Novel Optoelectronics Devices for Broadband Photonics Network Applications

WOCC'2004, March 9, Taipei, Taiwan

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Major Breakthroughs in Optoelectronic Materials and Devices and Impacts on Communication

- **1970's:**
  - □ Low loss fibers & Heterojunction semiconductor lasers, e.g low threshold devices
  - □ Impacts: Foundation of modern fiber communication
- **1980's:**
  - □ DWDM & EDFA
  - □ Impacts: Deployment of Broadband DWDM systems
- **1990's:**
  - □ VCSEL, Raman amplifers
- **2000's:**
  - □ QD devices, Photonics crystals
  - □ Impacts: ?

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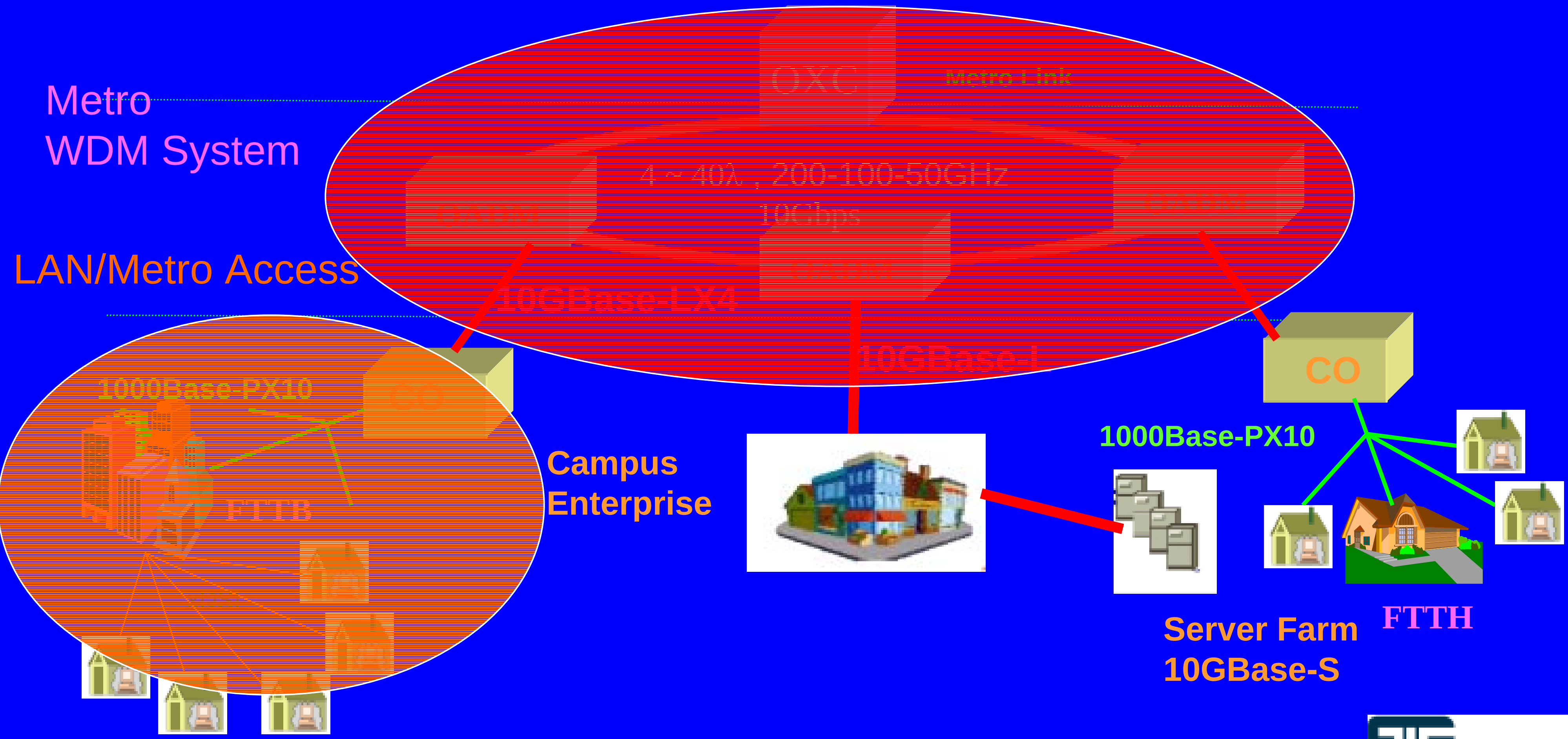
Metro/Access and Ethernet-based Technology

- FTTX
- 10Gbps Metro Ethernet



Device Technologies for Optical Communication

- **Current Devices technologies**
  - □ **High speed Ethernet modules**
  - □ **Low cost WDM modules**
- **Current development**
  - □ **GaAs-based Long wavelength VCSEL**
  - □ **Optical MEMS, PLC**
- **Future devices technologies**
  - □ **Nano-photonics technology**
    - QD devices
    - Photonic Crystals
    - ...

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Device Technologies for Optical Communication

- Current Devices technologies
  - High speed Ethernet modules
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  - long wavelength VCSEL
  - Optical MEMS, PLC
- Future devices technologies
  - Nano-photonics
    - QD devices
    - Photonic Crystals

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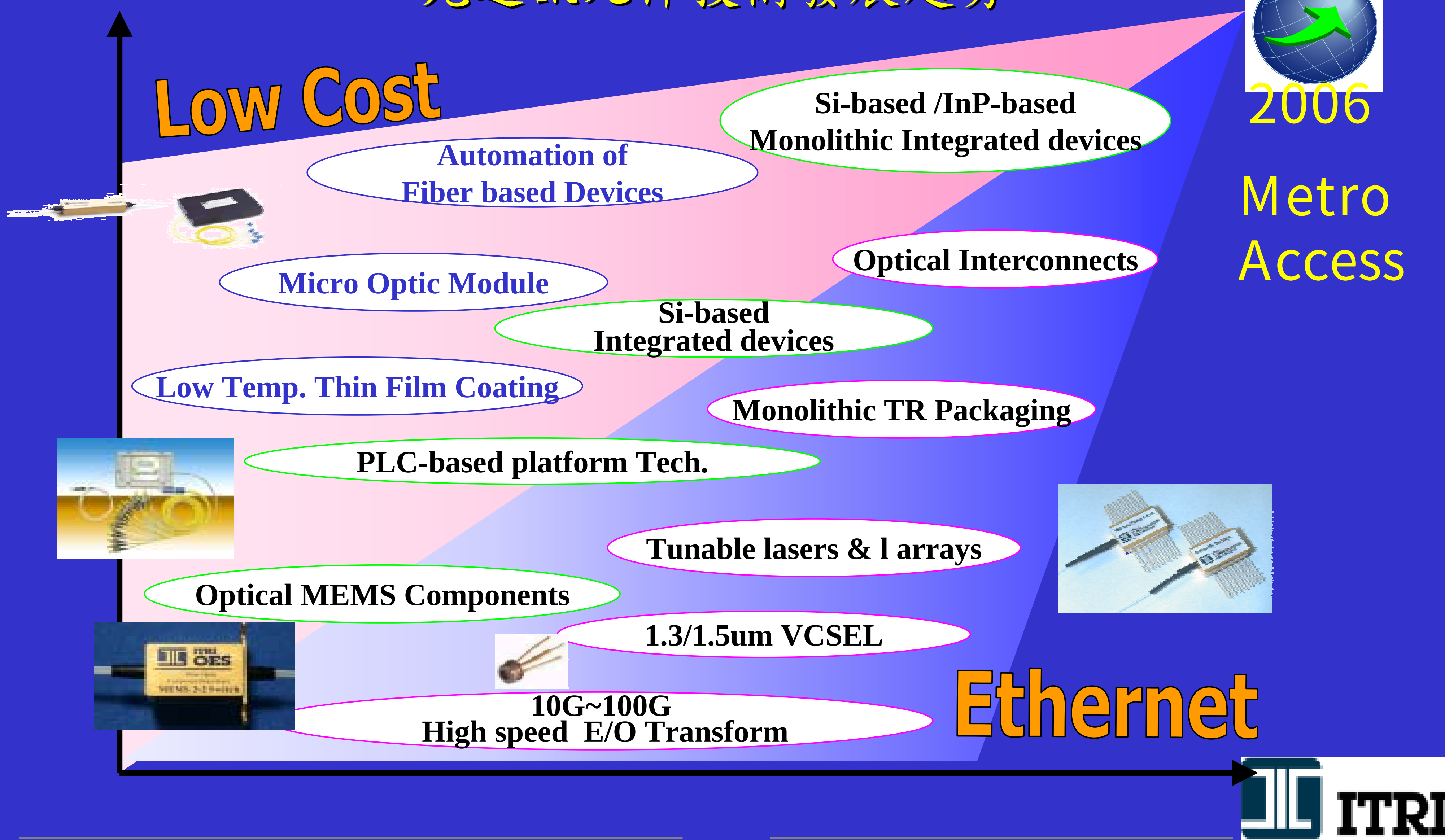
Technology Roadmap

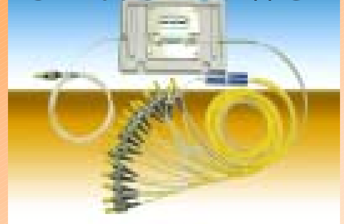
光通訊元件技術發展趨勢



Current Devices Technologies

PLC type Interleaver

1x32 100GHz AWG

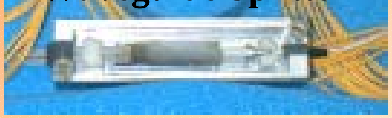


1x2/2x2
MEMS Switch

MEMS VOA

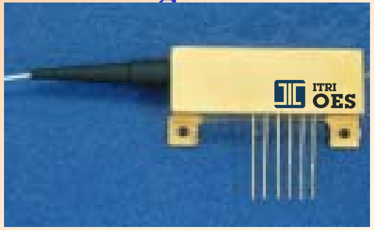
10G 高速光通訊元件
1550 nm DFB LD Chip

1 x N Planar
Waveguide Splitter



高功率Pump雷射耦合器

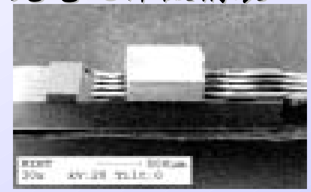
Wavelength locker



10Gb/s XFP Transceiver

蝶式模組封裝技術

光電元件微構裝



12 Channels
Array Transmitter

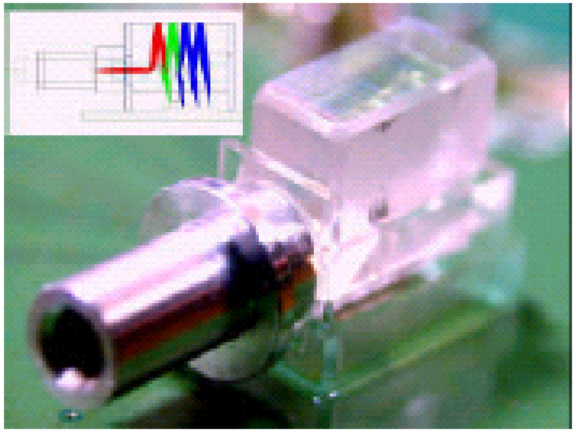
10Gbps LC XENPAK
Transponder

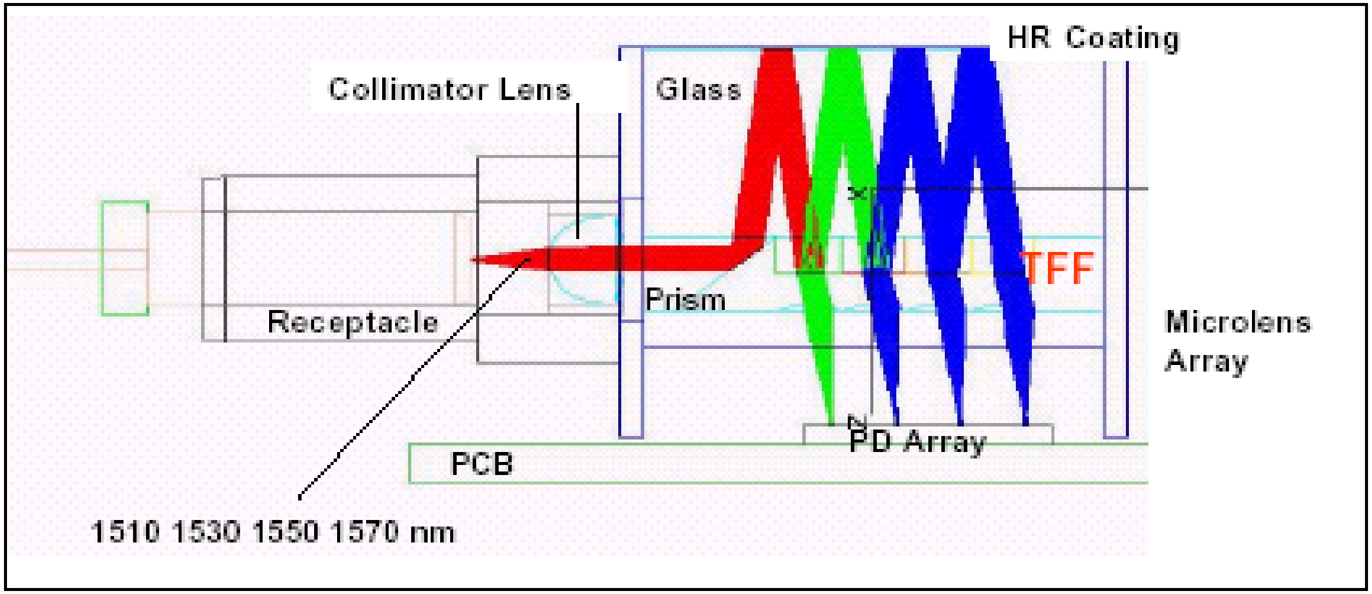
10Gbps SC XENPAK
Transponder

10Gbps Mini-Flat TOSA

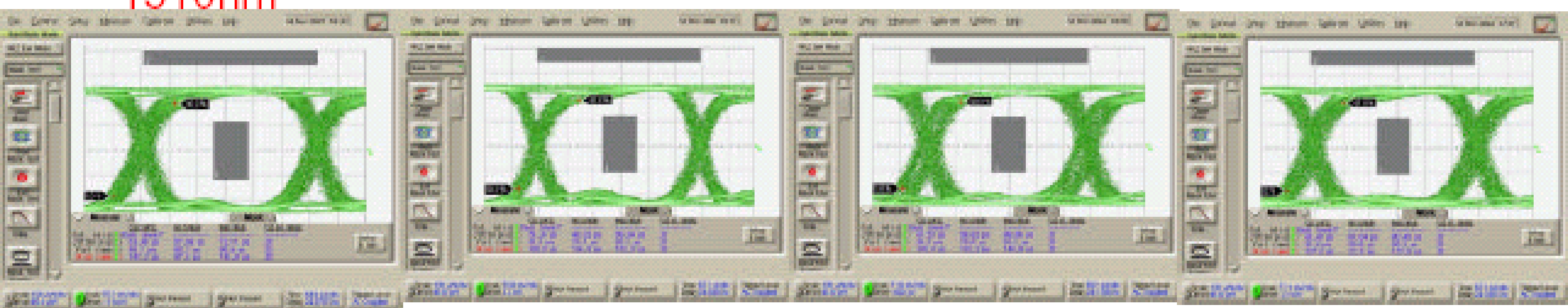
10Gbps 1310nm
DFB TOSA

CWDM Mini-ROSA_Eye Pattern





1510nm 1530nm 1550nm 1570nm



RS=-20.45dBm RS=-19.38dBm RS=-18.23dBm RS=-16.94dBm

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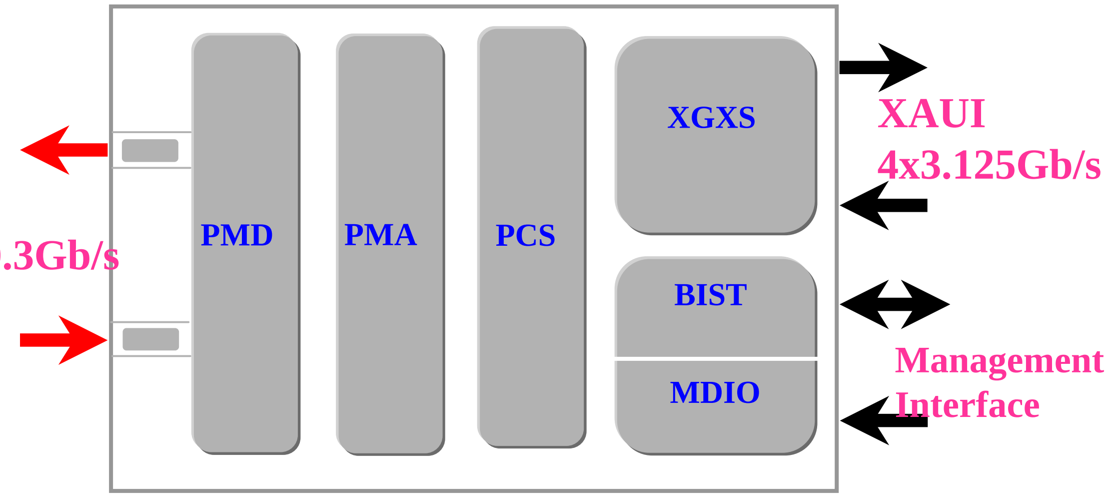
10Gbps XENPAK Transponder



Applications:

- Ethernet switches and routers
- Cross-connects
- WDM terminals
- Metro system equipments
- Optical test equipments

Shown at OFC 2003

Features

- 10.3 Gbps optical Tx/Rx with 4-channel XAUI 3.125Gbps I/O electrical interface
- Compliant with IEEE 802.3ae
- Compliant with XENPAK MSA
- 850nm VCSEL laser, and PIN Detector
- Hot pluggable in the Z- direction
- SC duplex fiber-optic connector

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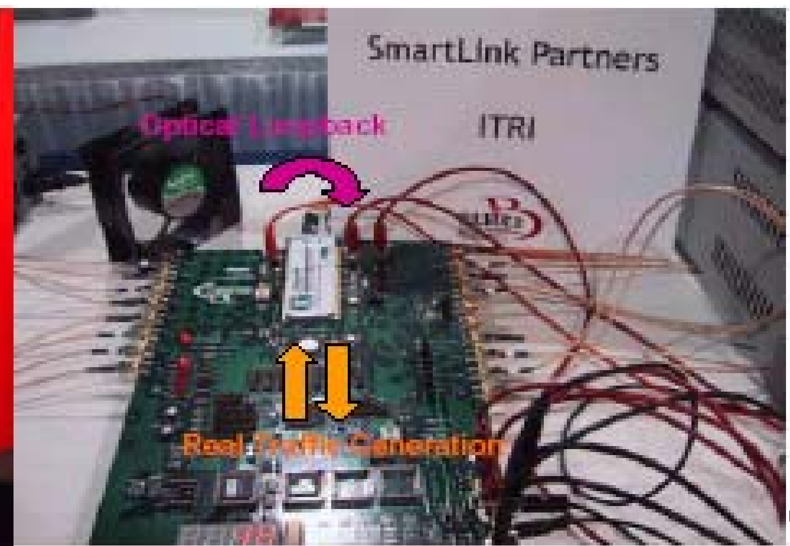
OES Developed 10 Gbase-SR Xenpak Transponder

Real Traffic Verification on OFC2003

Blaze Molex OES Alvesta Ignis E2O

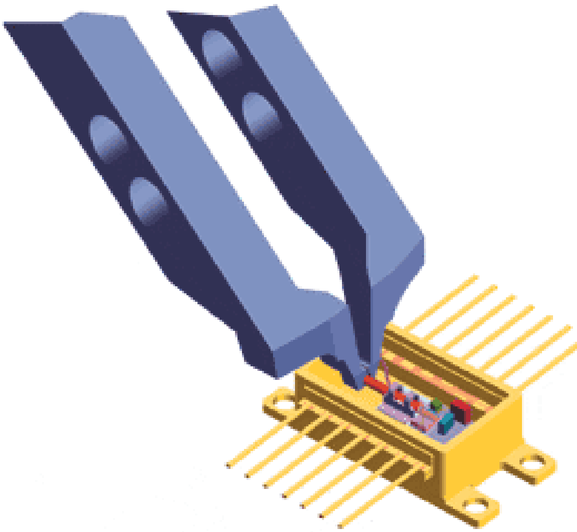


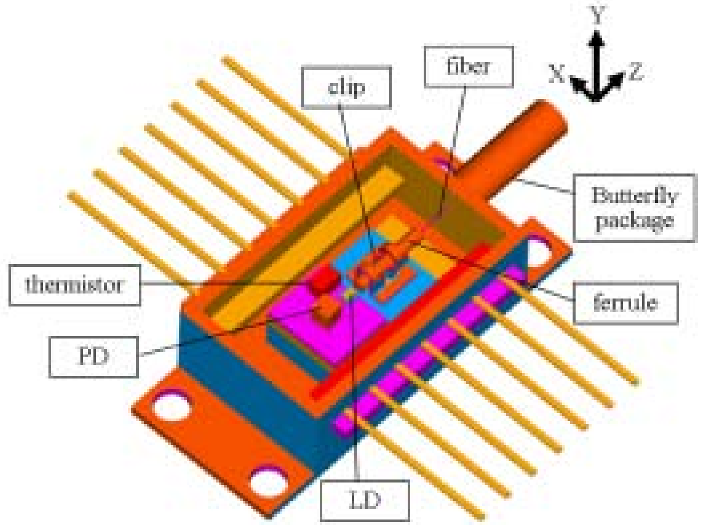
Clear & Open Eye

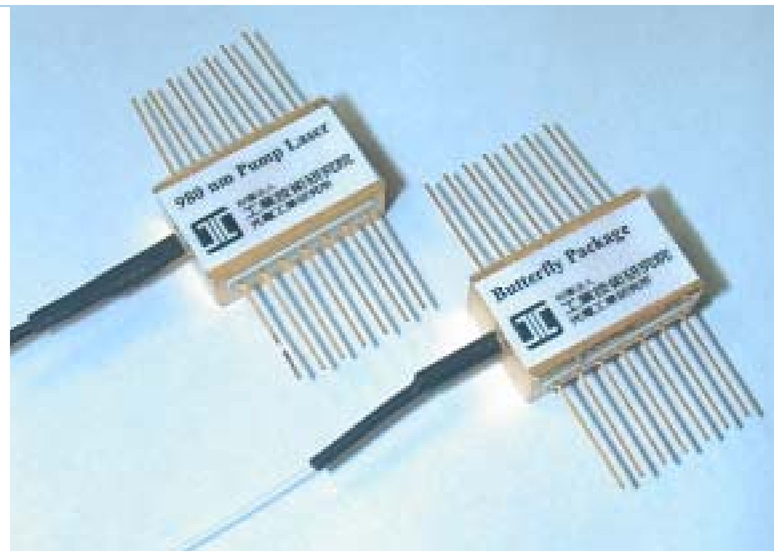
Error Free Indicator on LED Display

蝶式模組封裝技術

(Butterfly Packaging for 980 nm Pump Laser Module)







關鍵技術

- 元件設計製作
- **LD/PD** 晶粒接合技術
- 透鏡光纖接合技術
- 模組封裝測試
- 主動對準
- 雷射焊接，
  精確度要求在**0.5**μ**m**以下

技術應用

- 高功率幫浦雷射元件的封裝
- 高速（**>2.5Gbps/s)** 雷射元件的封裝
- 光纖放大器

特 色

- 高功率模組
- 高穩定性
- 低成本封裝
- 散熱效率高
- 電磁干擾（**EMI**）低

Device Technologies for Optical Communication

- Current Devices technologies
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  - Low cost WDM modules
- Current development
  - GaAs-based Long wavelength VCSEL
  - Optical MEMS, PLC
- Future devices technologies
  - Nano-photonics technology
    - QD devices
    - Photonic Crystals

