High-Speed Opto-Electronic Components for Digital and Analog RF Systems

K. Y. Liou
Director
Laser Technology & Government Business
Multiplex, Inc.
kyliou@multiplexinc.com

WOCC
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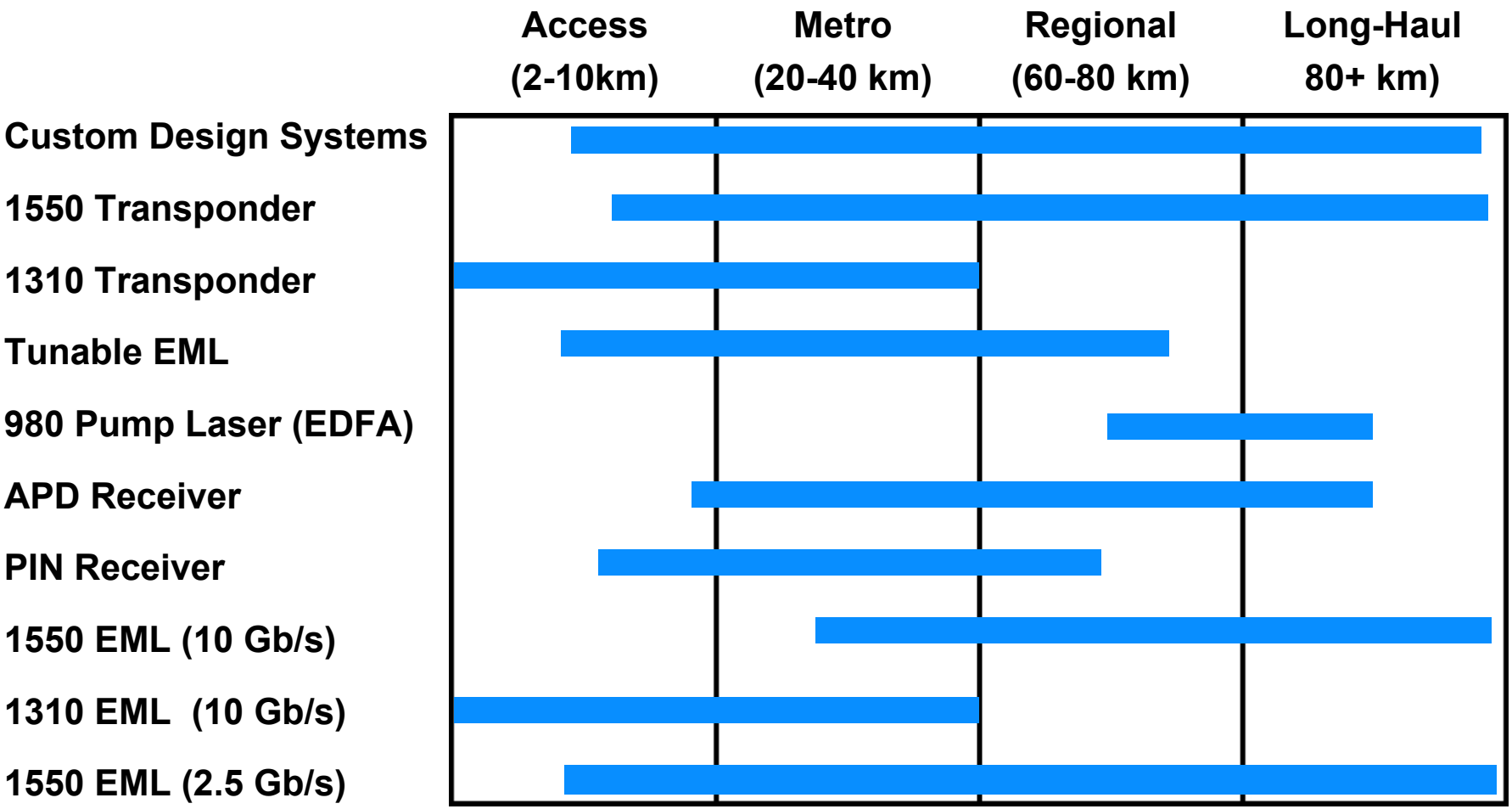
Multiplex, Inc.
Photonics for Communications

5000 Hadley Road
South Plainfield, NJ 07080 USA
www.multiplexinc.com

Active Opto-Electronic Component Solutions for Optical Networks



* 2.5Gb/s application extends to >640 km

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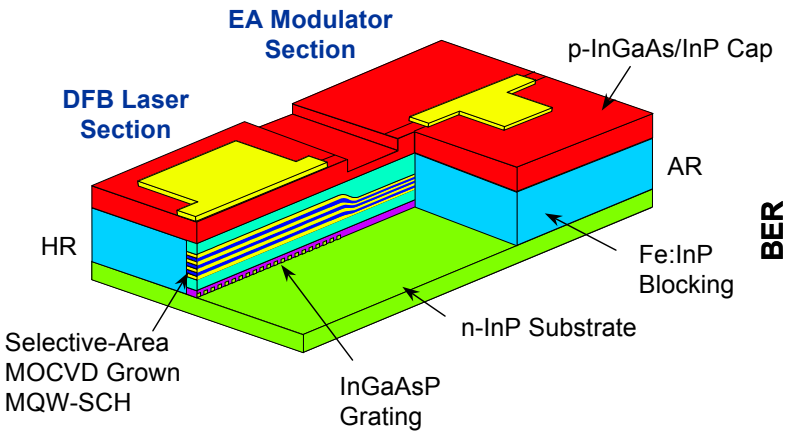
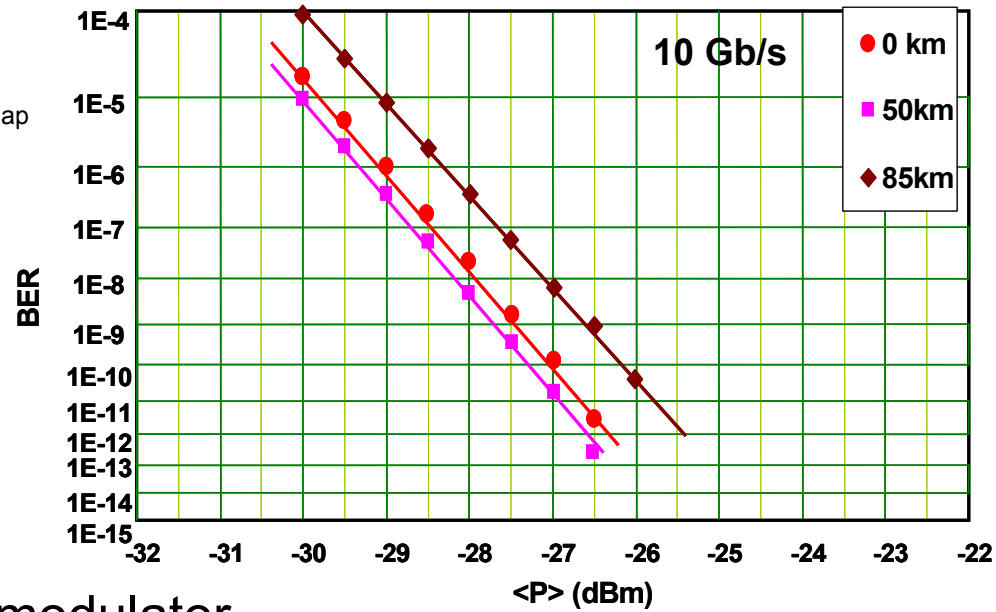
Electro-absorption Modulated Laser (EML)





- MQW DFB laser and EA modulator
- Low cost integration by SAG (selective area growth)
- Fiber packaging same as DFB laser
- 80-km DWDM transmission
- Replaces hybrid-packaged Laser-LiNbO3 modulators even for long-haul DWDM

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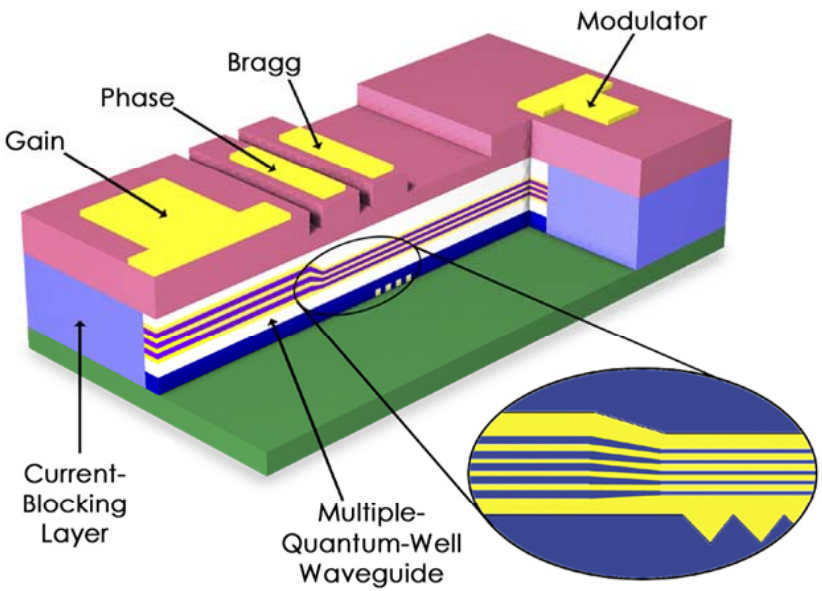
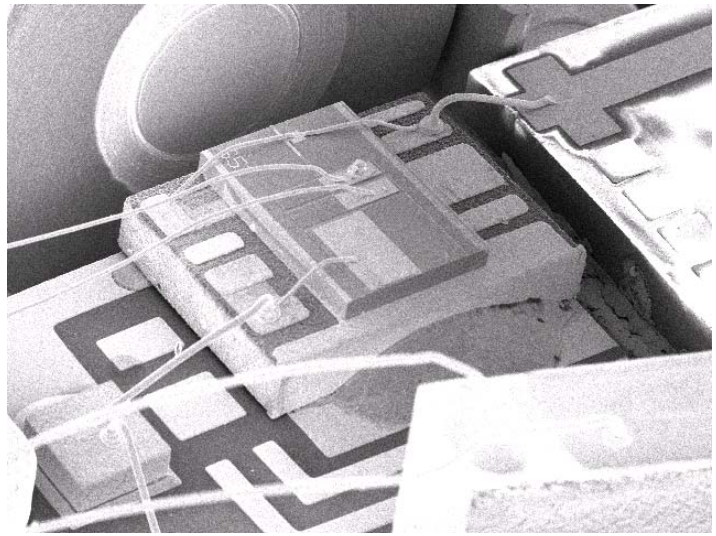
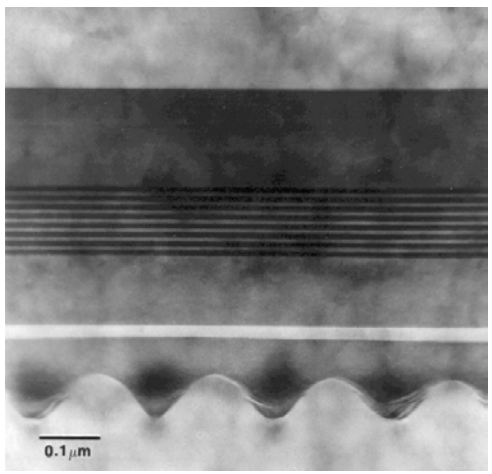
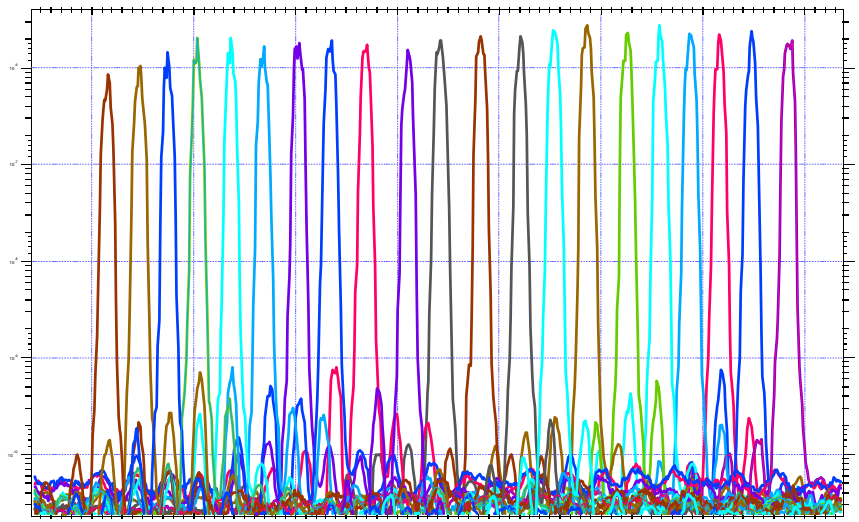
Wavelength Tunable EML









