# Assembly & Test

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SENIOR ADVANCED PACKAGING ENGINEER
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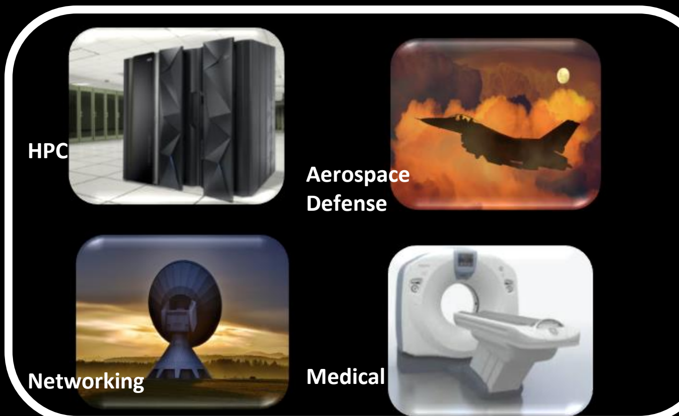
# North American Assembly and Test Provider

**Packaging & test solutions**
- Advanced Flip Chip & Photonics
- Any wafer source
- "Masters of Complexity"
- Outstanding characterization
- Design for manufacturing/Test
- OSAT > 40 yrs of experience

**Market Segments**



Advanced & Complex Package
- Design → prototypes → HVM

Efficient & Effective Production
- Low/High Volume
- High mix environment

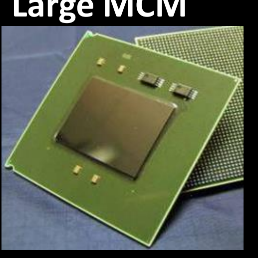
*Better Time to market*

5G
IBM
SIP
Custom
Mainframes
RF
Datacom

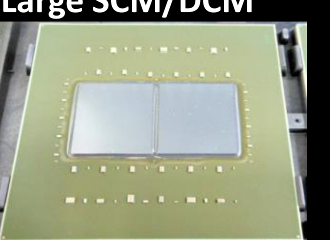
# IBM Bromont – Advanced Packaging

Heterogenous integration of various node function in SiP

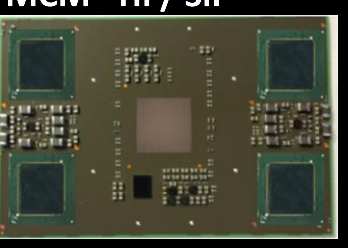
Large MCM



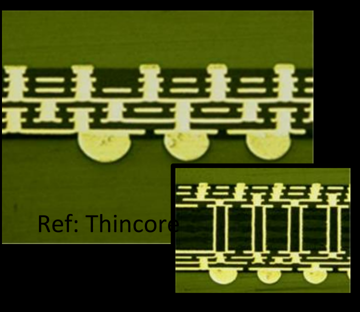
Large SCM/DCM



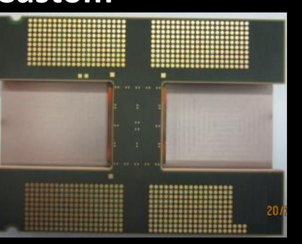
MCM - HI / SiP

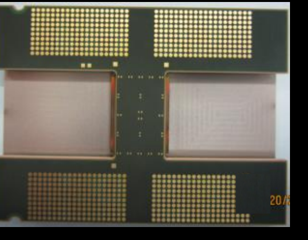


Coreless




Custom

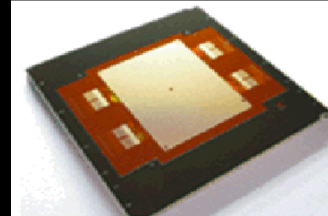




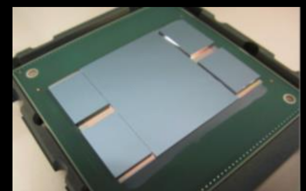


CSP

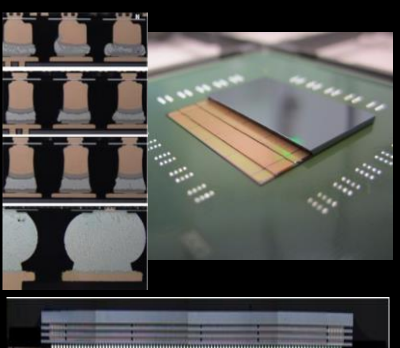
2.1D/2.3D



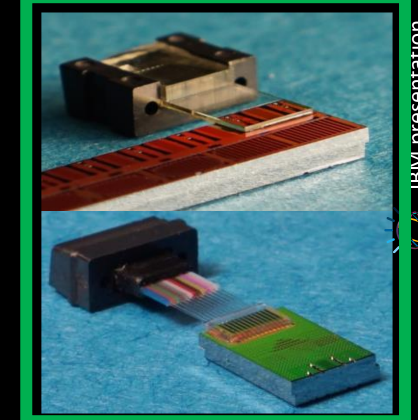
2.5D



3D

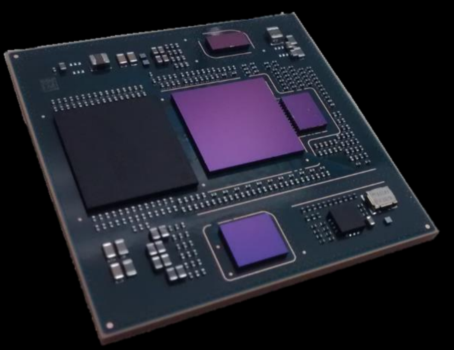


Photonics



IBM presentation

# System in Package



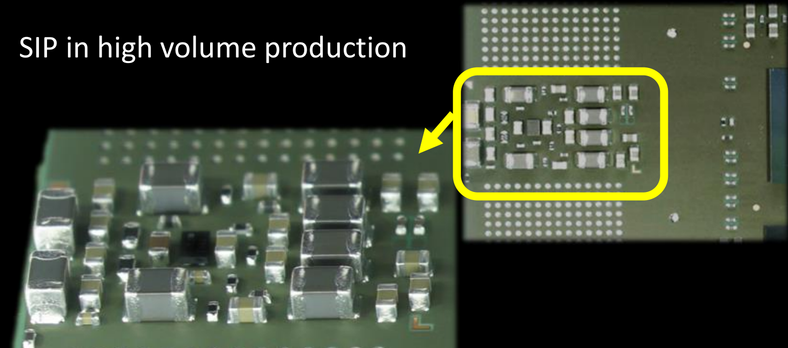
## FC-PBGA SIP solutions

Board level integration
→ Cost reduction

Mixing device technologies at package level provides:

- Very close die & components positioning
- Higher bandwidth and lower power
- Better signal integrity
- Smaller system level footprint
- Modularity for cost savings
  → Next generation component drop-in