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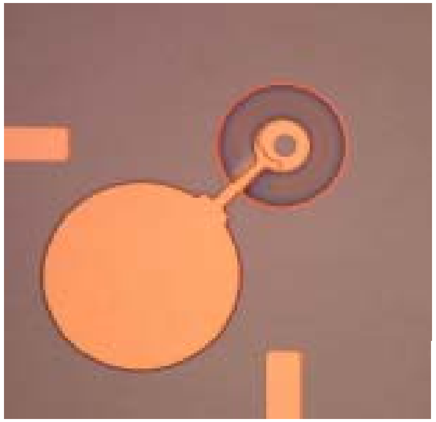
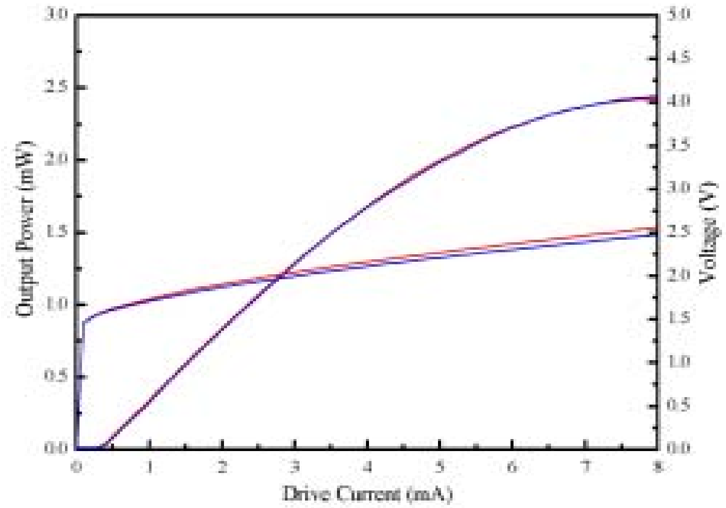
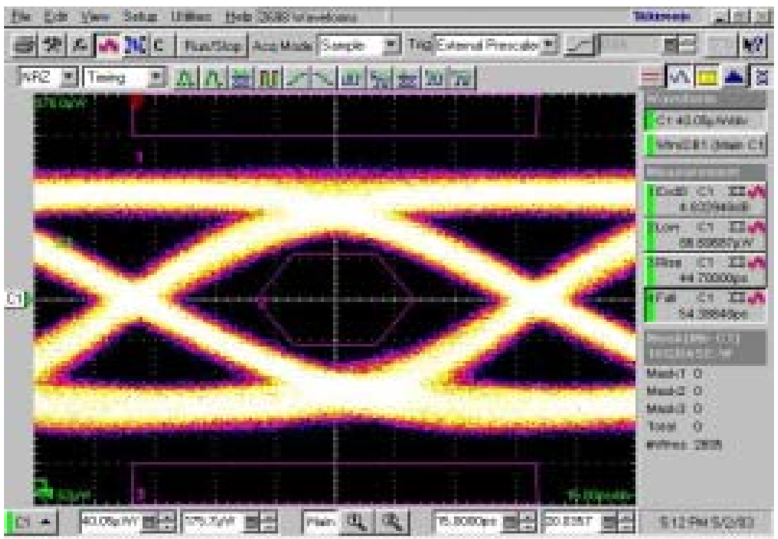
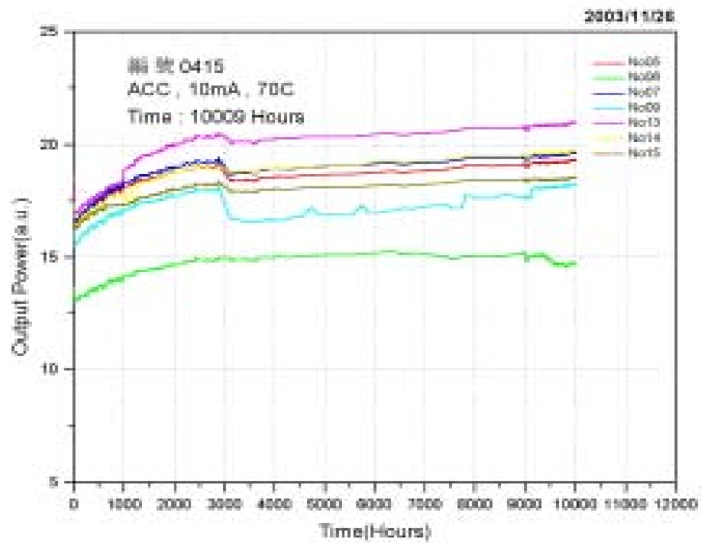
850nm SM VCSEL Operating up to 10G



- N-tpye GaAs substrate
- Simple and manufacturable process
  (as the general semiconductor process)
- Probe screening prior to package



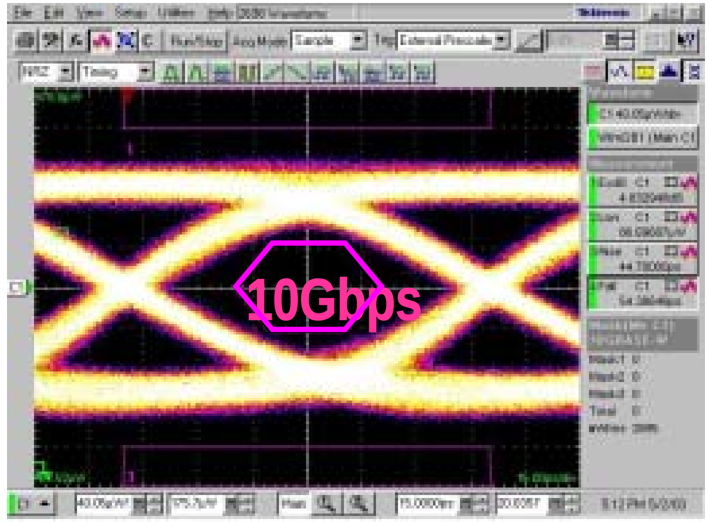




10Gbps 850nm VCSEL

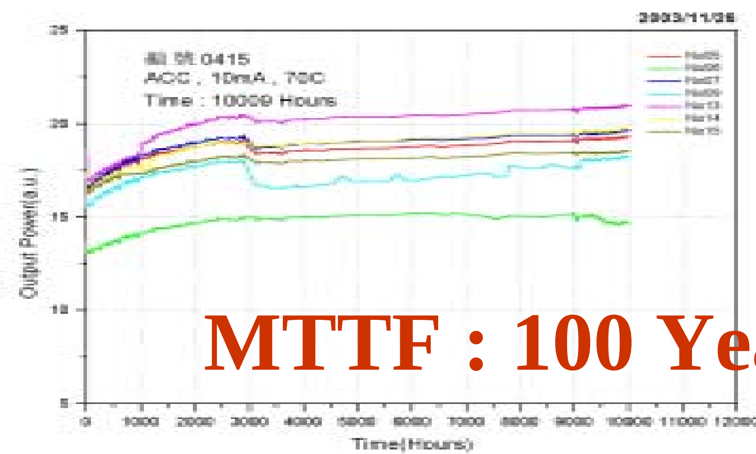
- Simple and manufacturable process
- Probe screening prior to package
- N-tpye GaAs substrate
- TO-46 package for high speed

Eye diagram



Epi-wafer & TO

Reliability Test for Oxide VCSELs



MTTF : 100 Years

10Gbps 850nm VCSEL TOSA

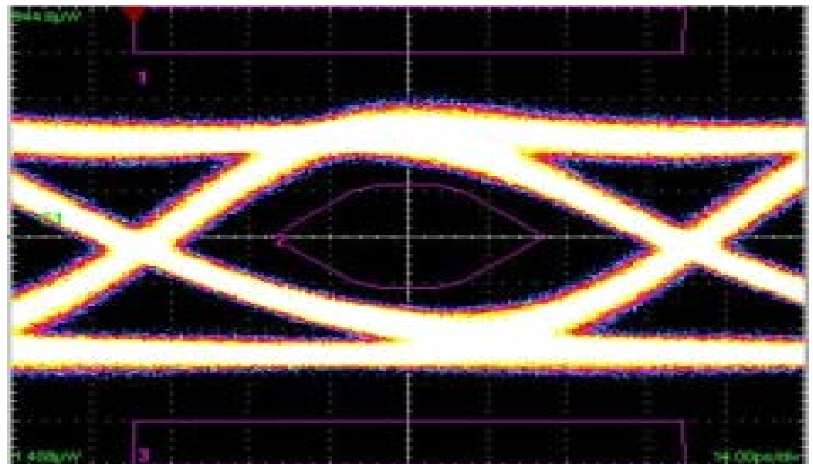
Features

- Low cost TO-Can Package
- 850nm VCSEL TOSA
- 10Gb/s suitable for 10GE/10GFC
- SC/LC receptacle package
- Flexible board option
- Operate in a temperature range from 0℃ to 85℃

Optical Specifications

Parameter	Symbol	Min.	Typ.	Max.	Unit
Operating wavelength	λ	830		860	nm
RMS spectral width (optional)	$\Delta\lambda_{rms}$			0.85	nm
Rise/Fall Time	Tr/Tf		35		ns
Average launch power in OMA	OMA	-5.2			dBm
Average launch power (max)	Pavg			0	dBm
Extinction ratio	r_e	3.5			dB
RIN_{12}-OMA	RIN			-128	dB/Hz
Optical return loss		12			dB
Eye Mask of optical output	Compliant with IEEE 802.3ae draft 5.0 specifications				

Eye Diagram



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10Gbps 850nm VCSEL-based XFP

Features :

1. IEEE 802.3ae compliant
2. XFP MSA compliant
3. 10 Gbps Tx/Rx with XFI high speed I/O electrical interface
4. Transmission distance up to 60M
5. Ultra small form factor
6. Hot pluggable in the Z direction
7. Duplex LC fiber-optic connector

Optical Specification

Parameter	Symbol	Min.	Typ.	Max.	Unit
Operating wavelength	λ	830		860	nm
RMS spectral width (optional)	Δλ			0.85	nm
Rise/Fall Time	Tr/Tf		35		ns
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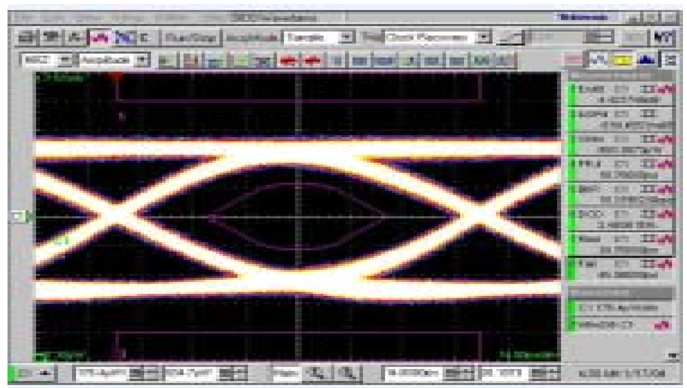

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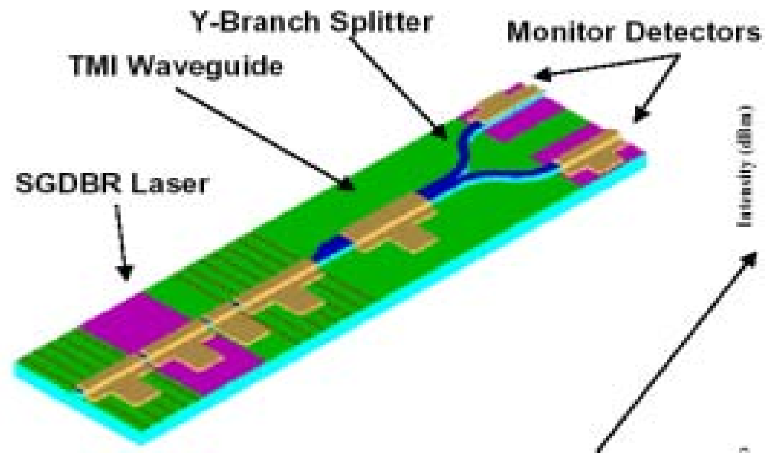
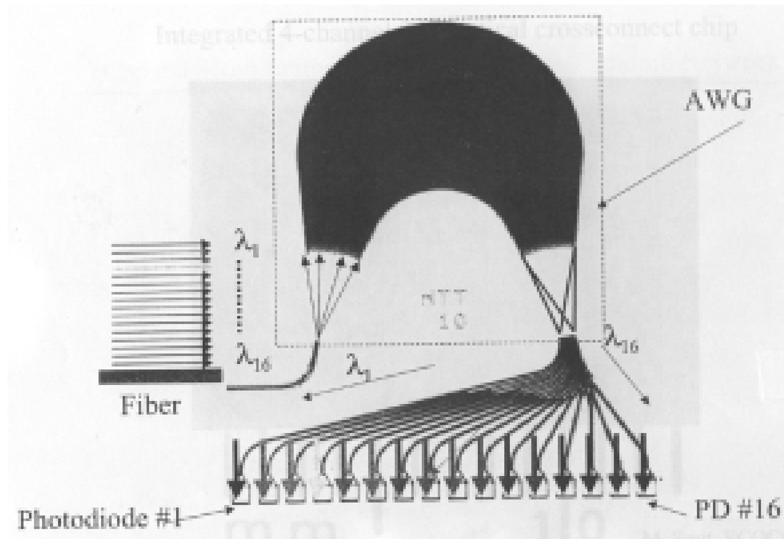
Applications of the New 1.3 μm Technologies

1. **VCSELs and FPs**
   - Low cost
   - Temperature stability
2. **Optical Interconnect**
   - Low threshold QD VCSEL arrays
3. **Integrated optical devices based on GaAs substrates**
   - III-V Waveguides
   - Monolithic CWDM array
   - Semiconductor Optical Amp. (SOA)
   - EA+DFBs
   - …..
4. **Low power HBTs**





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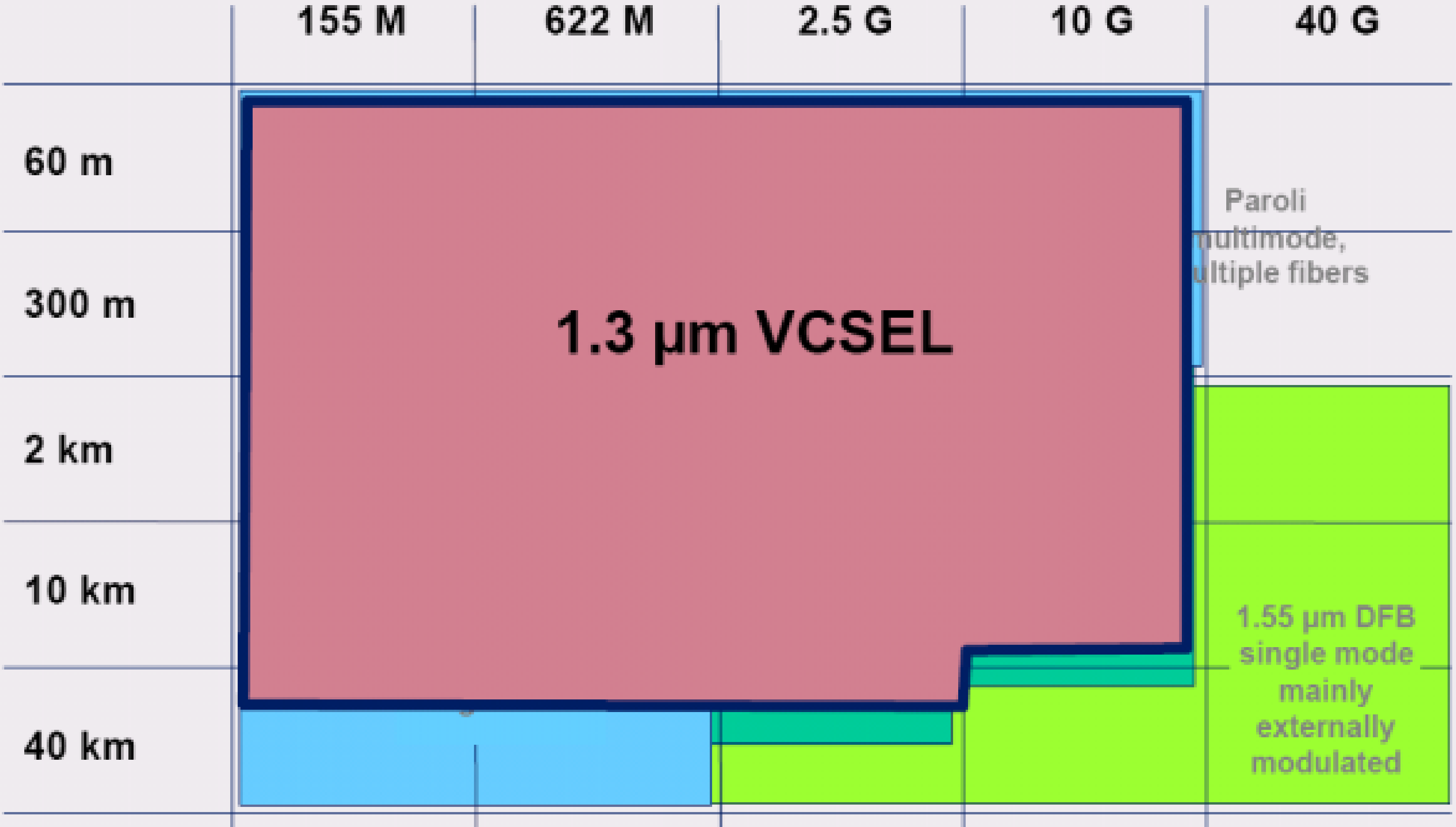
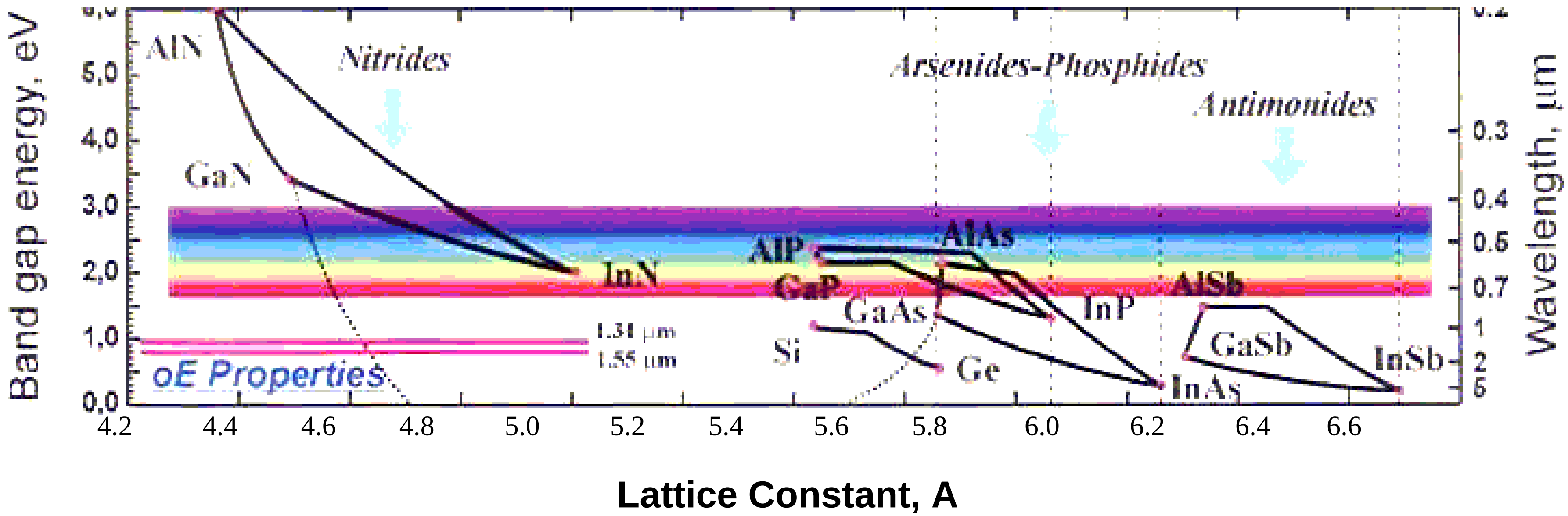
Features & benefits

Unique properties of 1.3 µm VCSEL make it applicable for largest part of todays transmission market

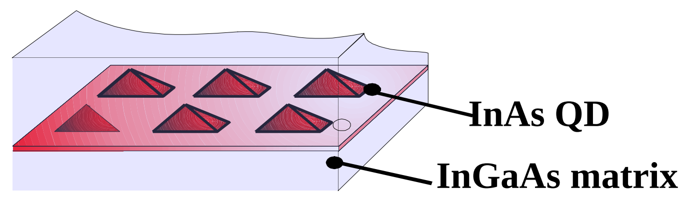


- → **Replacement of 1.3 µm edge emitters in Datacom due to more cost effective packaging**
- → **Replacement of 850 nm VCSEL due to increased laser safety, larger reach in multimode fibers**

Epitaxial materials for 1.3 um VCSELs



- Conventional long wavelength epitaxial materials, InGaAsP/InP, is not suitable for 1.31 um VCSELs!
- New approaches are needed!
  - **Approach 1. InAs/InGaAs QDs/GaAs**
  - **Approach 2. InGaNAs/GaAs: Adding N to InGaAs to reduce the lattice strain and lower the bandgap**



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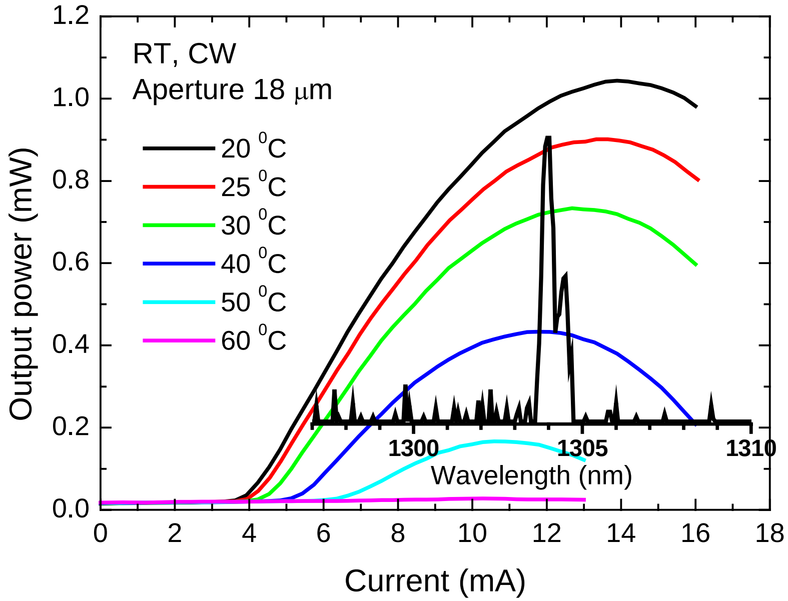
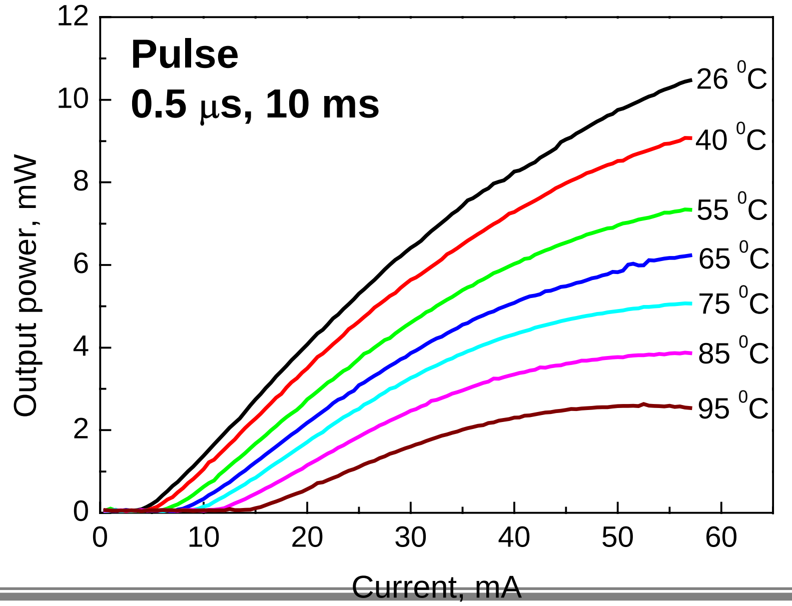
1310 nm InGaAsN VCSEL (MBE)





Intra-cavity design grown by MBE

Performance of 18 μm aperture

RT, CW, I_{th}=4 mA,

Max power=1 mW,

Slope efficiency=0.15 W/A,

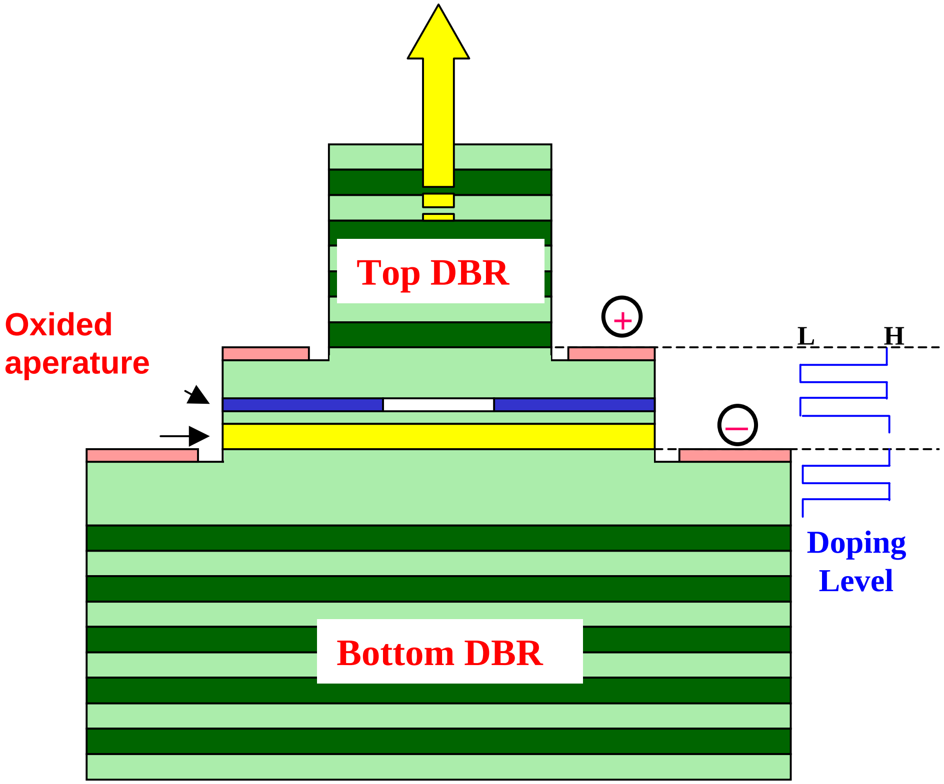
J_{th}=1.6 KA/cm^2,

Wavelength =1304 nm

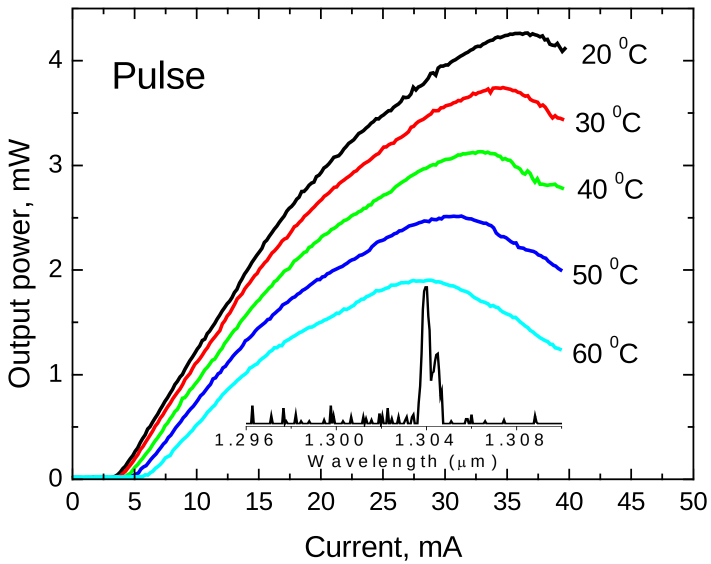
MBE InGaNAs QW VCSELs

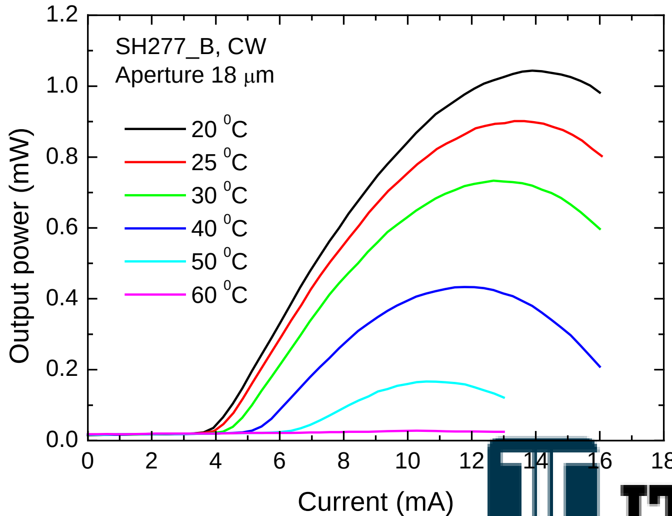
CW@RT, I_{th}=4 mA, P_{max}=1 mA, J_{th}=1.6 kA/cm²