1542 Wavelength (nm.) 1556

From MOCVD Wafer Growth to Subsystems and Fiber Transmission Test

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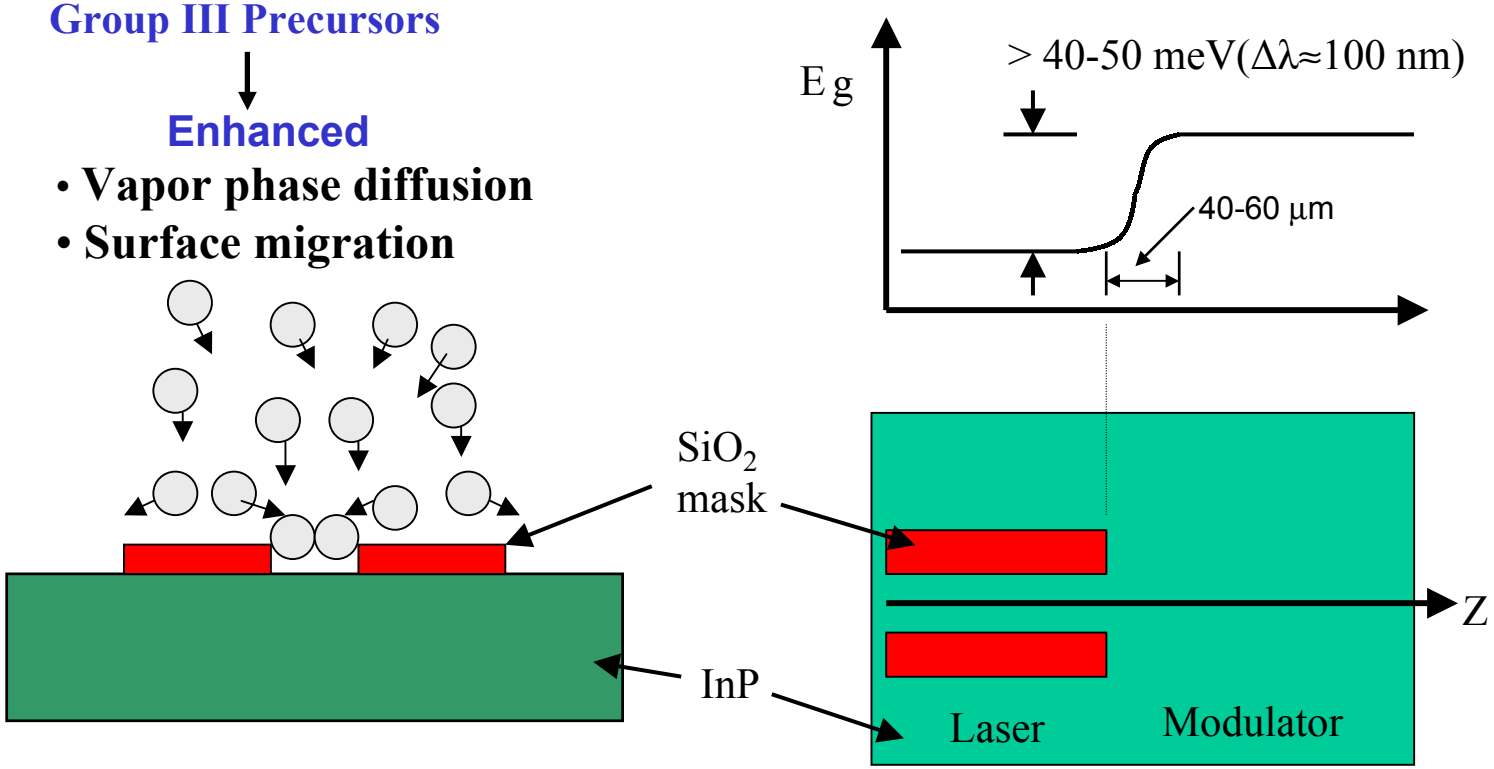
Selective Area MOVPE Growth

Increased concentration
Group III Precursors

↓

Enhanced

- **Vapor phase diffusion**
- **Surface migration**



(1) Indium rich (compressive strain) MQW inside slot
(2) Thicker MQW layers inside the slot (Red shifted)

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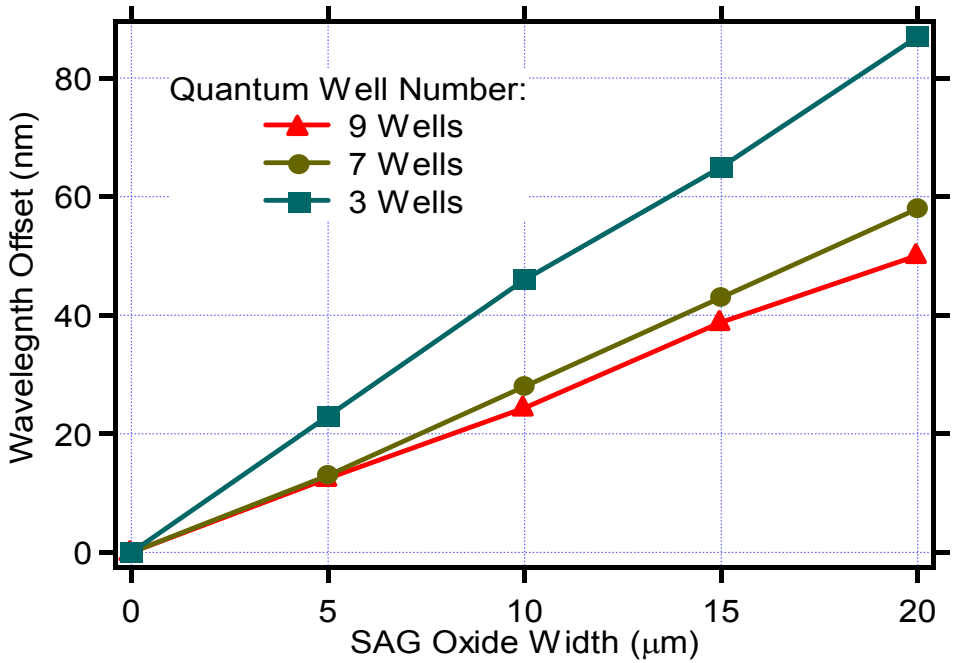
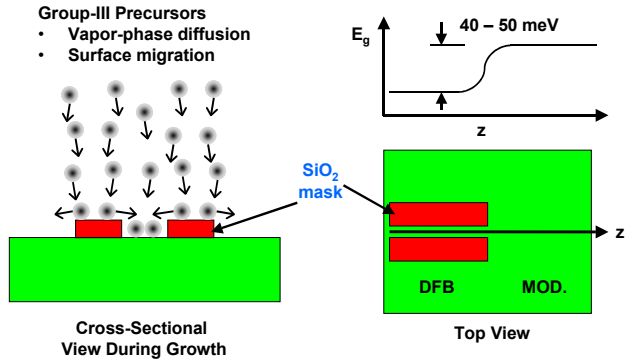
Micro Photo Luminescent Measurement





- Calibration of SAG-MOCVD growth
- Bandgap λ shift by well thickness (and alloy composition, strain)
- SAG mask design for active (source, modulator, detector) and passive waveguide integration