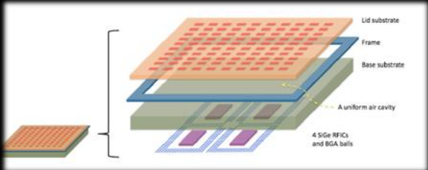
SIP in high volume production



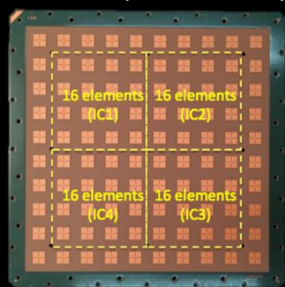
# Antenna on Package

## 5G radio access application AoP SIP

- phased-array antenna-in-package module
- 64 dual-polarized elements
- Package size 70 x 70 mm
- Tight spacing control in assembly
- over 50dBm EIRP in TX mode
- ±40 degrees scanning range



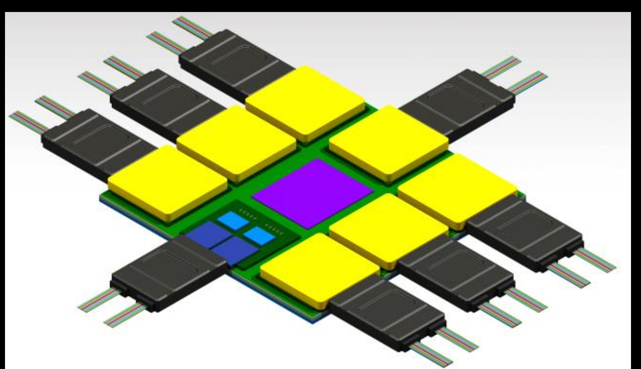

Assembled phased array with four transceiver ICs showed

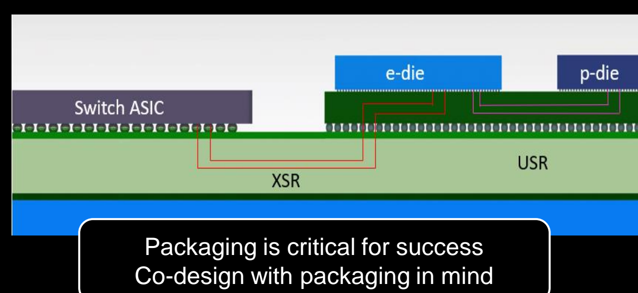


# Co-Packaging – Advanced integration

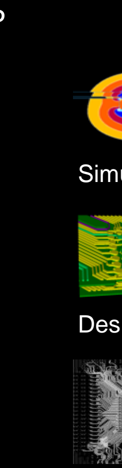


Disaggregation → Package integration
Heterogenous integration of various node function in SiP



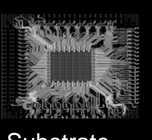



Packaging is critical for success
Co-design with packaging in mind



Simulation

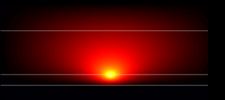
Design



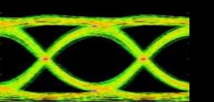
Substrate

Manufacturability

Miniaturization



Optical Performance

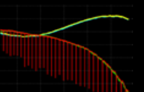


Electrical Performance

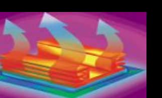
Reliability

Industry 4.0

Modeling



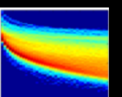
Measure & Test



Thermal Management

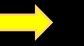
CPI

Cost / yield



Predictive manufacturing

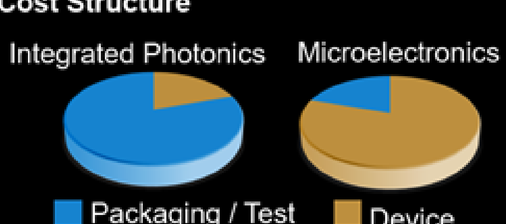
# Silicon Photonic Packaging Vision

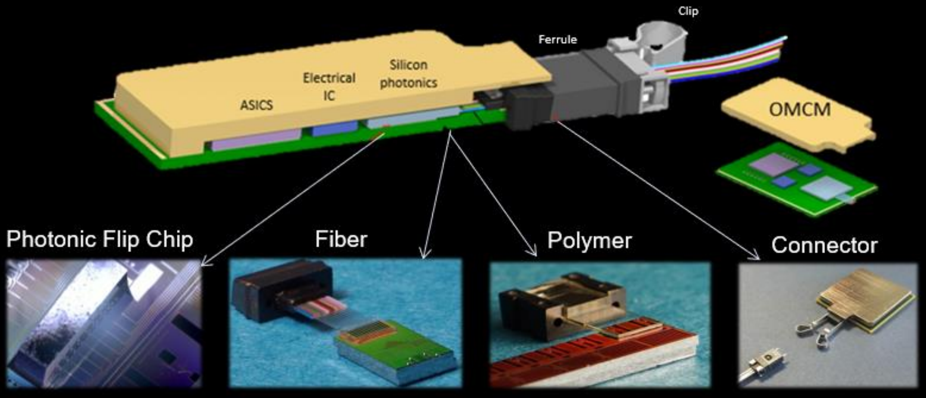
**Lowering packaging cost**  **Increased scalability**

## Manual / Low volume → Automated / High volume

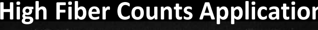
- Active alignment
- One connection at a time
- Custom design

- **Self alignment**
- **Multiple connections at a time**
- **Standard design**

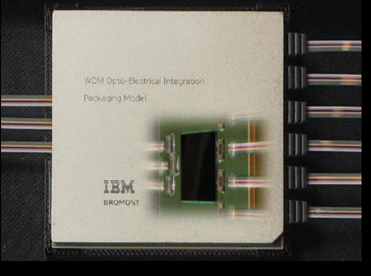




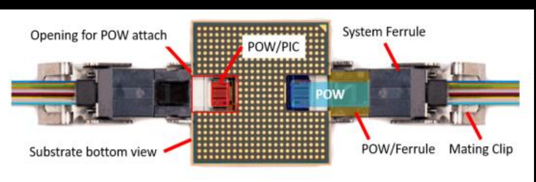
# Photonic co-packaging demonstrator



## High Fiber Counts Application




## High Density Optical Port Counts Application



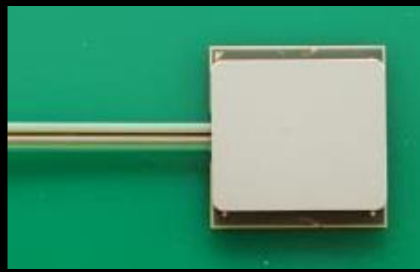

## Integrated Connector

MT ferrule attached to CSOP lid

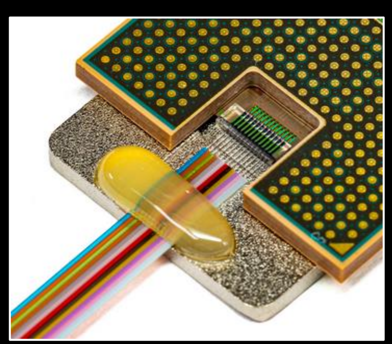
MT ferrule part of fiber cable to be plugged in

