광통신용 소자의 패키징

주 관 종

Optical Device Packaging

2001.7.13.

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Outline

- Introduction to optical communication & optoelectronic device
- Consideration of optoelectronic packaging
  - Optical aspect
  - Electrical aspect
  - Thermal aspect
  - Mechanical aspect
- Low cost optical package
  - V-grooved silicon optical bench fabrication
  - Flip-chip bonding and passive alignment process
- Optical array device packaging

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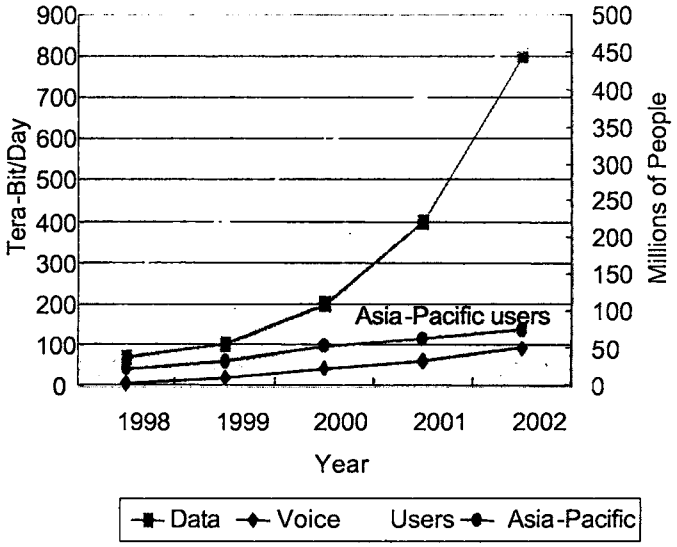
인터넷 사용자와 트래픽의 성장

■ **Year 2000**
Data Traffic (200Tb/Day) go beyond Voice Traffic

■ **Year 2002**
Data Traffic (800Tb/Day) become 6.5 times greater than Voice Traffic

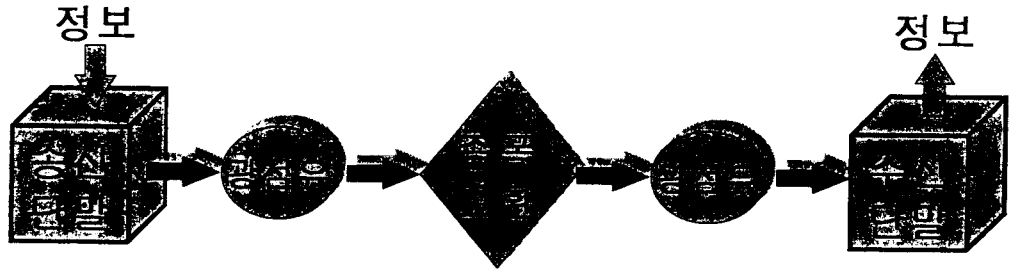
□ ***Current trends of communication service change :***

Voice → Data → Multi-Media
(Image+Voice+Data+etc.)



광통신이란?

빛을 이용하여 정보를 송신 및 수신하는 방식
기존의 동선대신 광섬유를 전달매체로 사용
전송용량, 중계거리, 신뢰성 등에 장점



광 송신기
(전기→광 신호변환)

광 수신기
(광→전기 신호변환)