(J_{th} world lowest reported data)



Intracavity





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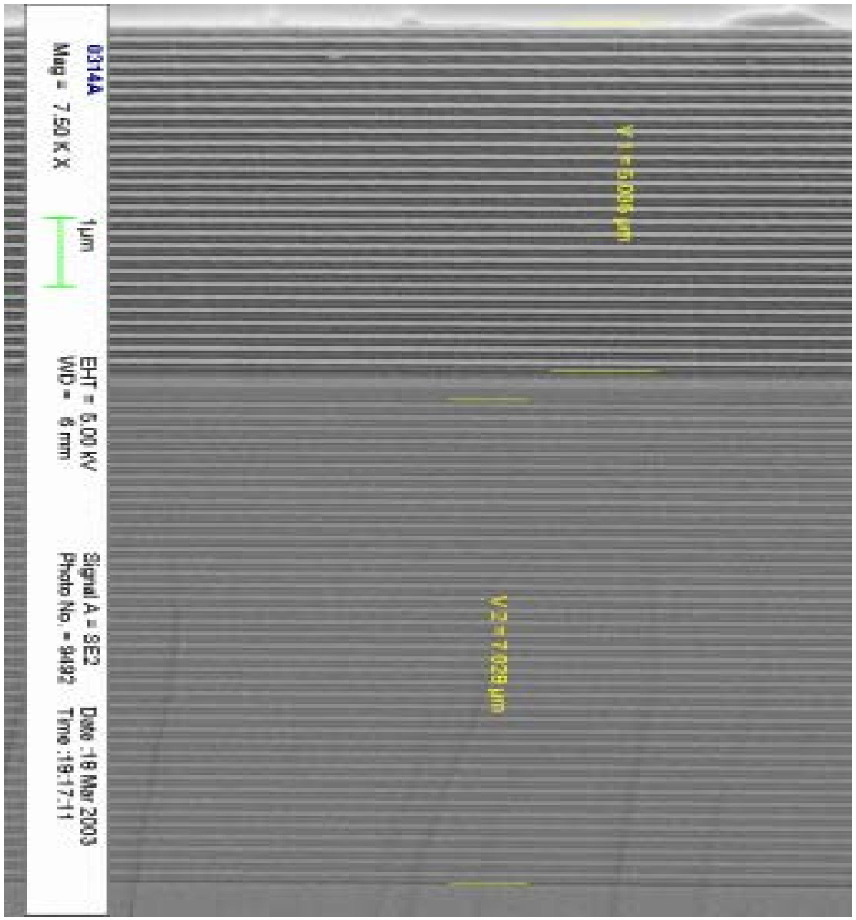
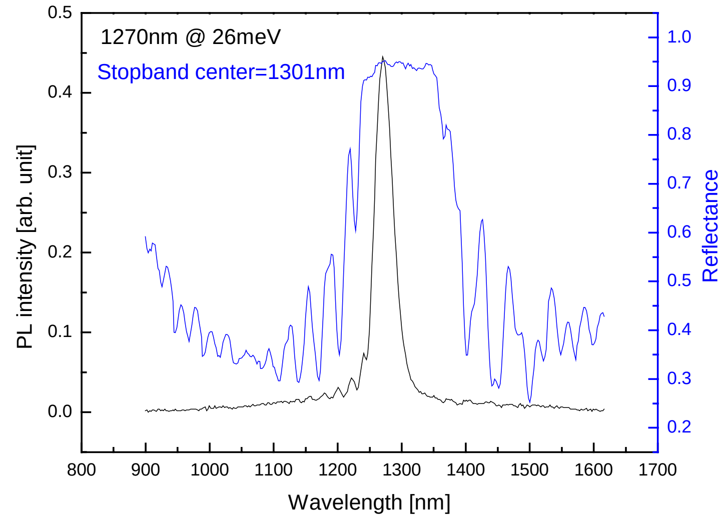
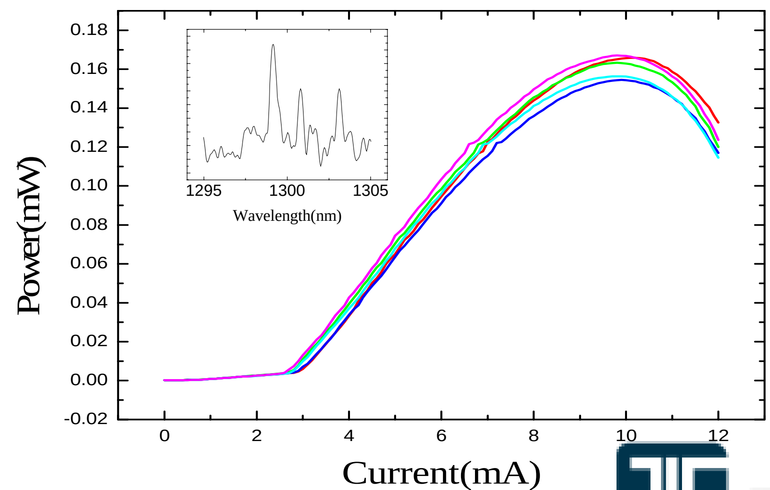
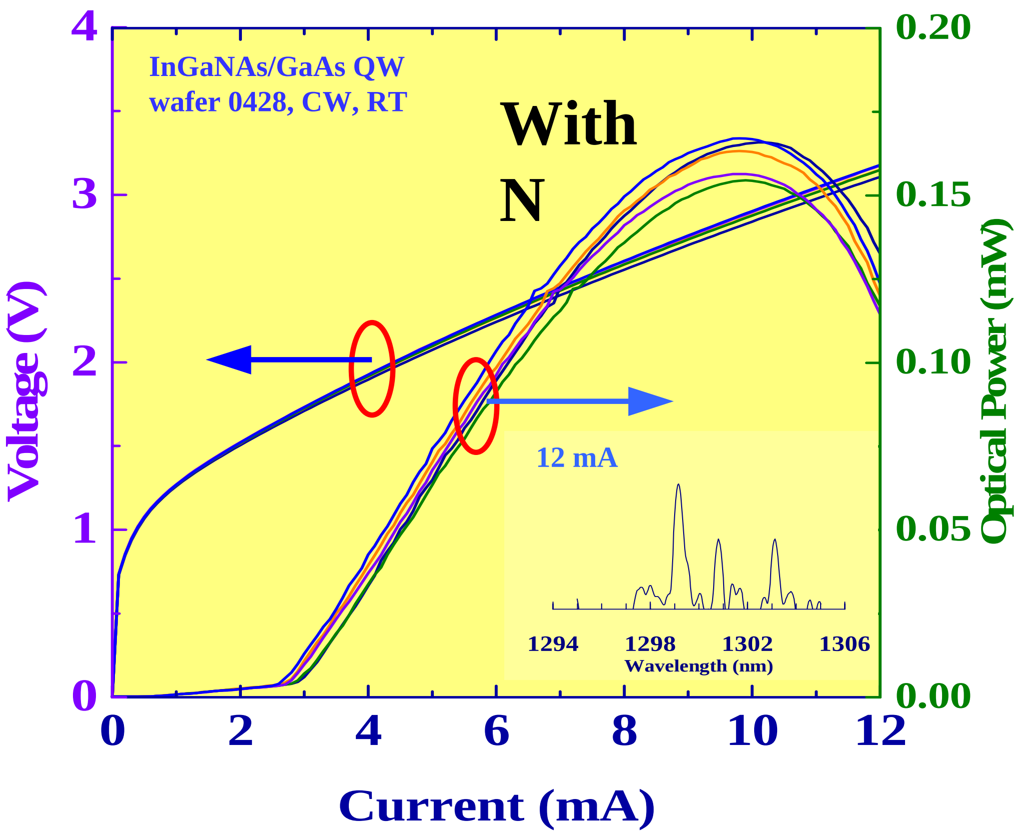
MOCVD InGaNAs$_{QW}$ VCSELs

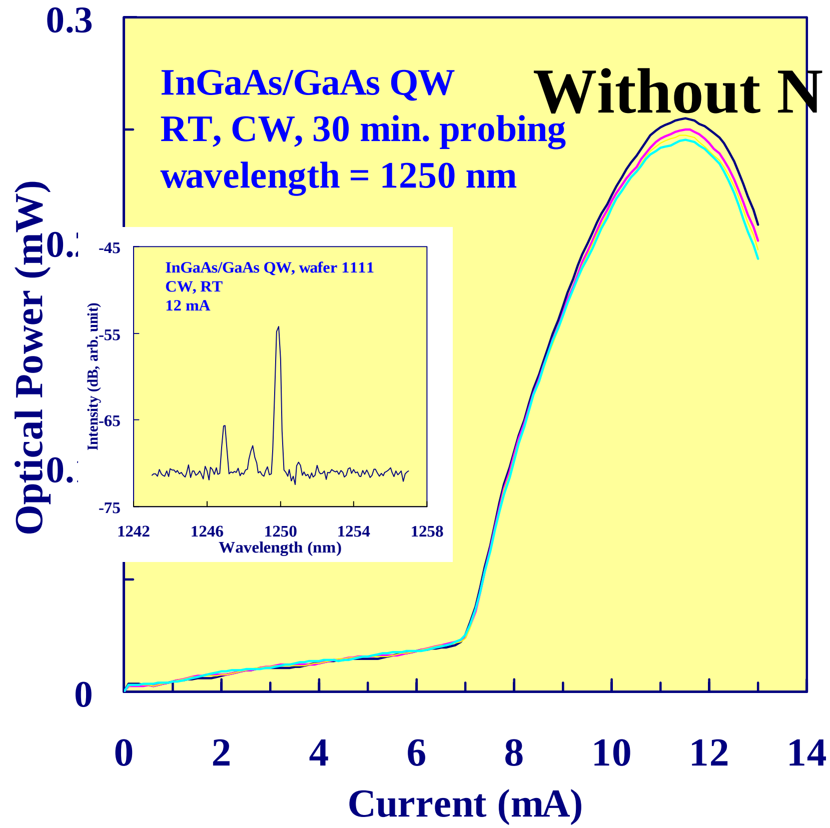






L-I-V and Spectra of InGa(N)As VCSELs(MOCVD)

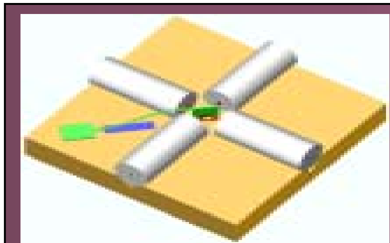




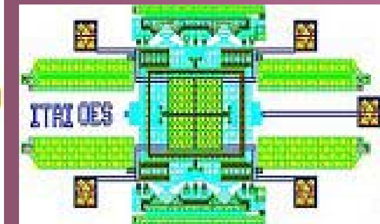
- I_{th} = 2.5 to 3 mA @ 20°C, J_{th} = 3.2 to 3.8 kA/cm^2. $P_{o,max}$ = 0.17 mW.
- Lasing wavelengths: 1299 to 1303 nm @ 10 mA.
- I_{th} = 6 to 7 mA @ 20°C, J_{th} = 5 to 5.6 kA/cm^2. $P_{o,max}$ = 0.3 mW.
- Lasing wavelength 1245 to 1250 nm @ 12 mA.

ITRI/OES Optical MEMS

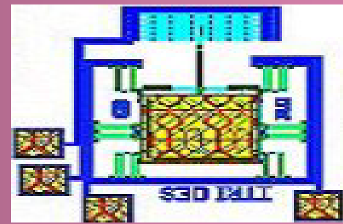
Design



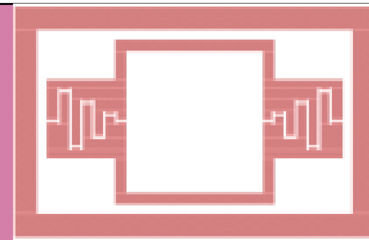
2x2 Design for OS



2D Scanning Mirror



1D Scanning Mirror

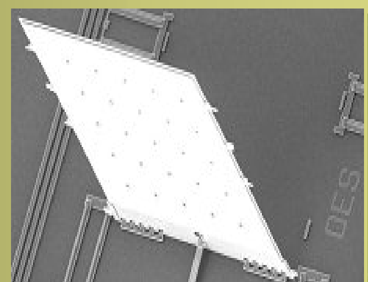


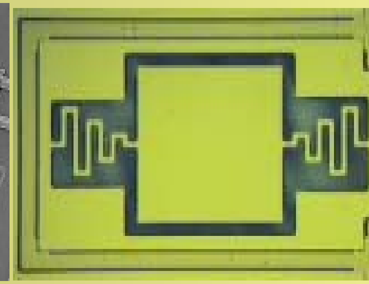
SOI Scanning Mirror

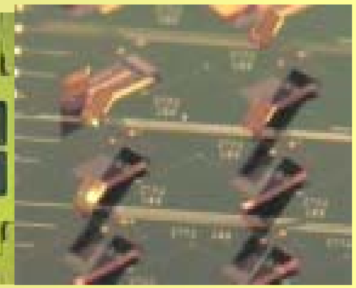
8x8 Optical Switch

Design & Core Technology

Fabrication







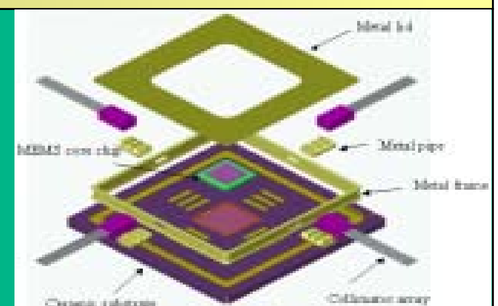
Fabrication

Packaging & Testing

2x2 Switch Package

VOA TO Package

Collimator Array



Hermetic Packaging

Packaging & Applications

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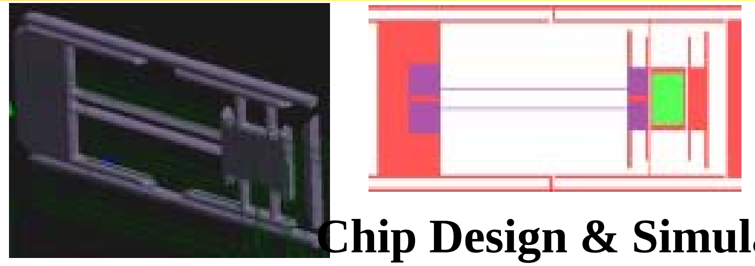
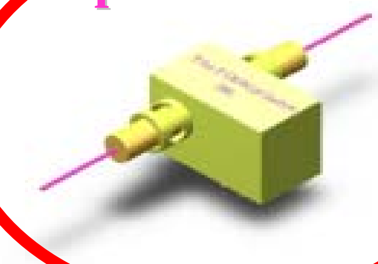
1D/2D Optical MEMS Switch

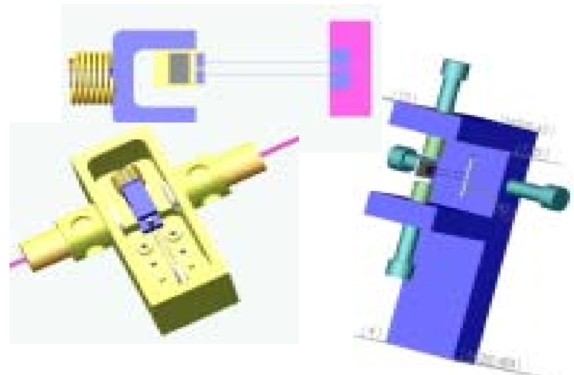
Bulk Micromachining & UV-LIGA Process



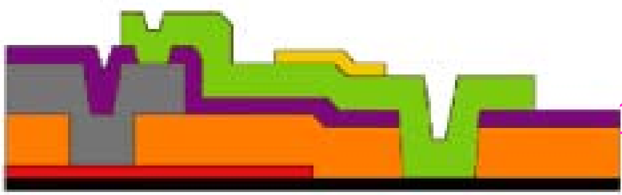
Chip Design & Simulation

2x2 Optical MEMS Switch



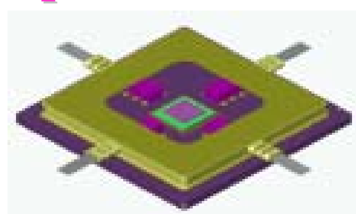


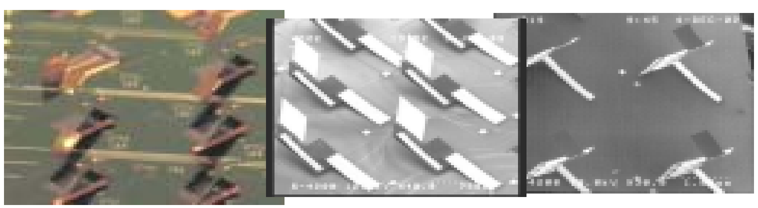
Magnetic Circuit Design



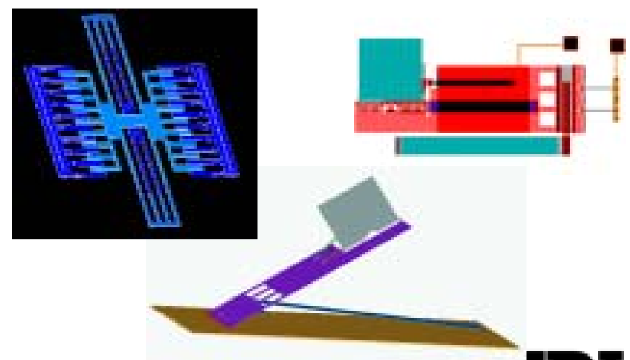
Surface Micromachining

1x4/4x4 Optical MEMS Switch



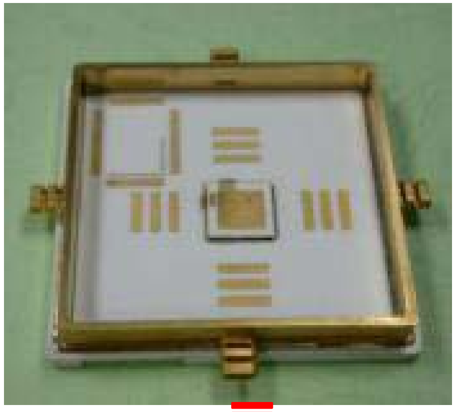


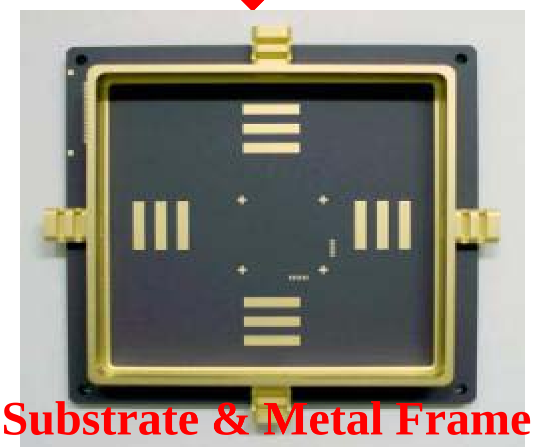
Stress-Induced Self-Assembly



Chip Design & Simulation

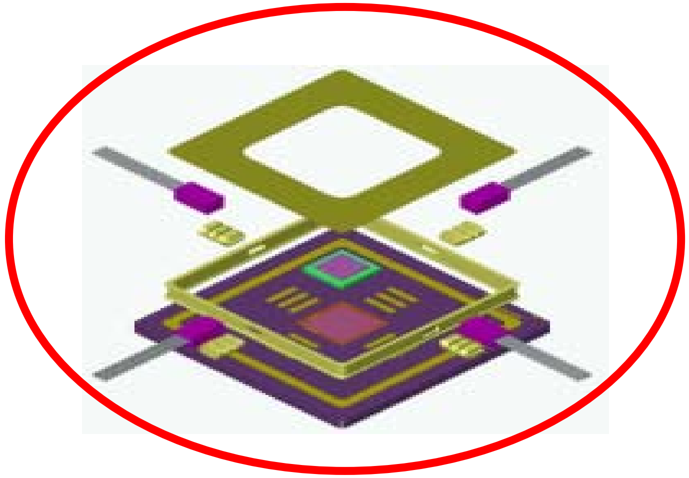
Packaging of NxN Optical Switch- ITRI/OES

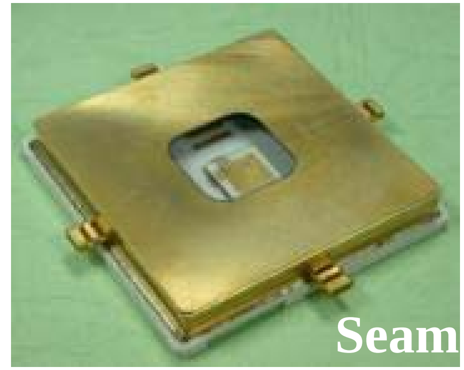


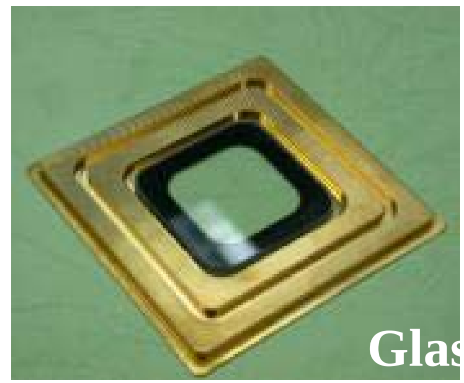


Substrate & Metal Frame

Hemertic-seal







Metal & Glass Lid

Hemerticity (leak test) : achieved specs. 1╳10-8 atm He.CC/sec

Isolation resistance : achieved specs. 1╳1011 ohm

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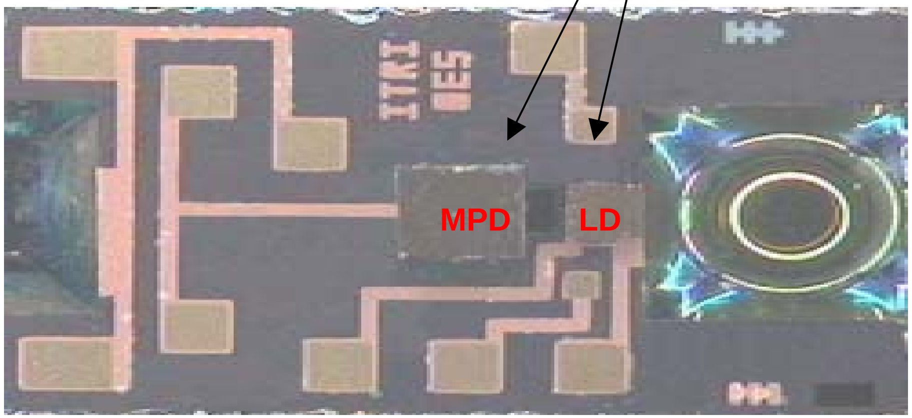
High Speed Passively aligned OSA



關鍵技術

- Si Bench製程技術
- AuSn soldering製程技術
- Flip Chip bonding技術

技術應用

- 1.25G, 2.5G, 10G Transmitter / Receiver module

特色

- 被動對位構裝技術
- 用於陣列式模組技術
- 用於高速mini-DIL 或 Butterfly模組

規格

- Single channel 1310nm/1550nm LD
- Single channel 850nm VCSEL
- Multi-channel1310/1550nm LD
- Multi-channel 850nm VCSEL

Device Technologies for Optical Communication

- Current Devices technologies
  - High speed Ethernet modules
  - Low cost WDM modules
- Current development
  - long wavelength VCSEL
  - Optical MEMS, PLC
- Future devices technologies
  - Nano-photonics technology
    - QD devices
    - Photonic Crystals

