Hybrid Integration Platform for Co-Packaged Photonics Using POET's CMOS Based Optical Interposer

Dr. Suresh Venkatesan, CEO
POET Technologies Inc.
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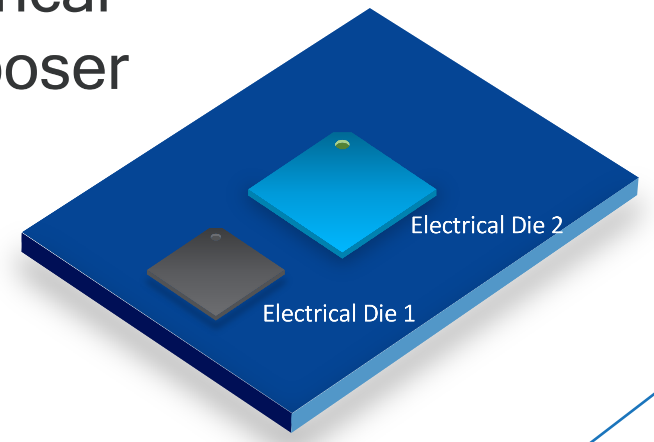
Topics

- Introduction
- Application Proof Points
- Conclusions

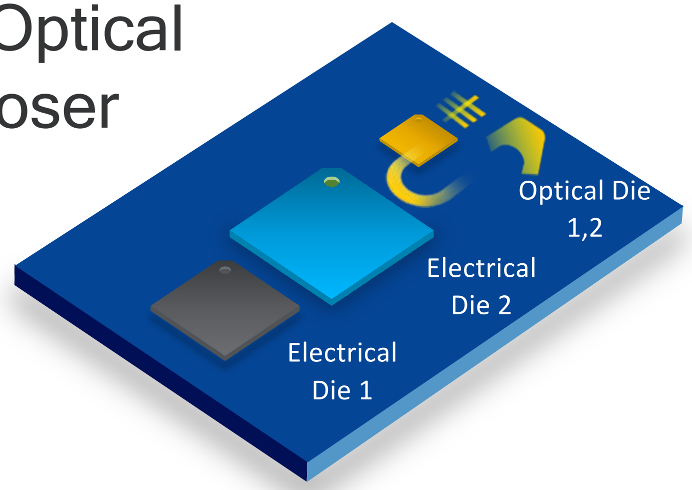
POET's Technology Solution

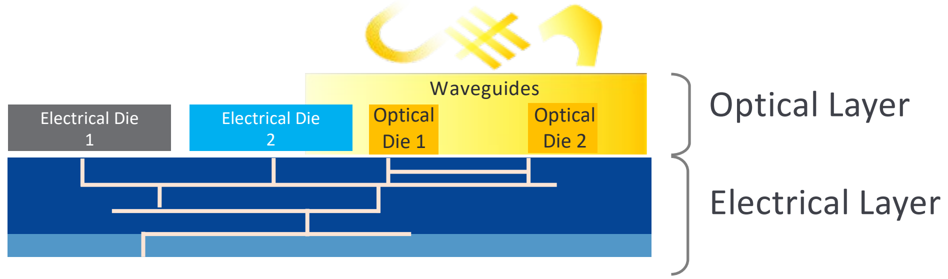
Electrical Interposer



- Typical electrical interposer with high-speed electrical connections among devices has been commonly used in devices like cell phones

POET's Optical Interposer



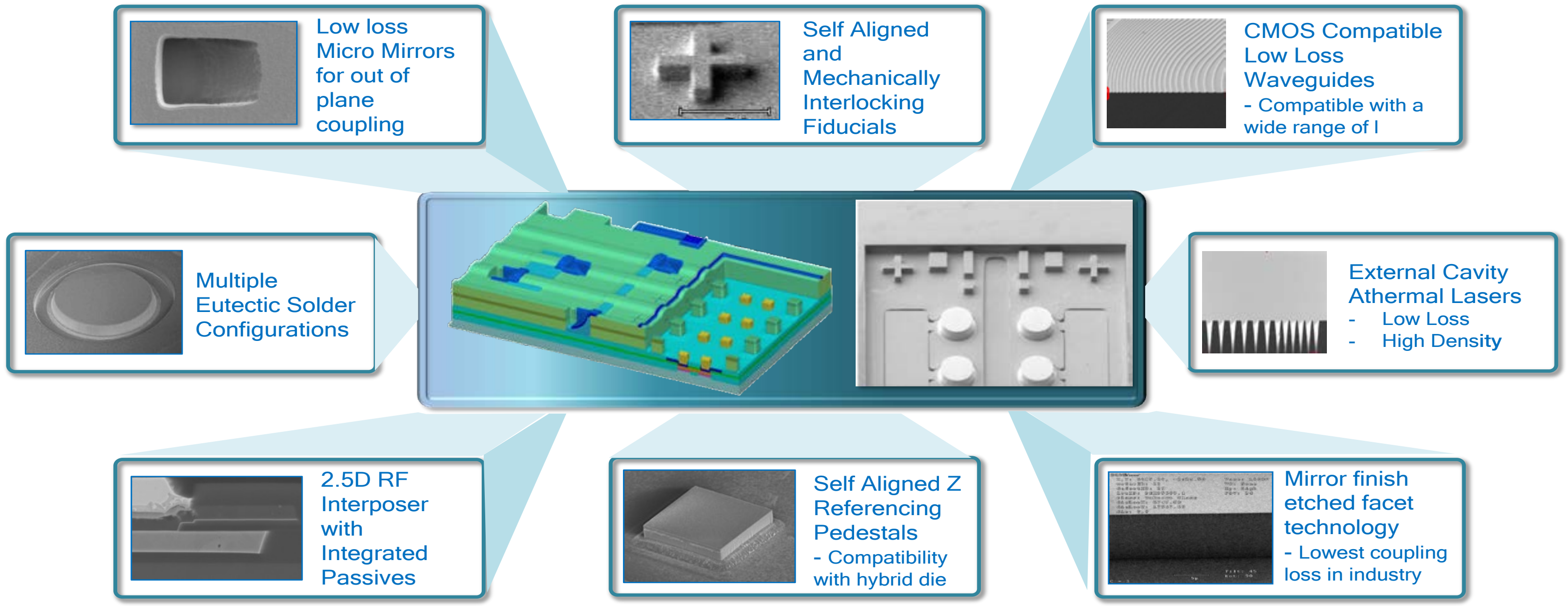


- POET's Optical Interposer that allows photonic devices to communicate seamlessly with one another and with the electronic devices at chip level
- Placement of components is done with automated semiconductor techniques without the need for "active" alignment

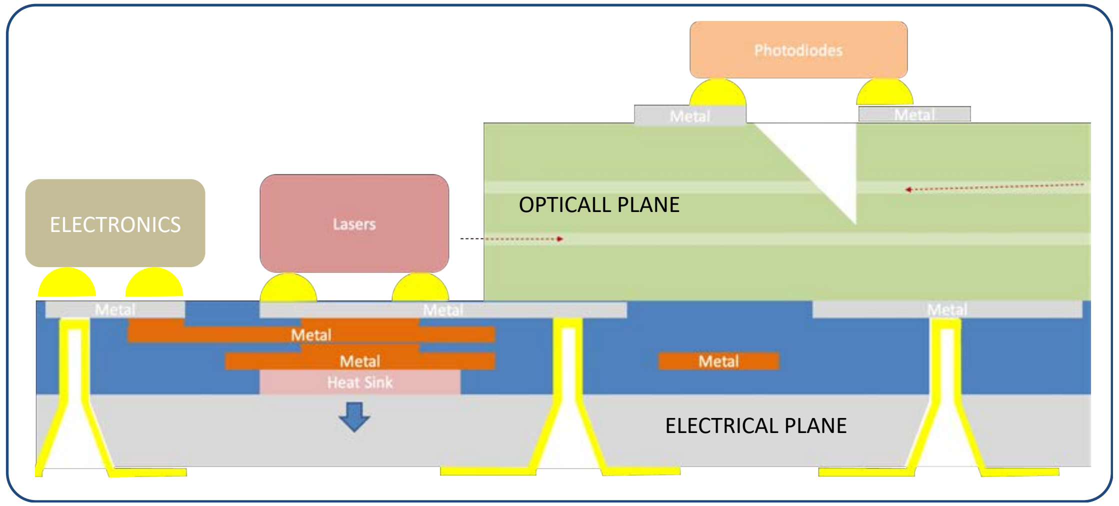
Adding Patented Waveguide Layers on a Conventional Semiconductor Wafer Enables the Integration of Electronic and Photonic Components at Wafer-Scale

POET's Optical Interposer

POET's Optical Interposer : A Co-Packaging Solution



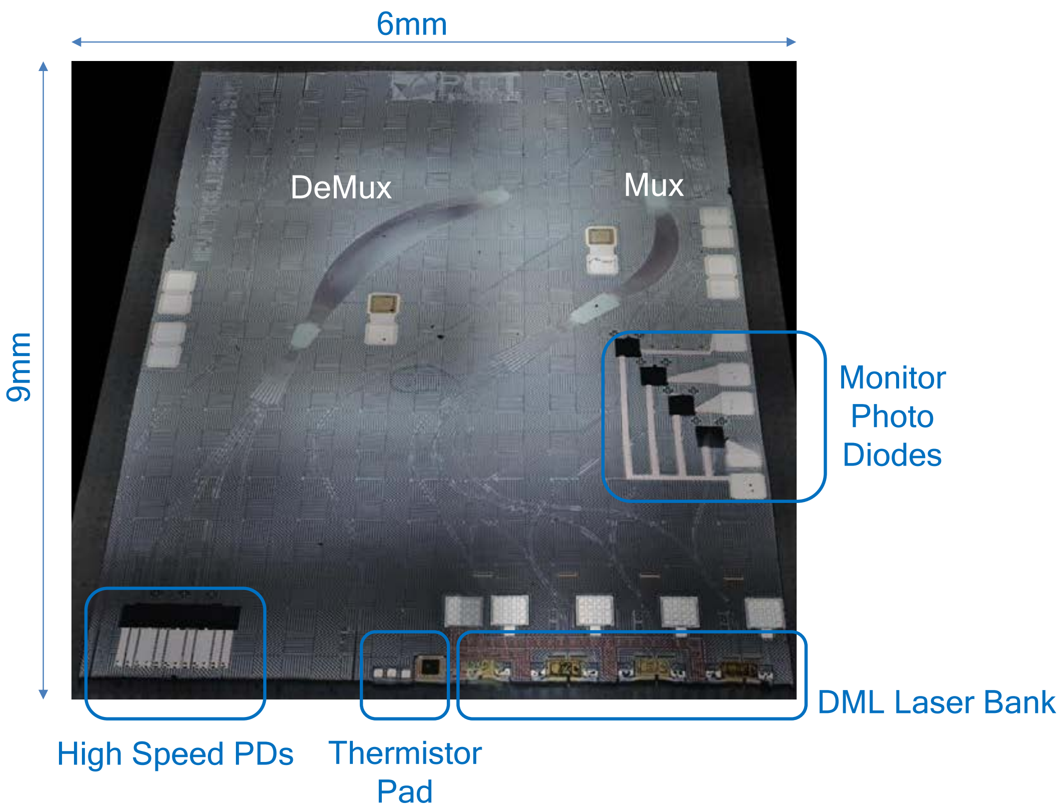
POET's Optical Interposer Platform is the most versatile photonics packaging platform in the Industry