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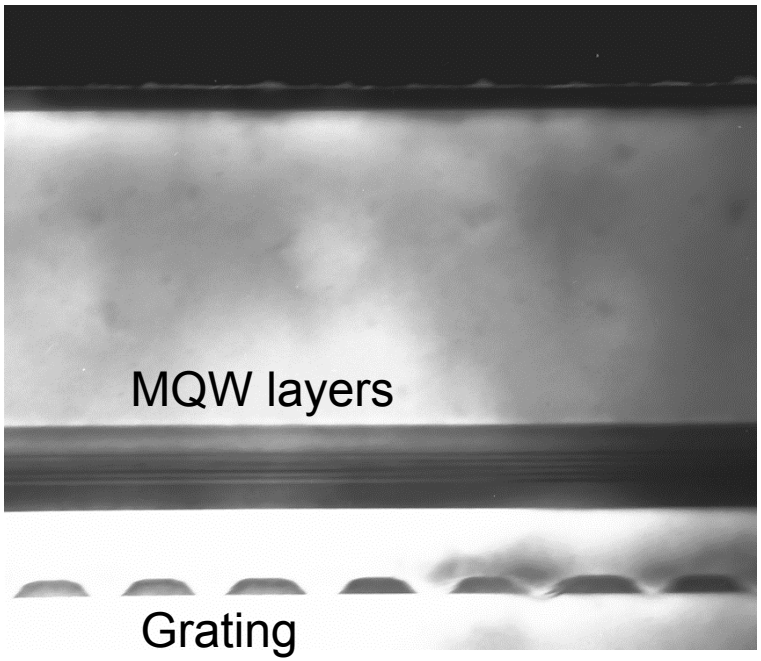
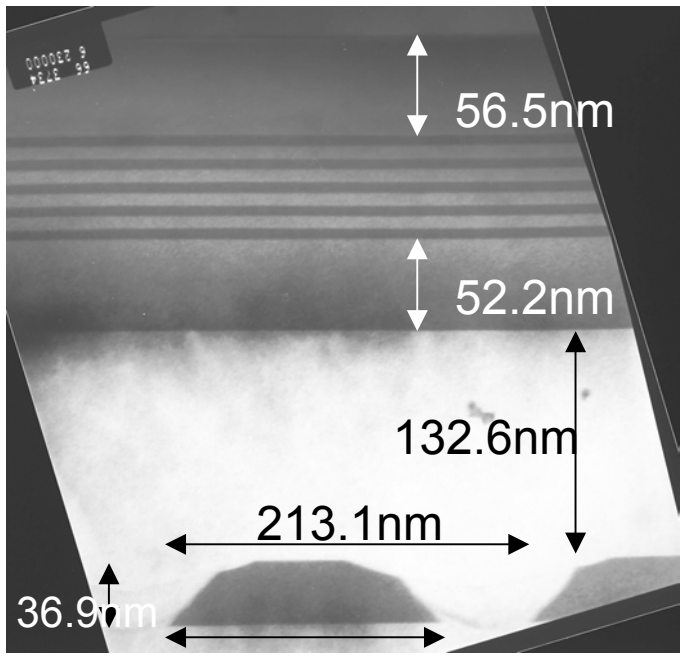
Cross-sectional Transmission Electron Microscopy of MQW and DFB Grating Structure





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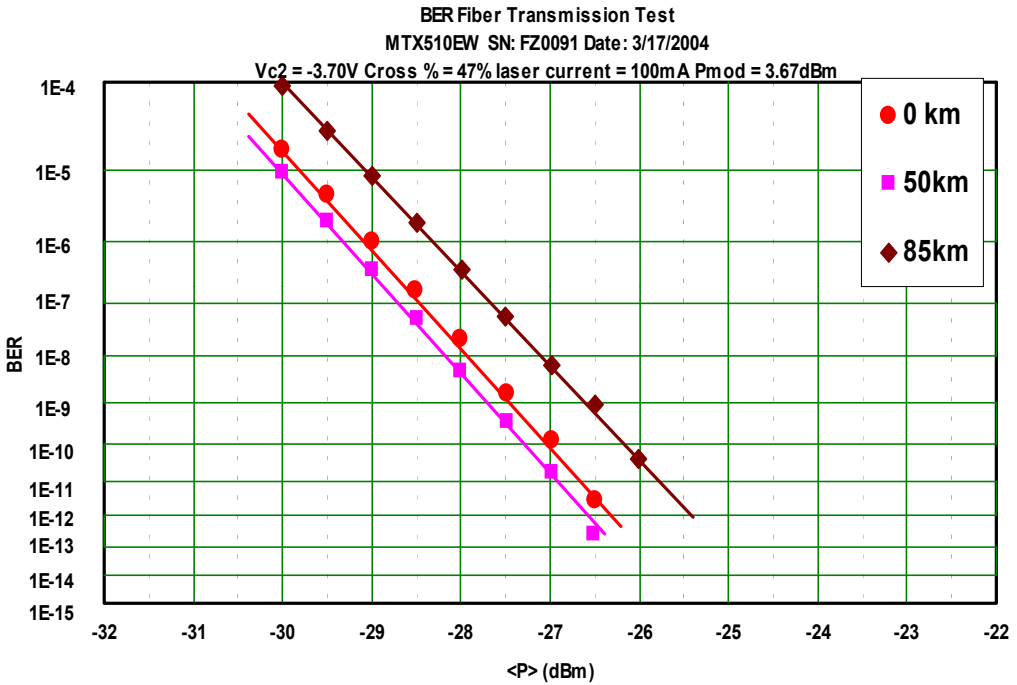
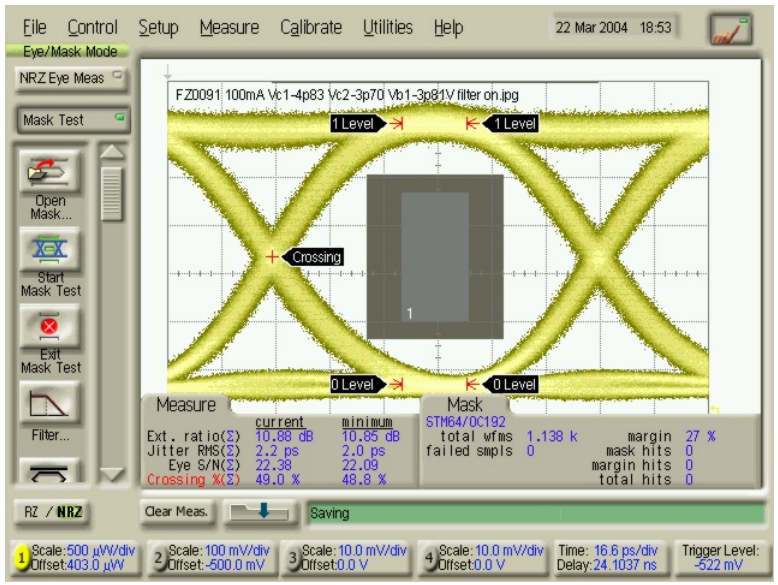
10 Gb/s 85km EML Module



Laser operating current 100mA, modulated power 3.67dBm



Filtered eye diagram of 85km EML module

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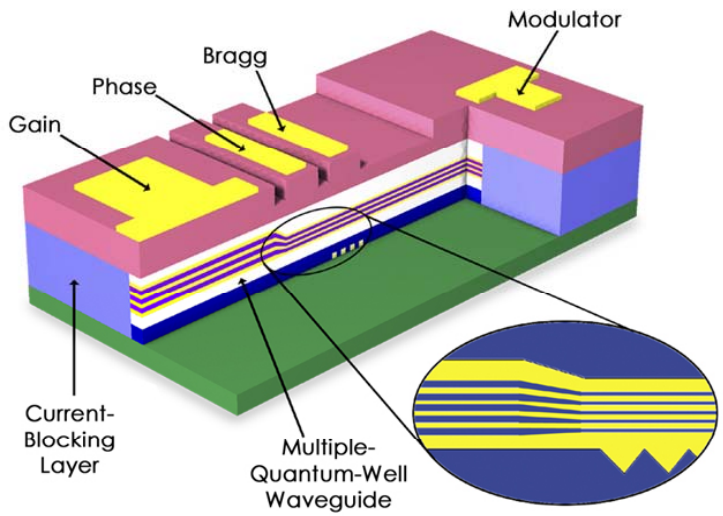
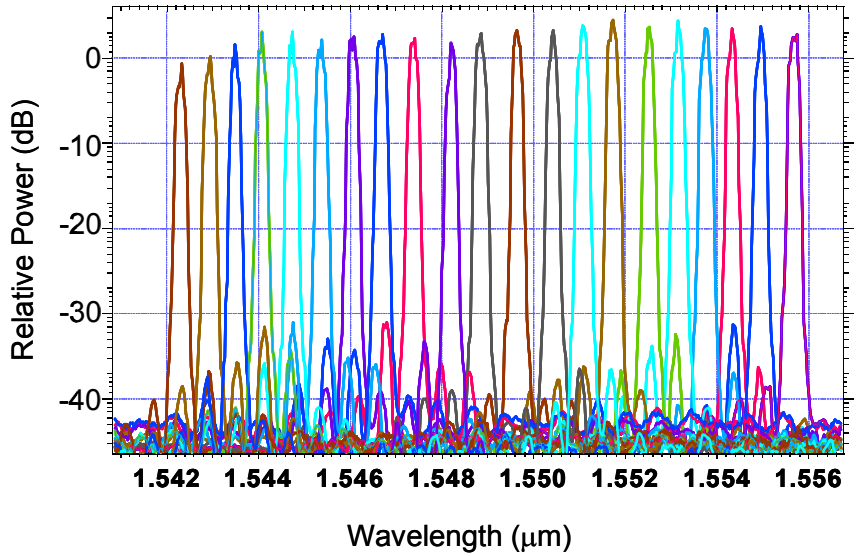
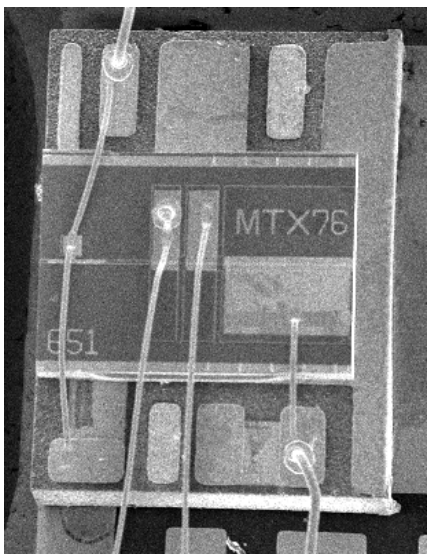
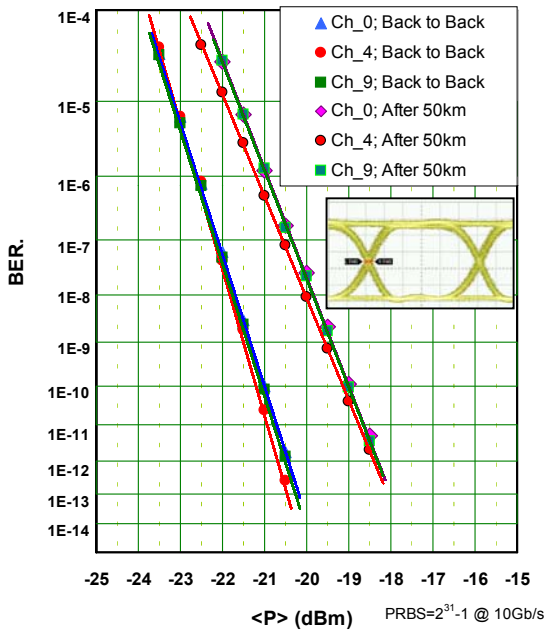
Tunable EML (DBR laser+EA modulator)







10 Gb/s TEML



- Wavelength tuning characteristics (12 nm range)
- Fiber transmission test at 50-GHz spaced ITU channels