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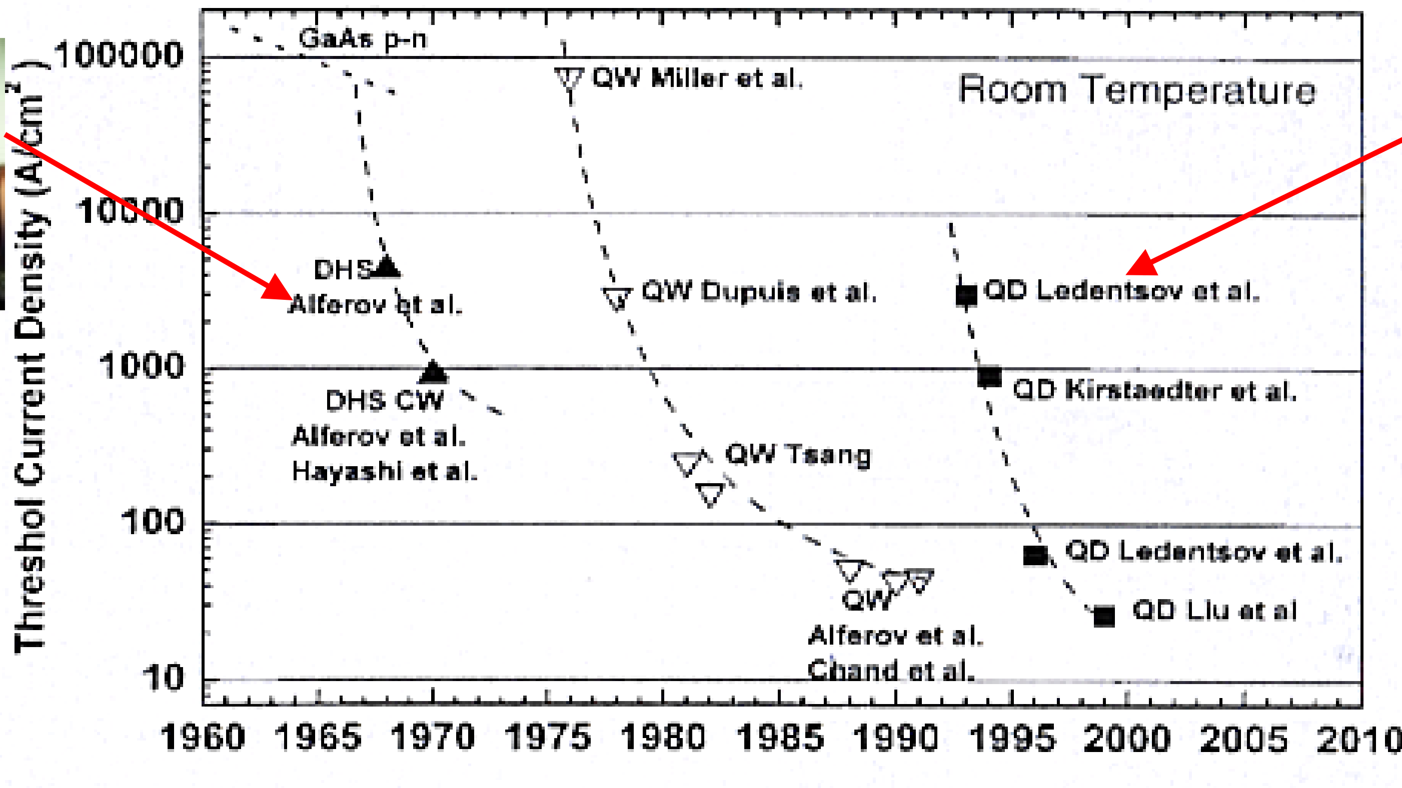
ITRI OES Development of Hetero-structure Laser Diodes

N. Ledentsov, IEEE J. Select. Topics Quantum Electron., 6, 439, 2000



After the success of the quantum well lasers, researchers began to investigate structures of lower dimensionality, e.g. quantum wires and dots. Several approaches has been investigated and soon found limitation due to the increased surface/interface area that lower the radiative recombination efficiency of the injected electron -holes. SK mode of growth has the unique ability to avoid the surface effects!

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Advantages of Quantum Dot Lasers
- *the Ultimate Nanostructure*

- **Tunability of emission wavelength by QD size and composition. *GaAs-based light sources* cover the entire range of wavelength, from 700-1310 nm that are important to communications.**

✓ **Extension of the possible wavelength regime on GaAs substrates to**

$\lambda \geq$ **1300 nm**

✓ **Lower threshold current densities**

✓ **High characteristic temperature T_0 at 1300 nm**

- **Suppressed carrier diffusion ⇨**
  - lower facet temperature,
  - no beam filamentation,
  - lower M_2 and
  - radiation hardness
  - higher output power
- **High modulation frequency, low alpha factor**
- **High-efficiency VCSELs at 1300 nm based on GaAs**

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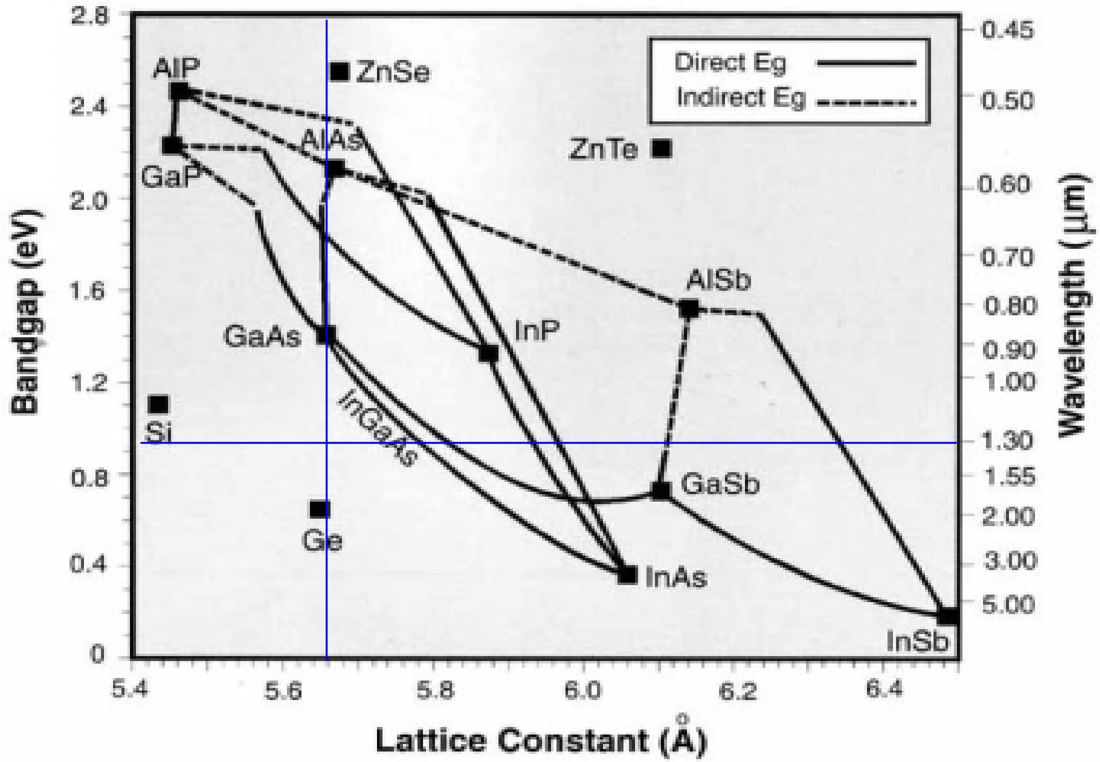
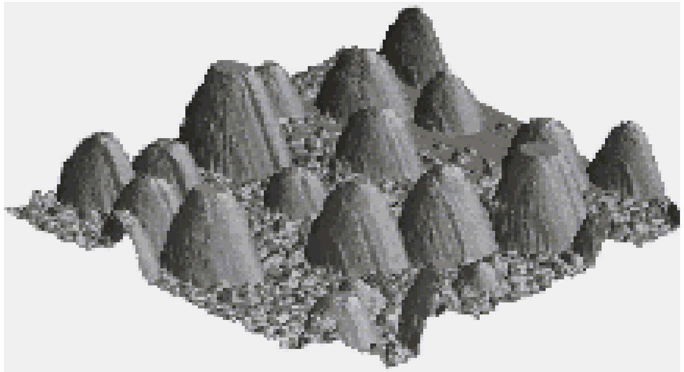
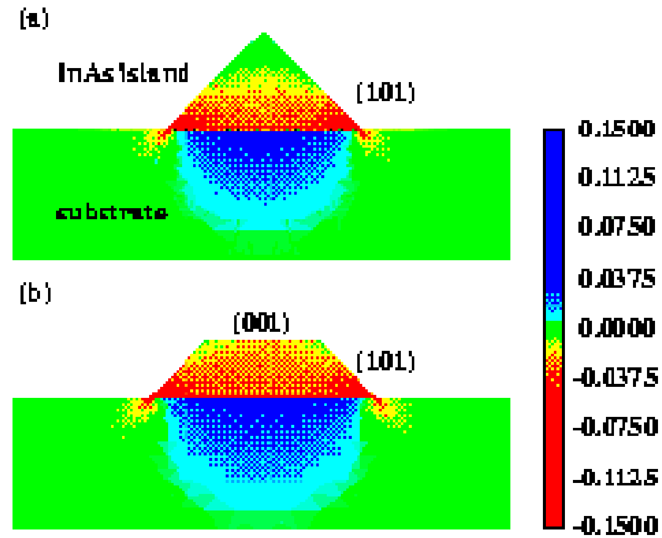
InAs/GaAs QD





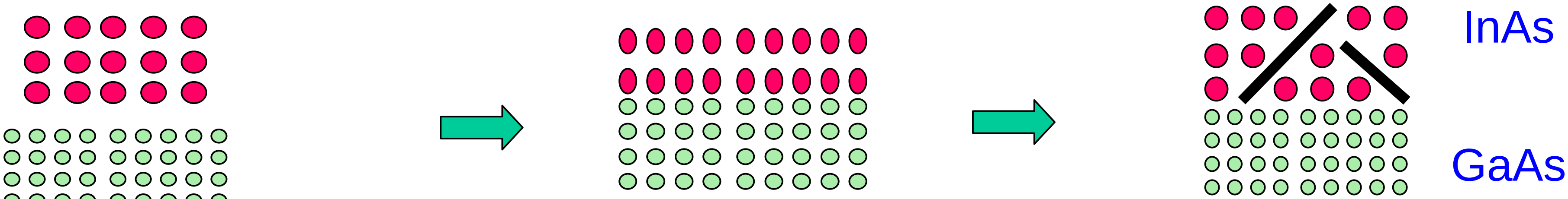


Dislocation-free epi-growth:

Lattice matched or slight lattice mismatched

Lattice mismatch: InAs/GaAs = 7.1%

Epitaxy Growth of QW and QDs

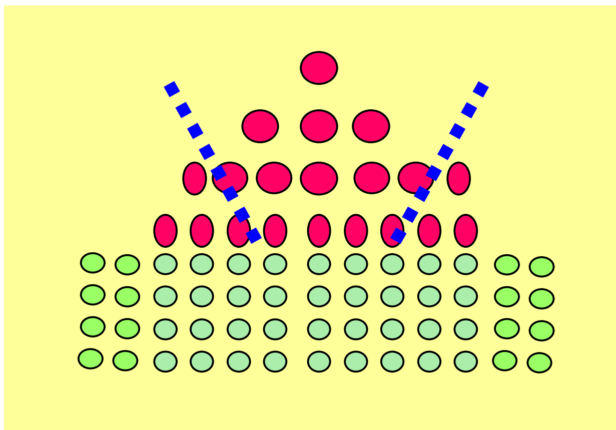


Two materials with different lattice parameters

Thin InAs is strained
But no dislocations

Thickness increases strain accumulates in the interface, dislocations form and crystal quality degrades

QD formation by Stranski-Krawstanov Growth



If islands are formed the strain may relax elastically

Our approach:

InGaNAs QWs — **MBE**

InAs/InGaAs QDs — **MOCVD**

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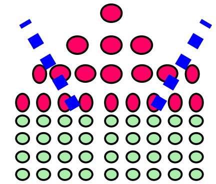
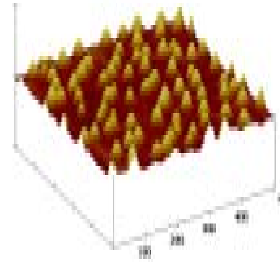
Quantum Dot Technologies

QD

- Bandgap engineering
- 3D confinement
- Low threshold current
- Thermal stability
- High efficiency

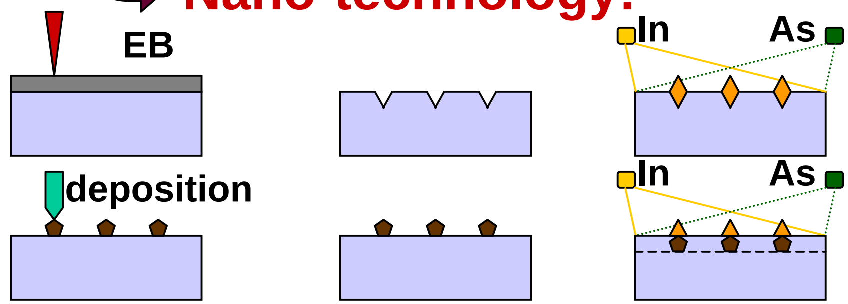
InAs/GaAs QD

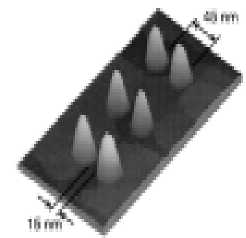




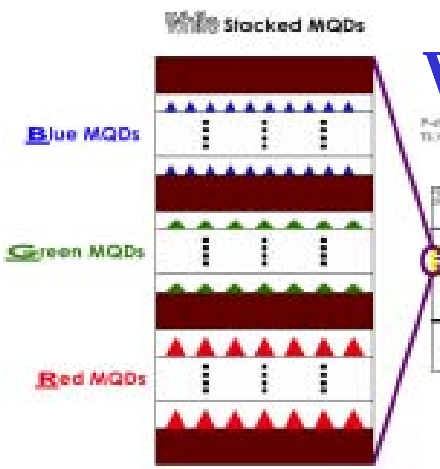
- Self assembled epitaxy
- Long wavelength emitting
- LD & VCSEL for fiber communication
- Patterned substrate for QD array

Nano-technology!

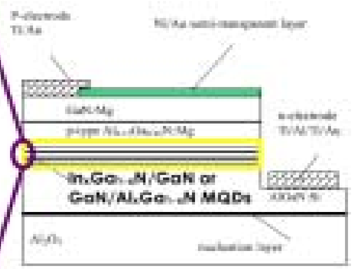




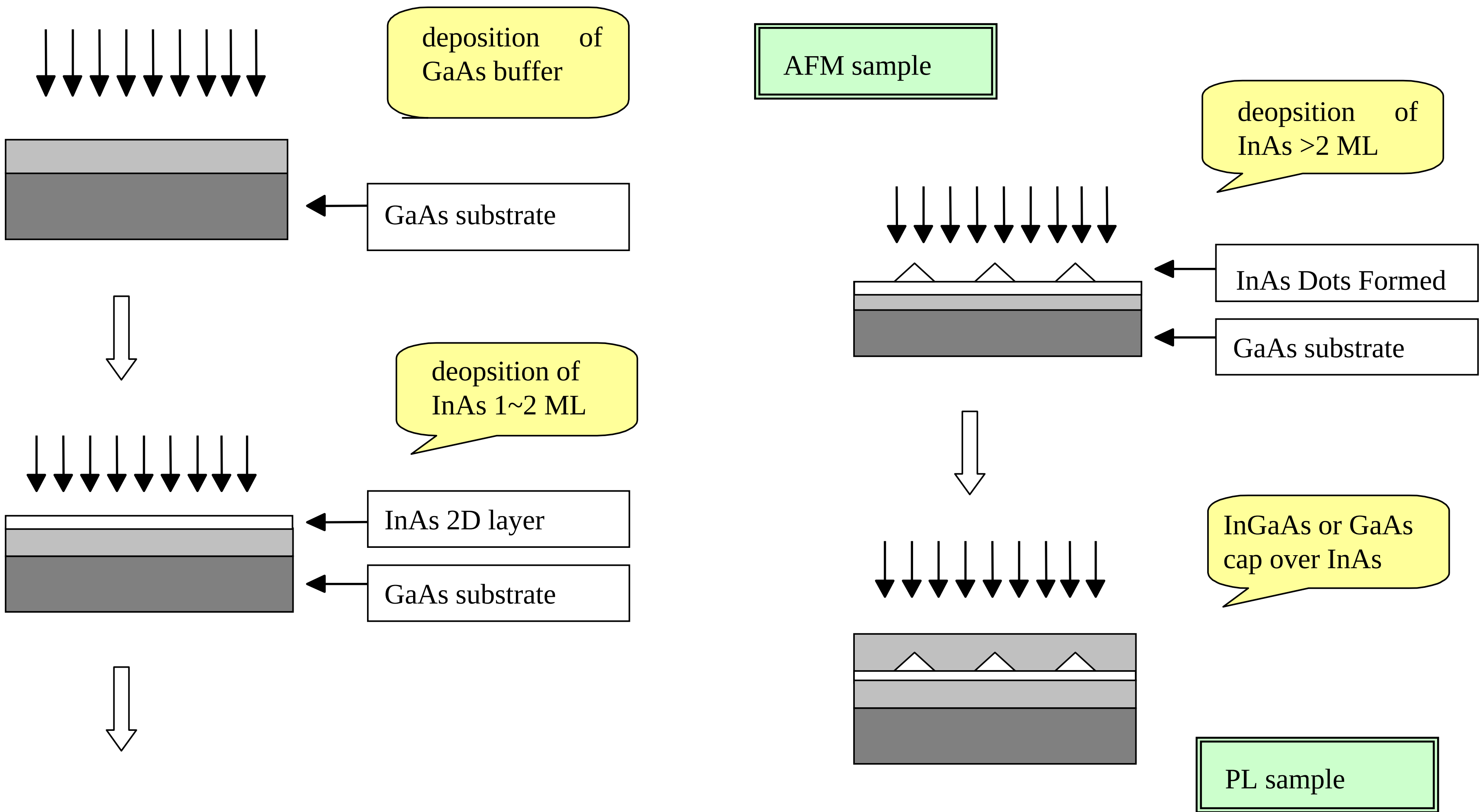
InGaN/GaN QD



White LED



Self-Assembled Quantum Dots



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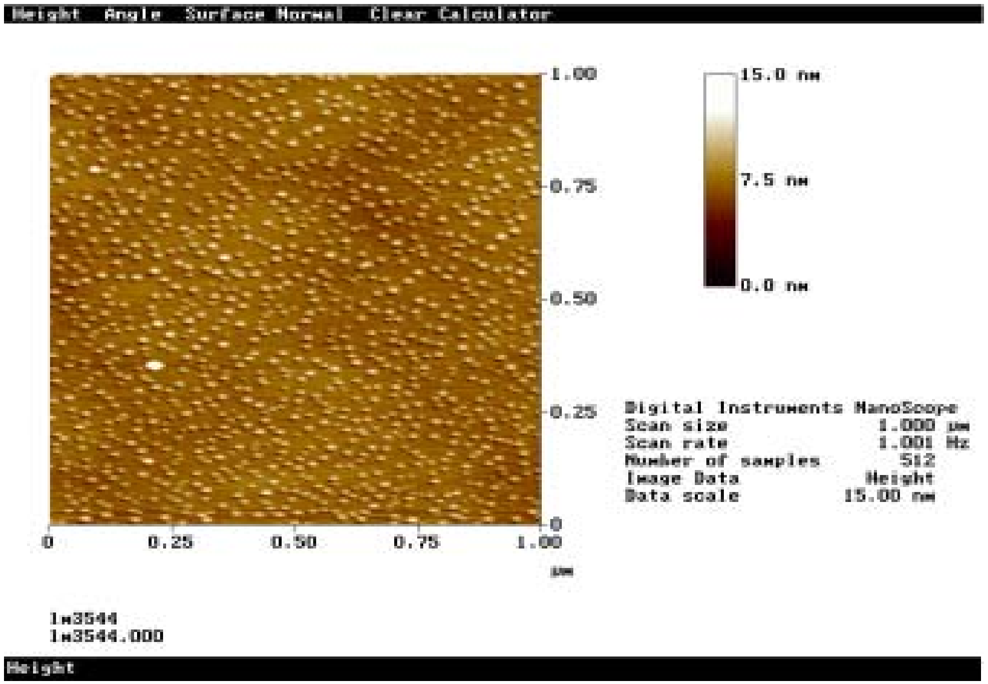
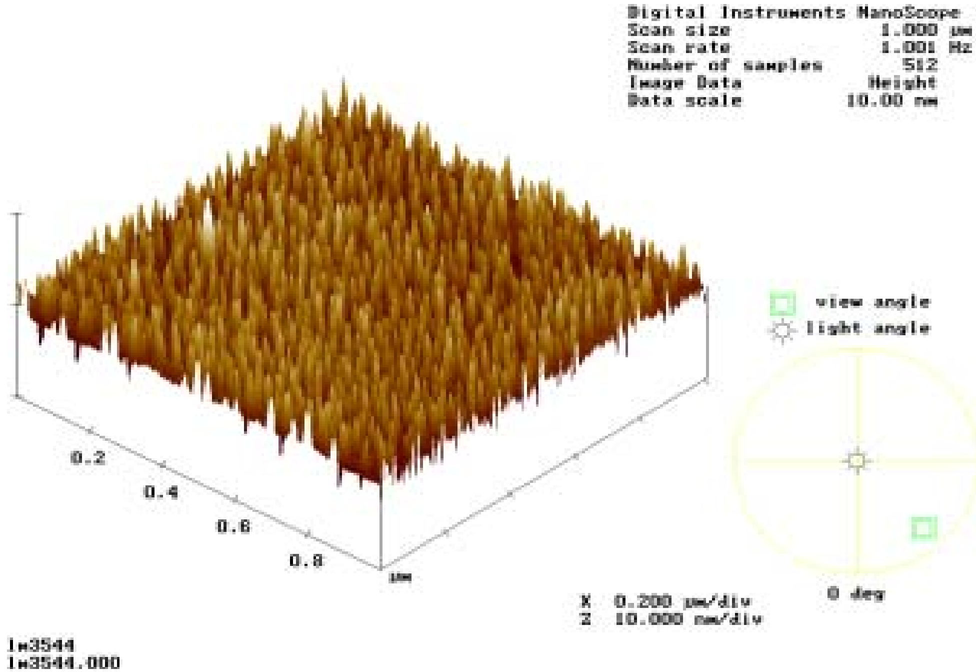
QD Laser：AFM





LM3544：1x10^{11} #/cm^{2} with base width below 30 nm

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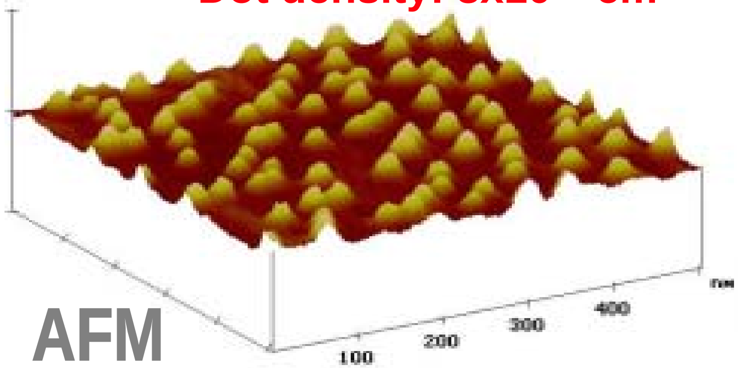
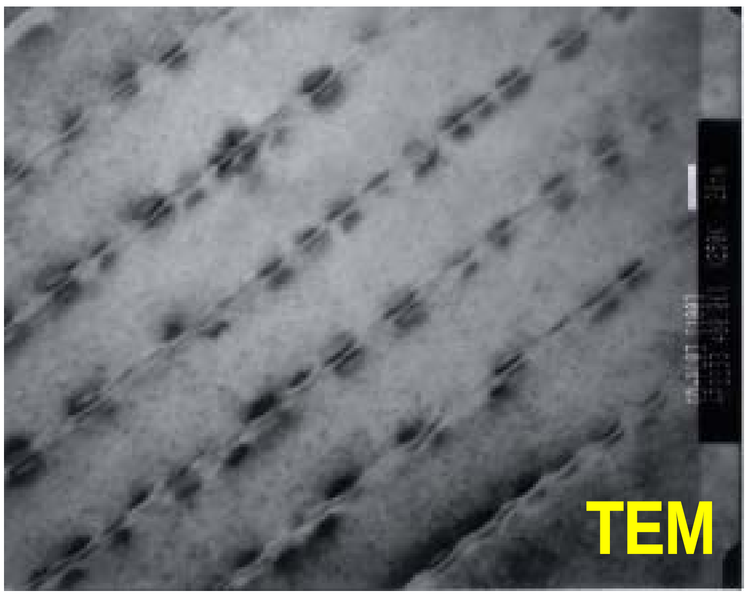
QDs：Characterization