- Two layers of low loss optical interconnects
- Multiple electrical redistribution layers with low RF insertion loss
- High throughput visually assisted passive "pick and place" assembly of electronics and photonics ICs and components
- In plane and Out of plane Optical Interfaces

Implementation into a 100G-400G Optical Engine

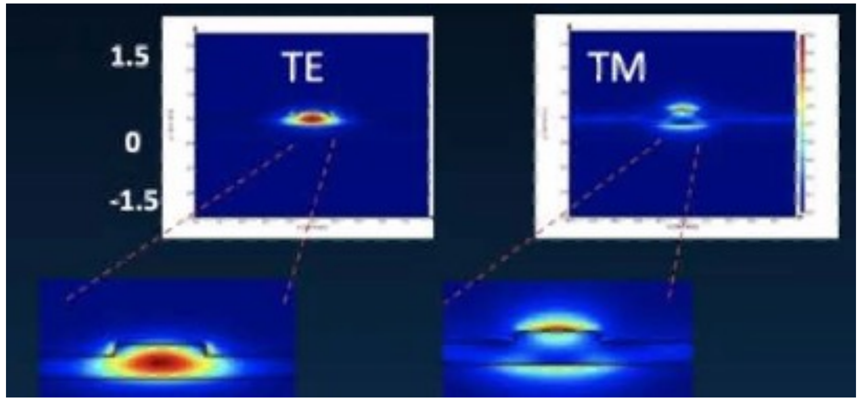
World's smallest single chip implementation of optical engines for 100-400G communications and beyond



Large Dielectric Waveguide Platform

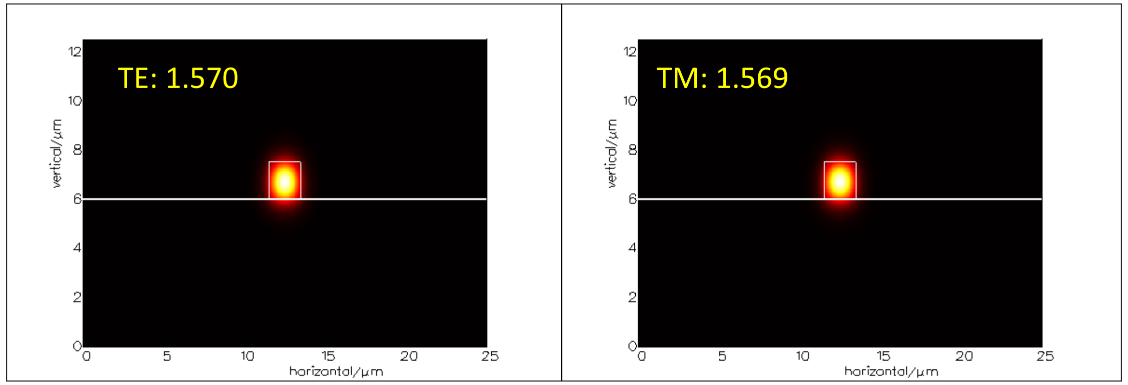
- Fundamental Building block is the waveguide
- Most of the industry is using sub-micron silicon waveguides
- Balanced tradeoff between performance and cost associated with dielectric waveguides (SiN) versus Si waveguides
- The large core waveguides are optimized for photonic applications

Sub-micron silicon waveguides



- Smaller mode, susceptible to dimensional variation and surface roughness
- Highly polarization dependent
- Relatively inefficient coupling to Single Mode Fiber and III-V materials
- Has been challenging to create integrated receiver solutions for multiplexed applications in small form factor pluggables

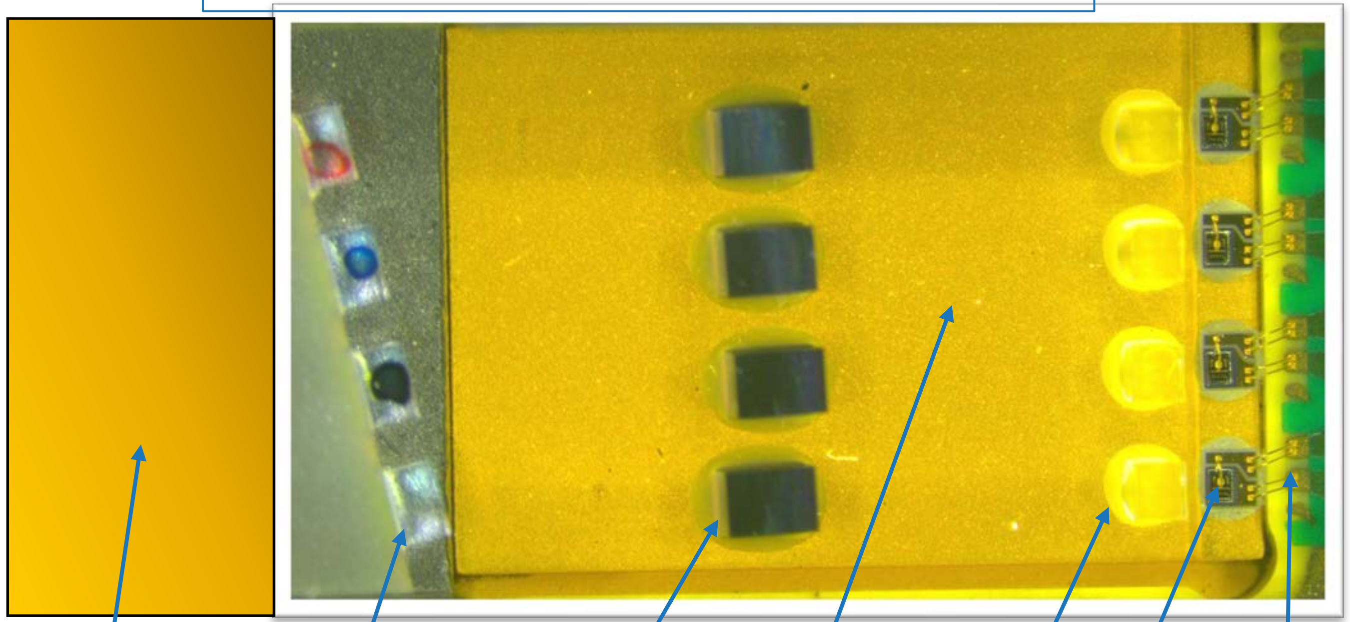
POET's Dielectric waveguides



- Moderately tightly confined and yet larger modes, tolerant of dimensional variation and surface roughness (low loss)
- Polarization Independent, small wavelength dependence due to the use of SiN versus Si
- Passive, efficient edge coupling to SMF Fiber and III-V materials

Comparison between POET's DML engine approach versus conventional CoB DML solutions

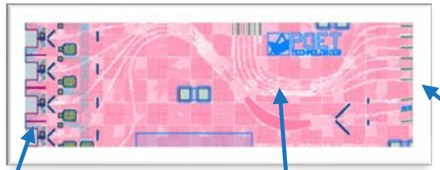
Conventional Chip on Board



Bill of materials : 34 separate pieces including carriers

Active Alignment : 8

POET's Optical Engine



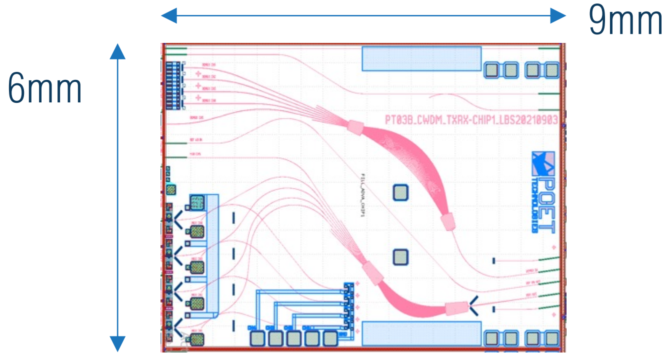
¼ the footprint

Bill of materials: 1

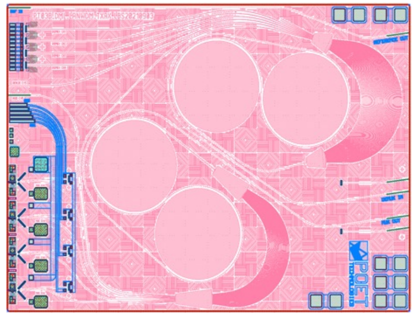
Active Alignment: 0

Application Platforms

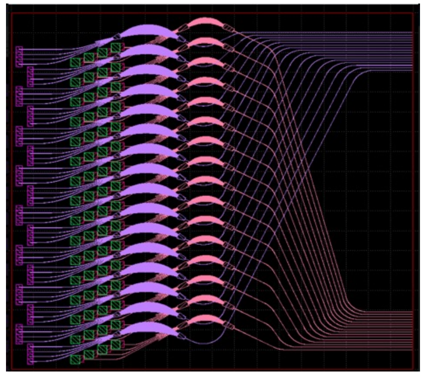
Directly Modulated Laser Platform



FR4
- 100Gbps
- 200Gbps
- 400Gbps
- 800Gbps

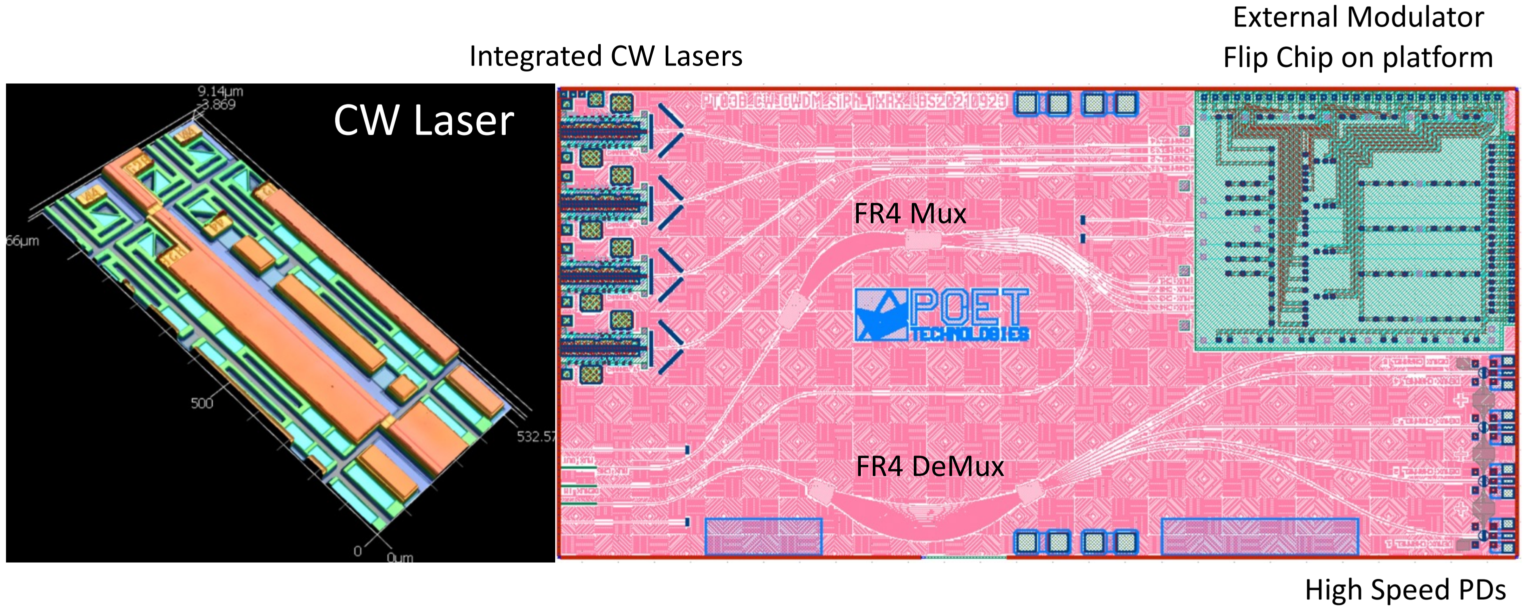


LR4
- 100Gbps
- Custom Configurations with multiple engines form factors



6.4Tbps
- DML/EML Implementation
- Custom Configurations
- Industry leading form factor with two layer waveguides (optical chiplet : 18mmx18mm)