Clip installed during fiber cable plug in

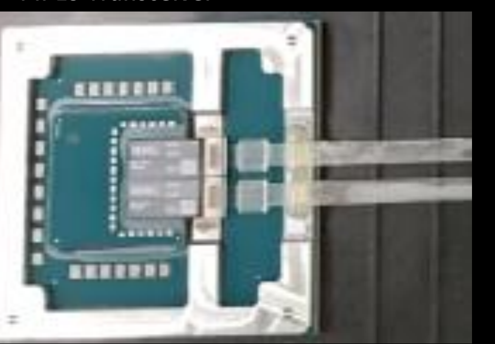
## Solder Reflowable Silicon Photonics Fiber assembly



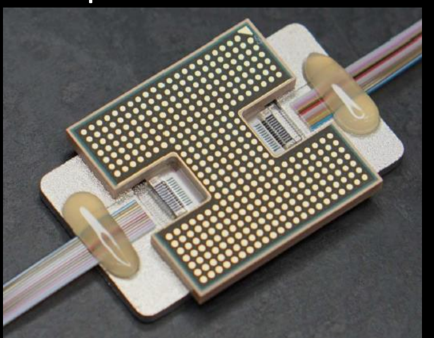
## Strain Relief of fiber assembly pigtail

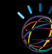


## PIPES Transceiver

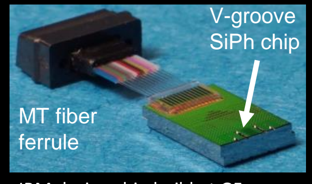


## Full Optical Switch





# Fiber Array – Single mode solder reflowable coupler




IBM design chip build at GF

GLOBALFOUNDRIES

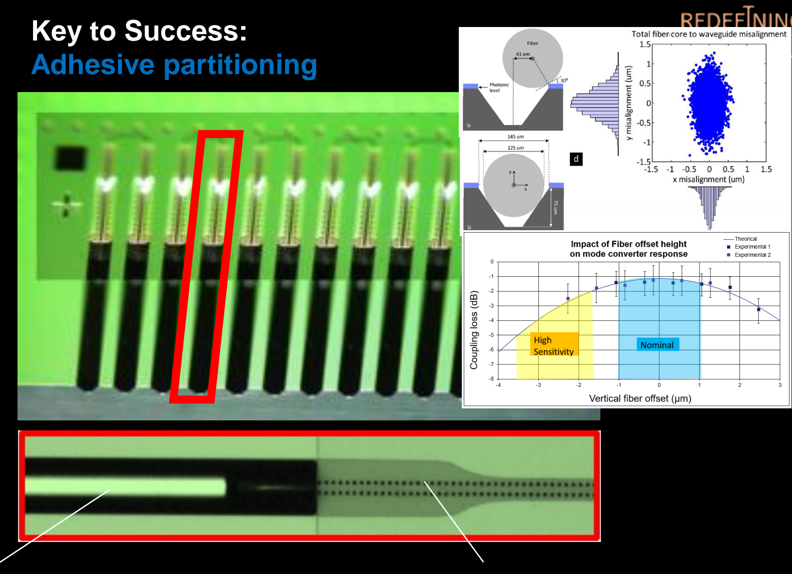
- Parallel channel array (12ch TV)
- O, S, C, L bands compatible
- Couples both polarizations (TE / TM)
- High throughput pick n place tools
- Solder reflow compatible (260 C)

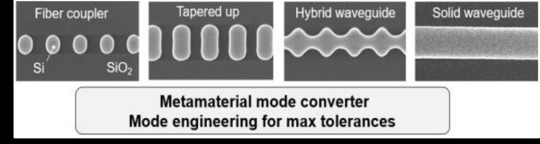
**Integrated Metamaterial Interfaces for Self-Aligned Fiber-to-Chip Coupling in Volume Manufacturing**

IEEE Journal of Selected Topics in Quantum Electronics

Volume: 25 , Issue: 3 , May-June 2019

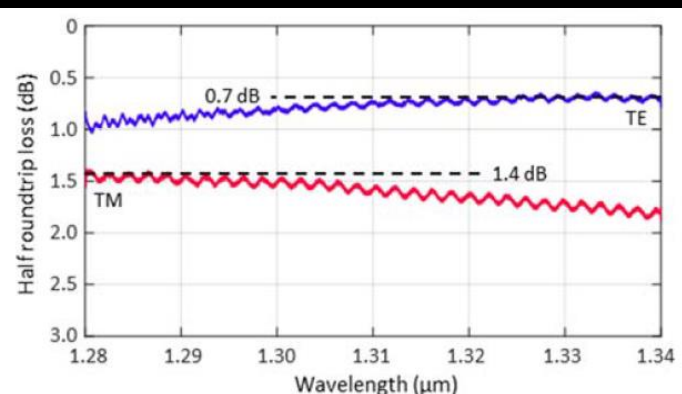
## Key to Success:
## Adhesive partitioning

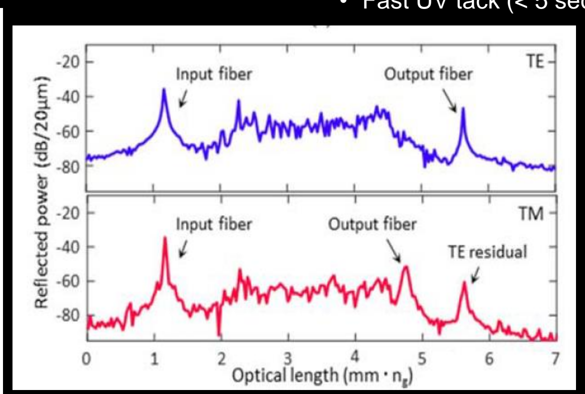


**Structural adhesive for fiber**
- Mechanical stability/robustness
- Fast UV tack (< 5 sec)

**Optical adhesive for suspended region:**
- Optical performance
- Reduce stress on fragile membrane



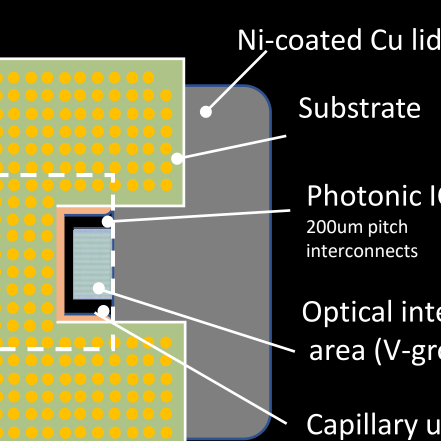

Fiber coupler | Tapered up | Hybrid waveguide | Solid waveguide

Si | $SiO_2$

**Metamaterial mode converter**
**Mode engineering for max tolerances**

Fiber ribbon assembly in V-grooves (X-ray tomo)