Dot density: $3x10^{10}$ cm^{-2}



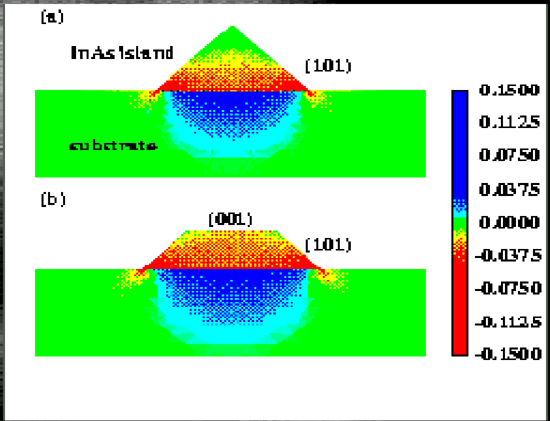
AFM



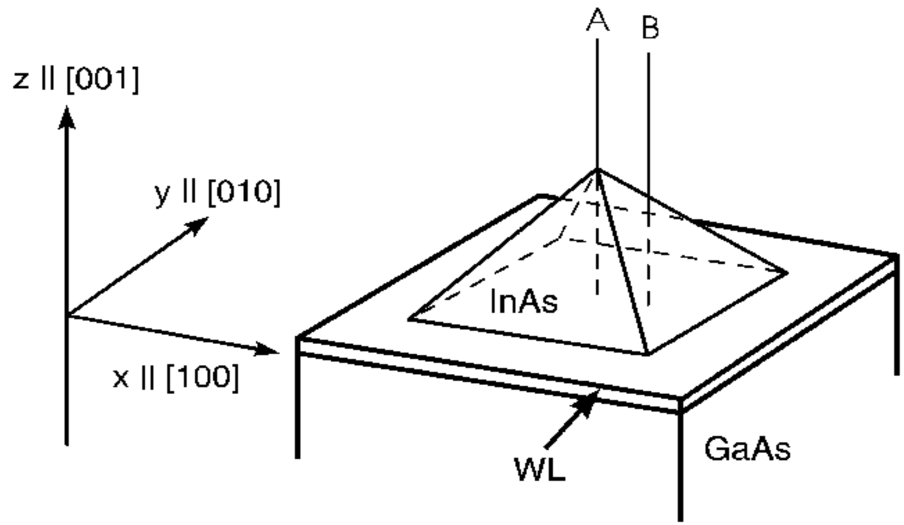
TEM

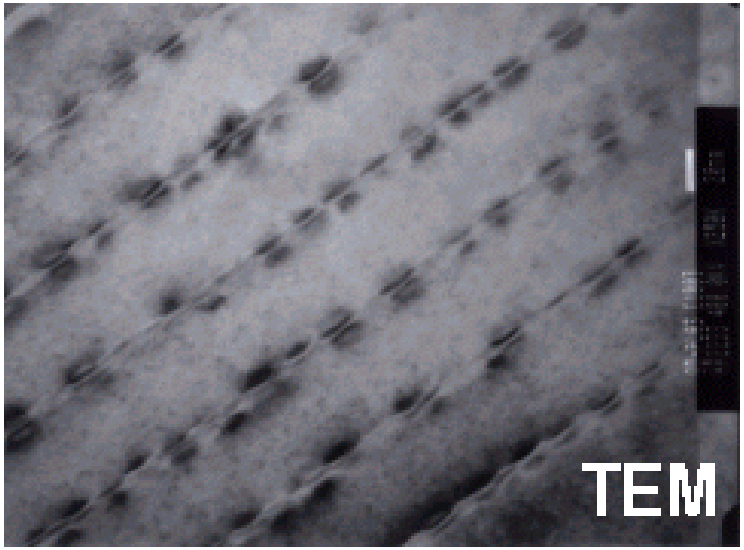
SEM

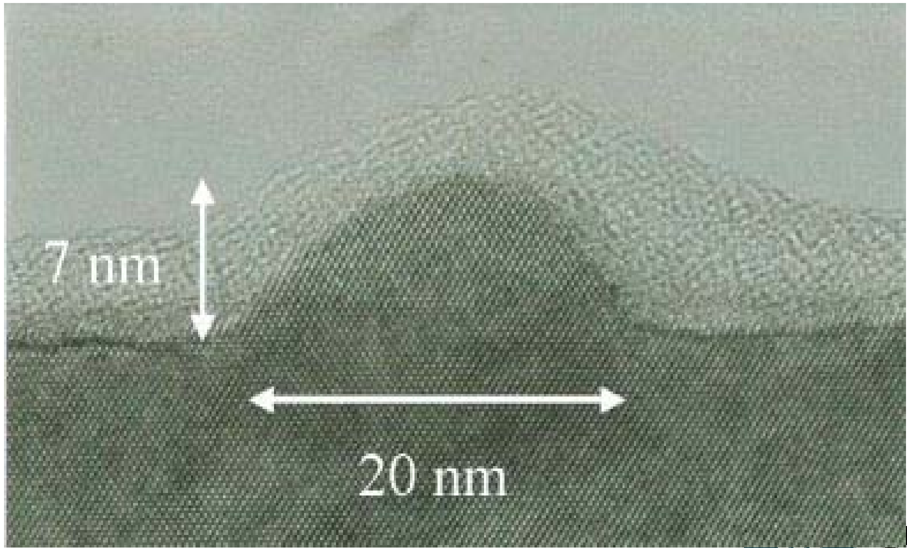
InAs Quantum-Dot Lasers



QDs Characterization：TEM







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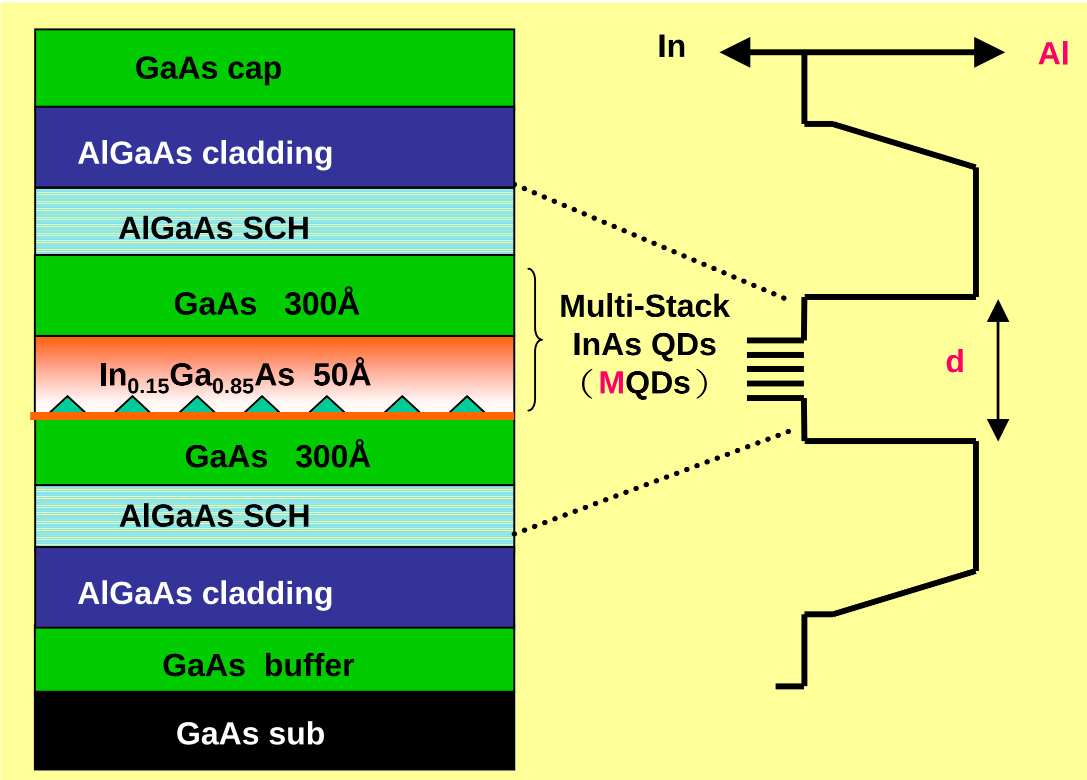
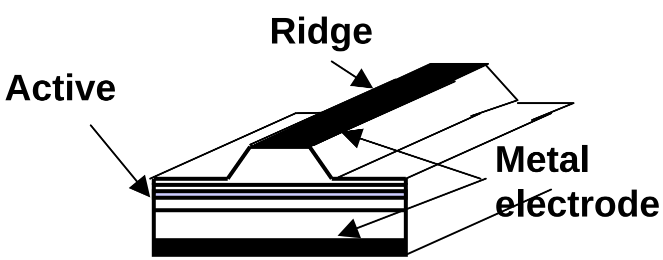
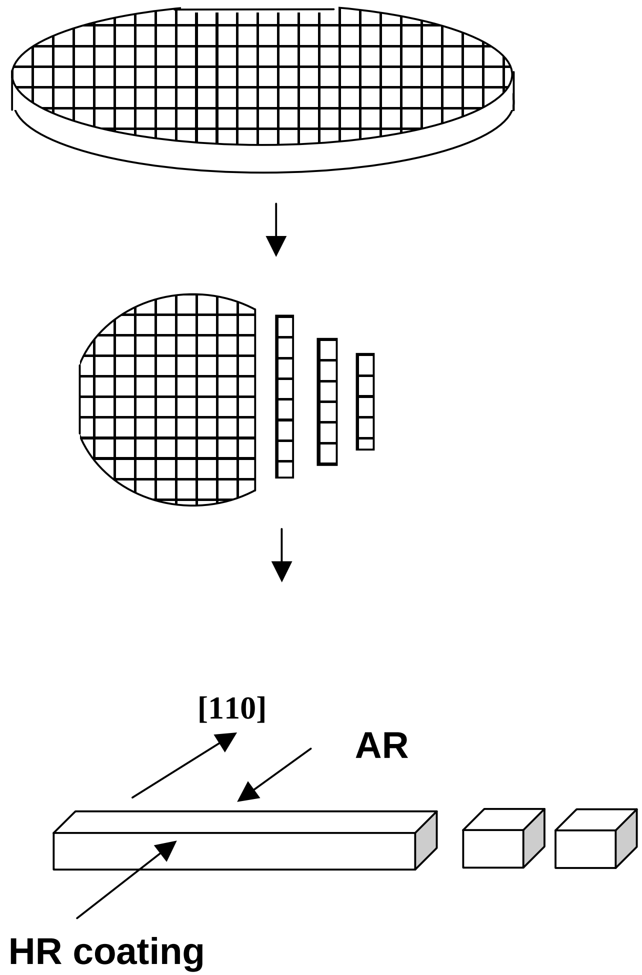
QD Laser Structure

Layer Structure



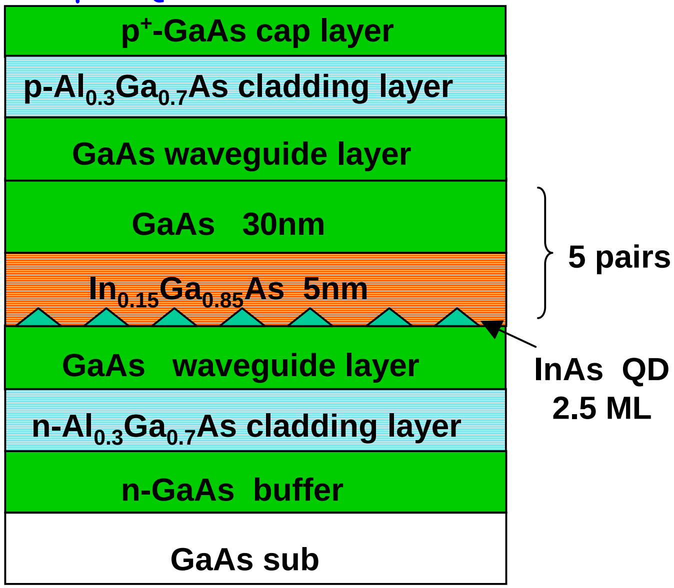


Laser fabrication

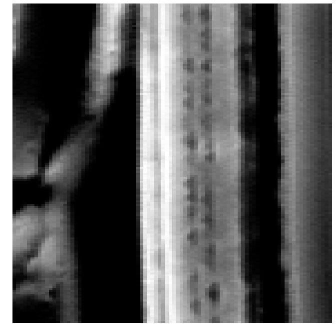


1.3 um Quantum Dot Lasers

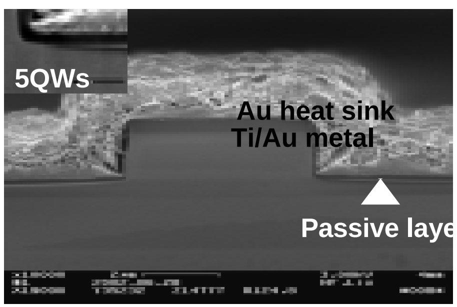
1.3μm QD laser structure



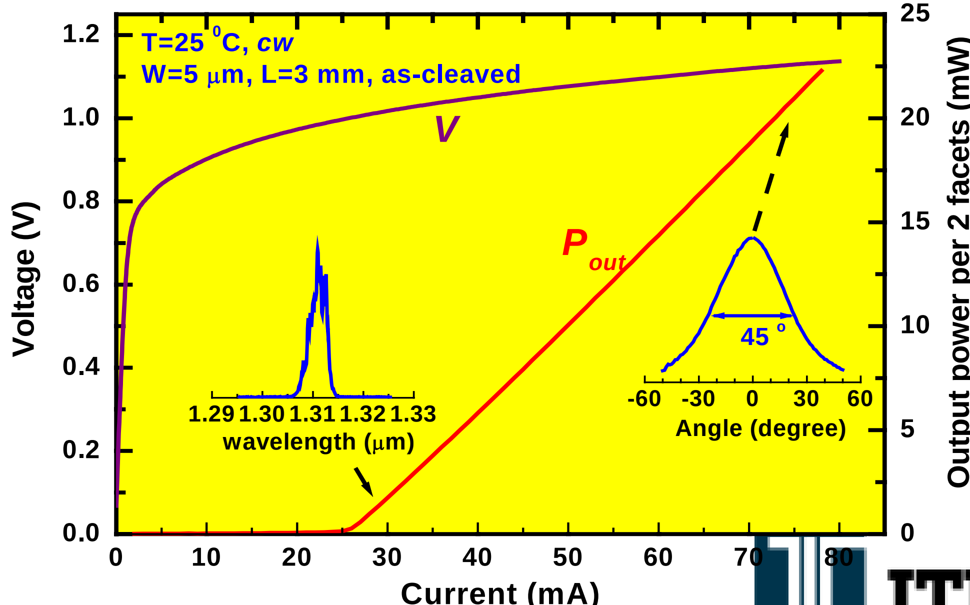
Cross-section TEMand SEM image of InAs/GaAs QD active layer



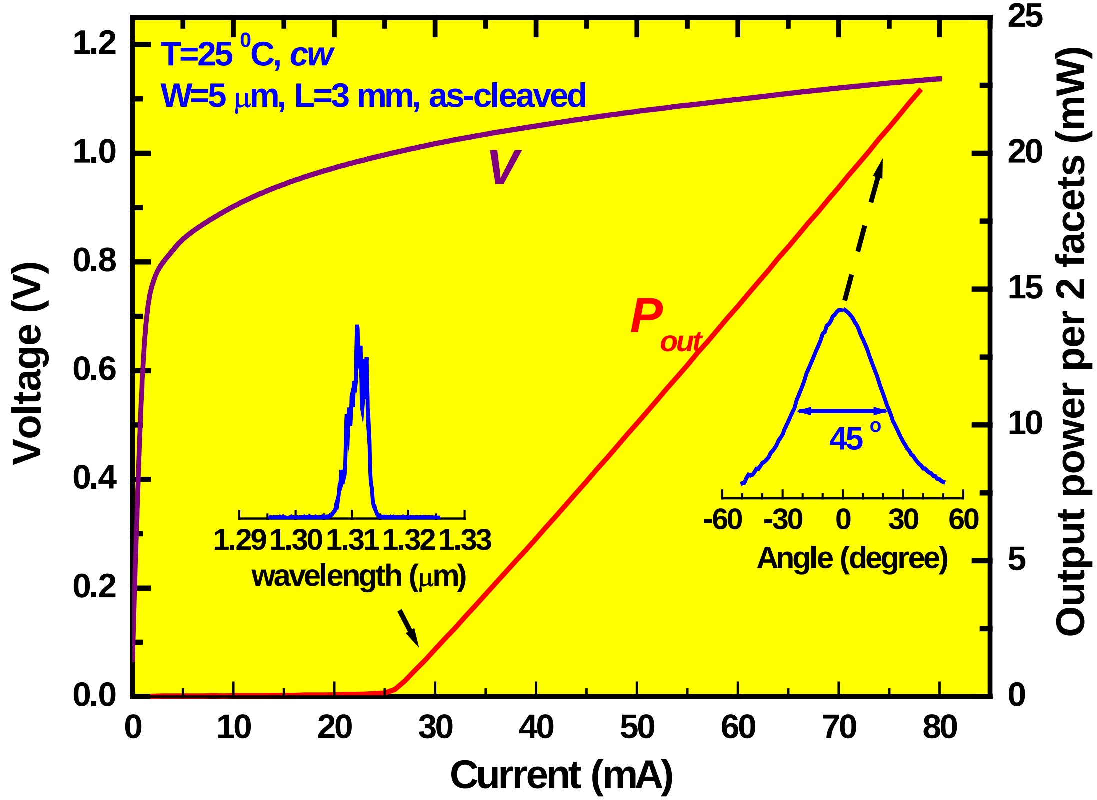
Cross-section SEM image of 1.3μm QD ridge-waveguide laser



1.3μm QD ridge-waveguide laser characterization



Ridge-waveguide QD laser characteristics



Low divergent angle, high differential efficiency, single mode QD lasers have been obtained !

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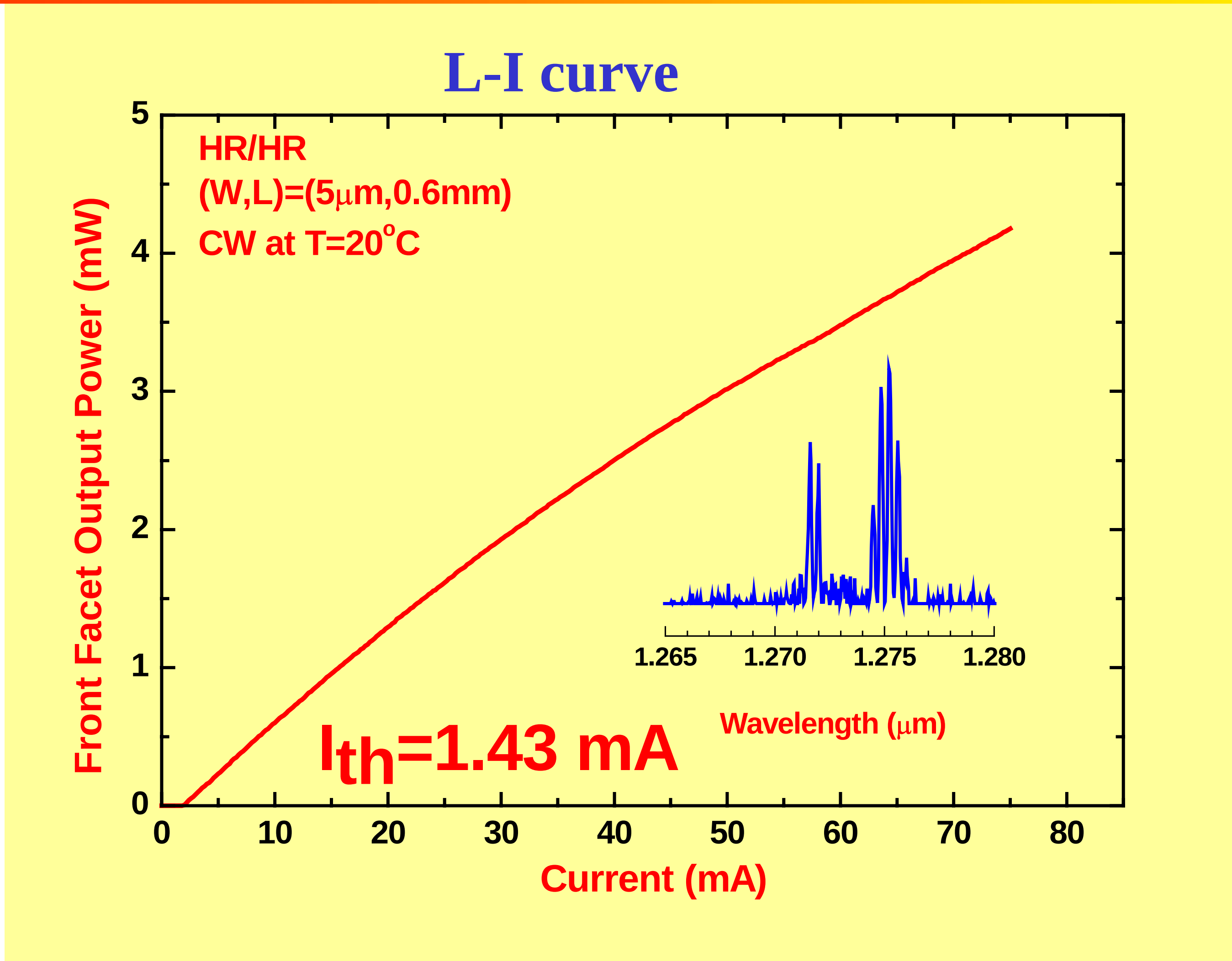
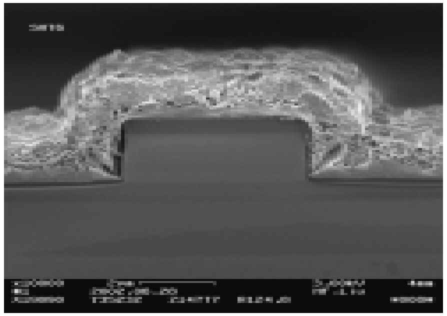
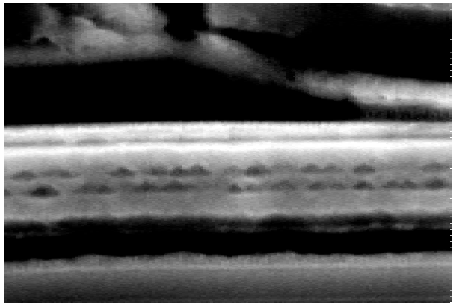
Ultra-low Threshold Current QD EELs







SEM of 2 stack QD layers

Cf. D. L. Huffaker et al., IEEE J. Select. Topics Quantum Electron, VOL. 6, 2000. : 4.1 mA

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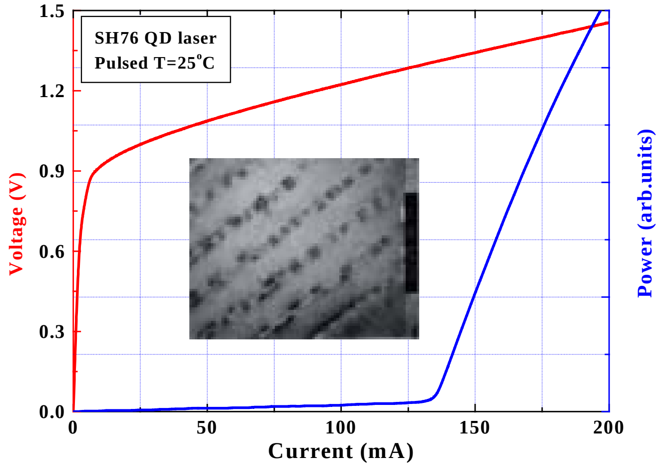
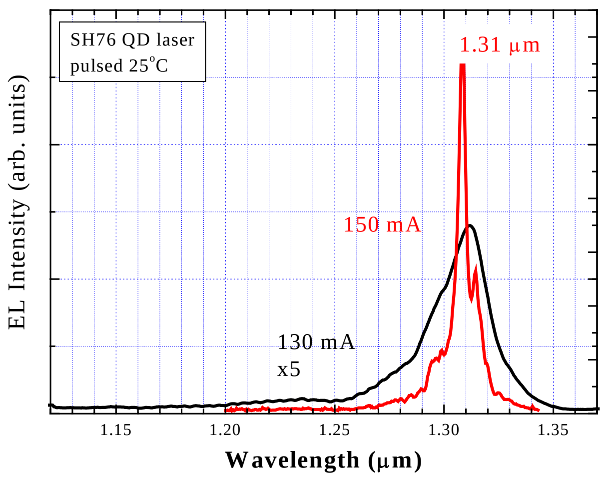
InAs/InGaAs QD 1.3 um Lasers





Lasing at 1.31 μm @ 25°C with low I_{th} and high efficiency!

Potential Impact: Low cost VCSELs and LDs for metro/local-access fiber networks.

Innovation: Allow GaAs technology for uncooled 1.31 um components to replace the less developed InP technology. QD can be made on the cheaper and better GaAs substrates and is less temperature sensitive. It also allows integration with GaAs high speed electronics to lower the system costs.

Importance: The characteristics of InAs/InGaAs QD epi-structure were shown to be as good as other QW LD structures. ITRI/IOFFE collaborative program will aim to be the first in commercializing QD devices at 1.3um in the world.