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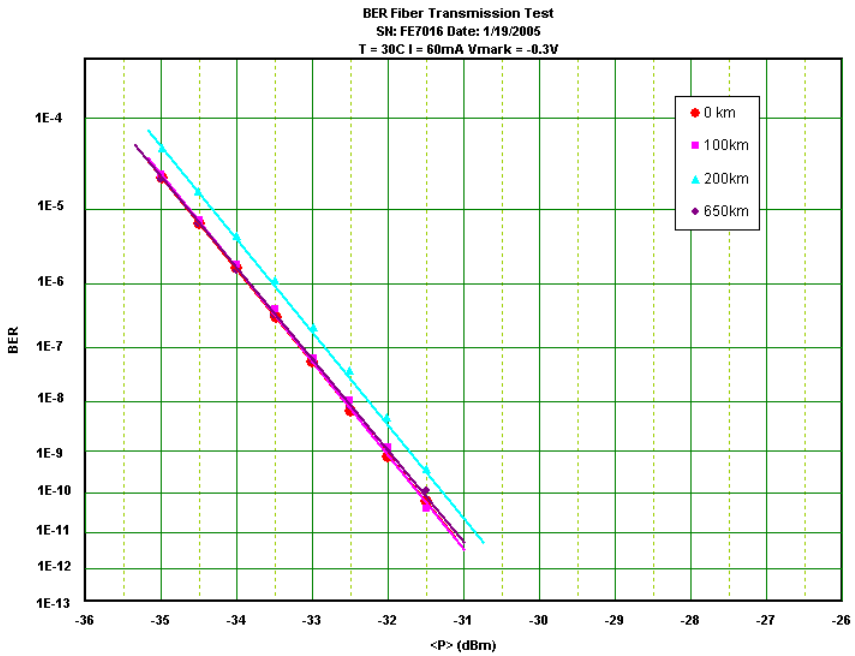
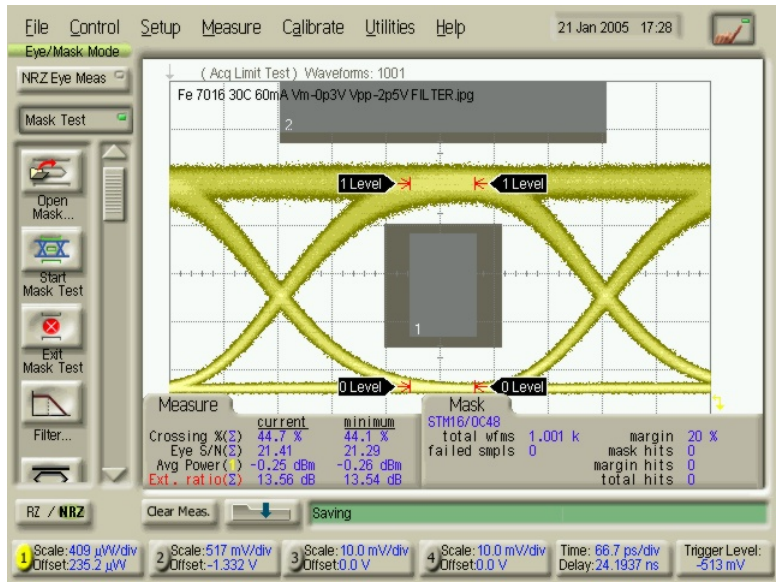
2.5 Gb/s 640km EML Module





Laser operating current 60mA, modulated power 0.07dBm

Integrated wavelength locker for DWDM

Filtered eye diagram of 640km 2.5 Gb/s EML module

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The Multiplex Family of EMLs

Gen-1 EML

7-pin with GPO

Industry-standard configuration

Qualified to Telcordia GR-468-CORE

Gen-2 EML

14-pin butterfly package

30GHz through pin replaces GPO

EML driver IC inside package

Qualified to Telcordia GR-468-CORE

Gen-3 EML

21-pin package

50GHz RF feed-through pins

G-S-G coplanar 50 Ohms ports

Integrated driver IC and wavelength locker

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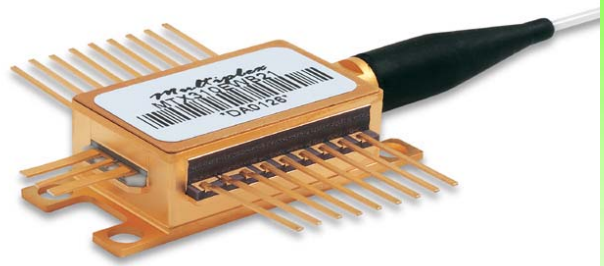
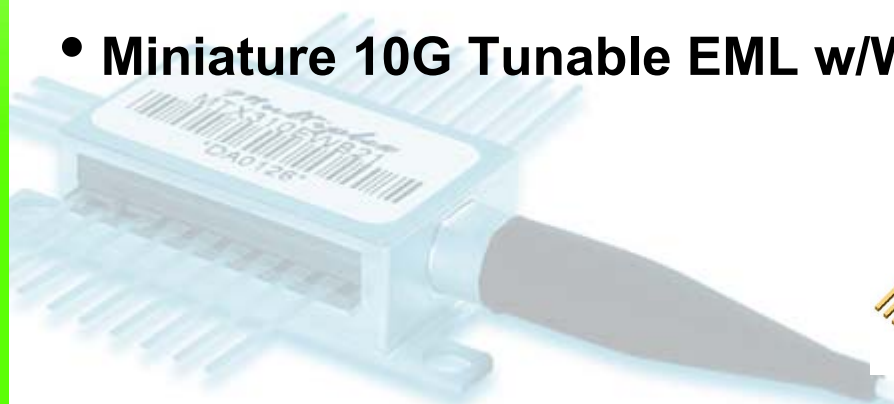
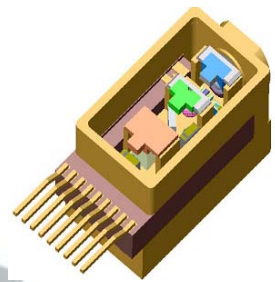
Next Generation EML Products

- 2.5G EML w/WLL - ***Current Product***
- 10G GPO EML w/WLL - ***March/2005***
- 10G Tunable EML w/WLL
  (5nm Tuning Range) - ***Current Product***
- 10G Tunable EML w/WLL
  (12nm Tuning Range) - ***Q3/2005***
- Miniature 10G Tunable EML w/WLL - ***Q3/2005***







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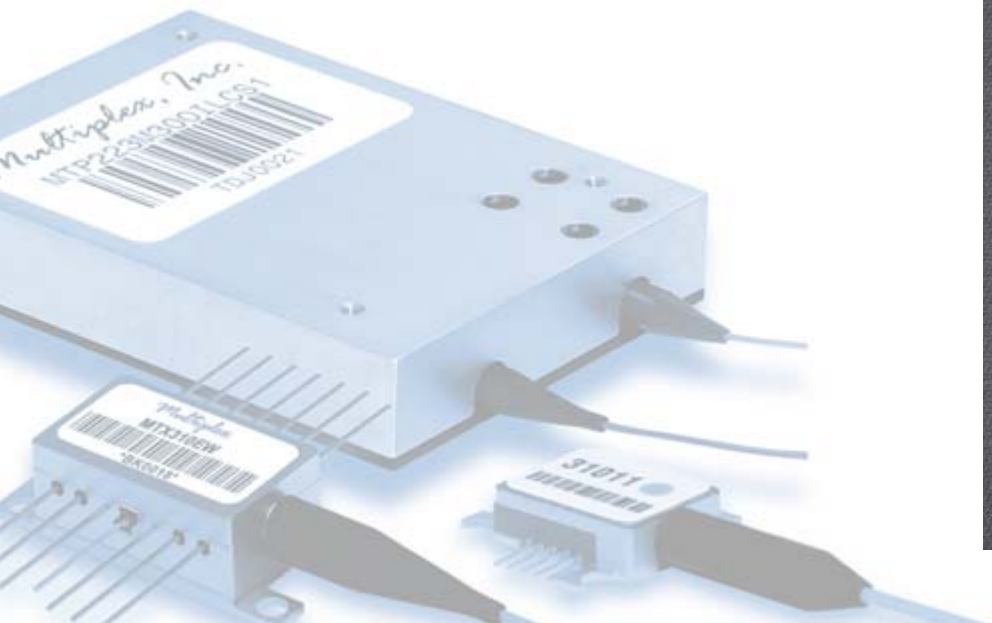
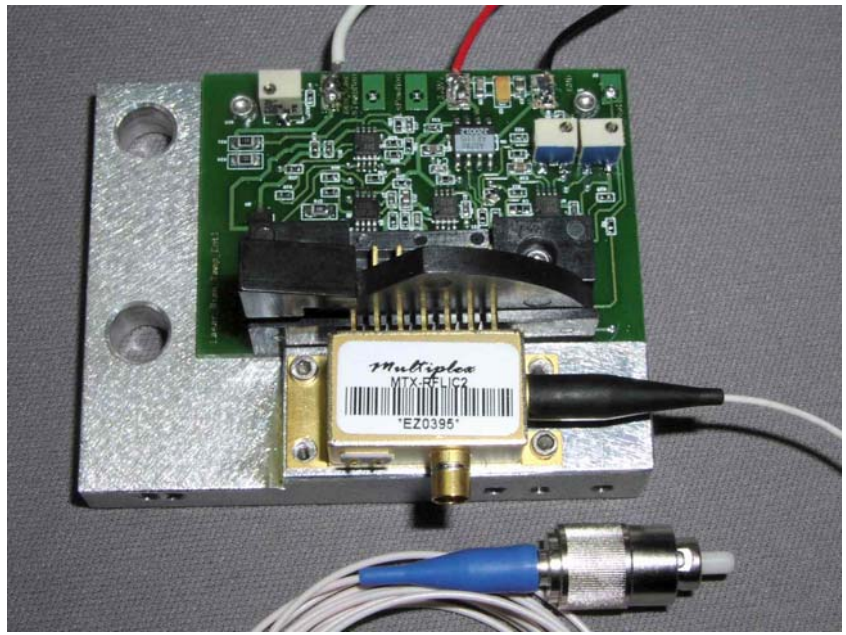
Introducing:
Injection Locked Laser Transmitter

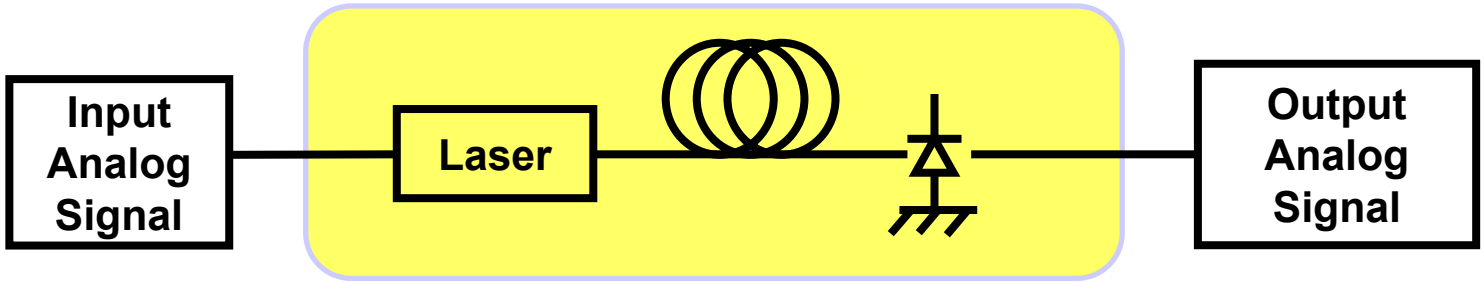
R&D Team: Multiplex Inc, UC Berkeley, UCSD