# Photonic Flip-Chip assembly example



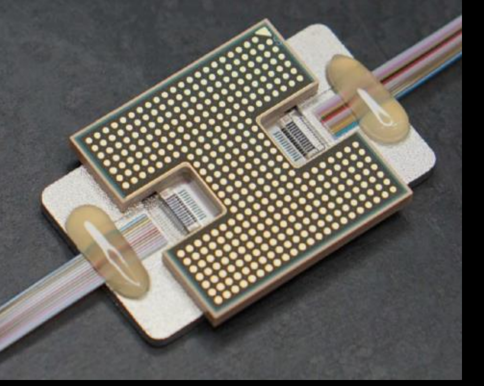

Bottom view substrate side of the module

Repeatability

N = 168
Avg. Loss: 1.6dB

Probability (%)

Average transmission loss (TE mode) per facet (dB)



Formic acid furnace

R&D formic acid oven also available

**Formic acid flip-chip bonding**

**Fluxless solution required to maintain grooves/facet cleanliness and SWG integrity**

**Fluxless formic acid reflow with temporary adhesive material (tacking fluid)**

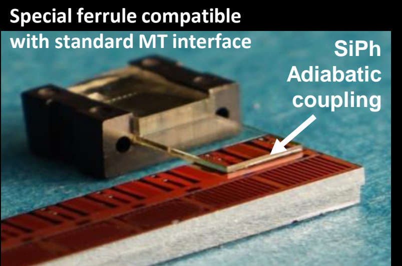
**No voiding / cracking of the IMC & solder**

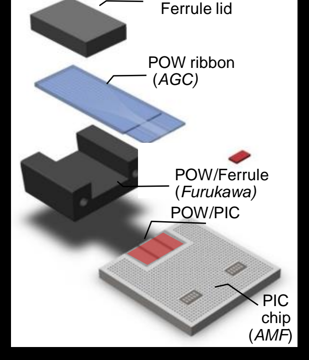
**Formic acid reflow available at IBM Bromont**

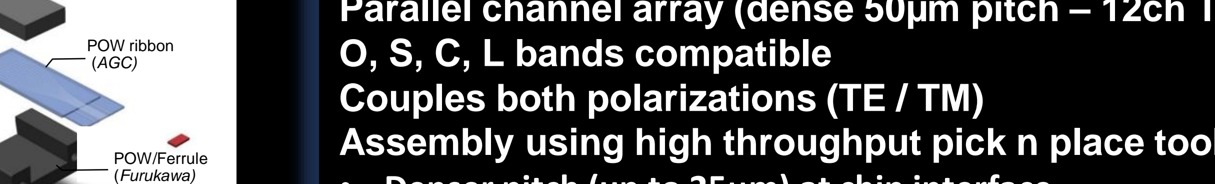
# Compliant Polymer interface – Dense Single mode coupler



Special ferrule compatible with standard MT interface



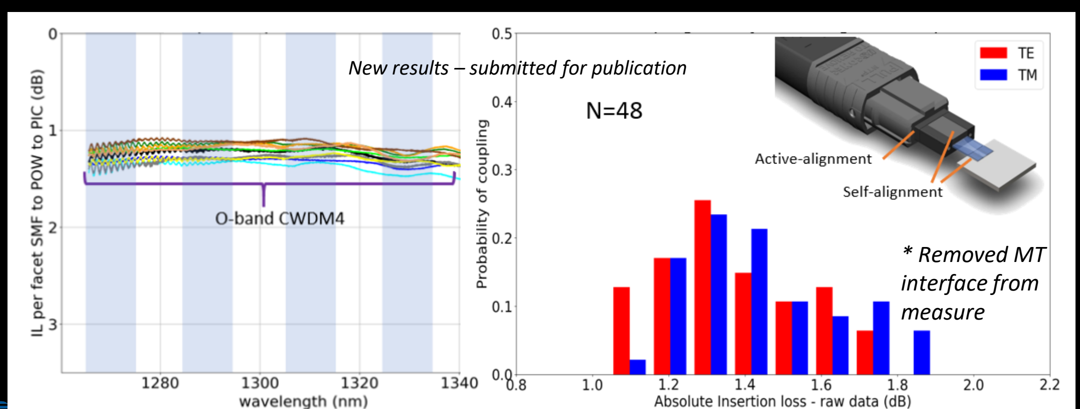



**Parallel channel array (dense 50µm pitch – 12ch TV)**
**O, S, C, L bands compatible**
**Couples both polarizations (TE / TM)**
**Assembly using high throughput pick n place tools**

- **Denser pitch (up to 25µm) at chip interface**
- **No need for deep grooves (wet etch process)**
- **Mode converter structure is simple**
- **Compliant material for CPI risk mitigation**

**Advances in Interfacing Optical Fibers to Nanophotonic waveguides via Mechanically Compliant Polymer Waveguides**
IEEE Journal of Selected Topics in Quantum Electronics - 06 January 2020

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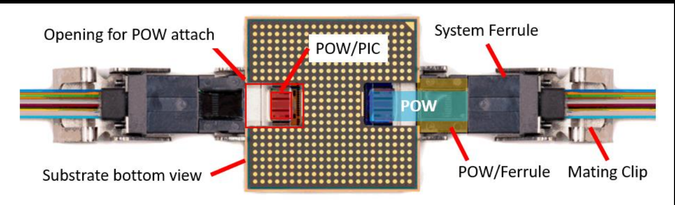
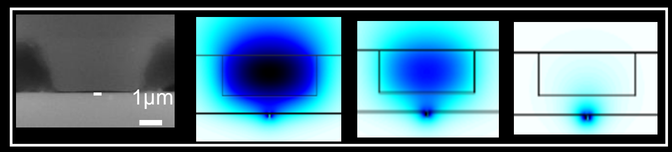
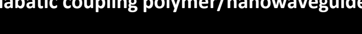


# Offer

## Expertise

- 7nm
- Proven material sets for high performance
- Prototyping to high volume manufacturing

## Time to market

- Benefit from existing models and designs to accelate MCM implementation
- Beyond groundrules:
  - ✓ Customization
  - ✓ Characterization

## Business Model

- Co design partners
- Streamlined manufacturing flow
- Integrated supply chain

We put our packaging know how at your service
Focusing on your application and performance

# IBM Packaging and Test

**www.ibm.com/assembly**

# Thank You

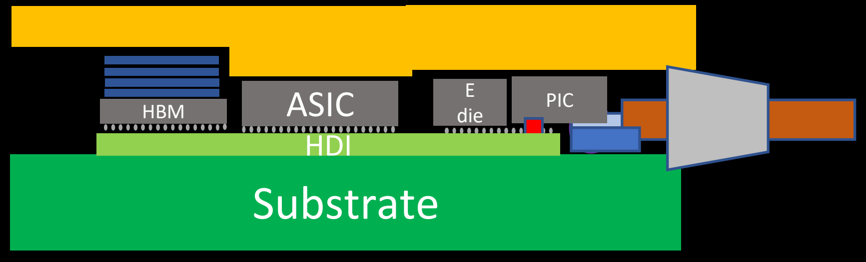
## We are here for you!