Ioffe Physico-Technical Institute

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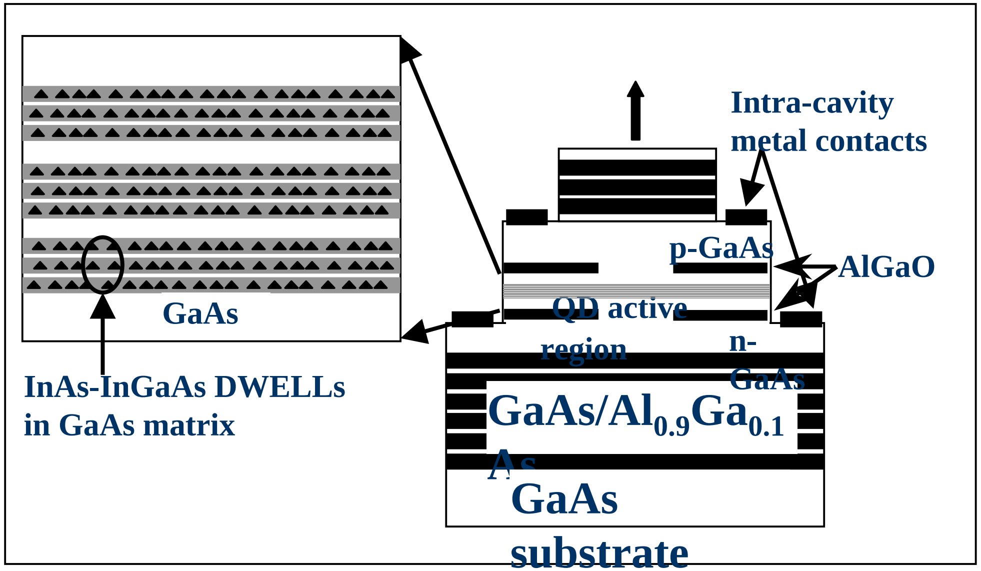
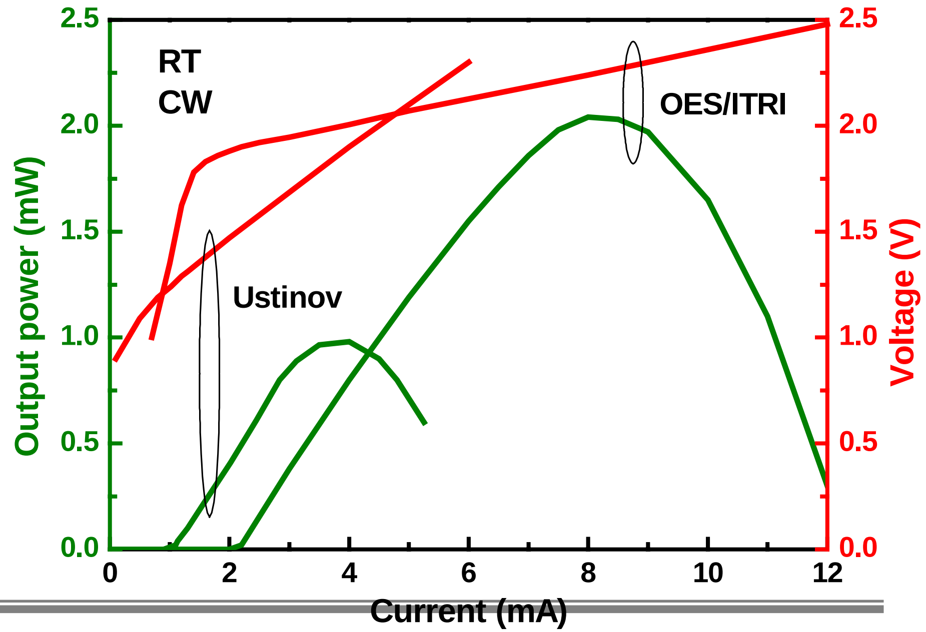
1310 nm QD VCSEL(MBE)





Room-temperature continuous operation of InAs QD intra-cavity VCSELs grown by Molecular beam epitaxy (MBE).

λ : 1.3 μm

I_{th} : 2.2 mA

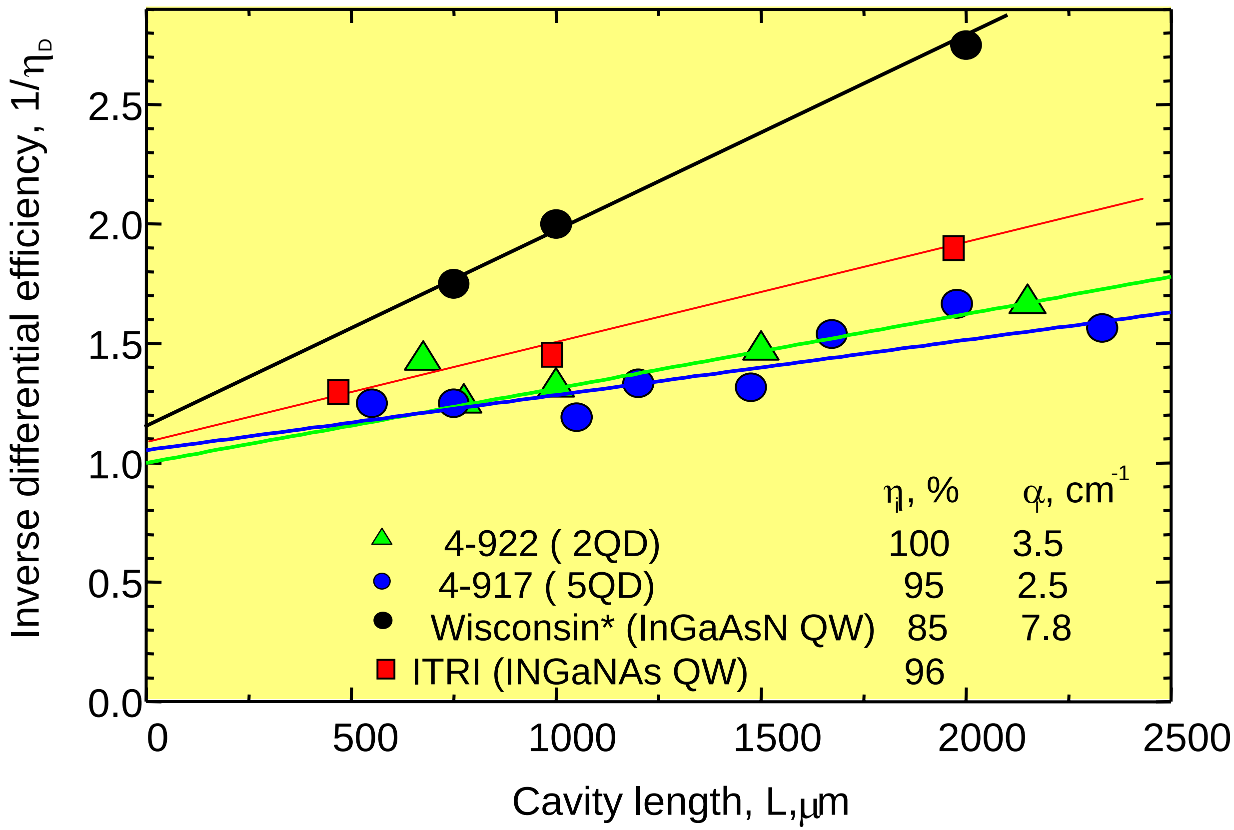
P_{max} : 2 mW

Slope efficiency : 0.41 W/A

The *first* room temperature 1.3 μm QD VCSEL with all semiconductor DBRs!

Comparison of QDs and InGaNAs QWs

Internal Quantum Efficiency of QDs close to 100%!



*N. Tansu and L.J. Mawst, IEEE Photonics Technol. Lett. 14, 444 (2002)

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Summary- QD Devices

- RW multi-stack (N=2, 5 and 10) InAs/InGaAs/AlGaAs QD lasers of 1.3 μm range have been fabricated. The threshold current densities per stack were about 25 A/cm^2, 18 A/cm^2 and 10 A/cm^2 for 2-, 5- and 10-stack QDs, respectively.
- Low threshold current of 1.43 mA, High wall-plug efficiency exceeding 40%, and record high current density above $100\times J_{th}$ for 10-stack QD lasers for RT CW and GS lasing emission was achieved.

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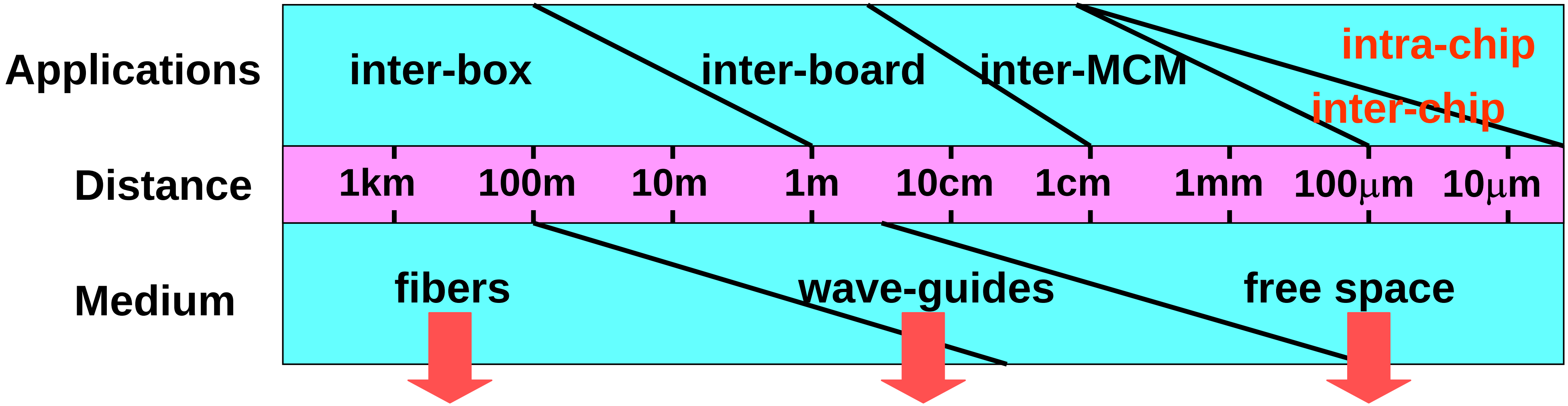
Optical Interconnection Types and Applications

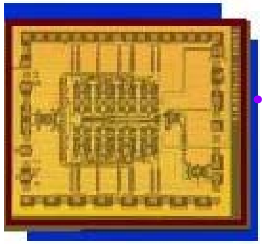


	Fibers	Wave-guides	Free space
Advantages	• Stability • Easy replacement	• Less cross talk • Curved path	• High channel density • 3D connection
Disadvantages	• Large volume • Low channel density	• Planar configuration • High loss	• Difficult alignment

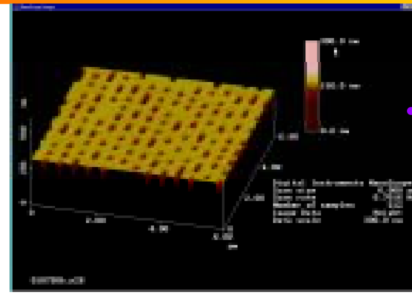
Application Products

- **Telecomm Switch, Telecomm Transmission Equipment**
- **High End Datacom Switch and Router**
- **Aerospace and avionics communication**
- **High End computer peripherals、 Enterprise computer server**
- **Mainframe Supercomputer**

nano-electronics (MRAM, SET)



high-density data storage (Terabyte)



carbon nanotube field-emission display (CNT-FED)

long-life fuel cell for mobile devices

Nanotechnology

Strategic Applications

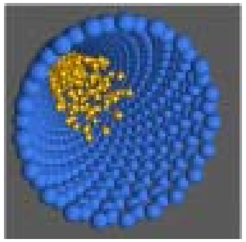
In Major thrust projects

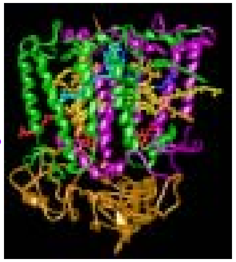
ultra-thin & flexible display

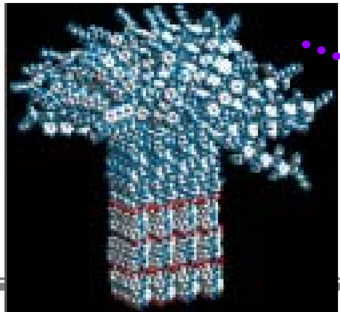
nano-fluid with superb thermal-conductivity

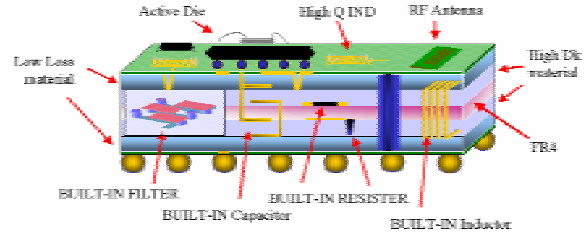
nano-optoelectronic communication components (QD Laser, Nanophotonics)

next-gen. electronic packaging technology









Nano-biotechnology

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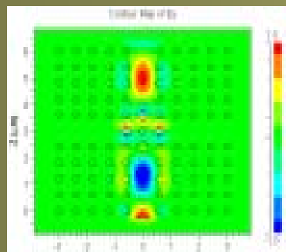
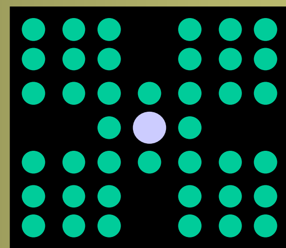
Nano-Photonics Roadmap

Device Target

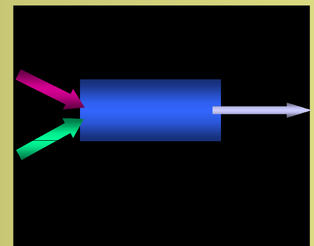
PCD



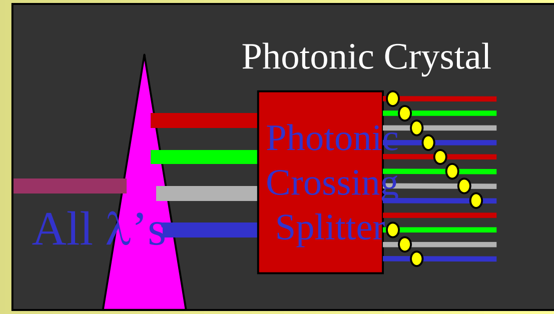
Crossing Splitter



Variable Optical Attenuator

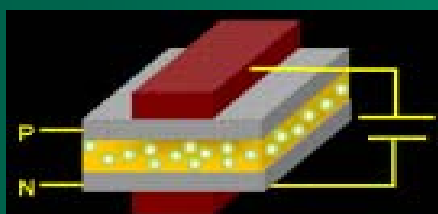


Polarization Combiner

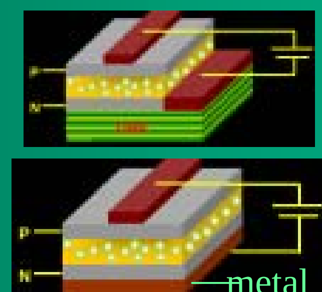


Total Integration

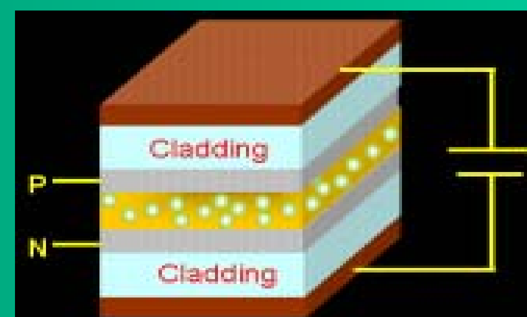
QD



Simple QD-LED



Enhanced QD-LED



Edge-emitting Laser

91 92 93 94 95

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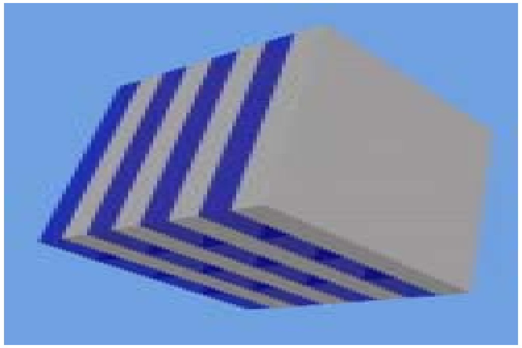
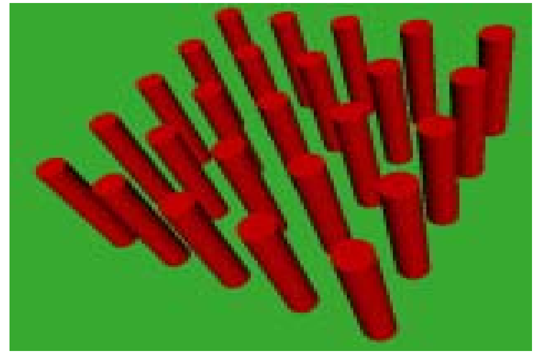
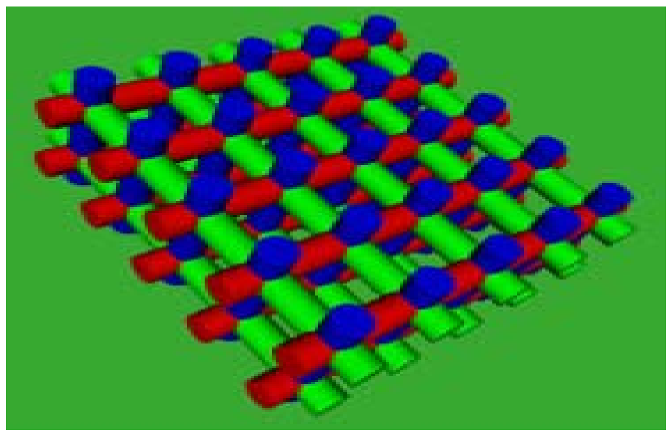
Types of Photonic Crystal Structures



(a) 1D



(b) 2D



(c) 3D

Nano-patterning Technology

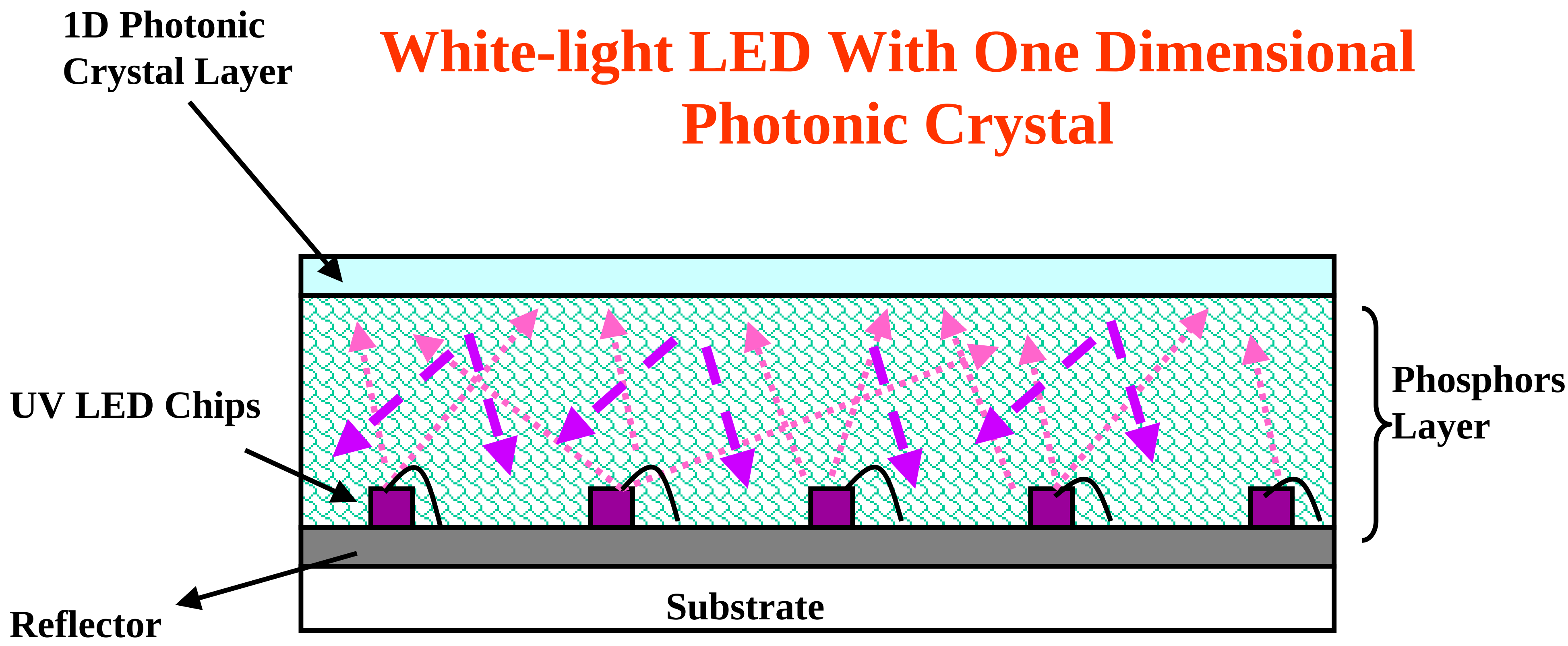
Nano-fabrication Technology

Features of Photonic Crystal

- periodic structure
- dimension in sub-wavelength region
- various device design

Dielectric Omni-directional Reflector

White-light LED With One Dimensional Photonic Crystal



One Dimensional Photonic Crystal Structure with High Reflectivity at Certain Wavelength (i.e. Band Gap) Irrespective to Incident Angles and Polarizations.

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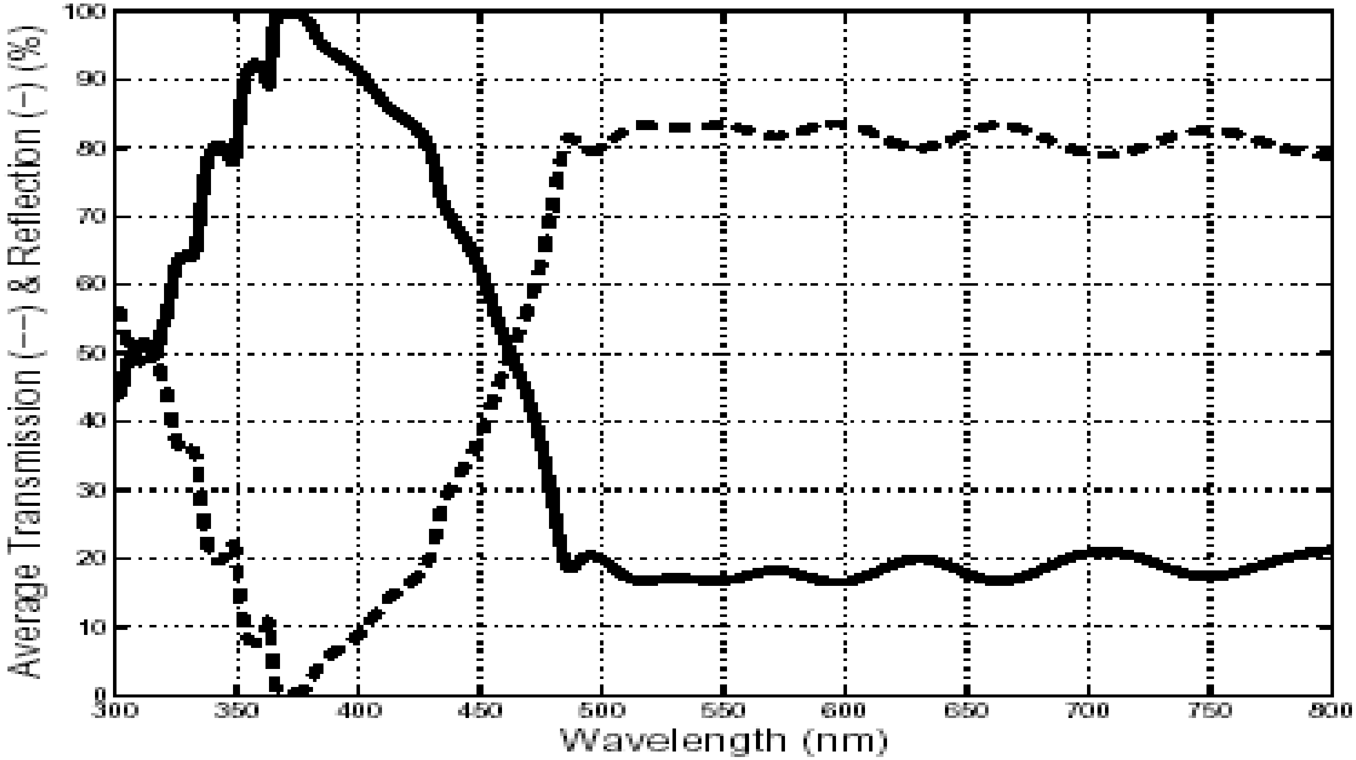
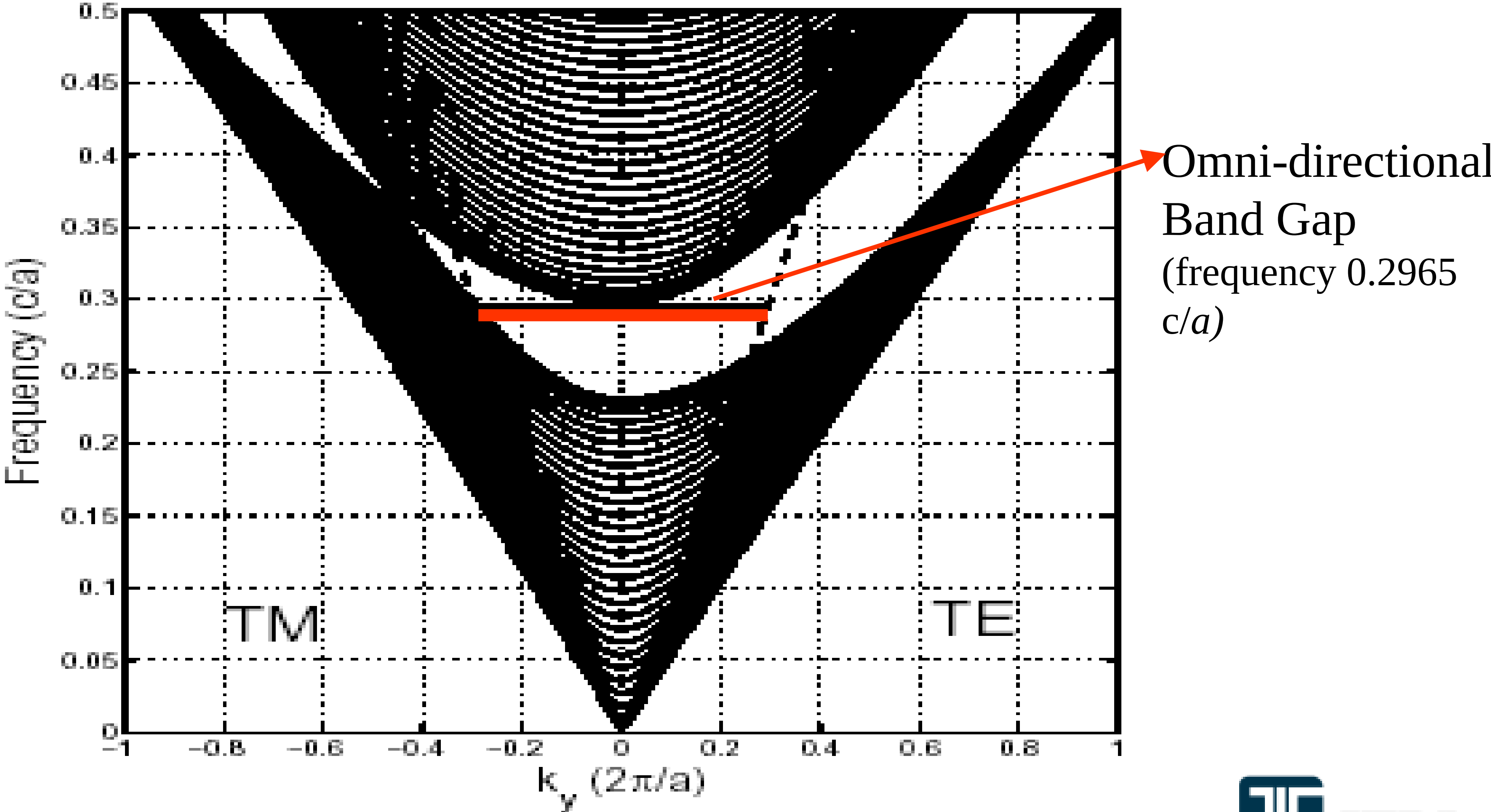
Dielectric Omni-directional Reflector