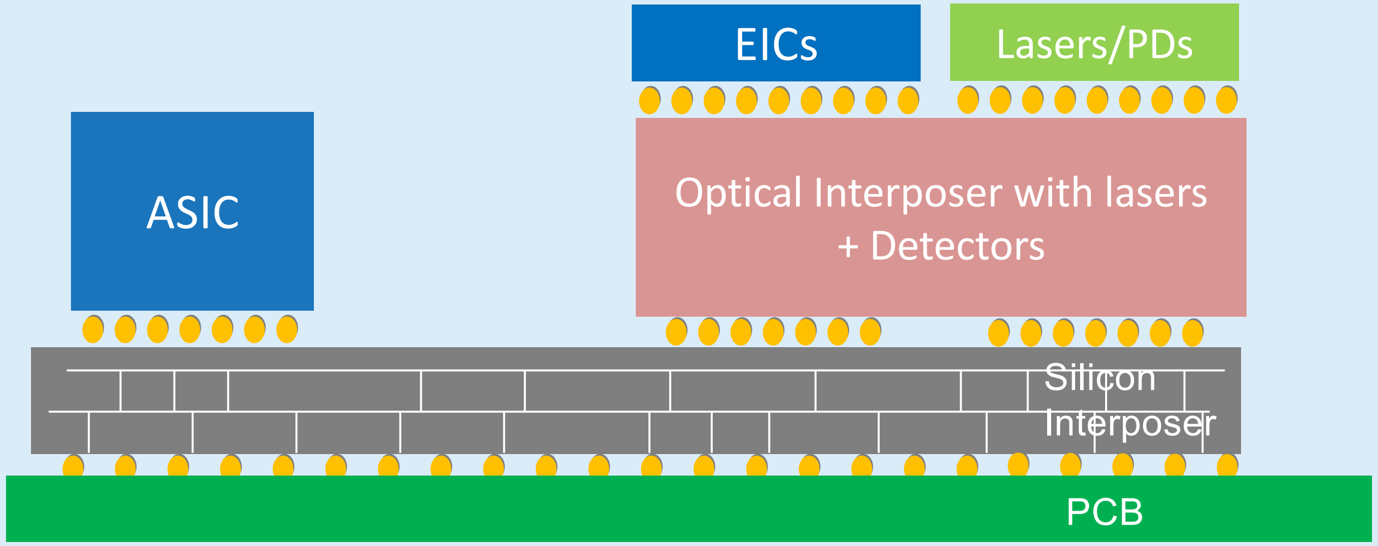
CW Laser Platform



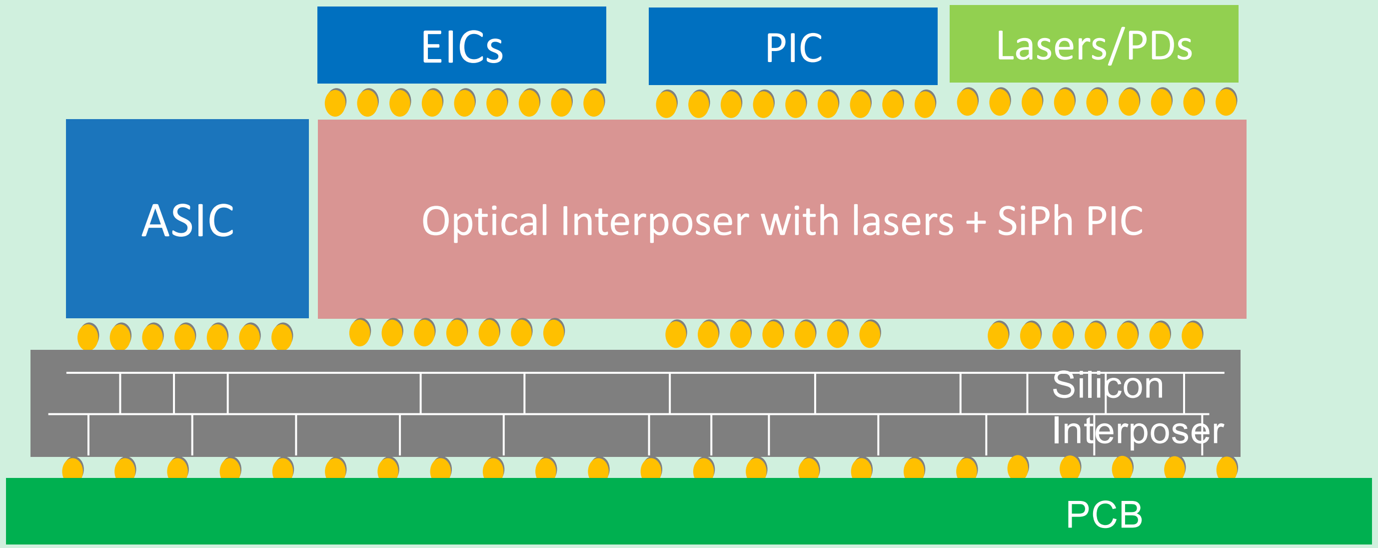
800Gbps (2x400FR4) and beyond
- Platform with CW lasers compatible with external modulators like Si Photonics
- Extensible to 200G/λ with TFL (thin film LiNbO3) modulators

Remote Light Sources
- C Band and O Band Applications
- CPO and AI applications

Flexible Architectures for multiple applications

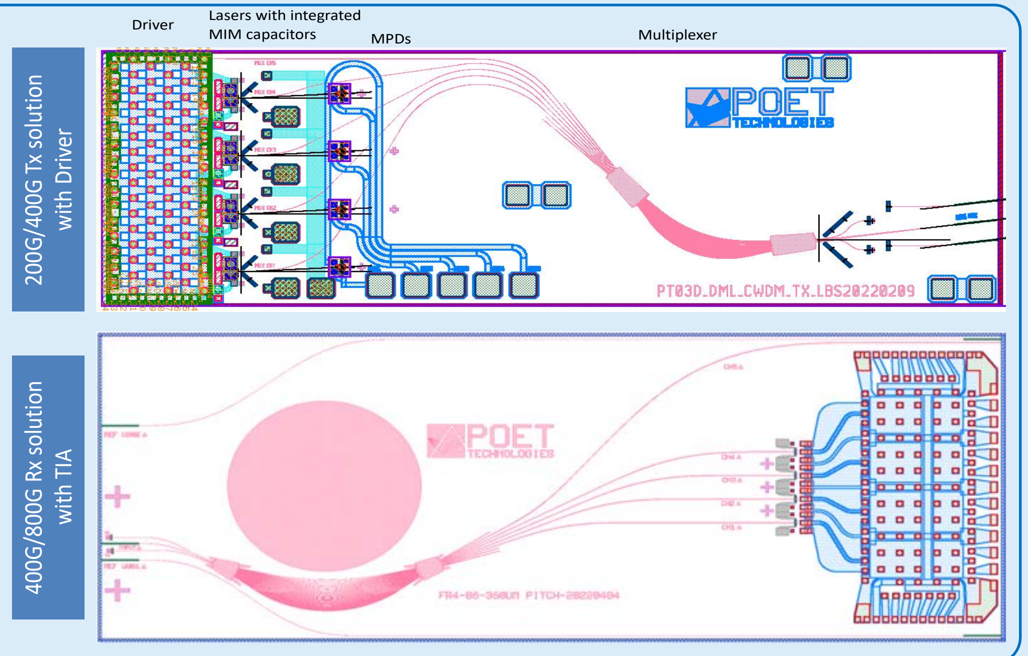


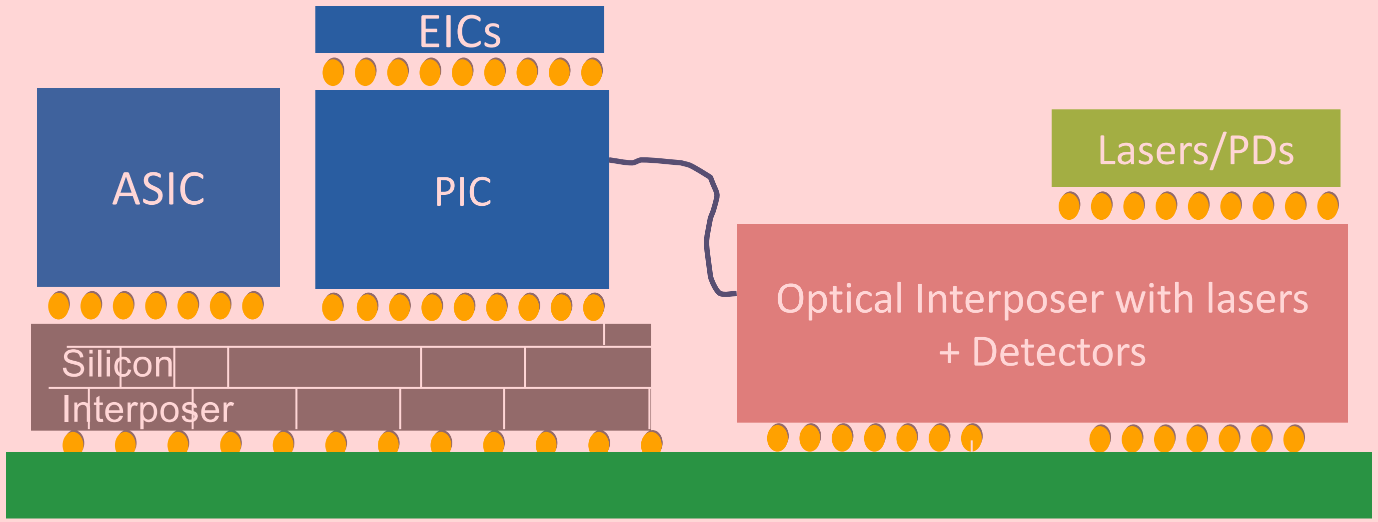
Modulated Laser solutions using the Optical Interposer



Integrated Laser/PIC solution using the Optical Interposer

400G Products with Integrated Hybrid Electronics





External Laser solutions using the Optical Interposer

POET's Optical Interposer Differentiators

System Architecture

- Hybrid integration of different material platforms
- Optimal partitioning for best power/performance/cost
- Extremely broad design freedom
- Athermal waveguides enabling multi channel scalability and expansion