ajantapo@ca.ibm.com

IBM

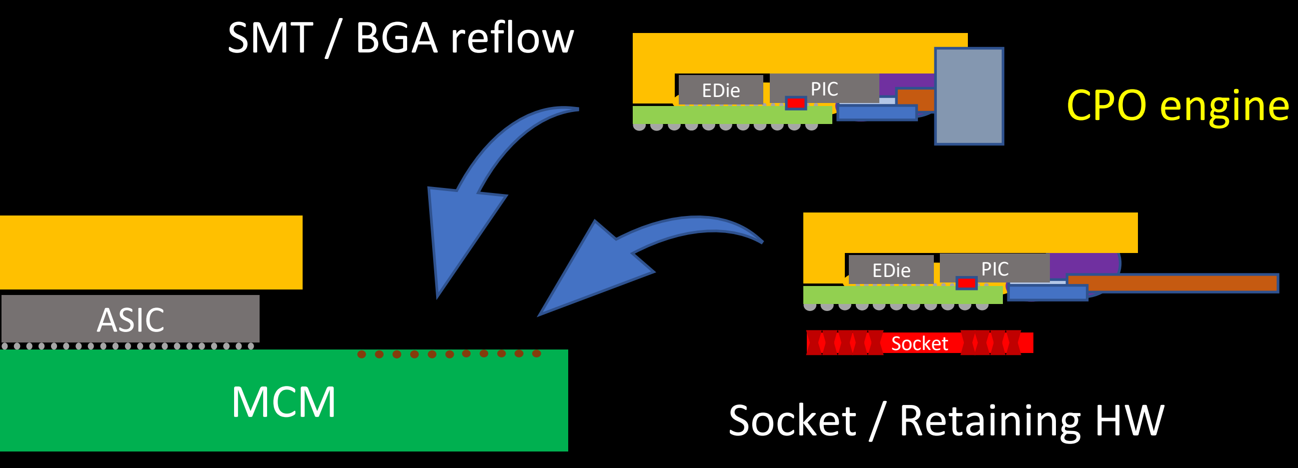
# Co-packaged Optics Configuration examples

HDI with Photonics




SMT / BGA reflow

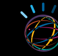
CPO engine




Socket / Retaining HW

MCM with CPO engine



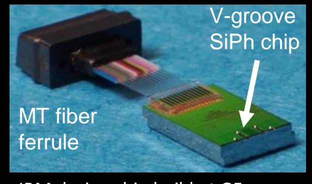


# Co-Packaging in Advanced integration

a — PIC
b — PIC
c — E-die, PIC
d — E-die, PIC
e — E-die, PIC
f — E-die, PIC
g — E-die, PIC
h — PIC, E-die

IBM presentation

# Fiber Array – Single mode solder reflowable coupler

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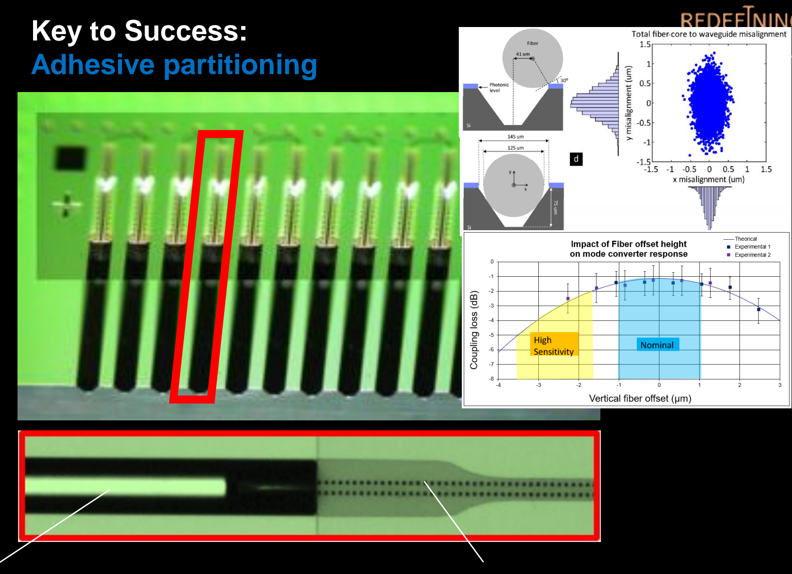


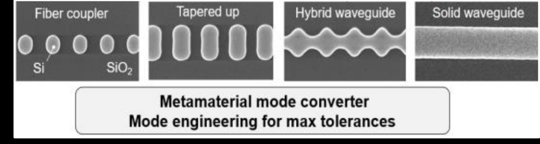

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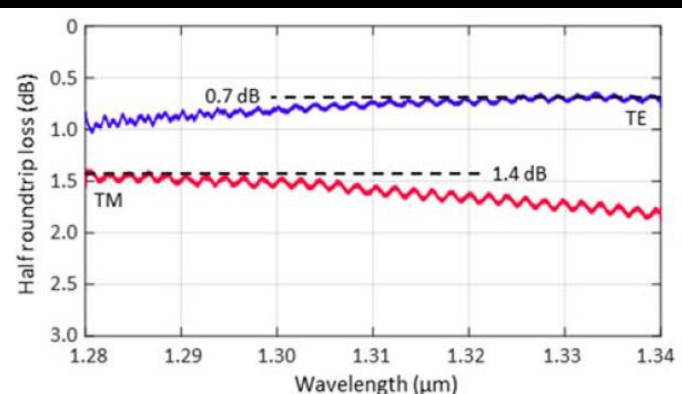


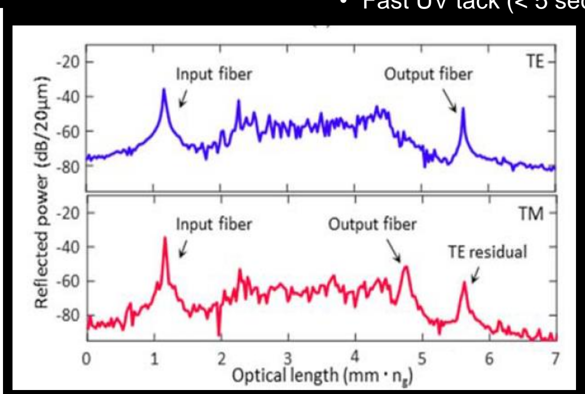


Fiber coupler | Tapered up | Hybrid waveguide | Solid waveguide

Si | $SiO_2$

Metamaterial mode converter
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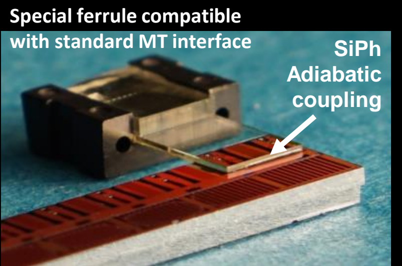
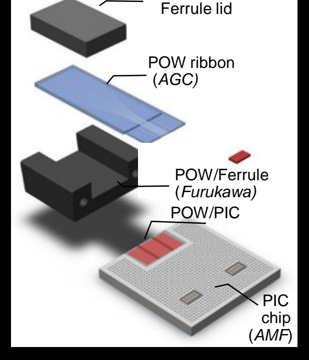
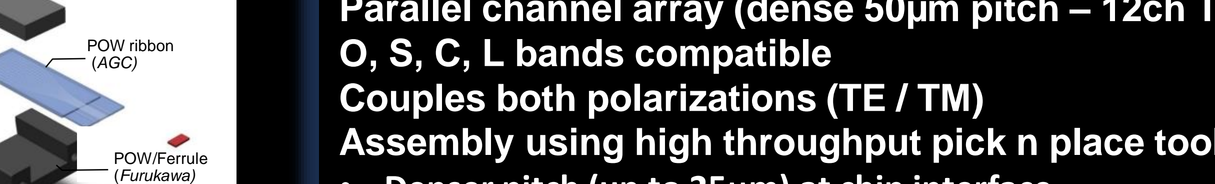