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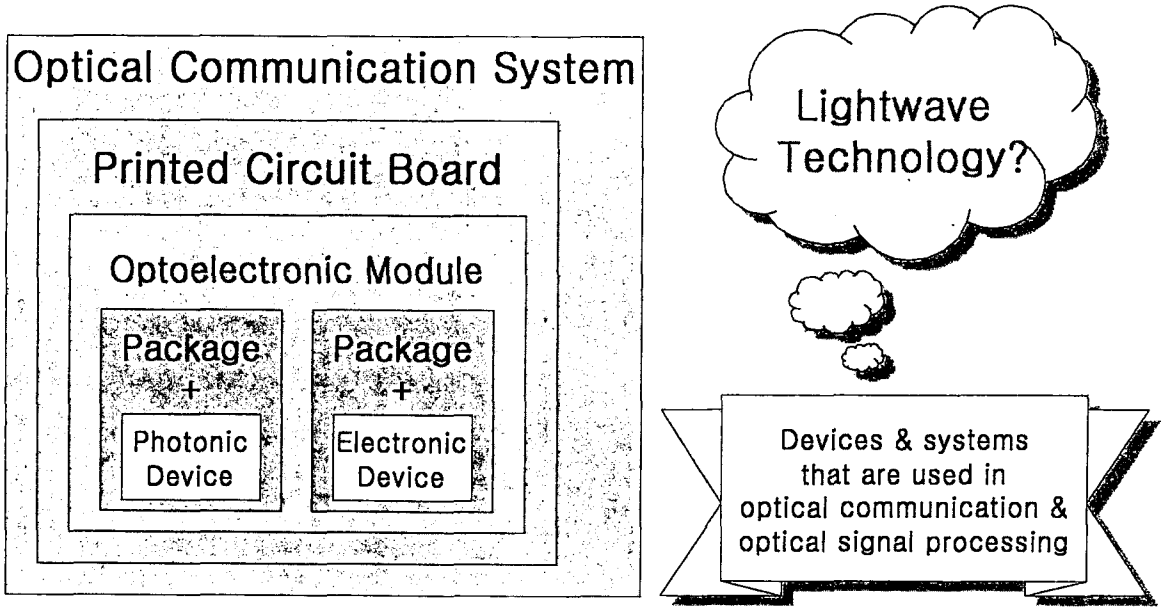
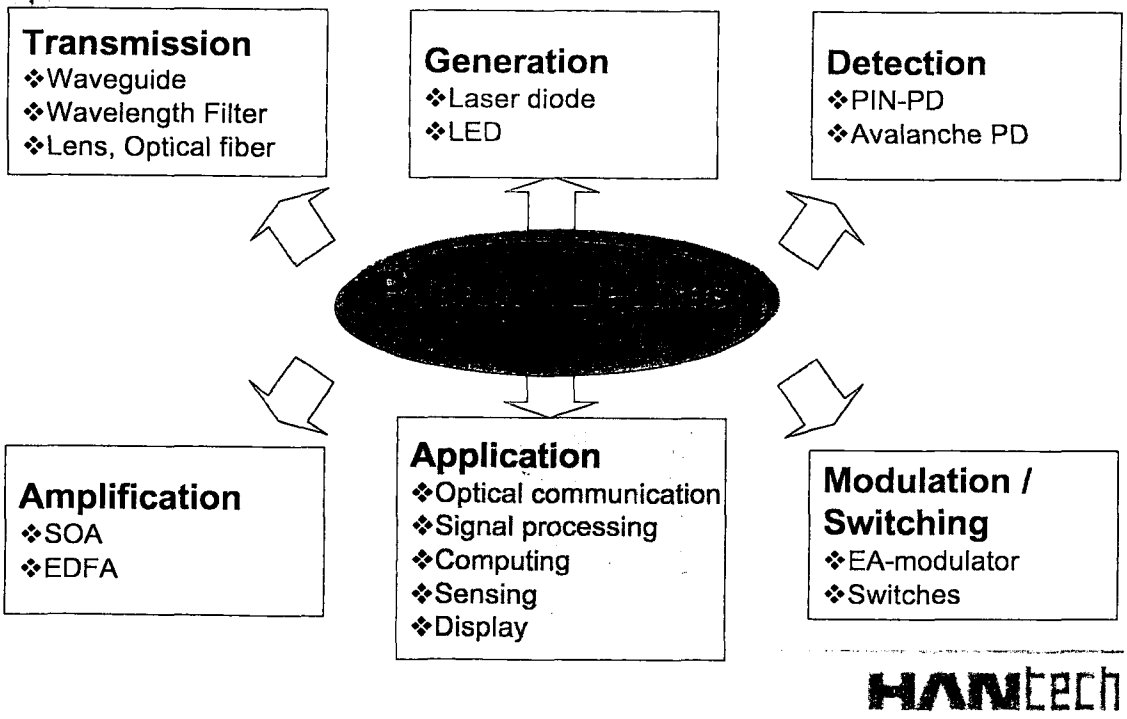
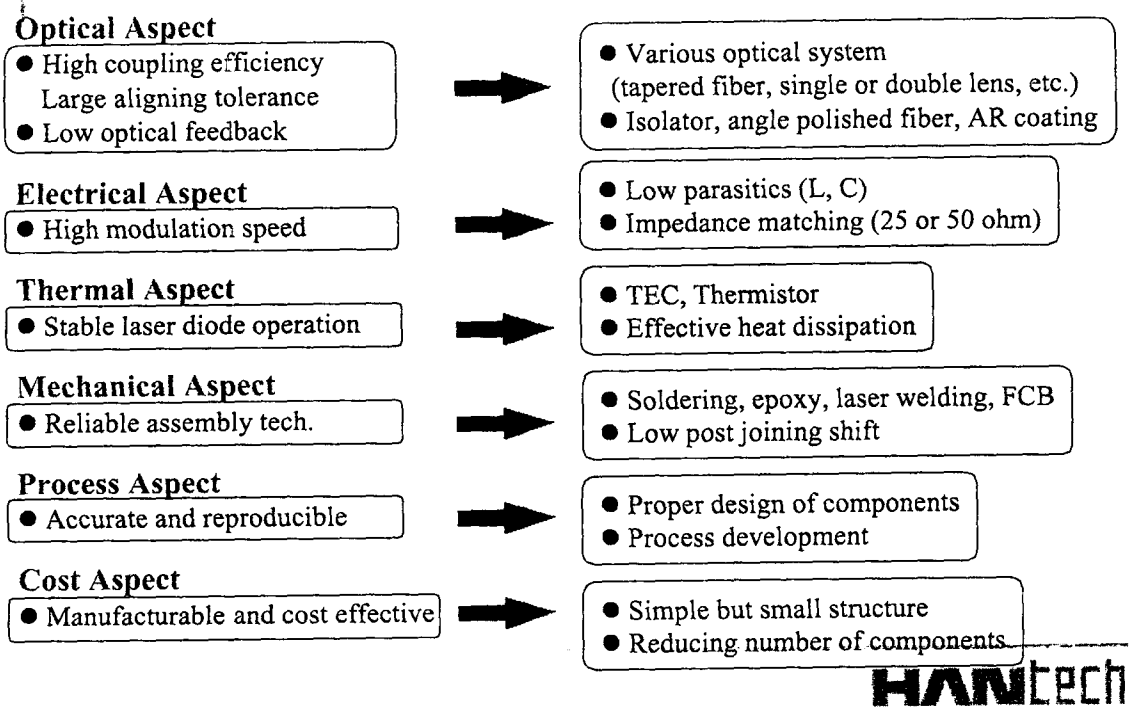
광통신 시스템의 계위