Wavelength Division Multiplexing (WDM) vs. Parallel Fiber

- Use duplex fiber pair instead of multiple SMFs or multi-SMFs
- Compatible with multi-core fiber technology

Wafer Level OE Testing

- Significant departure from component level testing which much of the industry does
- High assembly yields through pick and place of known good die

Wafer Level Packaging

- Use automated pick-place equipment to enable high speed and low cost manufacturing
- Reduce industry assembly costs from as much as 70% to less than 20%
- Passive Laser placement with high coupling efficiency

Small Form Factor

- Significantly reduced sizes for the Mux/De-Mux through utilizing the waveguide interposer
- Multi-engine implementation in a standard QSFP form factor

Utilization of Si packaging capabilities

- 2.5D and 3D Interposer functionality for co-packaging of electronics/photonics with Thru Silicon Vias

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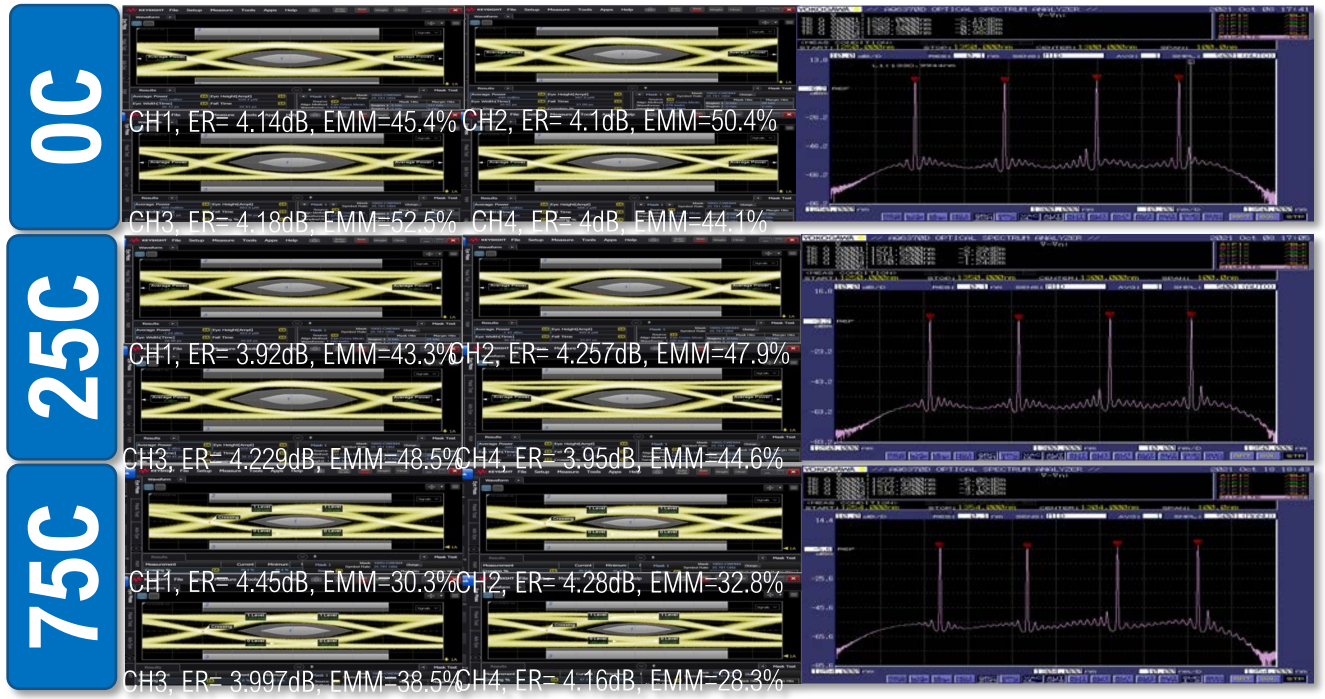
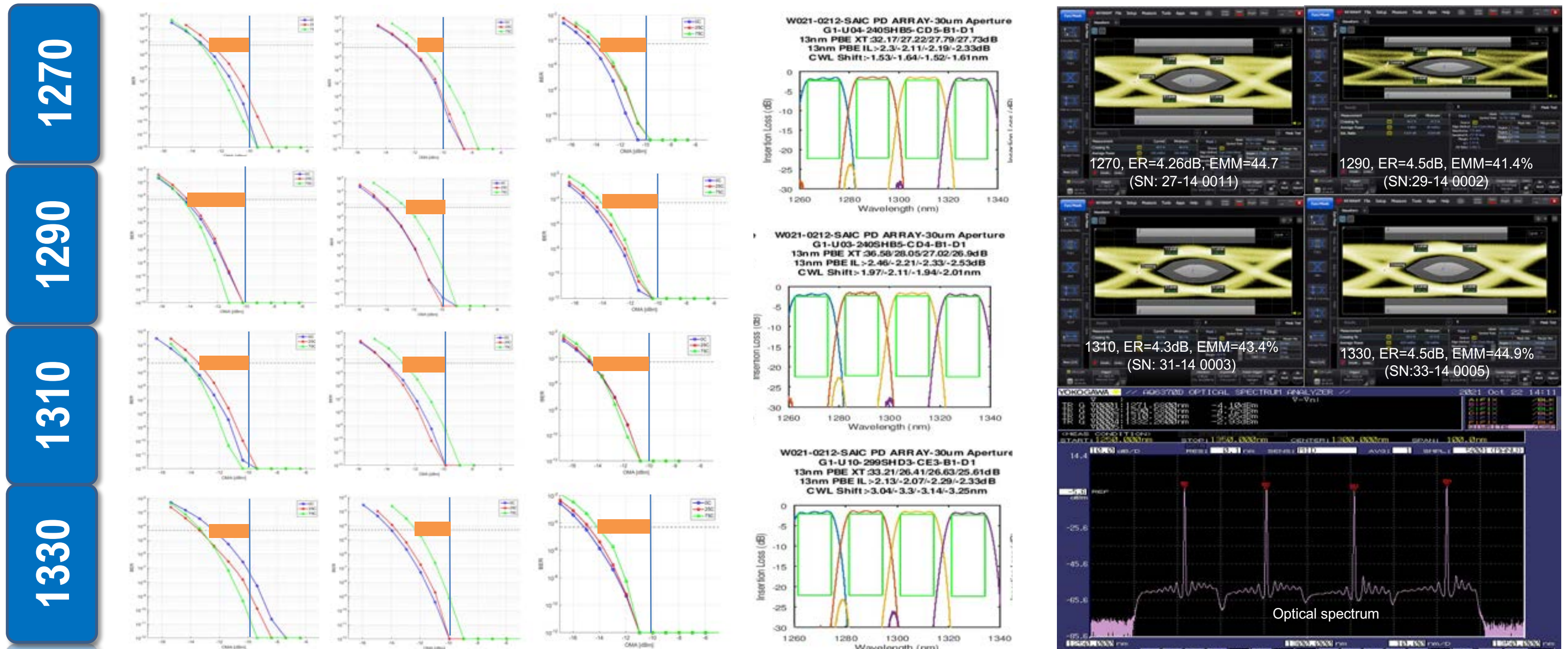
100G CWDM Optical Engine

POET Technologies

TRANSMITTER



RECEIVER



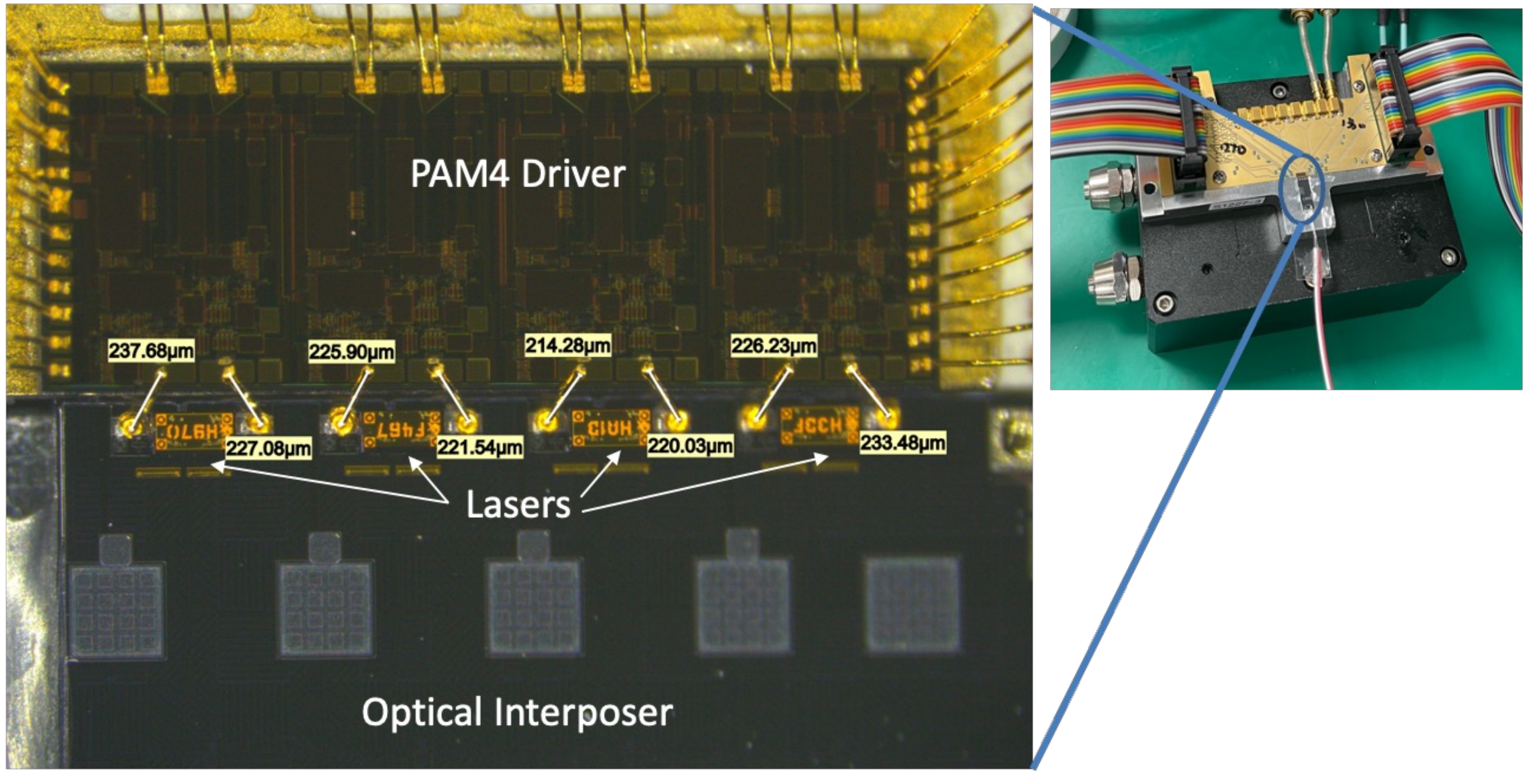
All units meet specs with sufficient margin

- Excellent Eye Margin and Extinction ration across the temperature range for Data Centers
- DML engine is extensible in performance from 100G -> 200G – 400G
- POET can offer the lowest cost, highest density DML engine by incorporating 56Gbaud DMLs into its platform
- Competitive solution for Co-packaged optics