amf ADVANCED MICRO FOUNDRY



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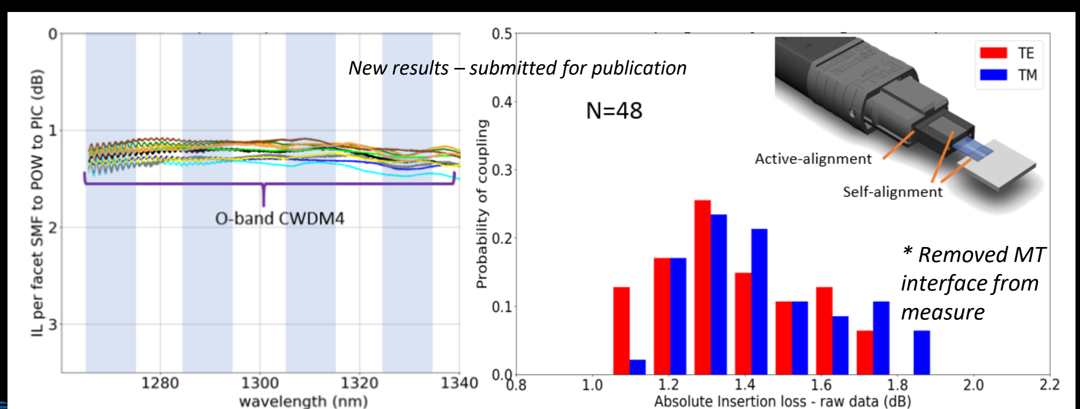
**Advances in Interfacing Optical Fibers to Nanophotonic waveguides via Mechanically Compliant Polymer Waveguides**
IEEE Journal of Selected Topics in Quantum Electronics - 06 January 2020

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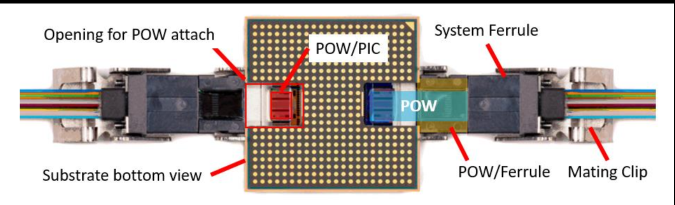
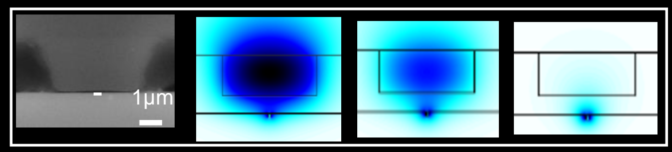
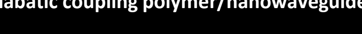


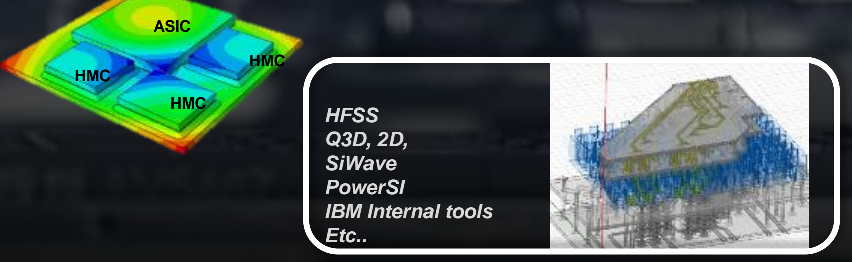

POW
Adhesive
SiN
SiO2


Adiabatic coupling polymer/nanowaveguide

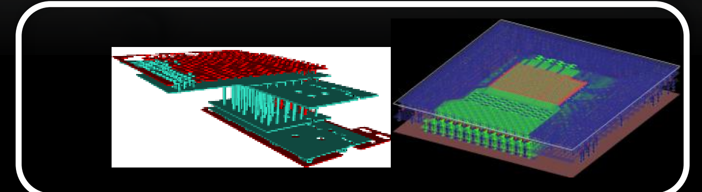
IBM

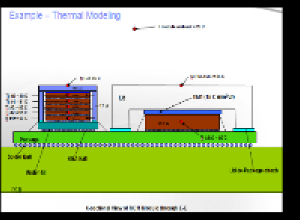
# Deep capability in design, modeling, failure analysis and qualification

**"First time right results"**




- Predictive and validated mechanical modeling
- Proven electrical modeling, simulation, analysis and characterization refined through empirical authentication
- Demonstrated thermal modeling capabilities confirmed through HVM products
- Innovative photonics single mode packaging and certified OSAT
- Top-of-the-industry **failure analysis** skills and labs
- Package and Product qualification services complying with reliability standards