What is Photonic Devices?



광소자 모듈 설계시 고려사항



Optical Aspects

To obtain Maximum Optical Coupling Efficiency:

- Laser diode
  - Circular beam pattern
  - Small angular beam divergence
- Optical components
  - Small aberration
  - Small reflection
- Optical path design
  - Matching mode field diameter
- Assembly technique
  - Precise aligning
  - Low post joining shift

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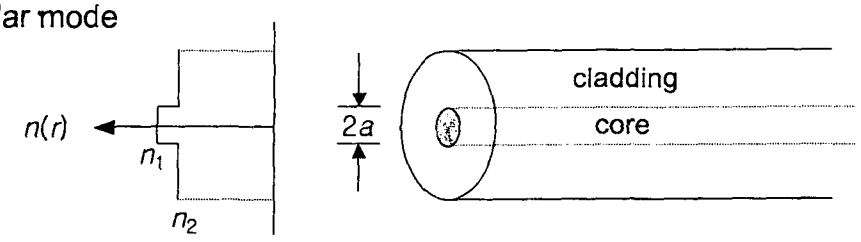
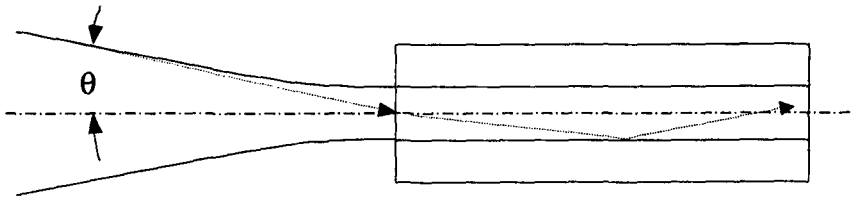
Single Mode Optical Fiber