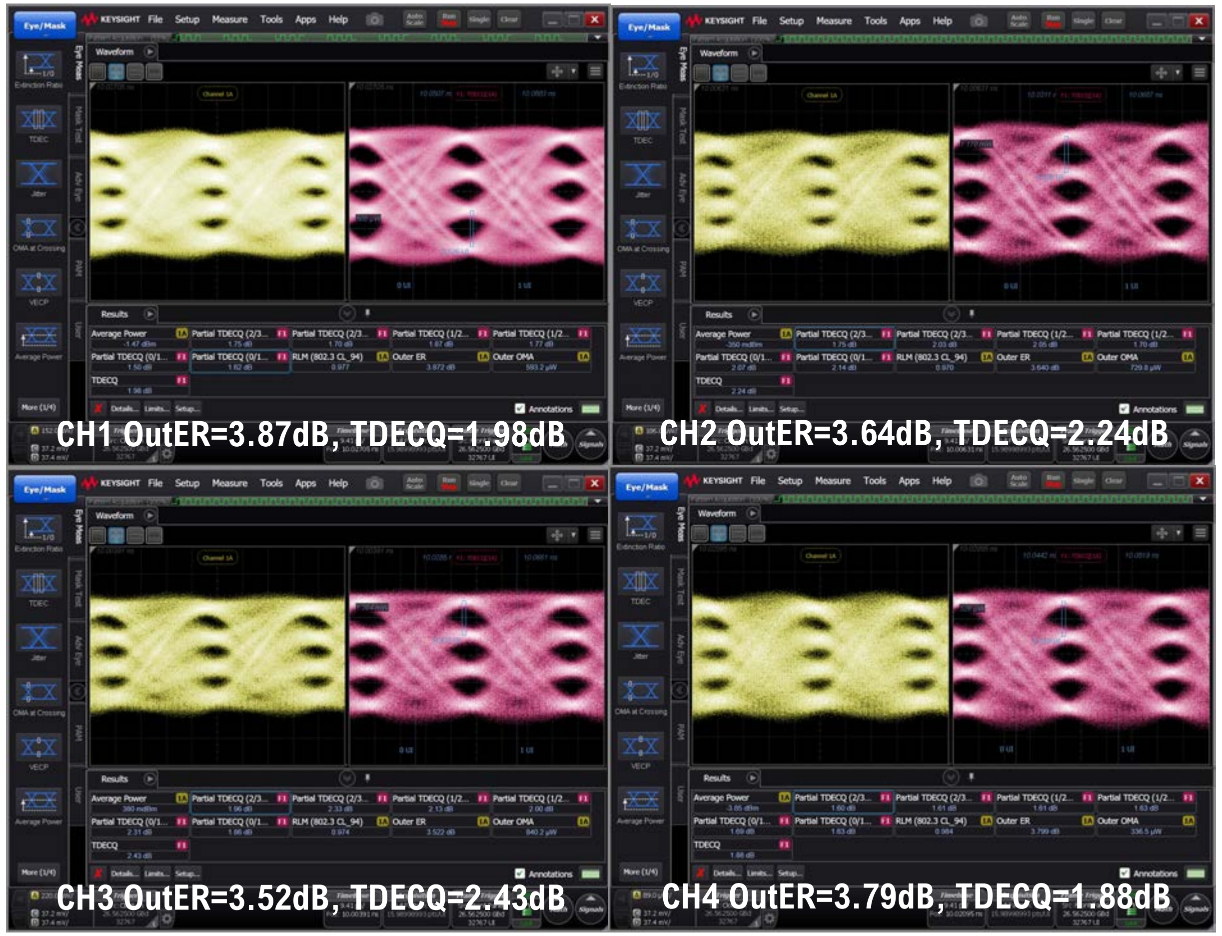
200G FR4 Optical Engine

- Common Optical Engine meeting the requirements of 100/200G

200G Optical Engine on Evaluation Board



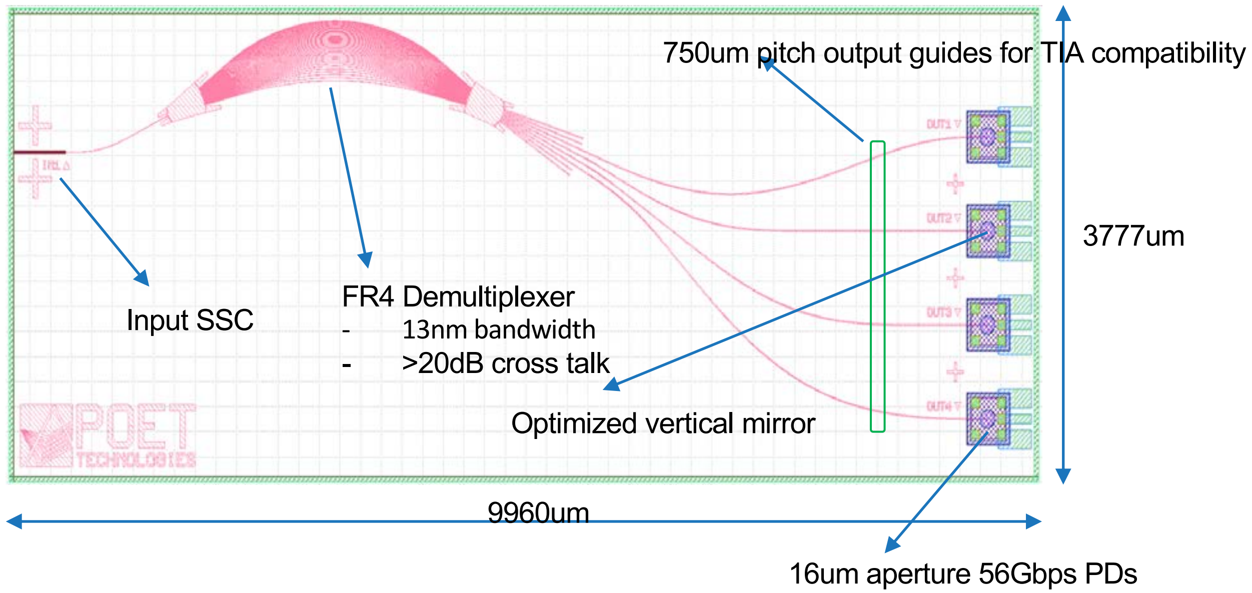
Optical Performance

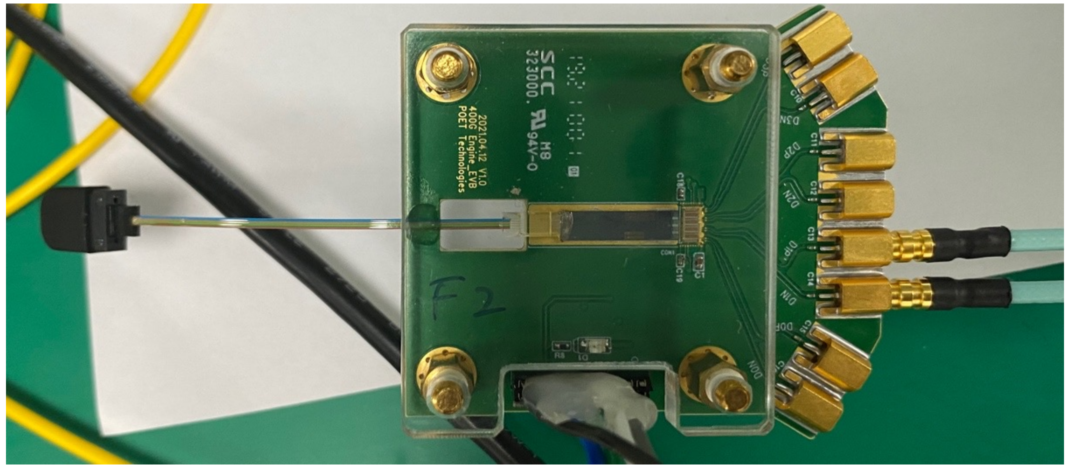


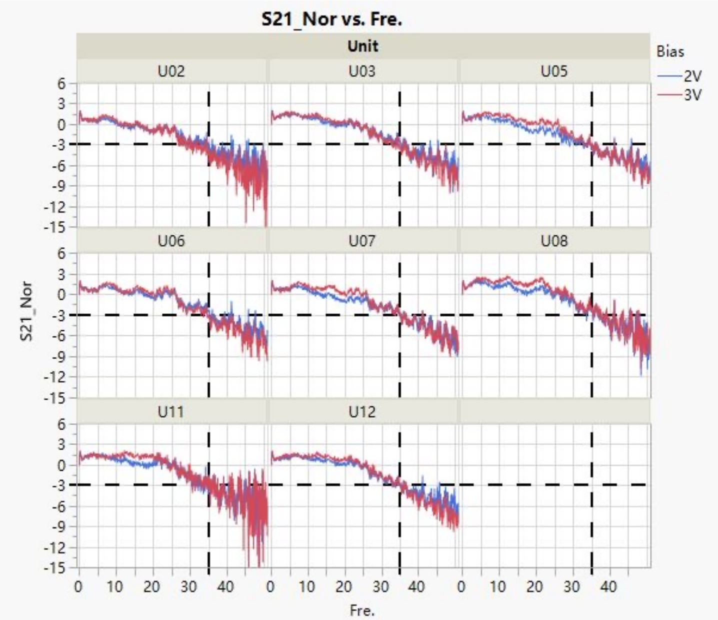
Excellent 200G PAM4 signals through the Optical Interposer
200G Rx also shows excellent performance (not shown)

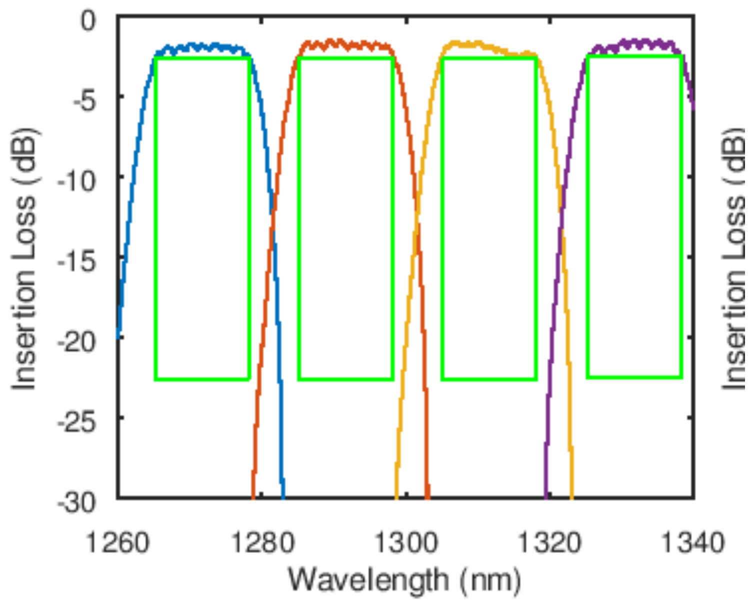
400G/800G FR4 Receiver Performance

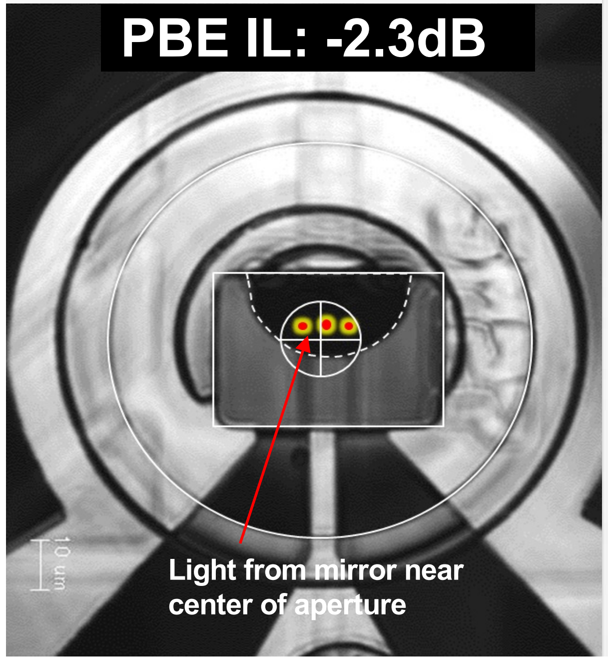
400G FR4 Receivers integrated into 400G FR4 engine