Sponsored by: DARPA RFLICS

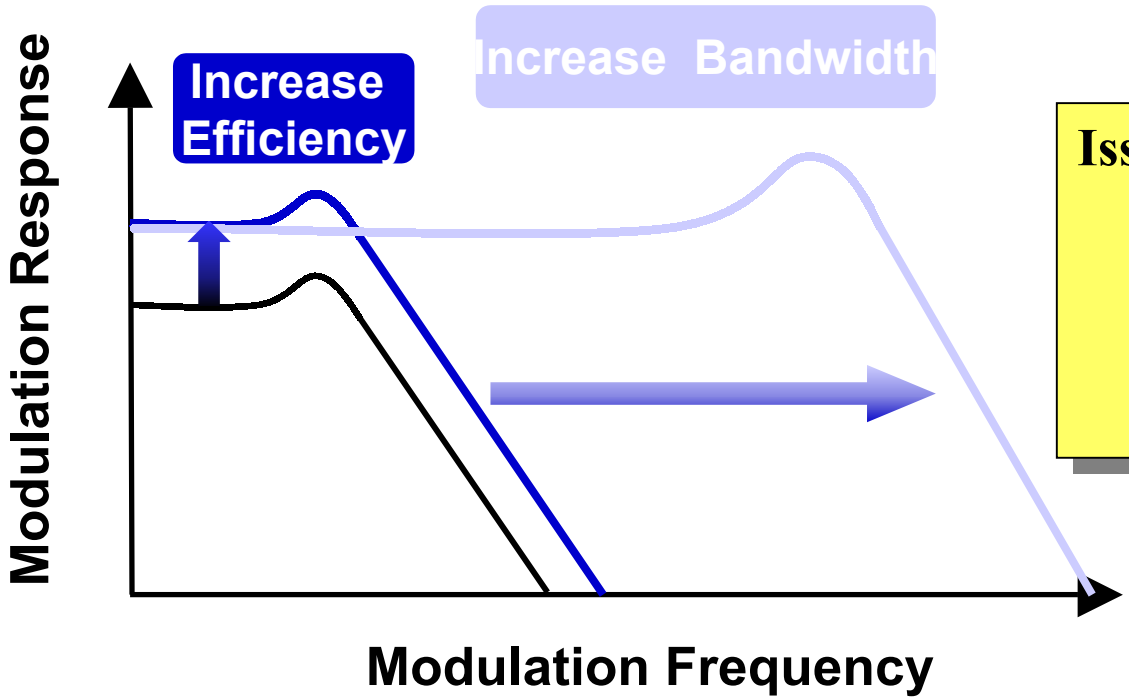




Directly Modulated Analog Fiber Optic Links



Direct Modulated Link



Issues of Direct Mod Laser

- Low RF efficiency
- Limited bandwidth
- Nonlinear distortions

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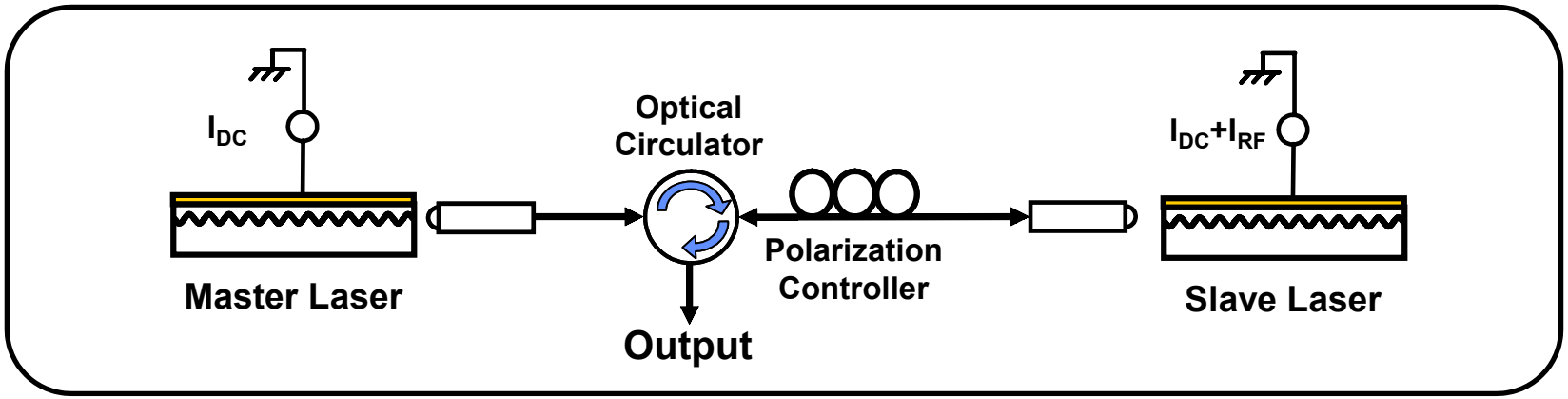
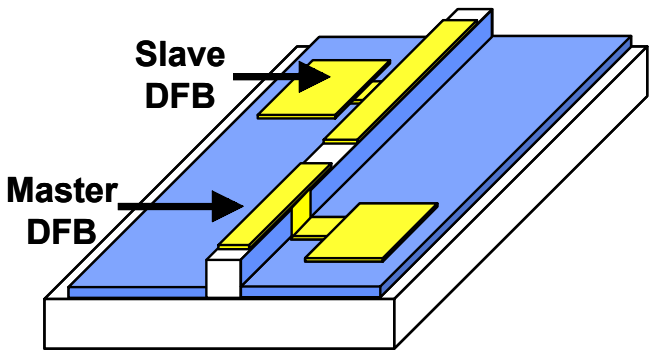
Monolithic Injection Locking Using Two Section DFB Laser



Conventional Optical Injection Locking: Bench Top



- Single laser package
- No optical isolator / circulator
- Automatic polarization match and optical alignment
- Current tuning
- Environmentally robust

New Monolithic Optical Injection Scheme Invented in RFLICS Program

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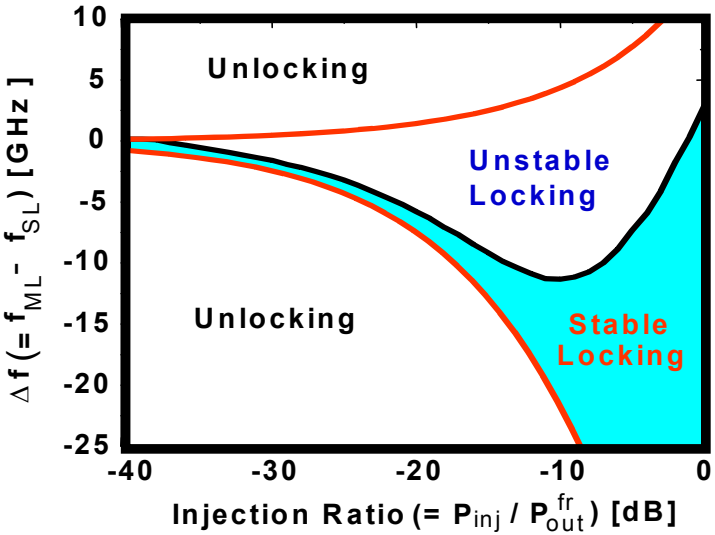
Injection-locking by Two-section DFB Laser

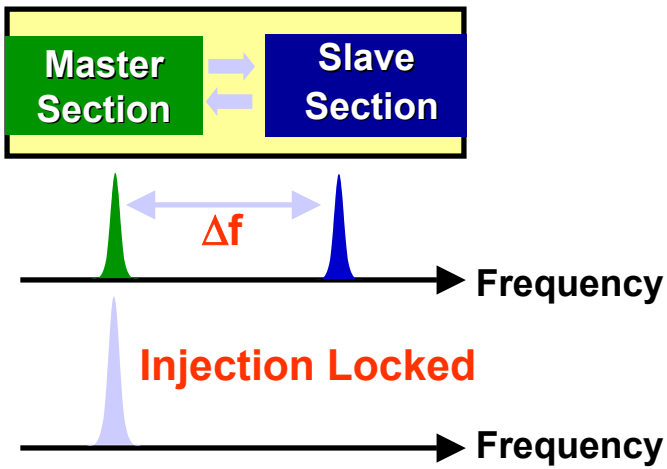
Locking Regime of Externally Injection-locked Laser



Linewidth Enhancement Factor α

→ Asymmetric Stable Locking Range

Negative Detuning in Monolithic Injection-locked Laser



No isolator between
Master & Slave Section

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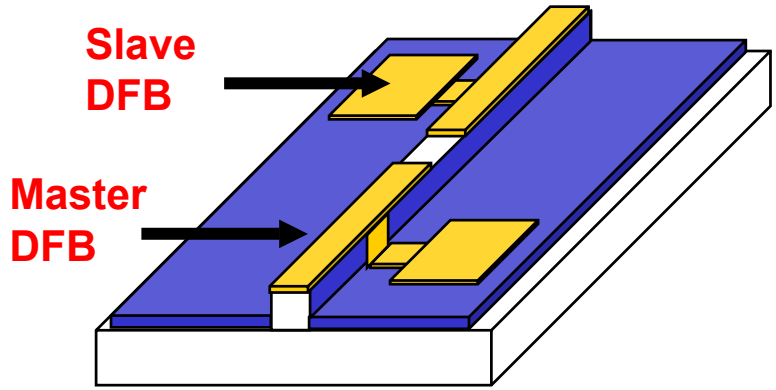
Monolithic Injection Locking Using Two Section DFB Laser