- Circular mode



- Acceptance angle: $\theta_a = \sin^{-1}\{sq(n_1^2 - n_2^2)\}$, guided mode: $\theta < \theta_a$



- Beam spot size : $\omega_{of} = a\,(0.65 + 1.619V^{-3/2} + 2.879V^{-6})$ for $V > 1.2$
  where $V = 2\pi / \lambda\, a\, sq(n_1^2 - n_2^2)$

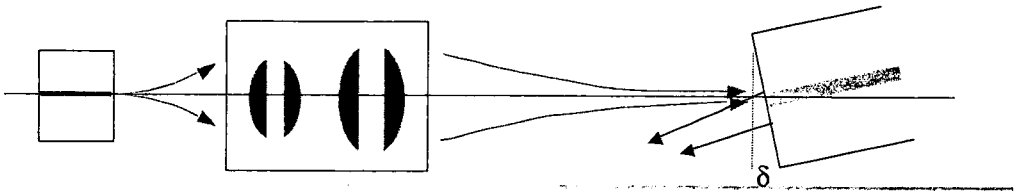
Factors of Additional Coupling Loss

- Misalignment among laser diode, coupling lenses and optical fiber
- Spherical aberrations of the coupling lenses
- Deterioration of the laser diode performance due to optical feedbacks
  - Fresnel reflections from coupling lenses
  - Reflections from both the near and far fiber ends
  - Backscattering from the fiber itself
- Imperfections of lens symmetry and surface quality
- Laser and fiber modes are not truly Gaussian

Techniques for Reducing the Optical Feedback

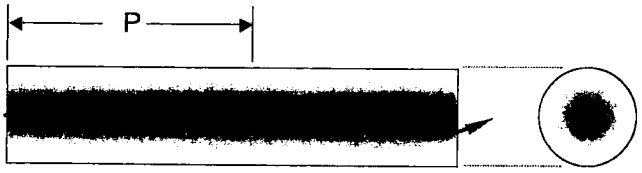
Near-end reflections (< ~cm away from the laser) can be reduced by

- Applying AR coatings to the sides of the coupling lenses and attaching an AR coated glass plate to the input end-face of the SMF residual reflectivity, $R = 10^{-3}$ (Direct AR coating on the narrow end face of SMF is not easy!)
- Index matching gel (n_0): The index n_0 of the gel is chose to be closely matched to the index n_2 of the fiber core. → Residual reflectivity, $R = 10^{-5}$ for $|n_0 - n_2| < 10^{-2}$ (Not so practical in real application!)
- Tilting the input end face of SMF to provide angular separation between incident of reflected light. → By choosing optimum tilting angle, residual reflectivity, $R = 10^{-6}$



What is the GRIN lens?