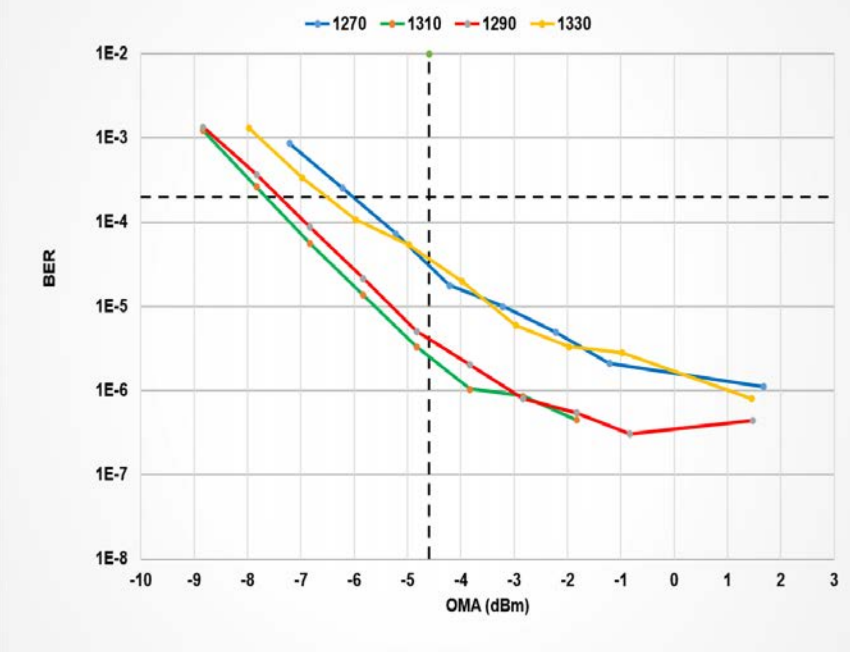






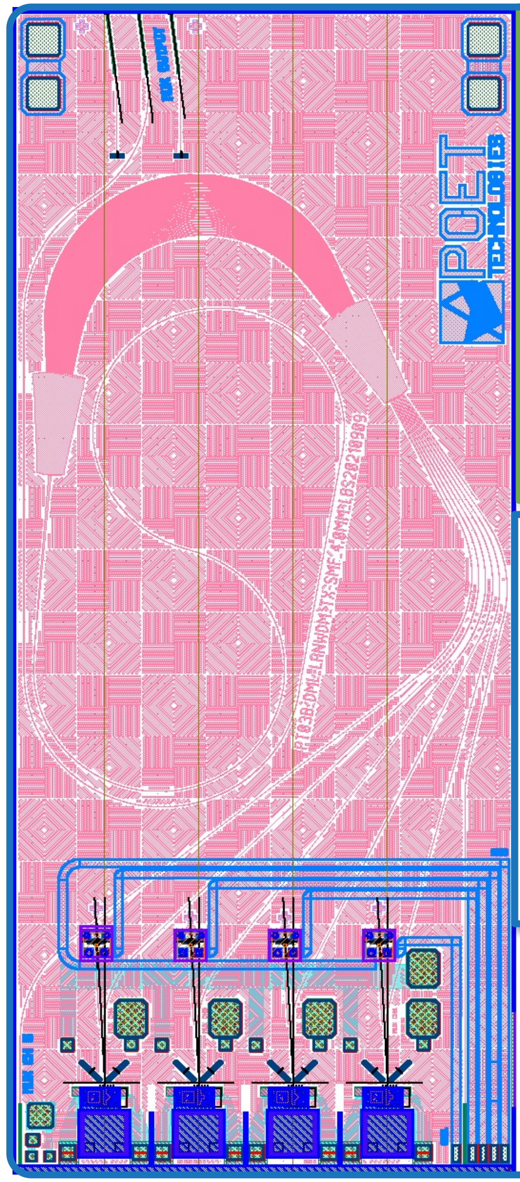


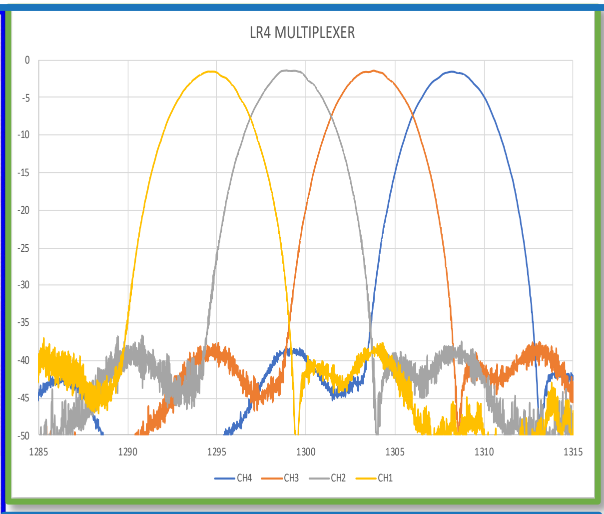


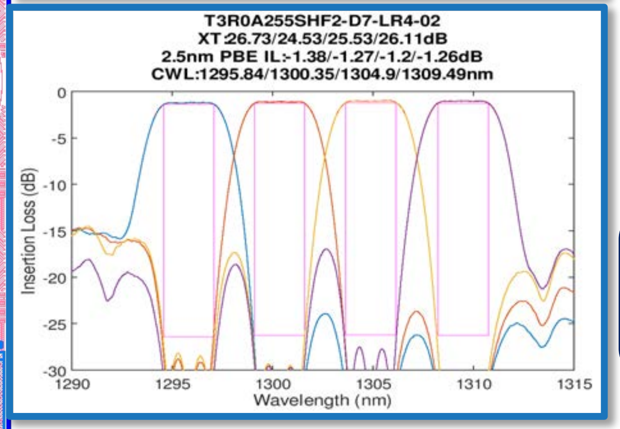


100/200G LR4 Solutions

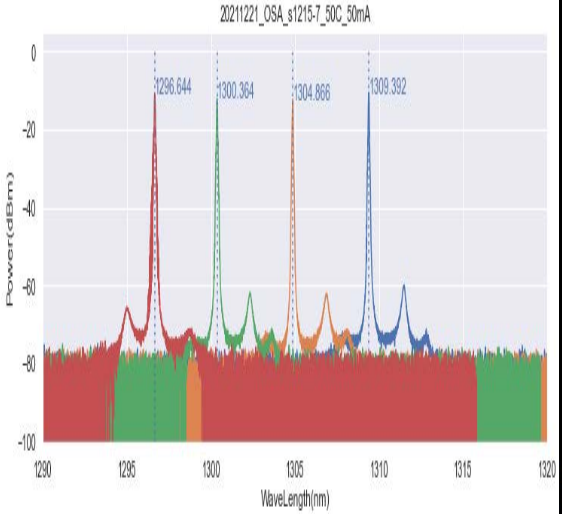
100G LR4 Optical Engines created utilizing the same fundamental platform as 100G CWDM



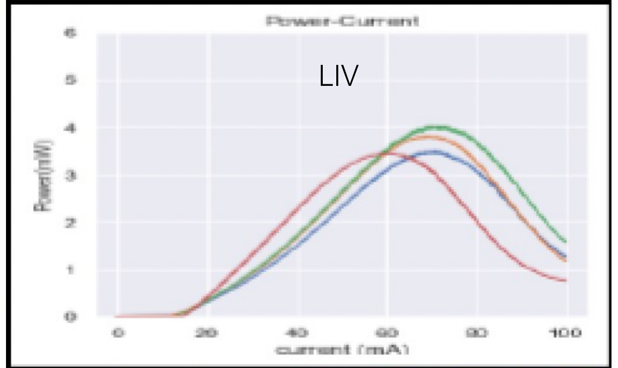




Passive Device Characteristics

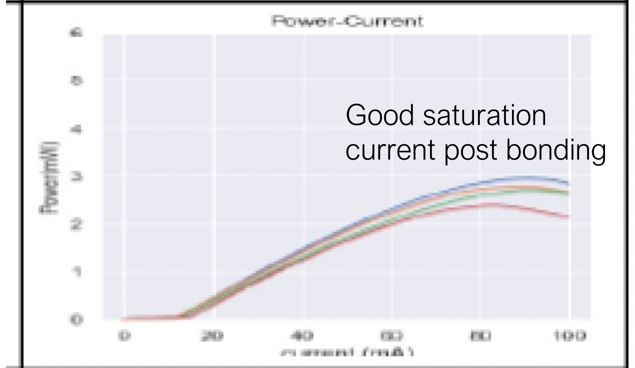


LR4 50C S1215-7



channel	CH1	CH2	CH3	CH4
power(mW)/50mA	2.3	2.58	2.6	3.08
power(mW)/peak	3.49	3.81	4.01	3.44
ROLL-OVER(mA)	70	69	70	60

rear LR4 50C S1215-7



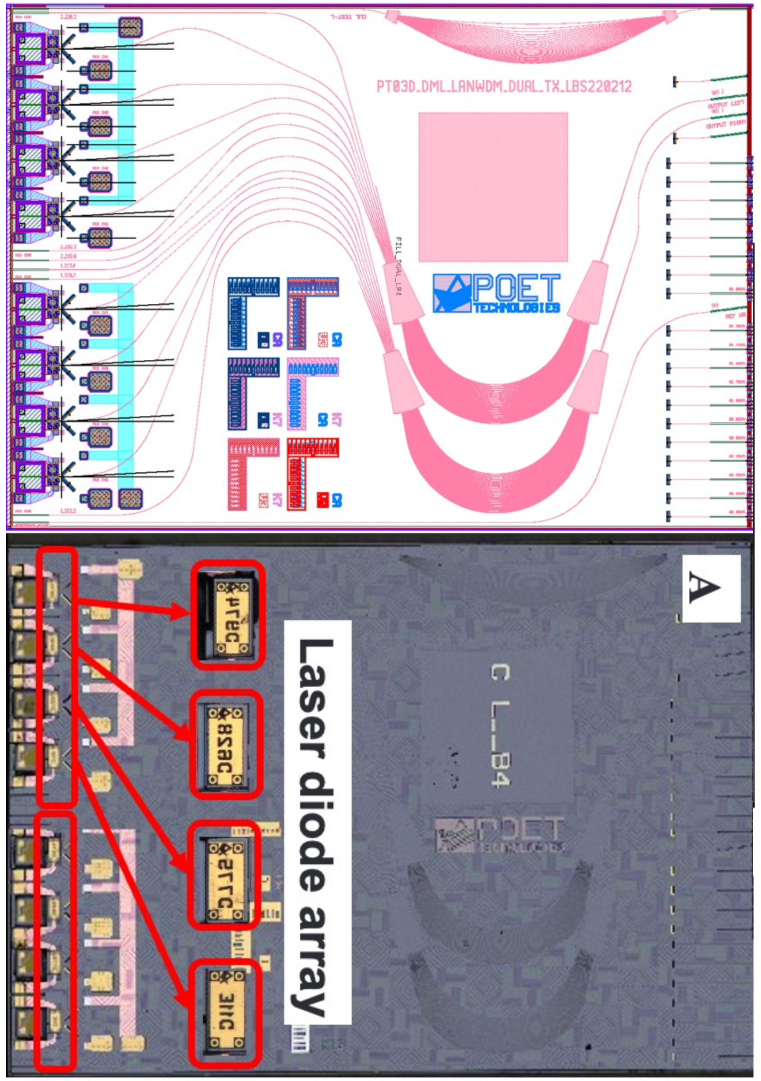
channel	CH1	CH2	CH3	CH4
power(mW)/50mA	1.89	1.83	1.7	1.63
power(mW)/peak	2.94	2.76	2.69	2.38
ROLL-OVER(mA)	90	90	91	82

