특화를 통한 경쟁력 강화

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