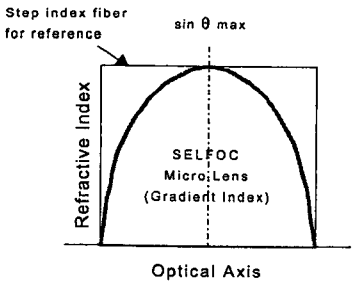
GRIN lens = GRadient INdex lens



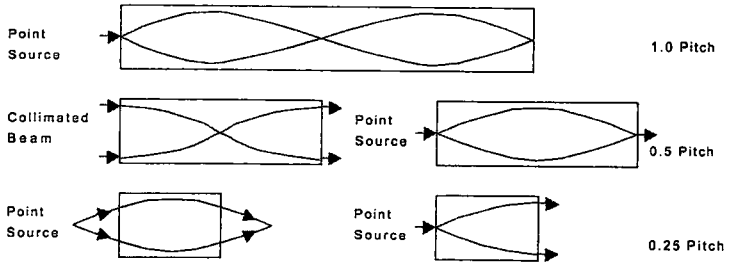
$$Z = \frac{2\pi P}{\sqrt{A}}$$

Z : actual lens length
P : pitch
$\sqrt{A}$: index gradient

Typical refractive index profile



Fractional pitch of a GRIN rod



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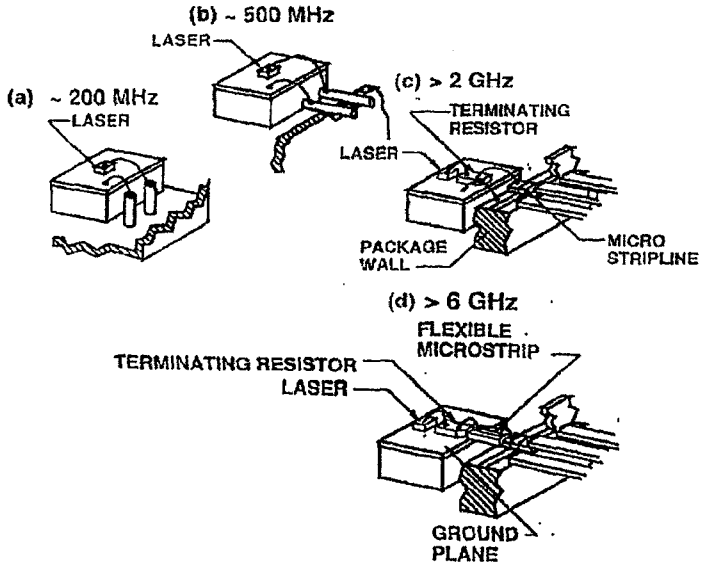
Electrical Aspect

Electrical Consideration of OE Packaging



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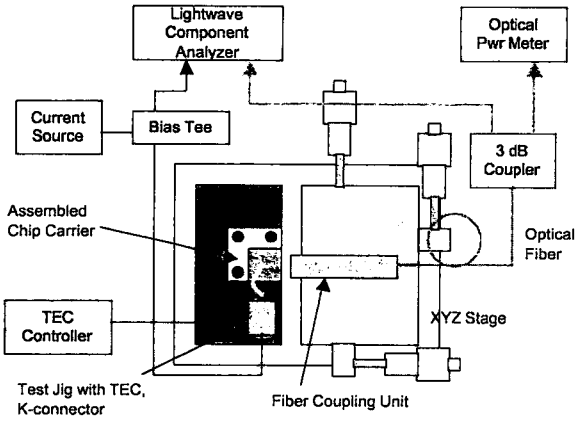
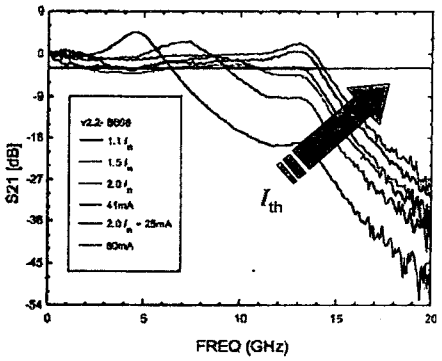
고속 광모듈의 전기적 고려사항