New Monolithic Optical Injection Scheme Invented in RFLICS Program



- Single laser package
- No optical isolator / circulator
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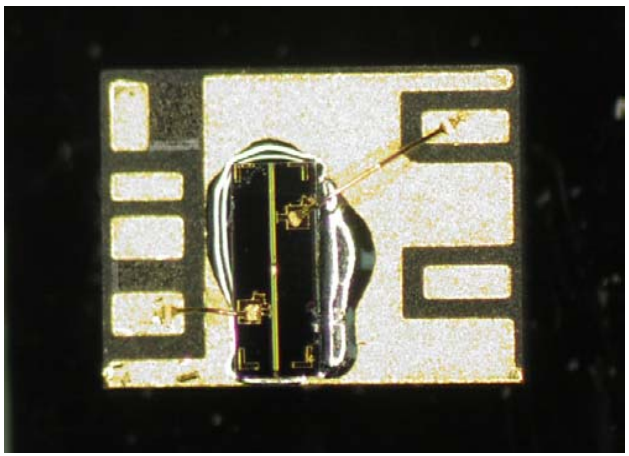
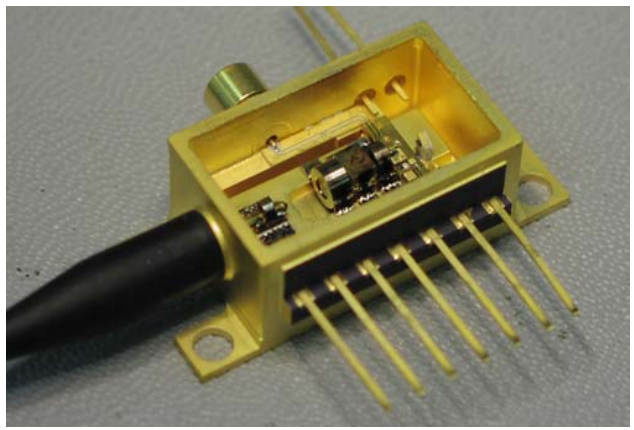


Integrated master-slave laser on submount with 25Ω termination for direct modulation



Fully packaged module with output fiber, optical isolator, master laser power monitor, TEC, RF input port

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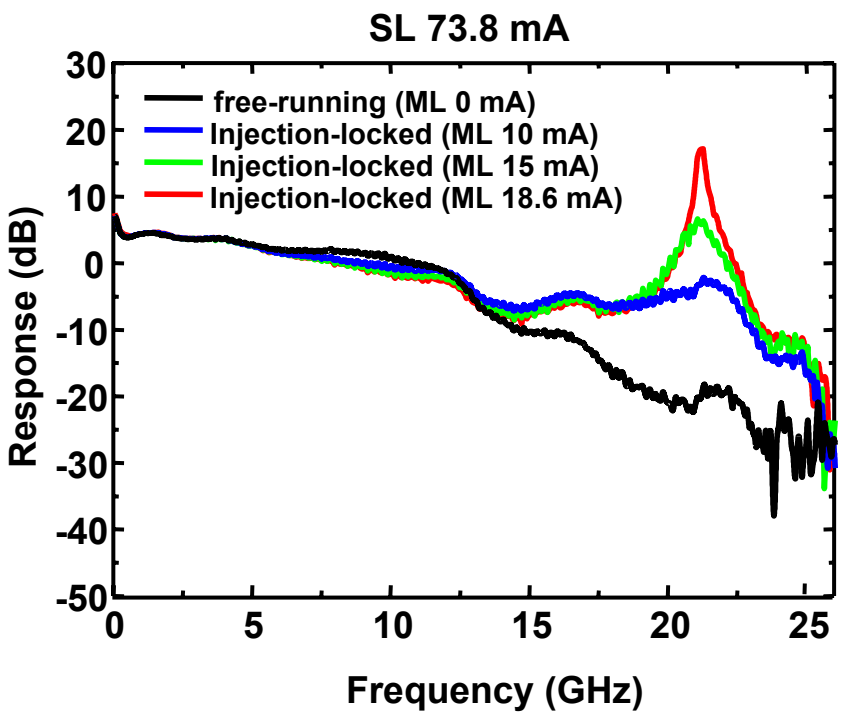
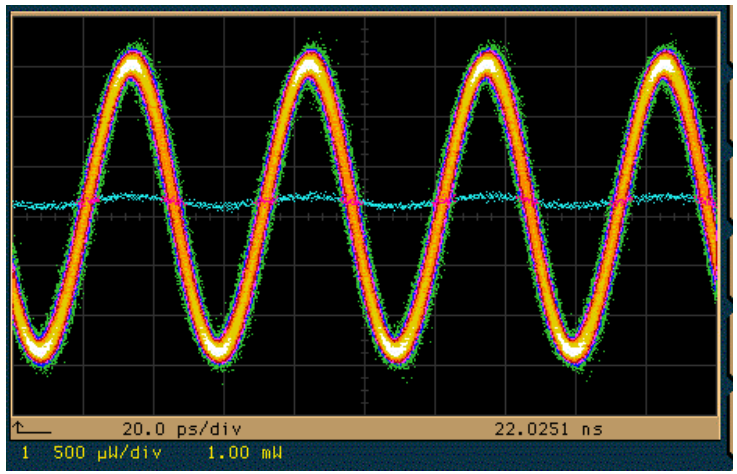
Monolithic Injection-locked laser in 25-GHz fiber-packaged module

Modulation Response



20 GHz Modulation Applied to Slave Laser



Red – injection locked

Blue – unlocked

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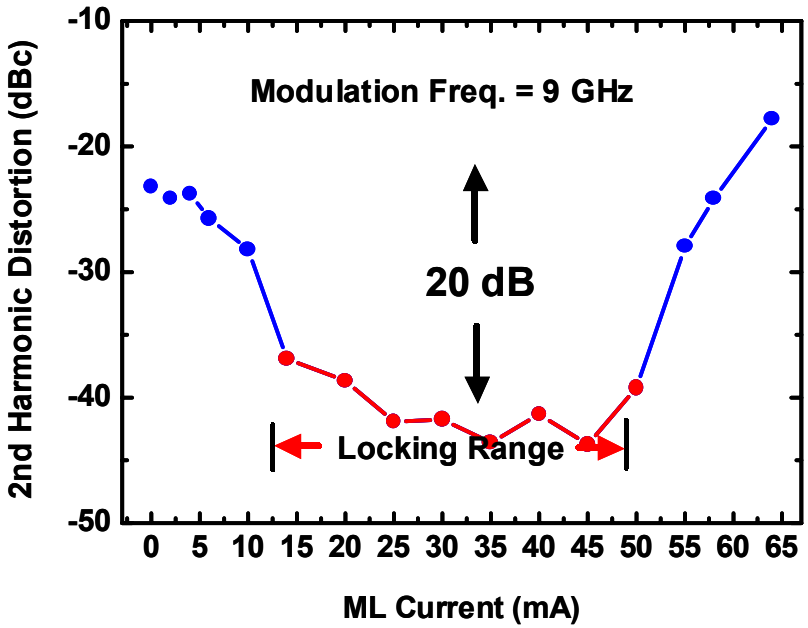
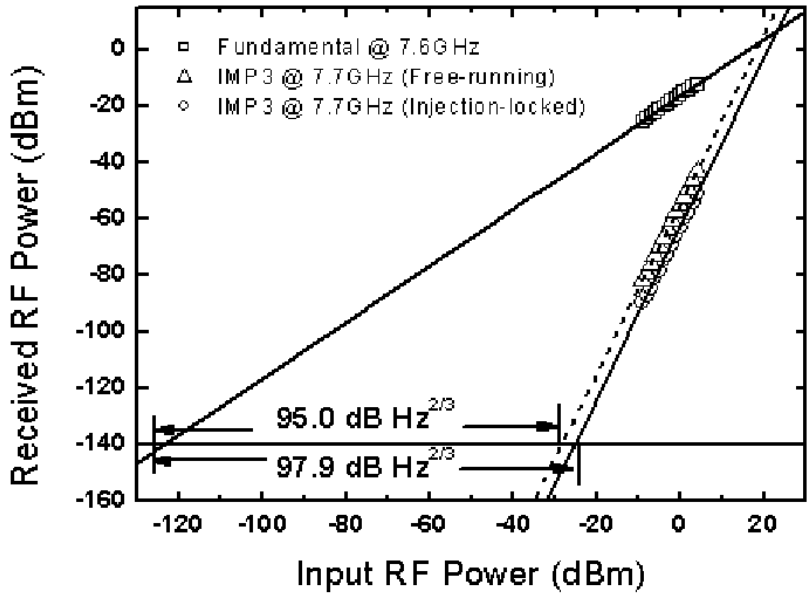
Monolithic Injection Locked DFB Laser





- Improved RF modulation linearity
- Suppression of harmonic distortion
- Increased spurious-free dynamic range
- Enhanced modulation bandwidth

Enhanced performance without increasing cost by InP-InGaAsP chip integration

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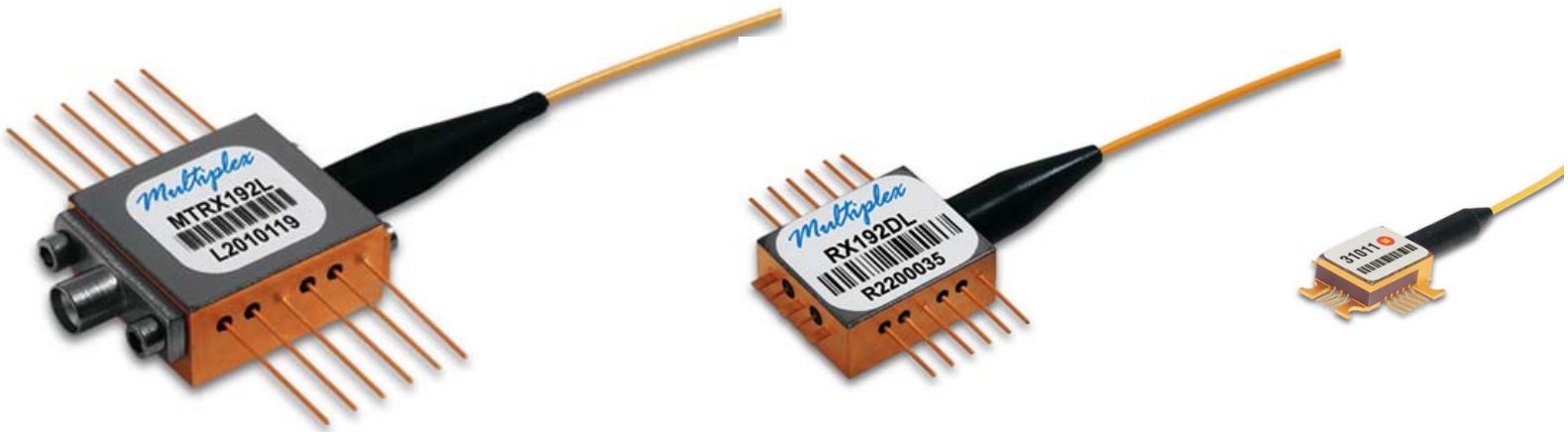
The Multiplex Family of Receivers



Gen-1 Receiver

PIN

Single Output

First with integrated limiting amplifier

Gen-2 Receiver

PIN and APD versions

Co-planar differential outputs

Small-form package

Gen-3 Receiver

PIN and APD versions

Ultra-compact surface-mount MSA package

Unique “Gull-Wing” Pins (> 20GHz BW)