Calculated Average Spectra of Omni-directional Reflector Structure For Unpolarized Light With All Incident Angle



Photonic Band Structure of an Omnidirectional One Dimensional Photonic Crystal



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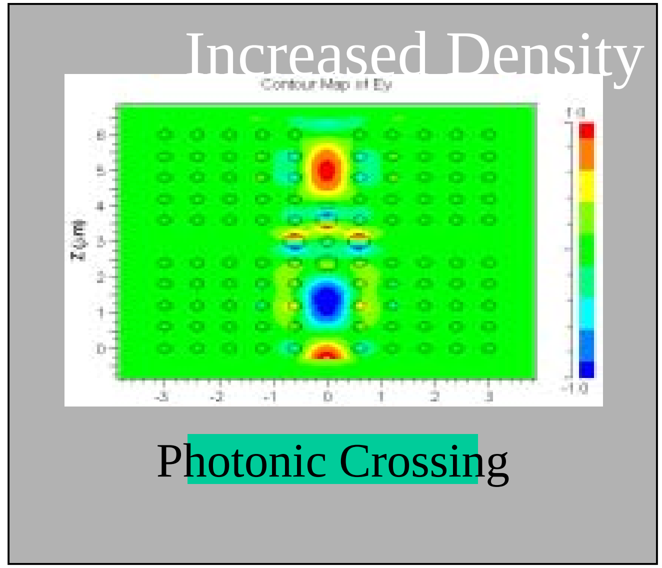
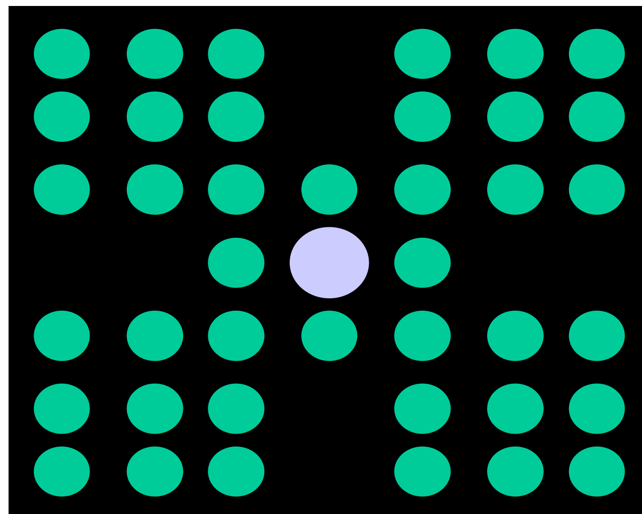
Photonic Crystal Devices

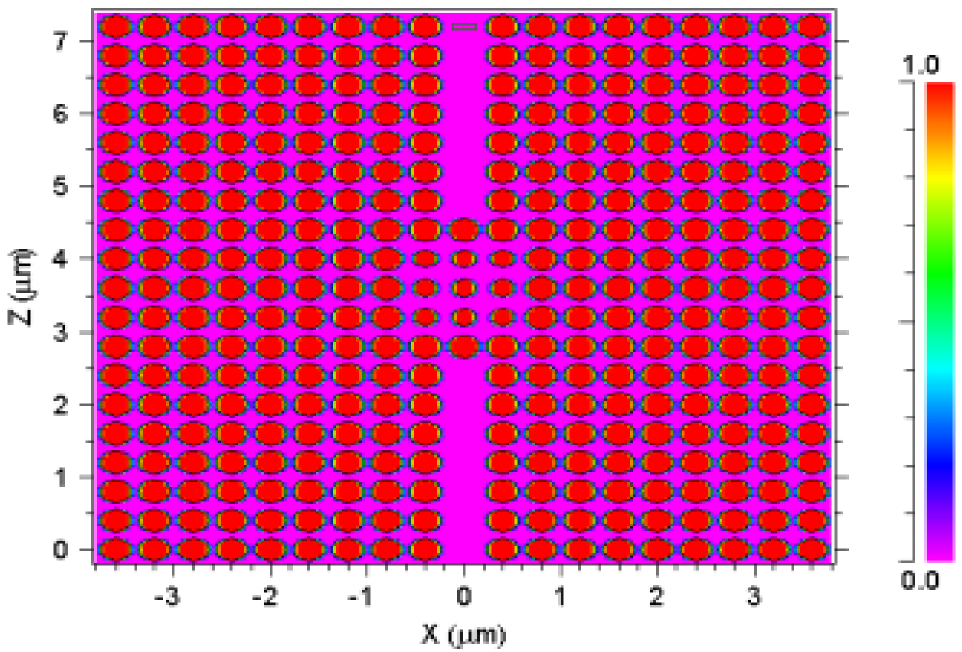
- **Photonic splitters**
  - ☐ **Integration with MUX/DeMUX**
  - ☐ **Increase Channel Count per Area**
- **Photonic Crystal VOA (Transmission)**
  - ☐ **Index Tuning**
  - ☐ **E-O Substrate**
  - ☐ **LC Filling**
  - ☐ **Geometric Tuning**

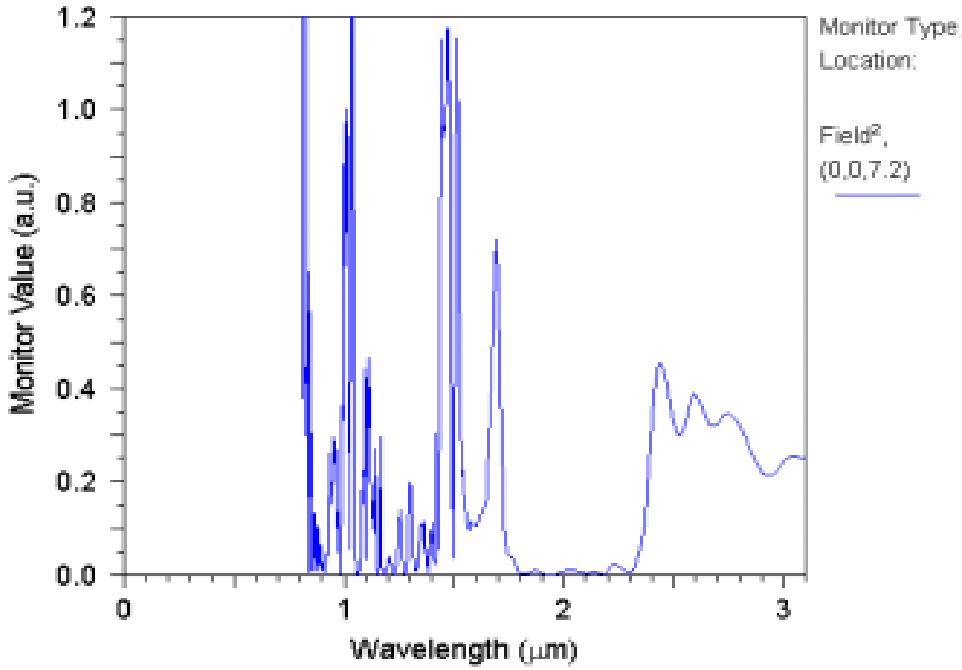




Device Design

- **VOA**





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Low Cost Sources (OFC 2004)

ThD1 Kouji Nakahara 1.3-μm InGaAlAs directly modulated MQW RWG DFB lasers operating over 10 Gb/s and 100°C

ThD2 Satoshi Shirai 120°C un-cooled operation of direct modulated 1.3μm AlGaInAs-MQW DFB laser diodes for 10Gb/s telecom applications

ThD3 Tetsuro Okuda Low-operation-current and highly-reliable 1.3-μm AlGaInAs strain compensated MQW-BH-DFB lasers for 100°C, 10-Gb/s operation

ThD4 Hélène Debrégeas-Sillard Low-cost coolerless 10Gb/s integrated laser-modulator

ThD5 Osamu Kagaya Record high mask margin in uncooled directly-modulated laser diode modules with a driver IC for 10.7 Gbit/s SONET applications

ThD6 Takashi Kondo Isolator-free, uncooled operation of highly strained 1.1 μm GaInAs/GaAs vertical cavity surface emitting laser for 10 Gb/s single mode fiber data transmission

ThD7 Alexei Sirbu VCSELs emitting in the 1550 nm waveband with 0.6 mW single mode output in 20-80 °C temperature range

Practical applications of holey optical fibers

D.J. Richardson, K. Furusawa, H. Ebendorff-Heidepriem, P. Petropoulos, V. Finazzi, J.C. Baggett, W. Belardi, T.A. Kogure, J.H. Lee, Z. Yusoff, J. Nilsson, Y. Jeong, J.K. Sahu and T.M. Monro
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Abstract: We review recent advances in the development of HF technology and describe various practical applications of the technology in the areas of nonlinear and active fiber devices.

OCIS codes: (060.2280) Fiber design and fabrication (060.4370) fiber lasers, nonlinear fibers, microstructured fiber

1. **Introduction:** The microstructured fiber is a new class of optical fiber that has emerged in recent years (for recent reviews see [1] and [2]). Microstructured fibers contain an arrangement of air holes that run along the fiber length, and examples are shown in figure 1. The holes within these fibers act as the fiber cladding, and light can be guided using either one of two quite different mechanisms.

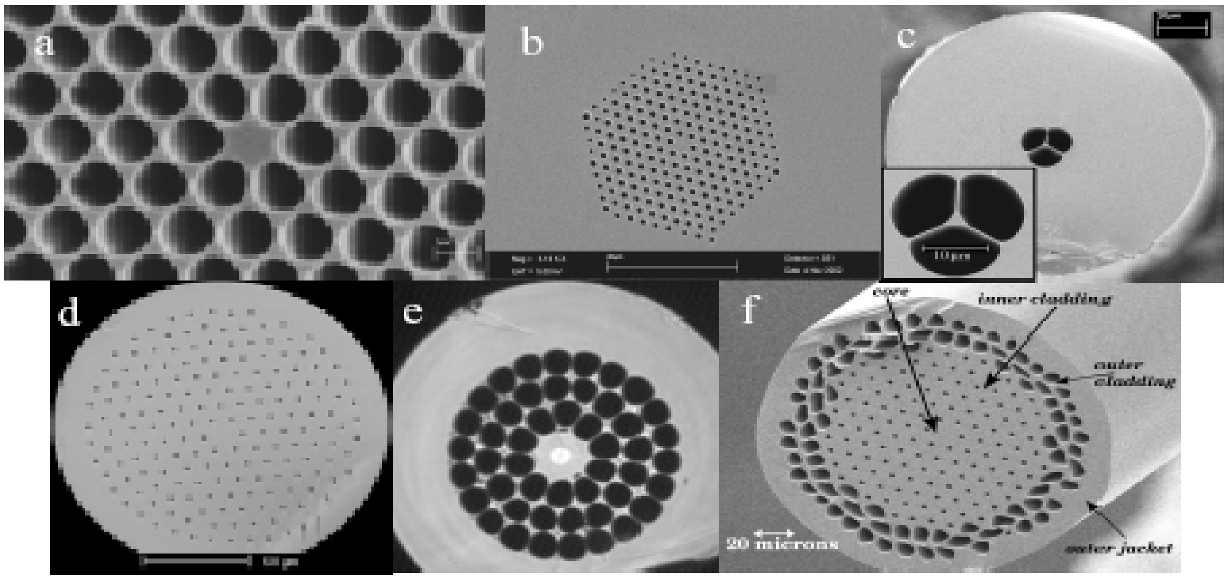


Figure 1 Various nonlinear and rare earth doped holey fibres: (a) Small core highly nonlinear silica fiber with ~2μm core [18].(b) small core Er doped fiber (dopant is confined to a region of diameter ~1μm within the ~2μm core) [29]. (c) High nonlinearity extruded SF57 glass HF [4]. (d) Large core endlessly single mode fiber [1,2]. (e) Cladding pumped fibre with a conventional core as used for high power Yb-doped 980nm lasers [26]. (f) Large mode area cladding pumped holey fiber for high power laser applications [25,27].

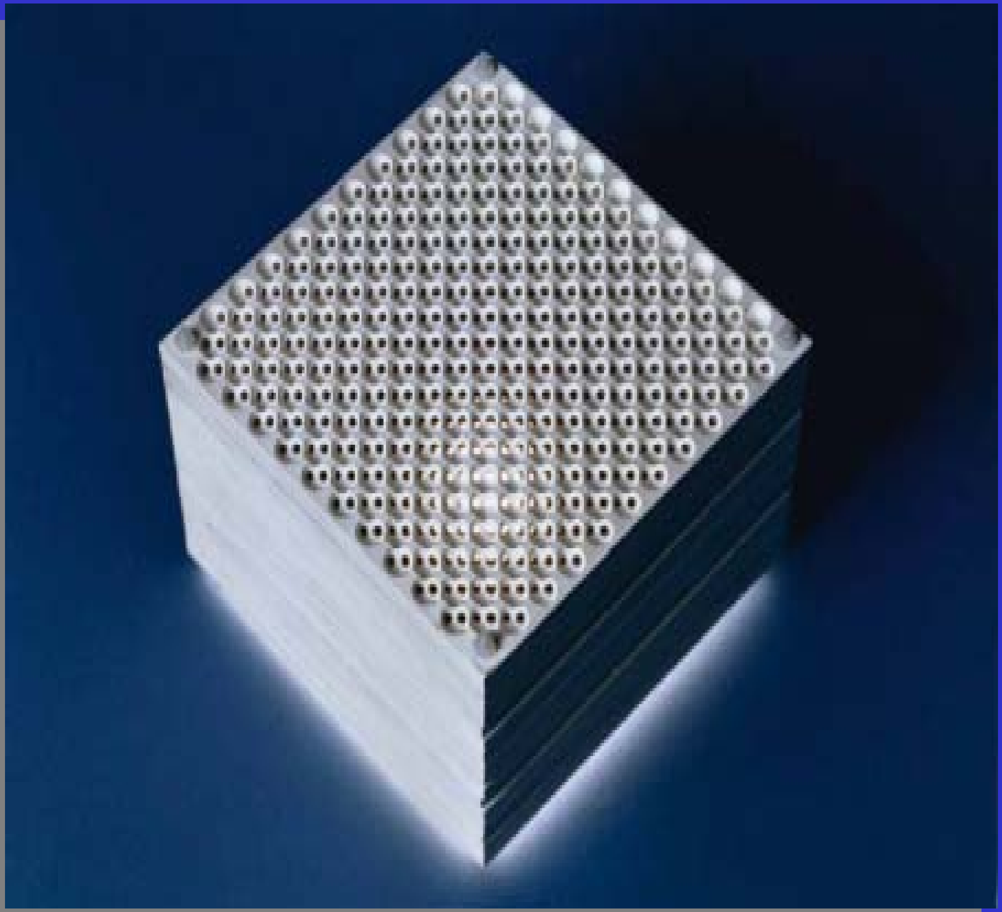
Practical Applications of Holey Optical Fibers

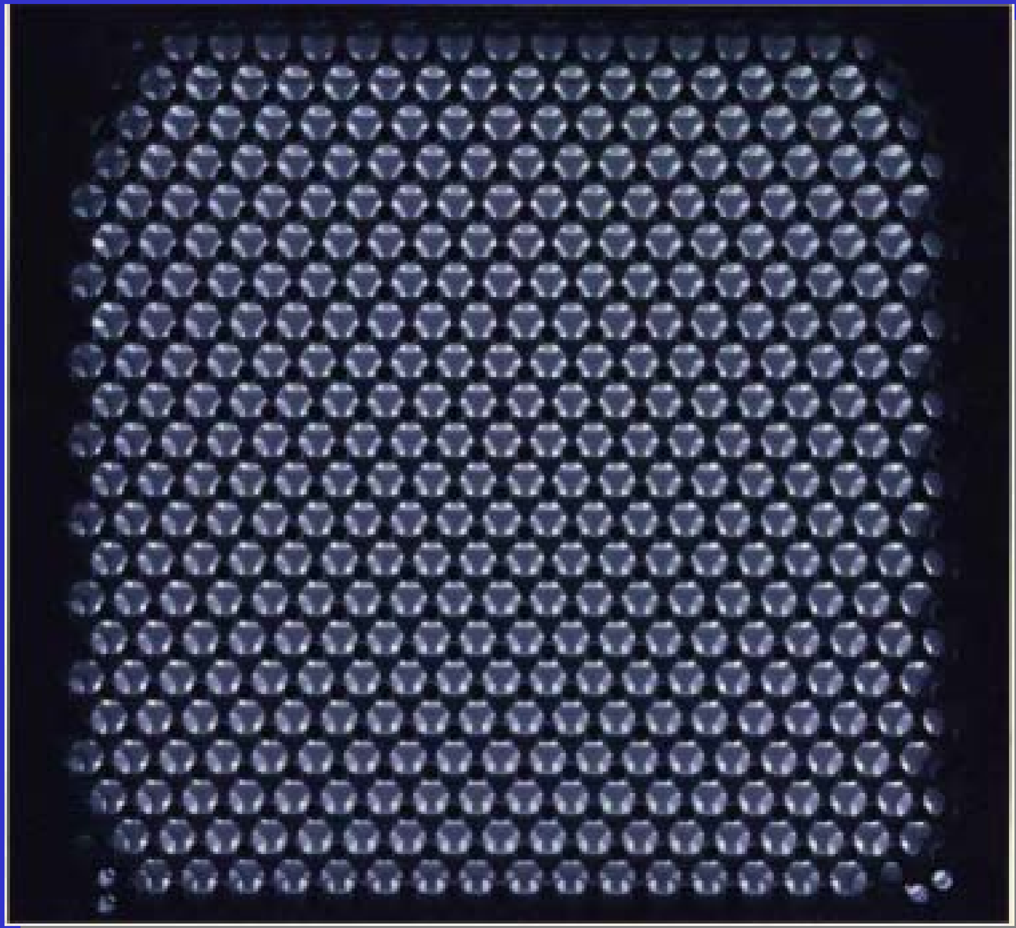
(cont.) - D.J. Richardson, et al, University of Southhapmton, (OFC 2004)

5. Conclusion.

In conclusion, HF technology has advanced to the point that km-lengths of robust coated fiber can be produced with losses approaching those of conventional fiber. HFs can be processed and spliced using established procedures and thus readily integrated with low loss to conventional fiber components and systems. HF fabrication, and associated post fabrication filling approaches have been shown to be compatible with a broad range of glasses and optical materials greatly enhancing the range and scope of devices and application that can be considered. HF technology thus promises a host of new functional passive and active fiber devices.

Photonic Crystals





Eli Yablonovich, UCLA (OFC, 2004)

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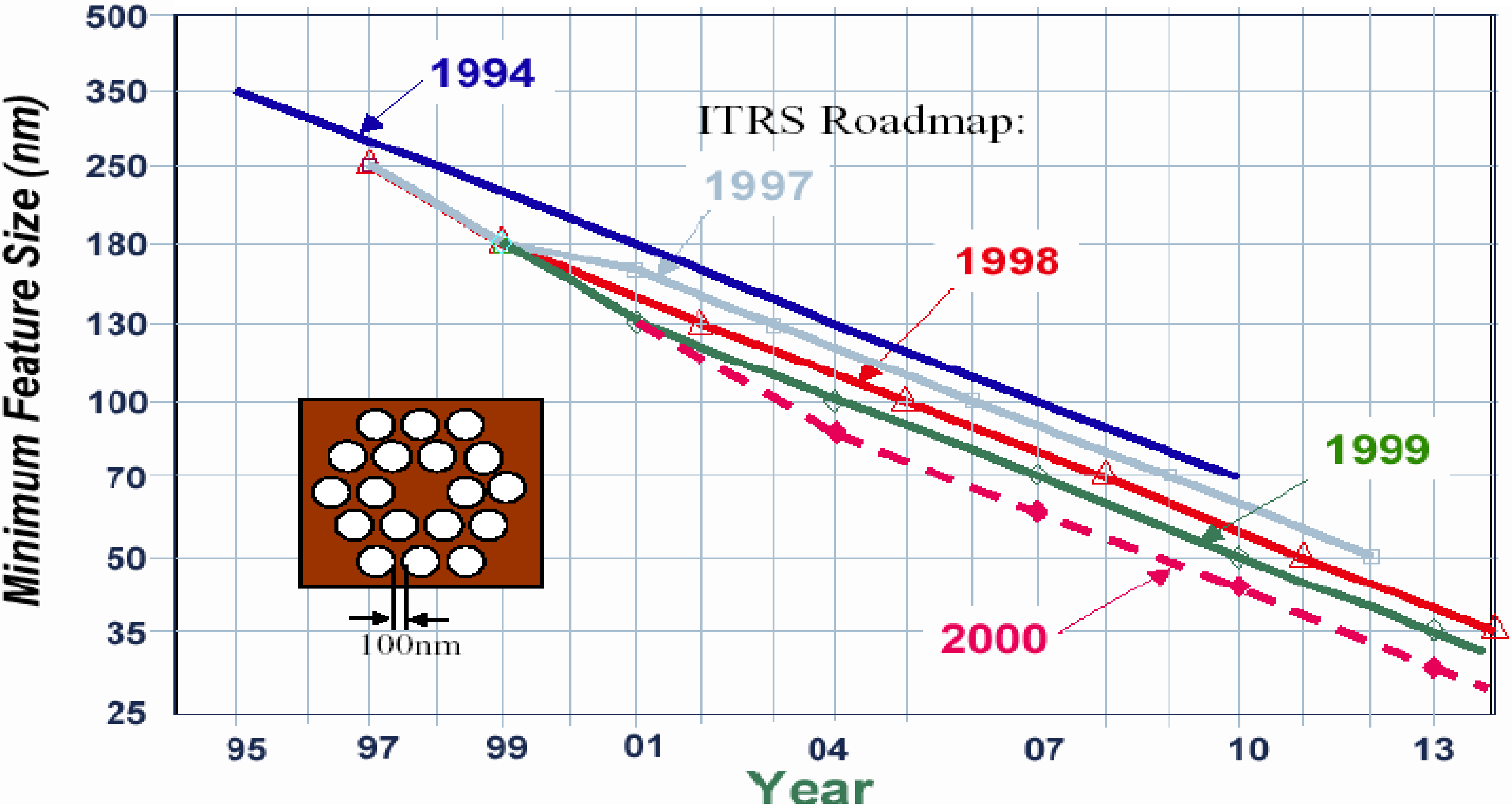
Critical Dimension for Photonic Integrated Circuit: $\lambda \approx 1550nm$

$\lambda/n \approx 440nm$

critical dimension for photonic crystal ≈ 100nm



Eli Yablonovich, UCLA (OFC, 2004)

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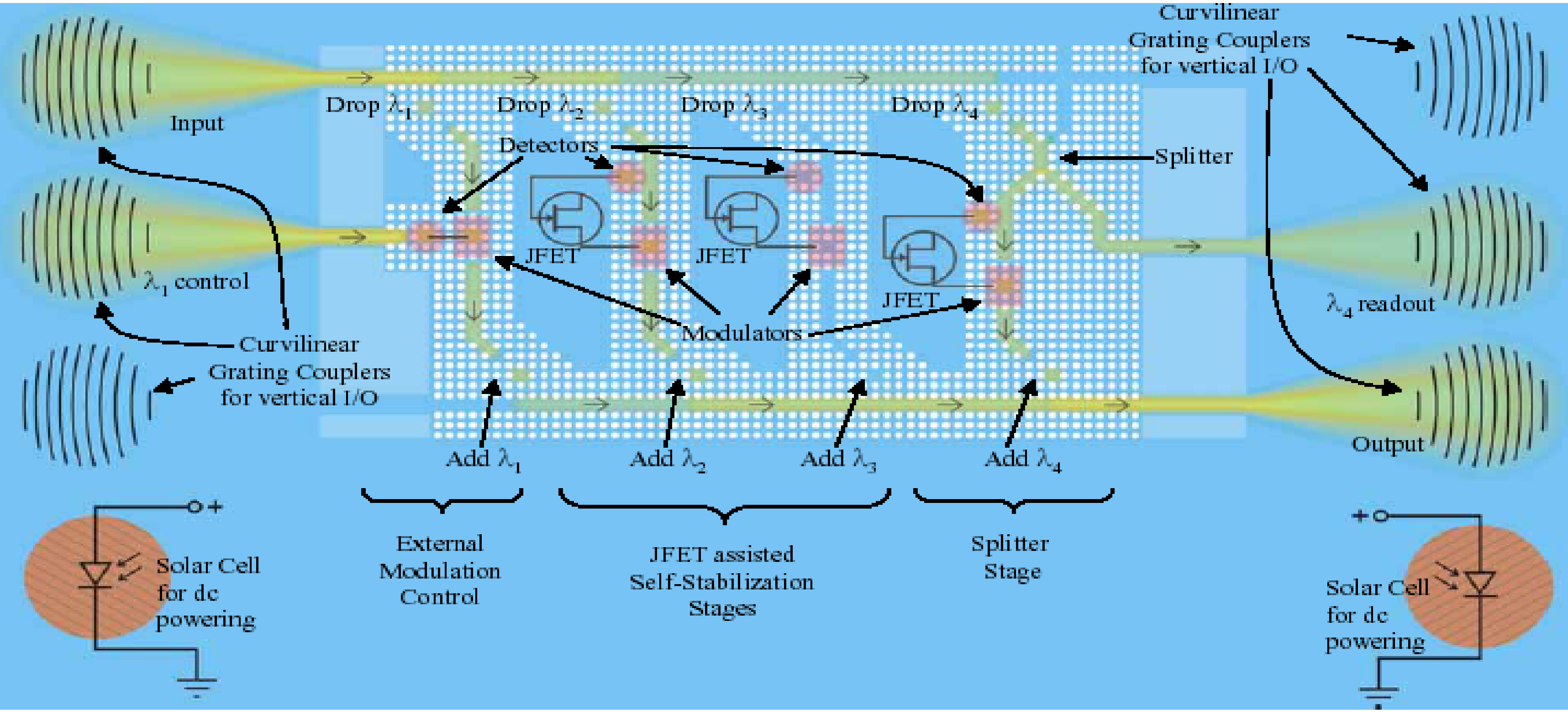
Photonic Bandgap based Nano-Photonic Integrated Circuit Concept



(4 WDM channels are shown, but are meant to be representative of many more channels per chip.)