Inductance, return loss, impedance, capacitance

- Wire bonding의 영향: wire의 굵기, 길이, 간격
- 기판의 회로 설계: 전송선의 굵기, 길이, 간격, 형태





Small Signal Modulation of LD

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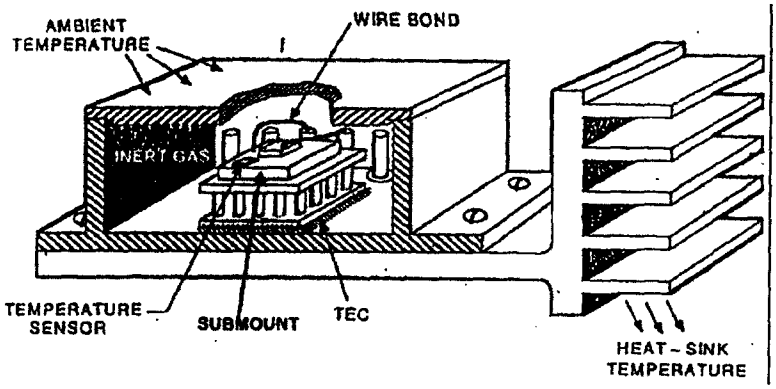
Thermal Aspect

Thermal Consideration of OE Packaging



- Thermal paths from chip to air
  - Chip to submount
  - Wire bonds
  - Fiber/optics
  - Conduction + convection through inert gas
  - Submount to TEC
  - TEC to package body
  - Package body to heat sink
  - Heat sink to ambient environment

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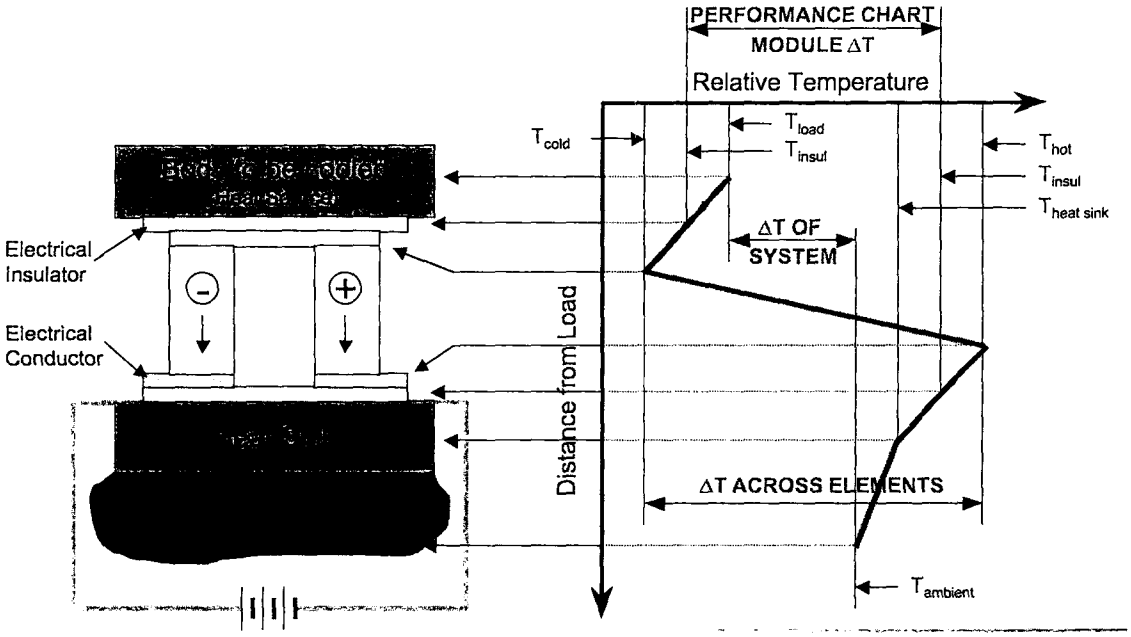
Typical Temp. Relationship in a TEC



Mechanical Aspect

Comparison of Laser Welding / Epoxy / Soldering

Epoxy

- Longer time for curing
- Large shift after curing
- Less reliable
- Small investment
- Easy to process

Soldering

- Relatively short process time
- Large shift due to thermal process
- Mass manufacturable component
- Simple structure

- Laser welding
  - Clean bonding process
  - High speed welding process
  - Small welding point (~600 μm)
  - Small size of thermal affected area
  - Small post weld shift (PWS): 0.1~0.2 dB
  - Weldable between various different materials
  - Rigid and reliable joining
  - Bulky size