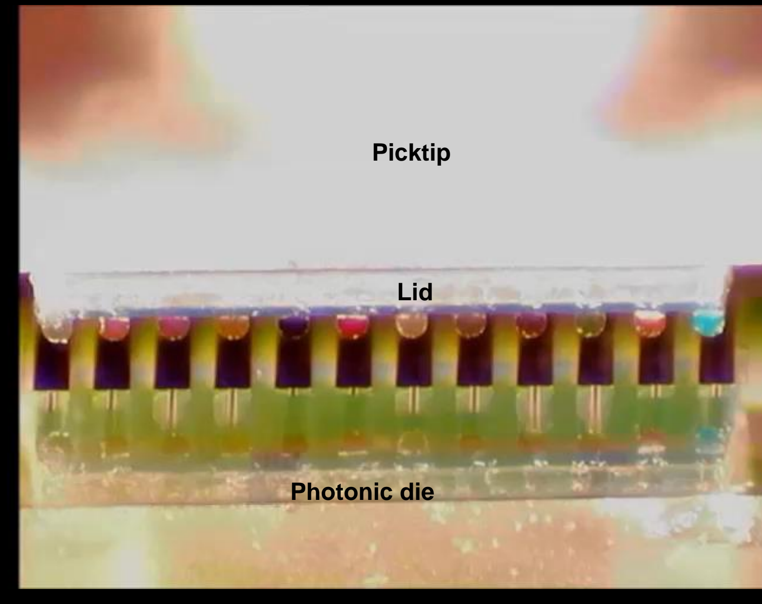
Robot handler

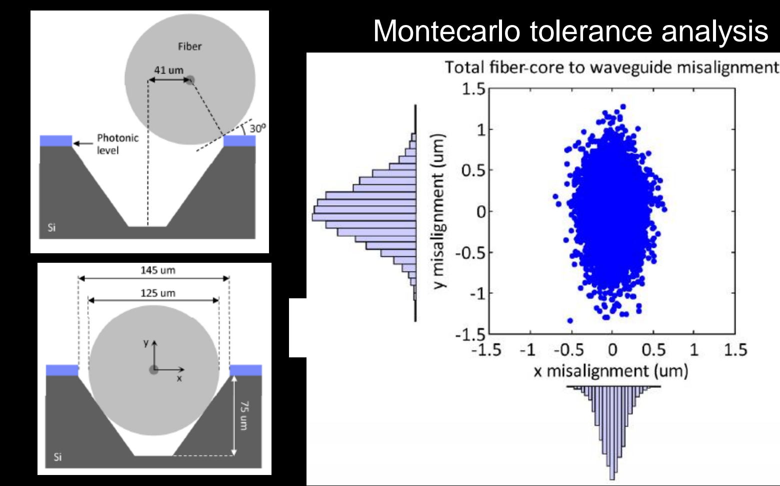
UV source

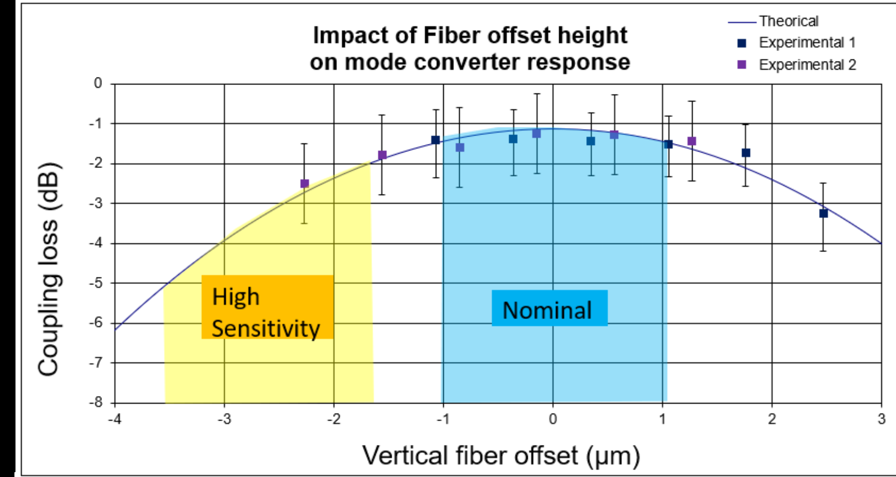
Lid

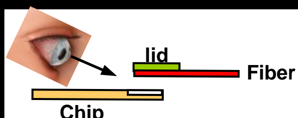
Tool base plate (adjustable)

# Fiber Array – Self-alignment



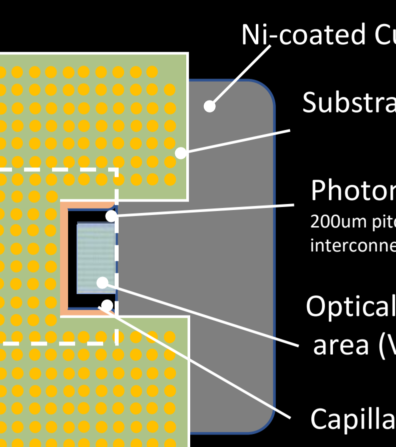



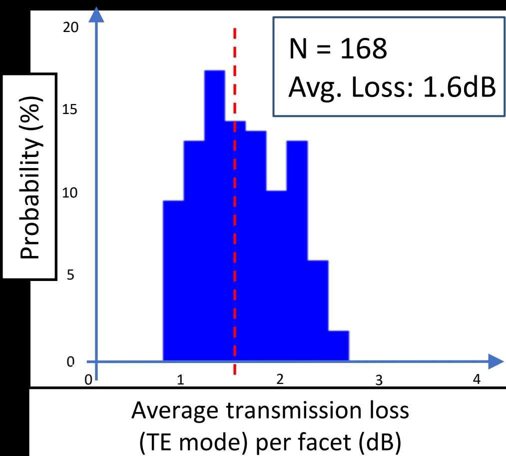

**10 µm pick and place**
**Self alignment to ~1 µm**

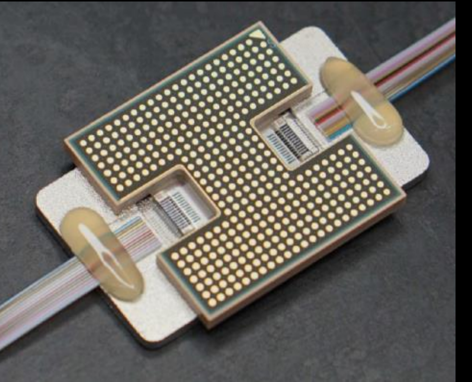
# Photonic Flip-Chip assembly example




Bottom view
substrate side
of the module

Repeatability



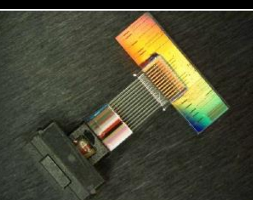



Formic acid furnace
R&D formic acid oven also available

- **Formic acid flip-chip bonding**
- **Fluxless solution required to maintain grooves/facet cleanliness and SWG integrity**
- **Fluxless formic acid reflow with temporary adhesive material (tacking fluid)**
- **No voiding / cracking of the IMC & solder**
- **Formic acid reflow available at IBM Bromont**

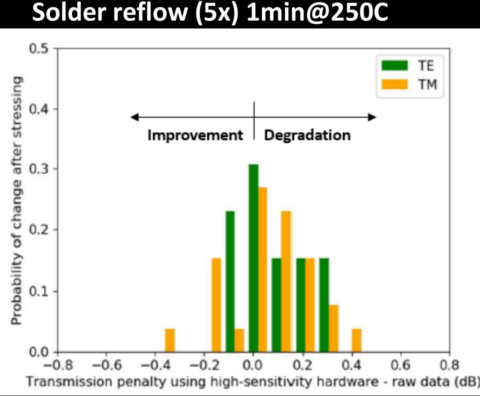
# Fiber Array – Reliability Demonstration