Eli Yablonovich, UCLA (OFC, 2004)

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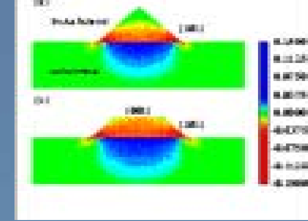
Nano-Photonics and Future Impacts

- Display, Lighting and Communication



" Where this thing is going to stop, only Lord knows."

**- Thomas Edison
October 1879**

**First Swiss-Taiwanese Workshop
on Challenges and Advanced Methods in Nanotechnology,
Zermatt, Switzerland, Oct 12-15, 2003**

Contributors

工研院光電所奈米光電中心

•**QD &InGaAsN VCSEL by MBE :** Jyh-Shyang Wang (王智祥) , Ru-Shang Hsiao [a] (蕭茹雄) , Chih-Ming Lai (賴志銘), Li-Chung Wei (魏立中), Kuen-Fong Lin(林坤鋒), Nikolai A. Maleev [c], Alexey R. Kovsh [c] and Jim Y. Chi (祁錦雲)

•**InGaAs(N) VCSEL by MOVPE :** Chen-Ming Lu (呂振民), Chih-Hung Chiou (邱志鴻) , Cheng-Hung Lee (李政鴻) and Tsin-Dong Lee (李晉東)

•**850 nm VCSEL Process:** Hung-Pin D. Yang (楊泓斌) , Hsin-Chieh Yu [b] (尤信介), Jing-May Wang (王靜美), Hao-chung Kuo [d] and Chia-Pin Sung (宋嘉斌)

•**850 nm VCSEL Package & Module :W division**

[a] Department of Electrophysics, National Chiao Tung University
[b] Institute of Microelectronics, National Cheng Kung University
[c] A. F. Ioffe Physico-Technical Institute, St. Petersburg,Russia
[d] Institute of Electro-optical Engineer, National Chiao Tung University

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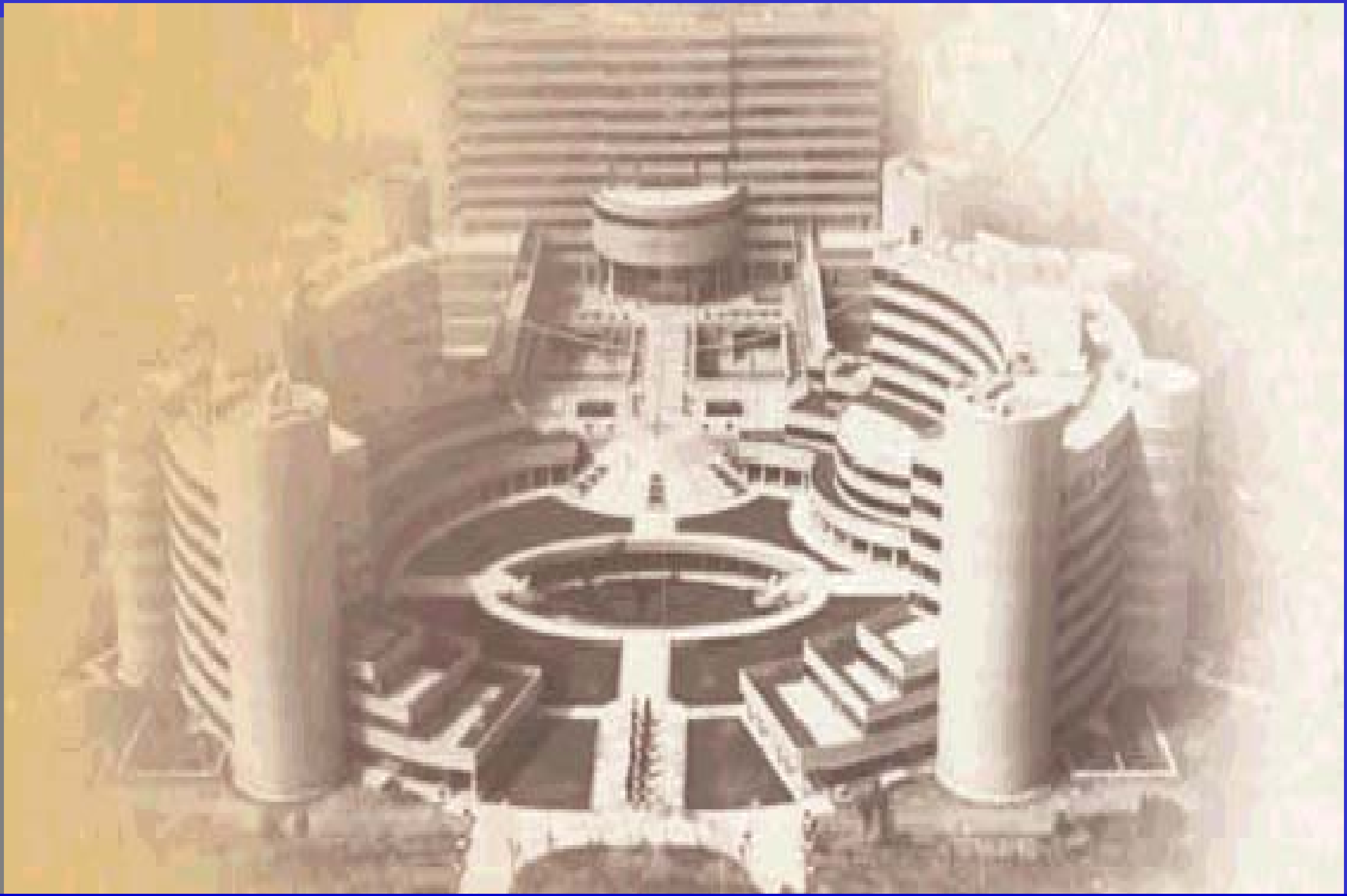
Industrial Technology Research Institute

Hsinchu, Taiwan



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Thank you

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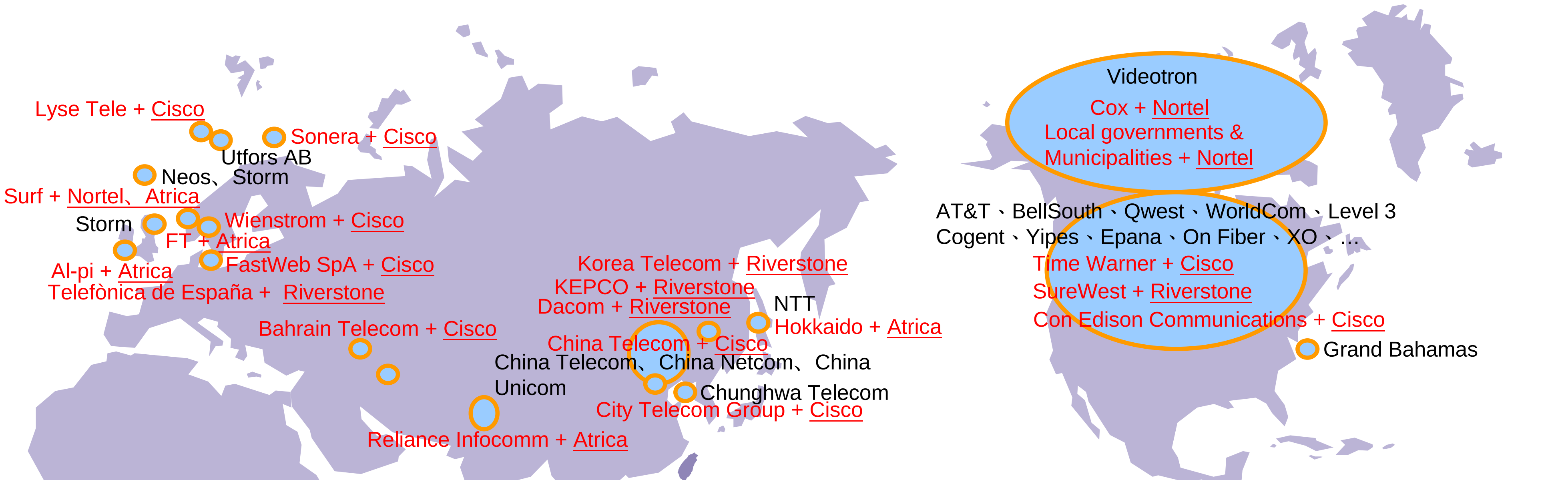
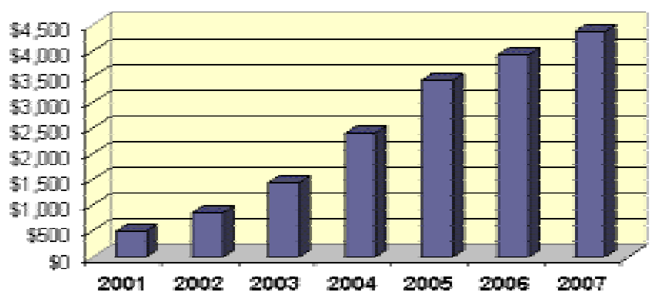
商機一：都會光纖乙太網路市場

- 2002年都會乙太網路建設正式起飛
- 設備方面主要競爭者：Cisco、Nortel、Riverstone、Atrica

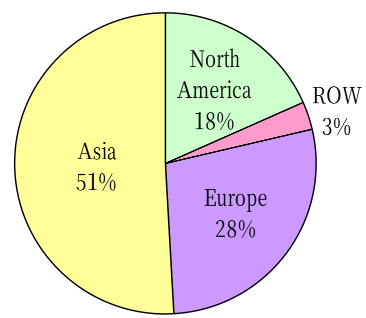


全球都會光乙太網路設備產值($M)



Source：IDC，2003/01

2002都會光乙太網路設備市場地區分佈

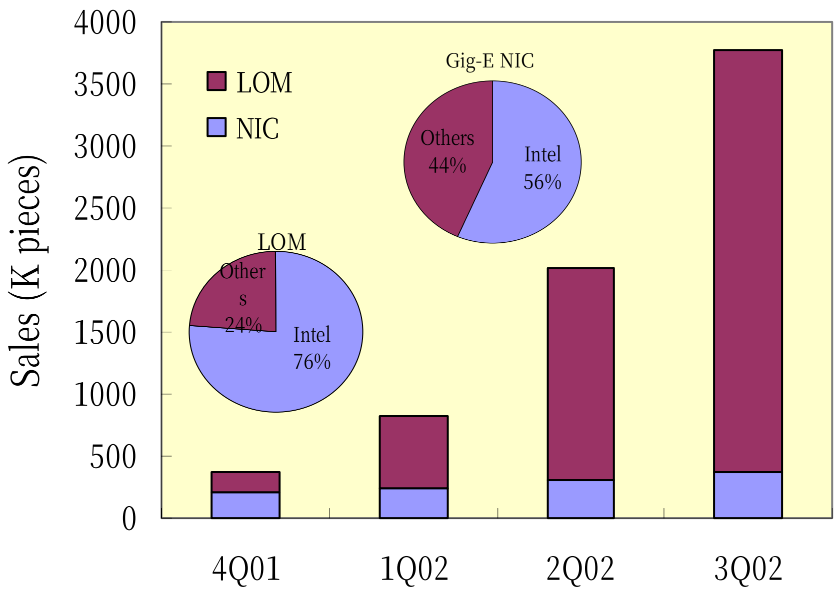


- 2002年已開通
- 2002年後新建設案

商機二:區域及儲存網路市場

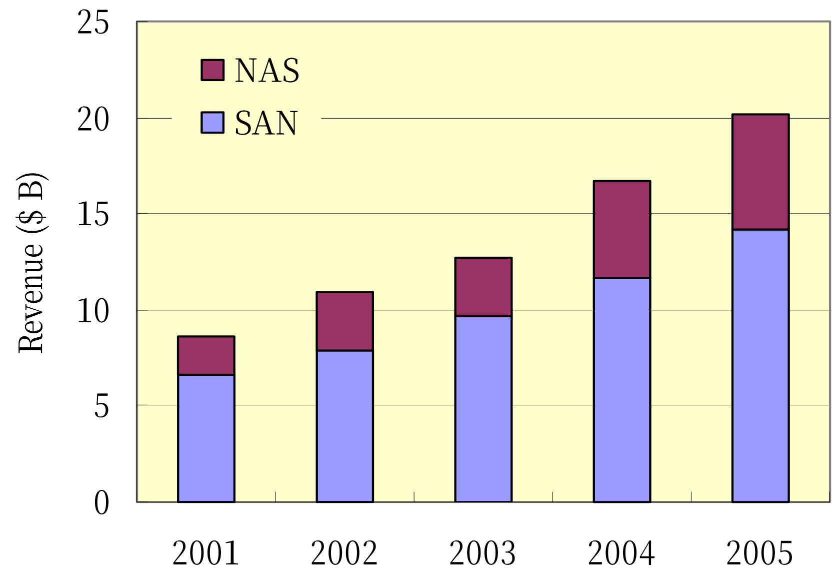
- 2002年Gig-E NIC出貨量大幅成長，顯示LAN市場的Gig-E需求開始成熟
- 儲存網路近期蓬勃發展，系統廠商的技術發展動向值得關切

Gig-E 網路卡出貨量統計



Source：Dataquest, 2002/12

儲存網路市場預測



Source：IDC, 2002/09

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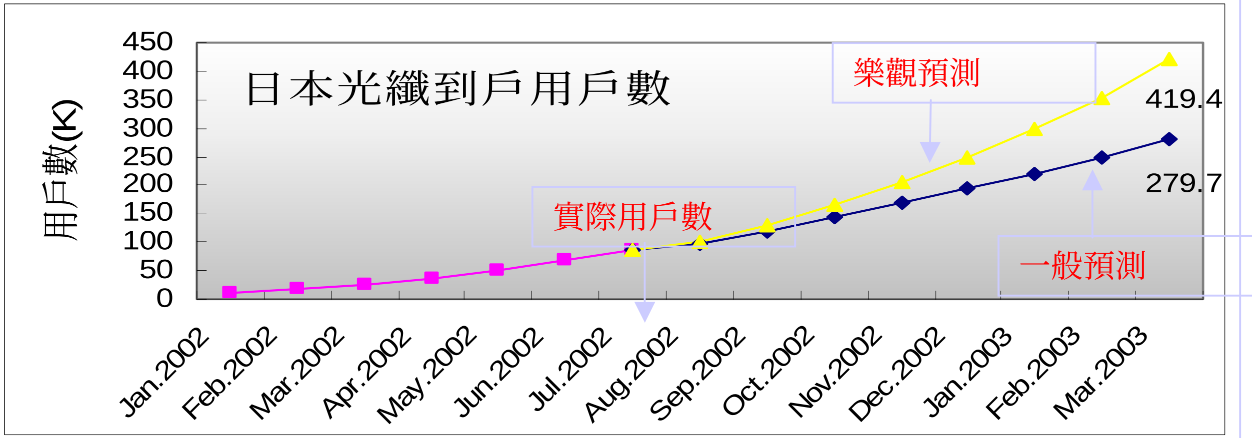
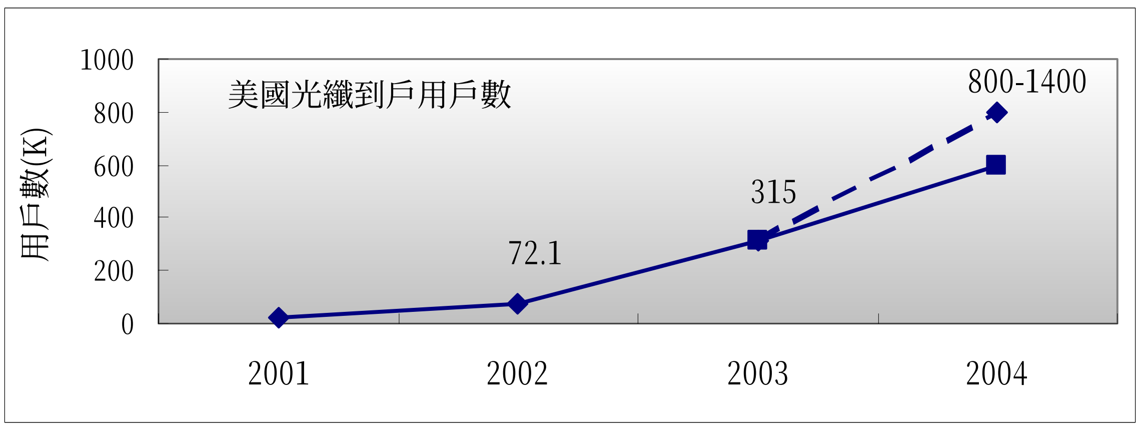
商機三：光纖到戶(FTTP)市場

- 美、日等國的經驗證明，透過數位內容的充實與服務價格的降低，**FTTH**發展可期
- 亞洲包括韓國、台灣與大陸都即將推出**FTTH**服務



- 日本-推行**FTTH**服務最力的國家
- 由政府政策主導，推動業者提供低價的**FTTH**服務
- 以**10Mbps**為例，月費**4,000**日圓
- 以**10Mbps**為例，月費**6,000-8,000**日圓
- **2001**三月開始提供服務之後，連續六個月成長率超過**130%**



- 美國–最早推出FTTH服務的國家(1995)
- 由電信業者根據市場需求推動
- 早期由於成本過高，內容服務不足，推行效果不彰
- 2001寬頻通訊熱潮之後，搭配數位內容服務的增加，開始有較大的成長

Source：矢野經濟研究所；Render；Vanderslice & Associates

- Taiwan's Optoelectronic Industry
- The Optical Communication Industry
  - Industry Overview
  - Technology Development
  - Infrastructure Building
  - International & University Collaboration
  - Future

加強推動國際合作建立領先優勢

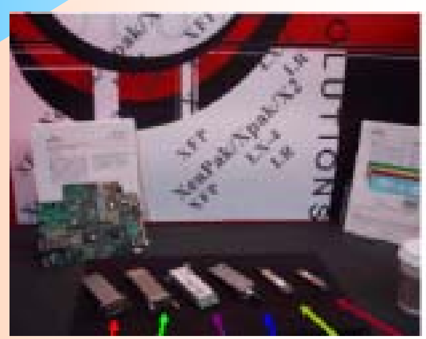
- **Cambridge** 40 G 高速元件
- **UMBC** 下世代 PLC 技術應用於 ROADM
- PLC based optical transceiver sub-assembly

- **Telcordia**
  標準驗證技術引進

- **Agilent**
  測試實驗室共同合作

- 可疊式開關技術合作 (ethernet stackable switch)
- Advanced transponder
- SOA 、SLED 及 DFB Laser

- **Standard Activities**
  - IEEE SA Cooperate membership
    IEEE 802.3ah EFM
    IEEE 802.3ae 10Gbps Ethernet
  - Multisource Agreement (MSA)
  - Optical Internetworking Forum
    Principal Member



- **在 OFC 2003 與國外大廠共同發表 10GE Transponder**

光通訊 FTTP產業的機會與挑戰

- 新興市場應用將帶動新一波產業成長
  - 都會乙太網路市場於2002年正式起飛，市場成長力道強勁，
  - 區域網路升級至**Gigabit Ethernet** 需求浮現
  - 儲存網路市場蓬勃發展，元件廠商需密切配合系統廠商技術規格發展
  - **FTTH**市場蓄勢待發，元件廠商需首重價格因素
- 光通訊產業屬新興產業，國際化規格正熱絡制定
  - **IP**及規格可引導新技術開發帶動產業發展，大陸及台灣協手協訂規格、跳脫以往跟隨者角色
- **LCD-TV will accelerate digital media centers to home and create demand for FTTP**
- 大陸、台灣應加强分工合作以掌握國際未未市場

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台灣光通訊產業現況與發展
Optical Communication industry in Taiwan - Present and Future

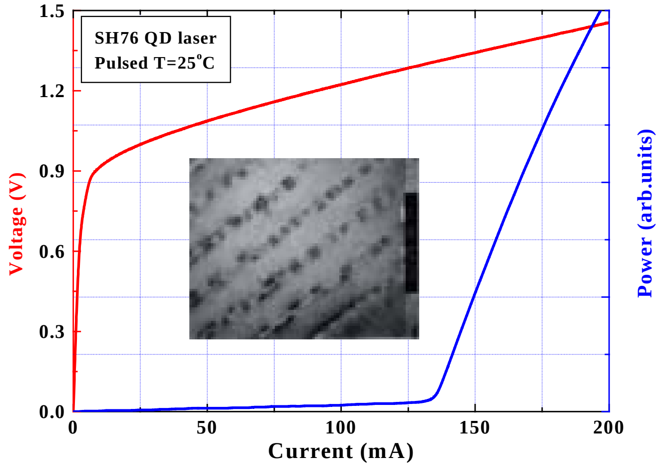
劉容生
工研院光電所
及
台灣光通訊產業聯盟

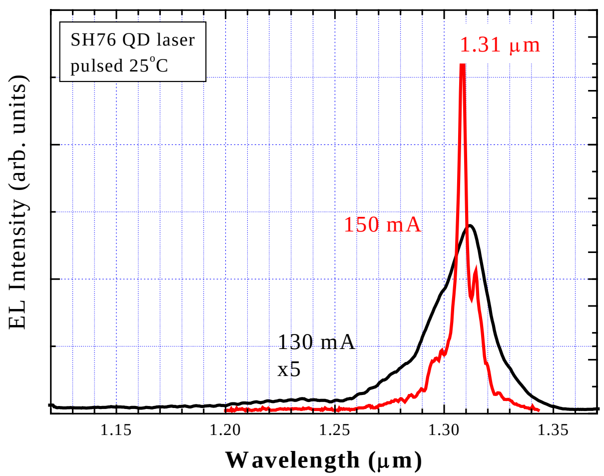
Y.S. Liu
Optoelectronics & Systems Labs. (OES)
Industrial Technology Research Institute (ITRI)
&
TOCIA - Taiwan Optical Communication Industry Alliance

ITRI

Ioffe Physico-Technical Institute

InAs/InGaAs QD 1.3 um Lasers





Lasing at 1.31 µm @ 25°C with low I_{th} and high efficiency!

Potential Impact: Low cost VCSELs and LDs for metro/local-access fiber networks.

Innovation: Allow GaAs technology for uncooled 1.31 um components to replace the less developed InP technology. QD can be made on the cheaper and better GaAs substrates and is less temperature sensitive. It also allows integration with GaAs high speed electronics to lower the system costs.

Importance: The characteristics of InAs/InGaAs QD epi-structure were shown to be as good as other QW LD structures. ITRI/IOFFE collaborative program will aim to be the first in commercializing QD devices at 1.3um in the world.

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