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Laser Welding Process

- Laser welding parameter development
  - Laser optics and positioning
  - Laser pulse parameters
    - Energy density, pulse duration and shape
- Package stability and post weld shift ties to:
  - Proper package design
  - Proper optical path design
- Metallurgy analysis
  - Cross-section analysis
  - Depth of penetration
  - Weld joint interaction distance

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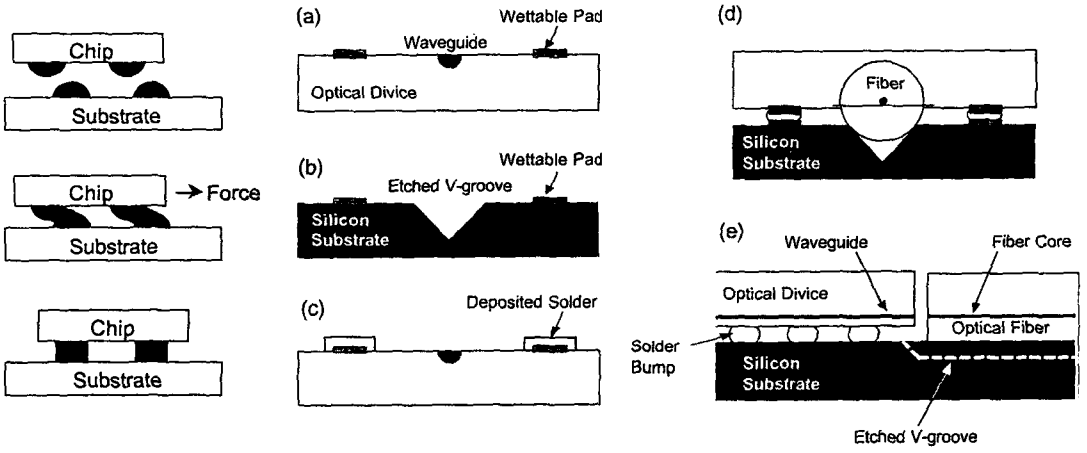
Low Cost Optical Package

Concept of Passive Alignment



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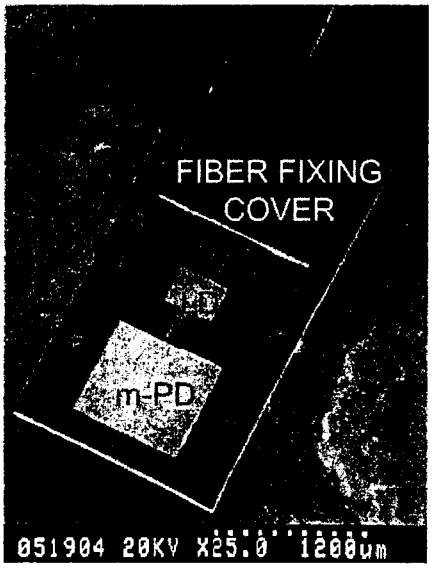
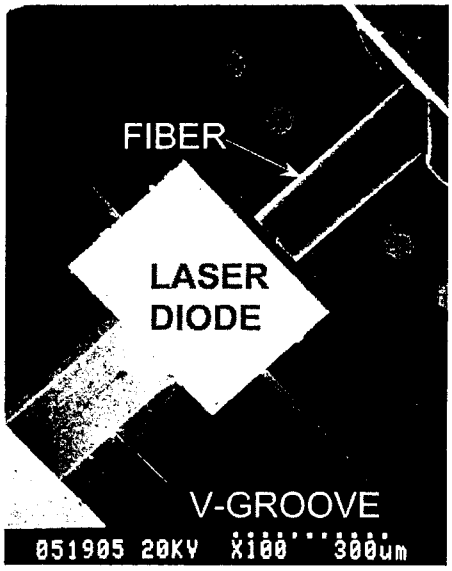
Example of The Passively Coupled