Scaling to high bit rates – Spatial Division Multiplexing

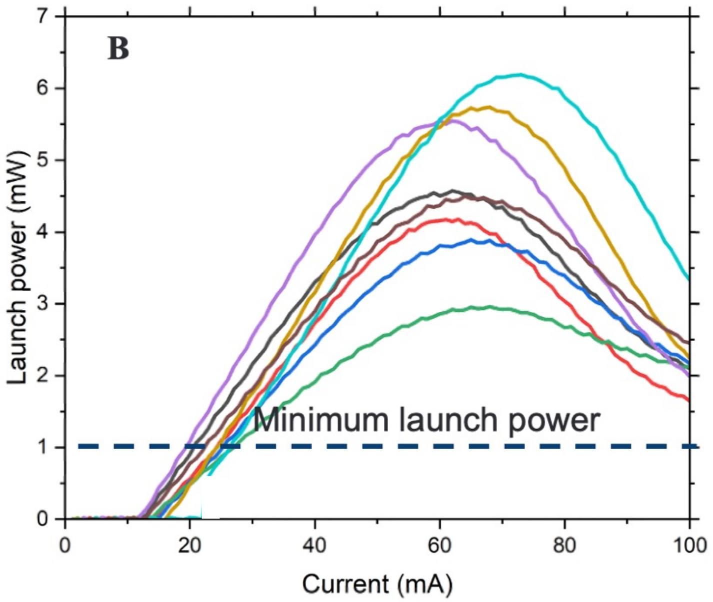
8 Transmit Lanes –> 2x FR4 solutions for 800Gbps Tx