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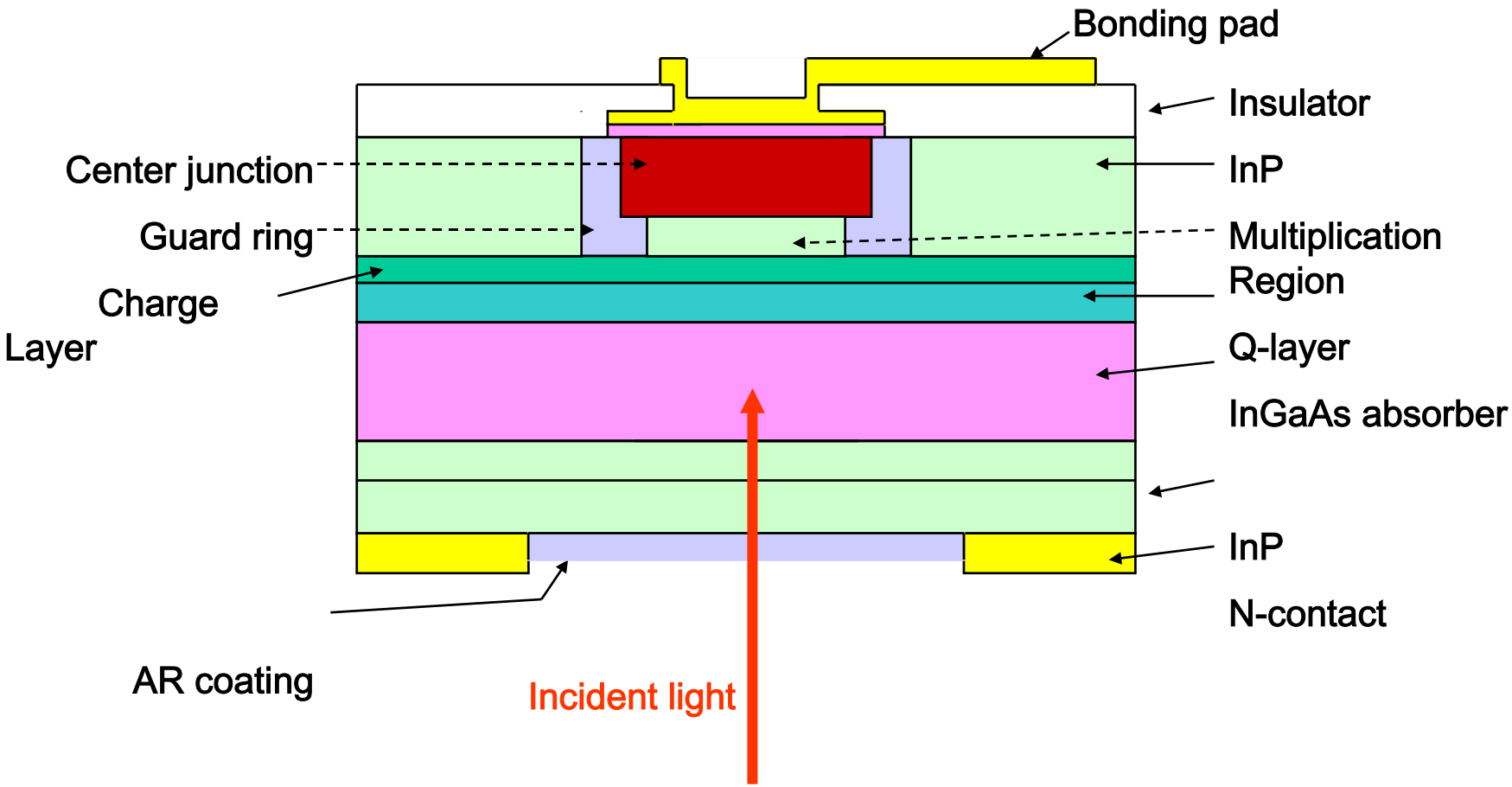
APD (Avalanche Photodiode) Design



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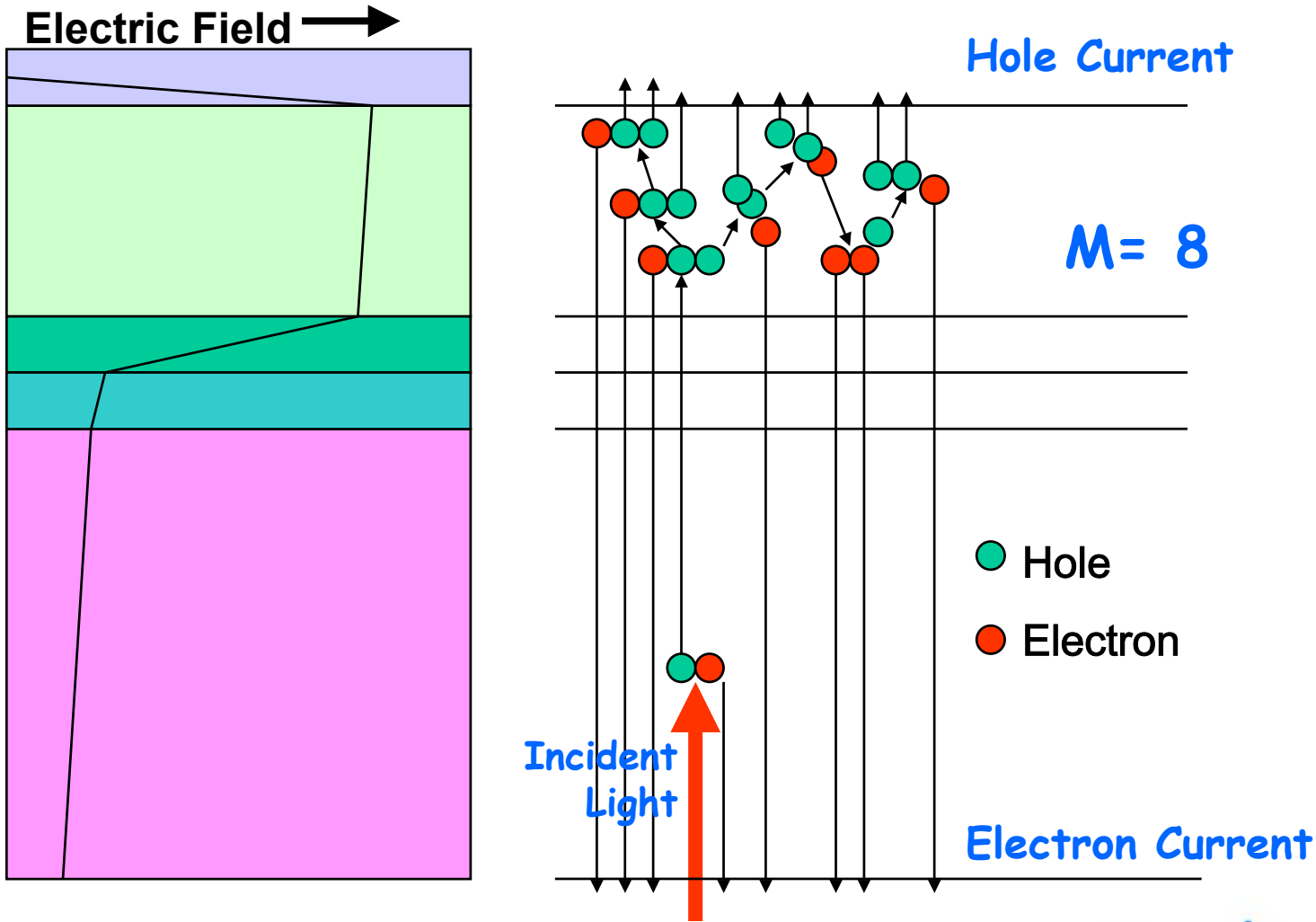
Avalanche Multiplication



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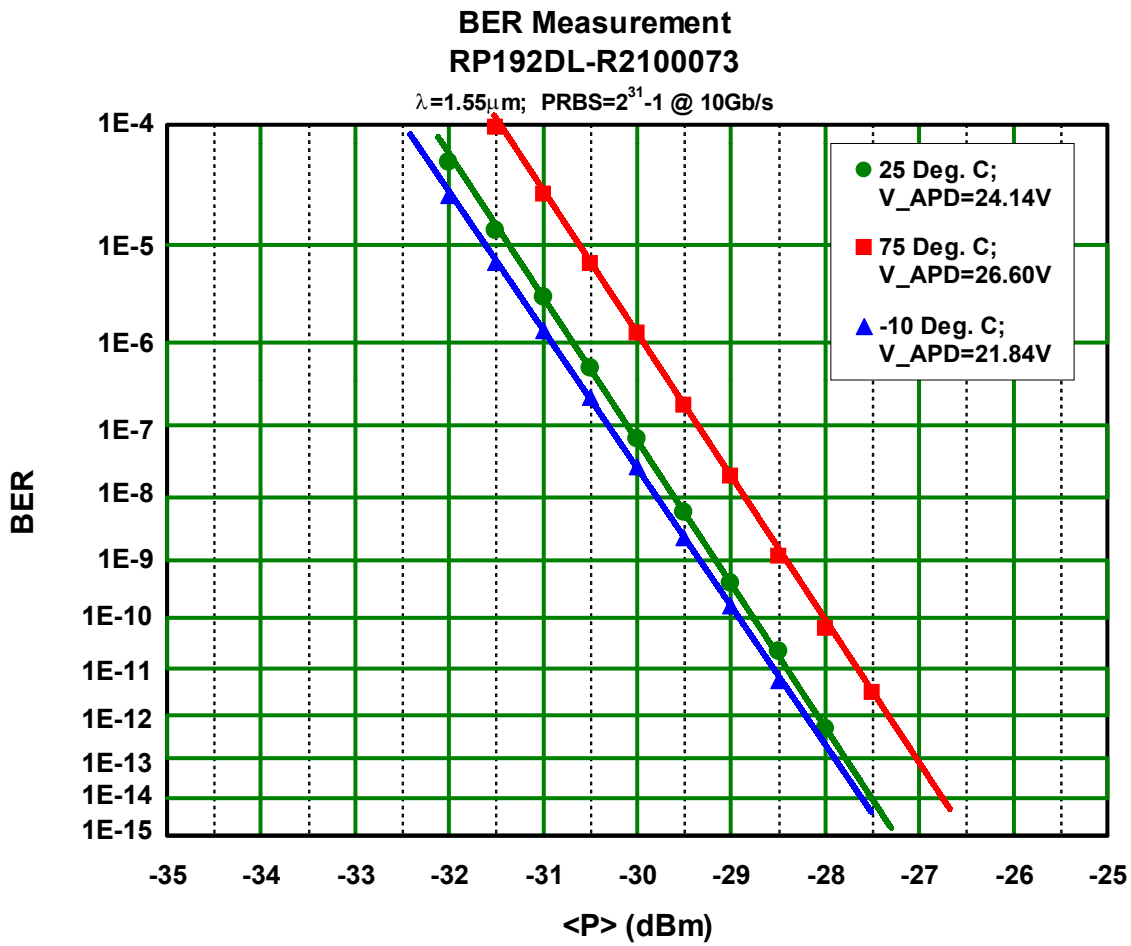
APD BER Measurement