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Optical Array Package

Need of Optical Array Packaging

장거리 광통신 망의 효율 증대 필요
- 시간배분을 통한 광섬유 이용 증대: 다채널 소자
- 신호전송의 효율성 극대화: WDM 소자, 대채널 소자

단거리 망의 활성화
- CATV, LAN 등 가입자 망 이용 증대: 다채널 소자
- 단거리 시내 망의 복잡성 증대: 복합 소자, 다채널 소자

광결합 모듈의 소형화/병렬화
- 시스템의 성능 향상 및 소형화: 집적소자, 다채널소자
- Circuit board 간 bus의 광화: 광 병렬 소자

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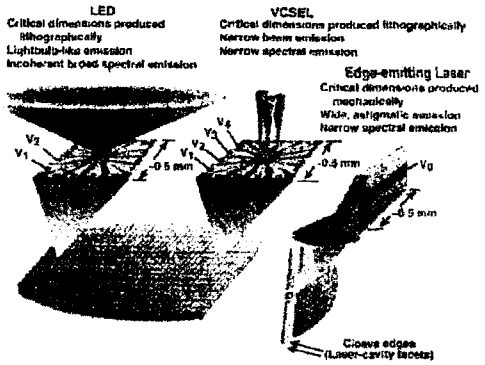
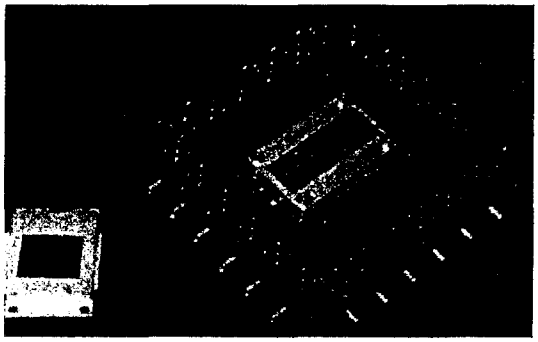
Parallel Fiber Optic Interconnect

광원의 종류



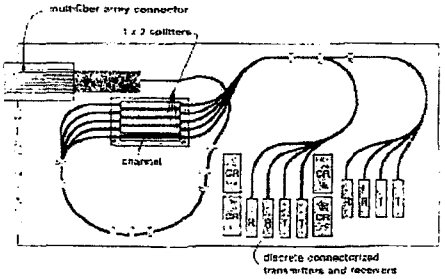
고속 병렬형 광배선 모듈



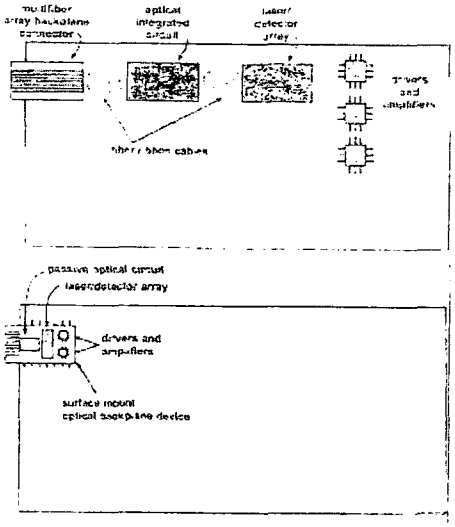
(Optobahn사, 미국)

Packaging Emerging Tech for Parallel Optics

1. Principal Feature of Backplane



2. Array Style of Backplane

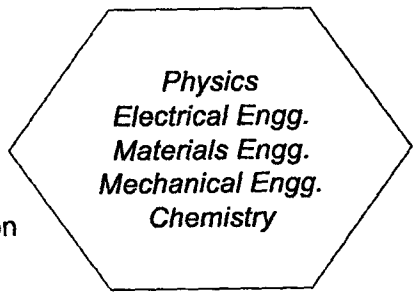


3. High Density Backplane

Summary

Thermal path
- Heat sink structure
- thermal characteristics

Optics
- High coupling efficiency
- Low optical reflection



Reliability aspect
- Failure mechanism
- Lifetime projection

Electrical consideration
- Modulation BW
- Impedance match

Process development
- Die bonding
- Wire bonding
- Epoxy bonding
- Flip-chip bonding
- Laser welding

Optoelectronic Packaging
= interdisciplinary research

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