9.0mm

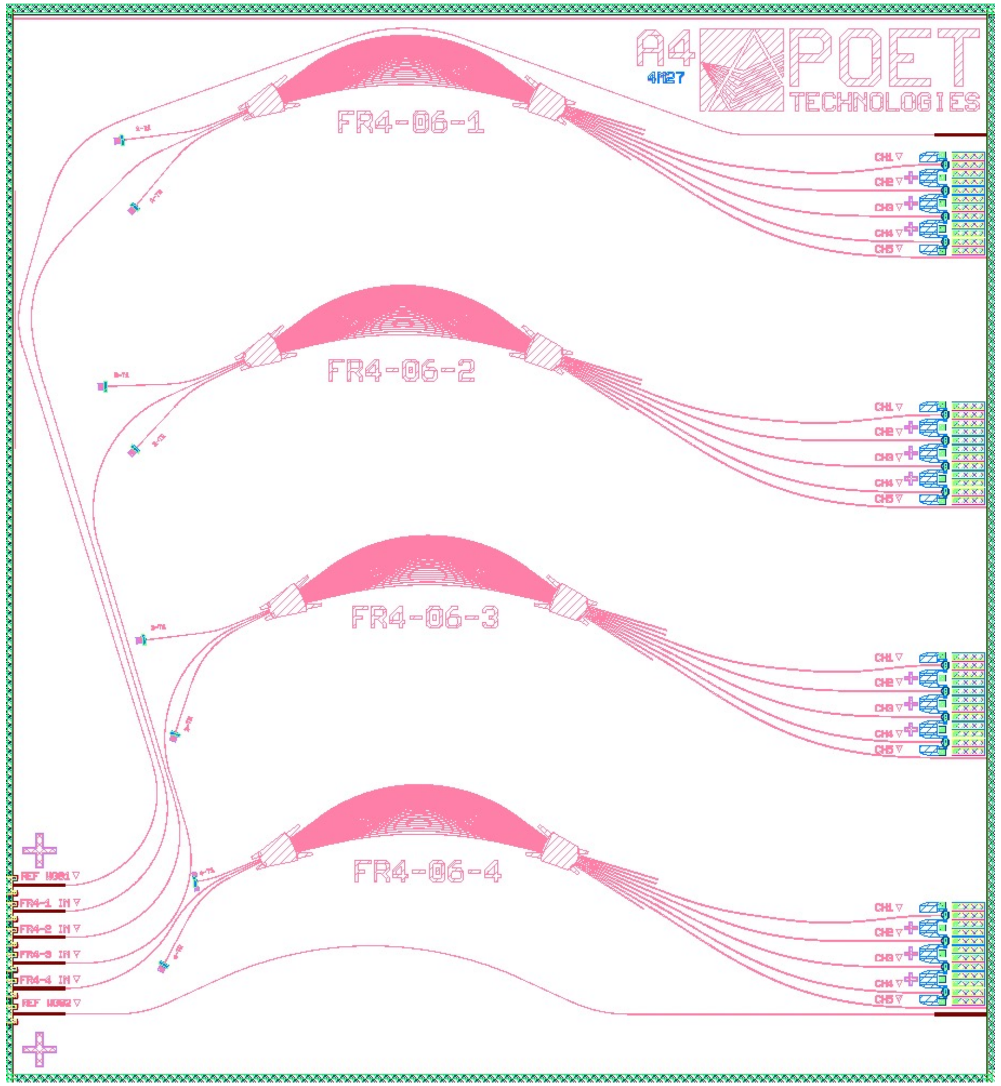
6.0mm



Data shown for LR4 (800Ghz) multiplexers



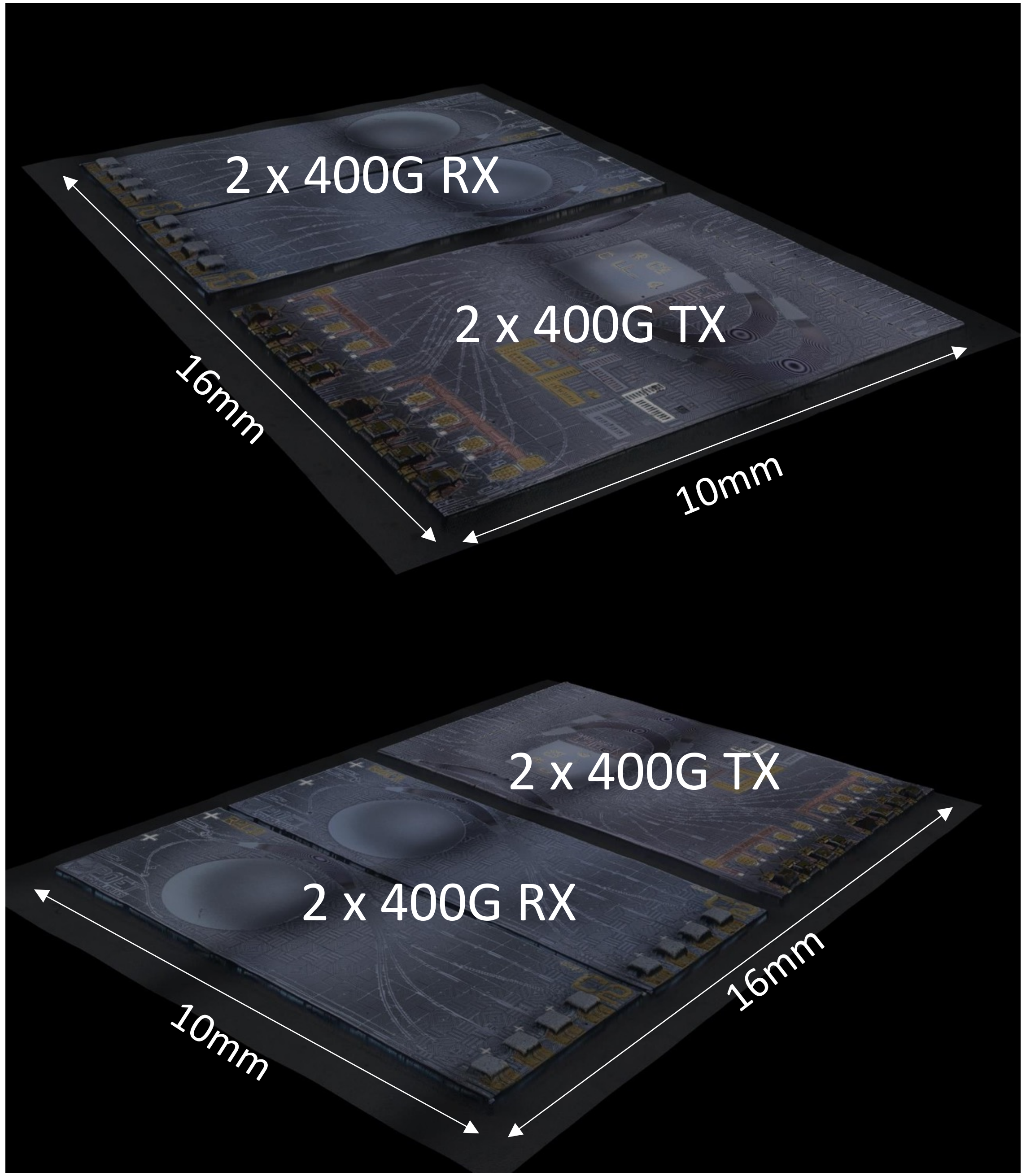
16 Receive Lanes – 1.6Tbps Rx



10.5mm

9.5mm

2 x 400G FR4 : Optical chiplets assembled in 2 x or 4 x configurations

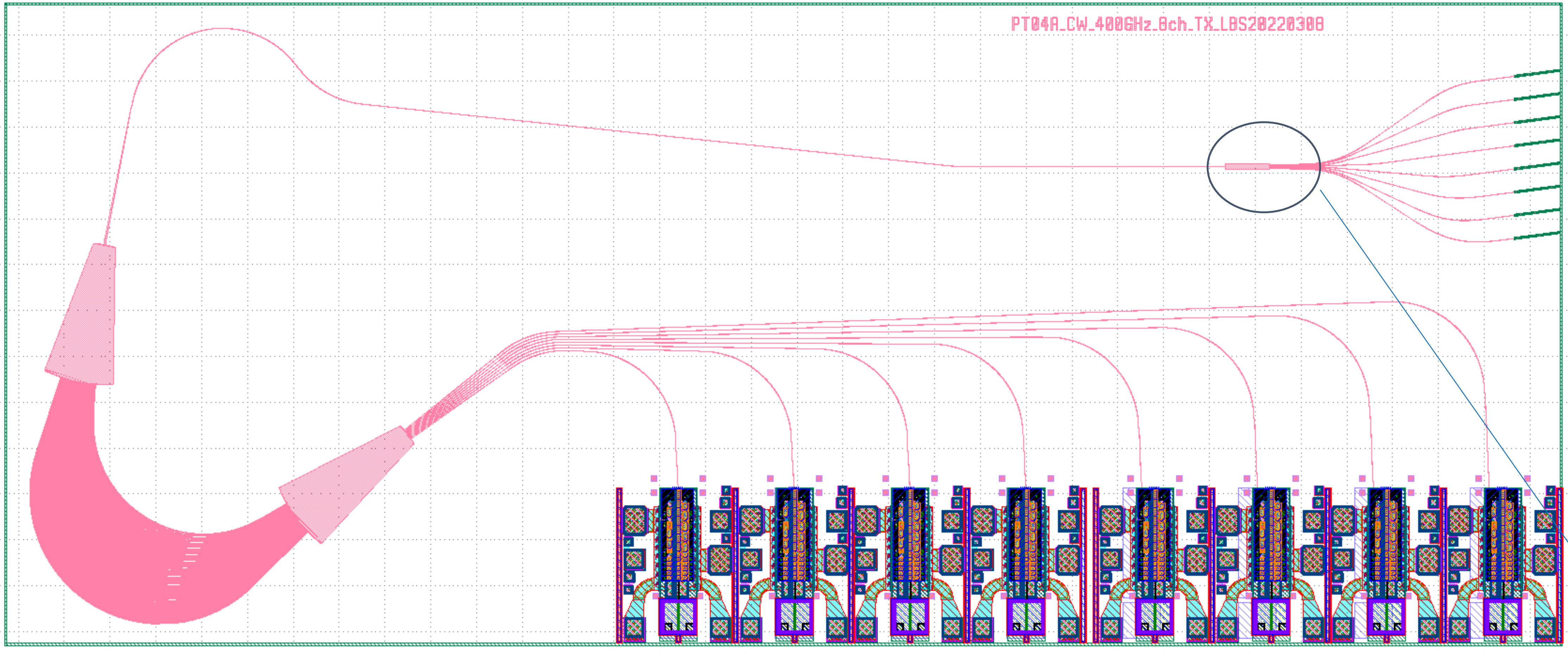


OSFP Package Footprint

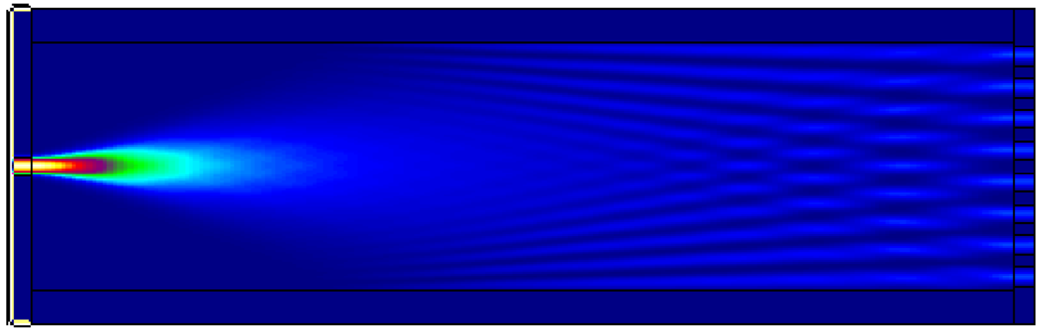
POET's 2x400G FR4 solution readily fits inside an OSFP package and in fact can readily fit inside the smaller QSFP-DD factor

- Smaller the form factor the higher the face plate density
- Integrated TIAs and Driver (not shown) simplifies board design
- Flip chip mounted components with Through Silicon Vias simplifies board assembly and eliminates the deleterious RF effects of wirebonds
- High density chiplet approach enables scaling to 1.6Tbps in a OSFP-XD package being discussed for 1.6Tbps (may also extend to 3.2Tbps depending on the gear box)
- Building block is the 400G Tx and Rx engine architected to be assembled as chiplets

8-Ch CW-WDM Laser Array (400GHz spacing)



- Design feasibility established for the Multiplexer/Splitter combination
- Link budget at a median of 4dB into the fiber

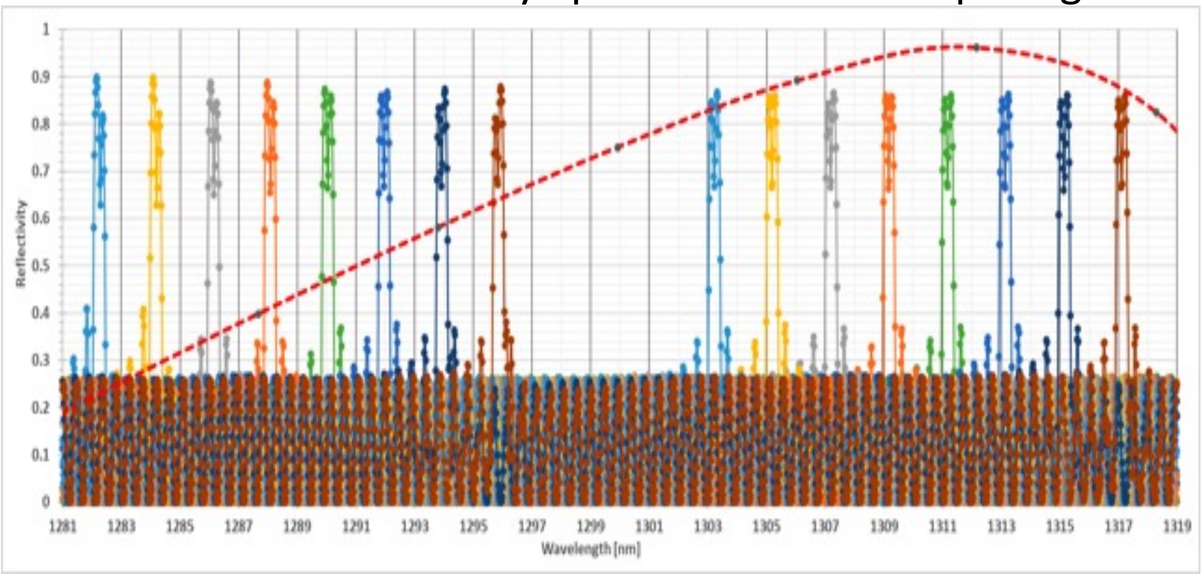


High Efficiency 1x8 MMI based splitter

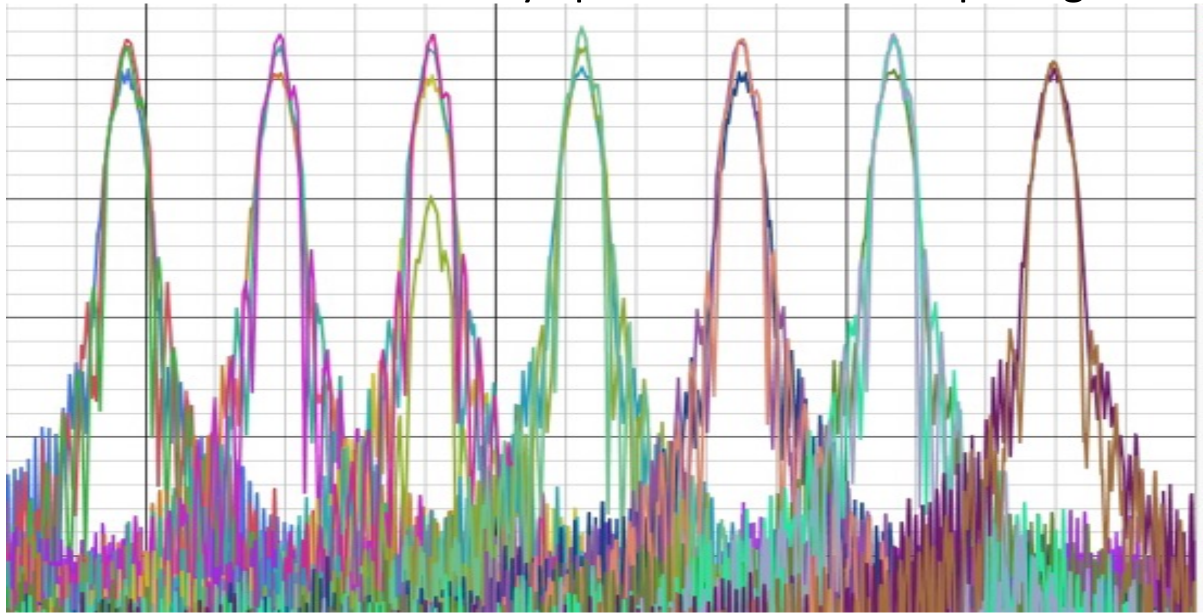
Next generation External Cavity Lasers

Novel design leveraging POET's low loss waveguides to create a "hybrid" external cavity laser

Simulated Reflectivity Spectra for 400GHz spacing



Measured Reflectivity Spectra for 400GHz spacing



- Novel and patented Grating design to form sub-nm high reflectivity stop bands for wavelength selection
- Front and Back Facet reflectivity at desired values using grating designs integrated into the Interposer
- 12pm/ºC wavelength shift enable tight wavelength spacings for >4 channel applications without TEC
- High Reflectivity sub-nm stop band possible with grating design on Interposer
  - Not possible with conventional DBR mirrors
- Simulated and measured reflectivity spectra for multi-wavelength applications overlaid with designed gain chip (AR/AR) for high power hybrid external cavity lasers

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Optical Interposer Summary

- POET has developed a Wafer Scale Hybrid Integrated Photonics Packaging Platform compatible DML, CW and EML Lasers
- Low Loss Transmission and Coupling with passive placement
  - Low Waveguide loss : **0.2dB/cm**
  - Athermal Waveguides : **CWL shift of 12pm/ºC**
  - Median CW/EML Laser Coupling Loss : **1.0** (with Spot Size Converter) ; DML Coupling Loss : **4.0dB** (without Spot Size Converter)
  - In plane “Butt Coupling” to SMF : **0.5dB ;** Vertical “Out of Plane” Coupling to MMF/PD : **0.5dB**
  - Established reference planes for **passive wafer scale packaging of hybrid components**
  - **High performance passive components** (Multiplexers, De-multiplexers, Mach Zehnder interferometers)
- POET has developed 100/200G Optical engines (CWDM4, LR4) using flip chip DML lasers
  - Optical engines deliver superior performance at industry leading cost, form factor and scale with wafer scale passive assembly
- POET has developed 400G/800G Receive Optical engines (FR4) with extensibility to 1.6Tbps
- The Optical Interposer unlocks the packaging bottleneck in photonics (Laser and Fiber Attach) by providing an efficient and low loss packaging solution
- **The Optical Interposer is THE ONLY chip scale integrated solution for modulated lasers (DML, EML) extending the applicability of these devices into the Tb era**

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