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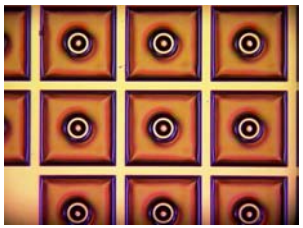
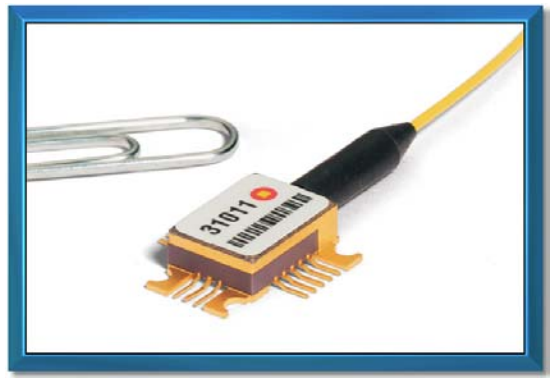
Next Generation10Gb Receiver Products

- **Ultra High Sensitivity APD Receiver: 2-3 dB better sensitivity than the current APD receiver.**

  Sample: Q3/2005; Production Q4/2005



(Ultra Low Noise Lens APD)



- **Dispersion Compensation Receivers: Optical dispersion compensation + Ultra High Sensitivity APD Receiver**

  Demonstration: Q2/2006

The Multiplex Family of Transponders

Gen-1 Transponder

200-pin MSA

MSA small-form-factor: 2” x 3” x 0.5”

1310 or 1550nm EML

Gen-2 Transponder

300-pin MSA

MSA small-form-factor: 2.2” x 3” x 0.56”

PIN and APD versions

Gen-3 Transponder

300-pin MSA Flat-Top

Ability to mount customer-designed external heat sink

DWDM ITU wavelength locked (stabilized)

Tunable over 16 channels

PIN and APD versions

SR-1, SR-2, IR-1, IR-2 and LR-2

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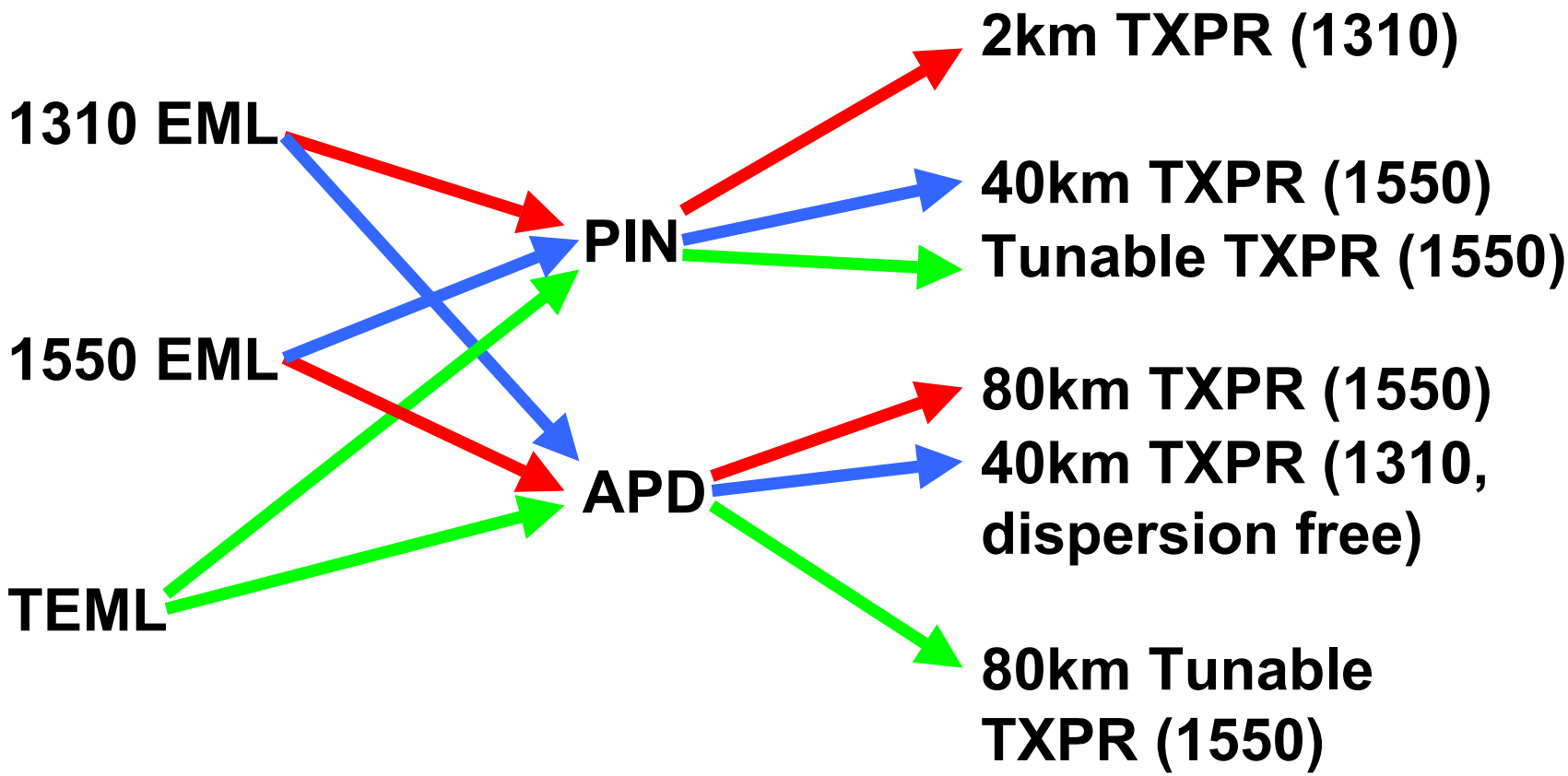
The Power of Vertical Integration



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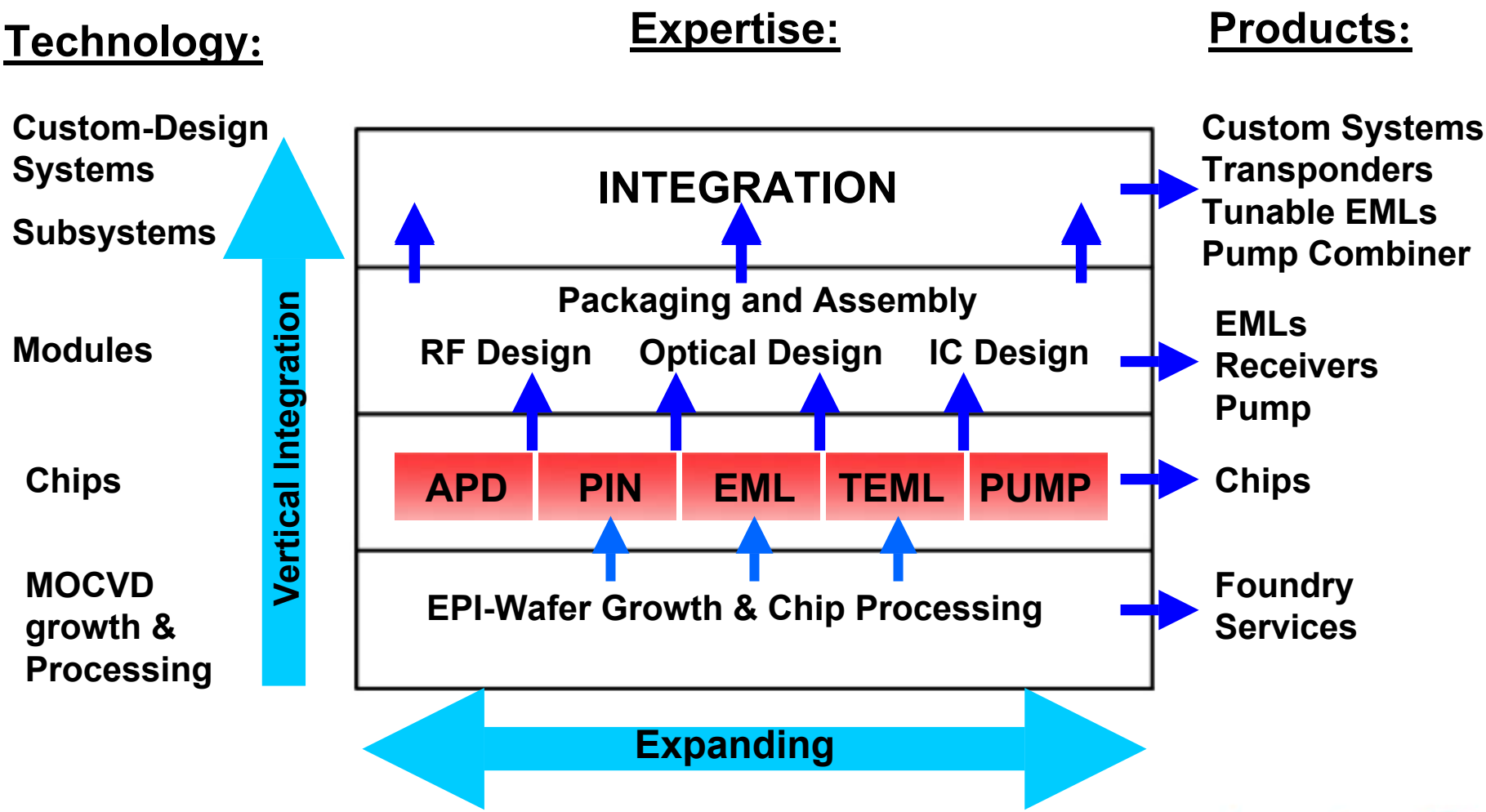
Core Technology Building Blocks



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Multiplex Facilities

Corporate Headquarters

& Front-End Manufacturing

- MOCVD wafer growth
- Chip fabrication
- Administration

Back-End Manufacturing

- Module packaging
- Subsystem Assembly

High-Speed Design Center

Facilities are located in South Plainfield, New Jersey

Multiplex, Inc. Beijing Office

3001 Bldg.4, Xian Dai City
88 Jian Guo Road, Chao Yang District
Beijing, 100022 China
Tel: 011-86-10-85800526

北京市朝阳区建国路88号现代城4号楼3001室

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