PIC

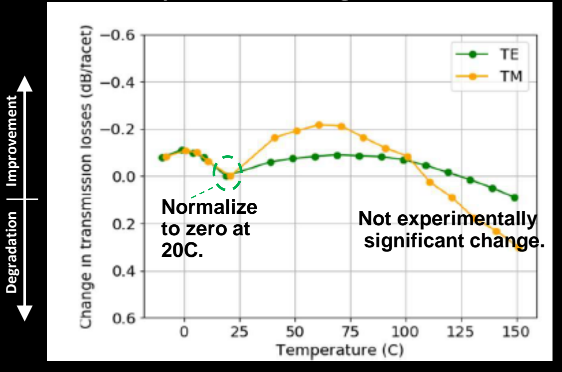


Assembly

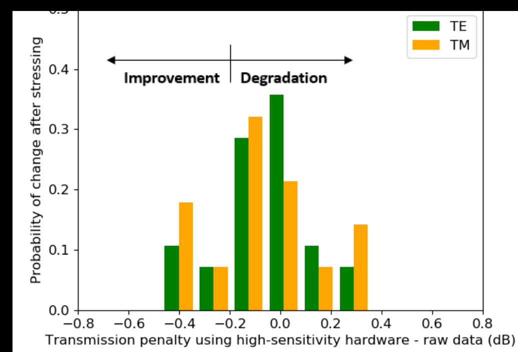
Solder reflow (5x) 1min@250C



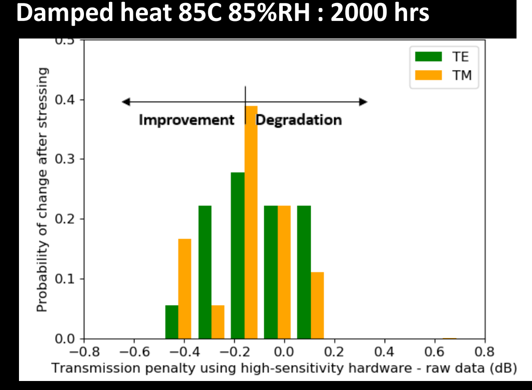

In-situ optical loss change from -10C to 150C



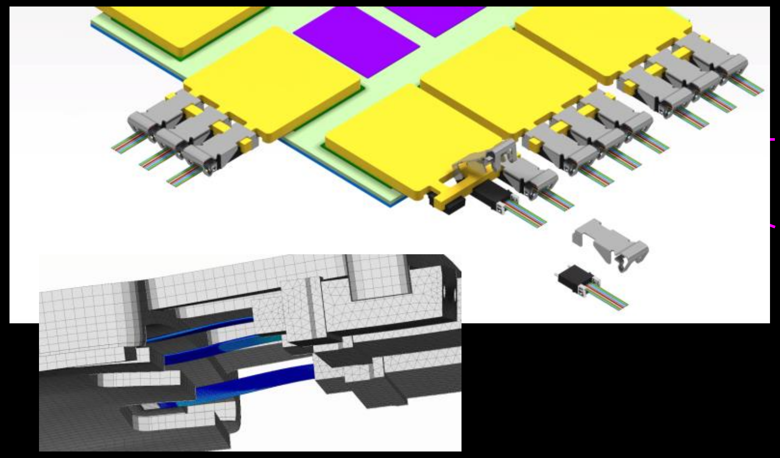

Thermal Cycling -40/85C&-40/125C : total 2000 cycles




Damped heat 85C 85%RH : 2000 hrs

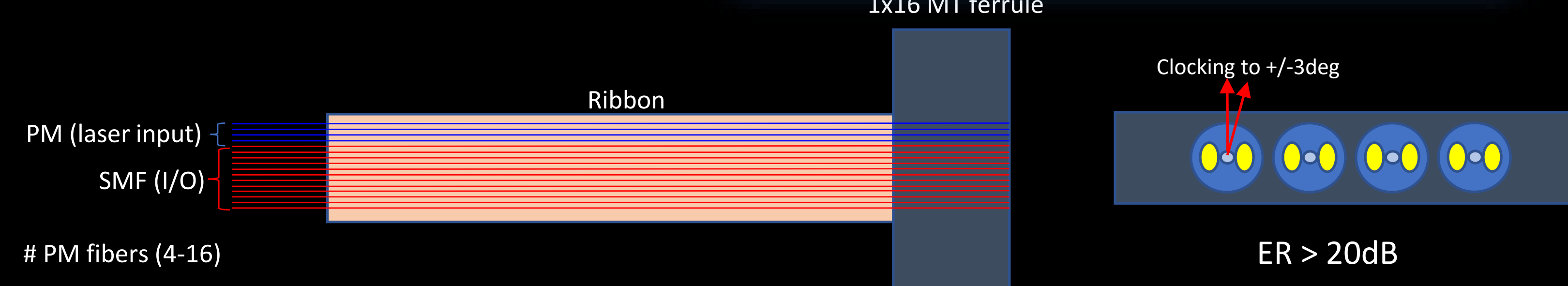


# Photonic copackage – Optical connectors



## What is needed from fiber component suppliers

- Disruptive innovation to reduce connector size (integrated version)
- Solder reflow compatible ferrules
- Low loss SM 1x16 .. 2x16 ? 1x24?
- SM with 80µm fiber on reduced pitch
- PM arrays and Combination of PM / SMF fibers
- Efficient shipping and expedition of fiber component and photonic module




* Ideally Integrated connector to be solder reflow compatible

# Global Foundries : 45CLO feature set

MZI modulators

Ring modulators

Ge EPI PD

Waveguides, passives

*Ridge, Rib WGs, Bends, tapers, Directional couplers, cross WIC, gratings, absorbers*

BEOL passives, inductors, VNcap

**PIC = SiPh + CMOS**

Thermal phase shifters standard & undercut

4x MUX/DeMUX tunable

RF CMOS, standard cell, GPIO, ESD, eFuse, TIA, driver, precision resistor,

Top grating couplers

BEOL STACK, SMF, V-GROOVE, Si, OXIDE, BOX, Substrate

Edge fiber couple, passive or active align

Direct laser attach

Polarization splitter & rotator

Legend:
**CMOS**
**Optical**

*courtesy of GF*
*source IBM-GF :*
*CPO Webinar Sept16,2020*

# Global Foundries – Chips for co-packaged photonics

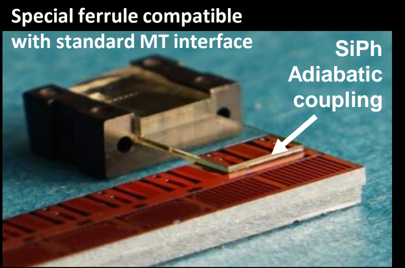
| | Electronic technology for hybrid integration | | | GF monolithic CMOS - SiPh | |
|---|---|---|---|---|---|
| | 14FF | 22FDX® | BiCMOS | 90WG | 45CLO |
| **nMOS Ft** | 270GHz | 350GHz | 500GHz | 150GHz | 280GHz |
| **Supply V** | 0.8V | 0.8V | 3.3V | 1.2V | 1.0V-1.1V |
| **Substrate** | BULK | SOI | SiGe HBT | SOI | SOI |
| **Mx res & rap** | High | Low | Very low | Very low | Very low |
| **Parasitic load** | 5-30fF | 5-30fF | 5-30fF | 2-3fF | 2-3fF |
| **ESD cap** | ~50fF | ~50fF | ~50fF | 0 | 0 |
| **Estimated TIA 3dB BW @1kΩ gain** | 24 GHz *(70fF) | 28 GHz *(70fF) | 33 GHz *(70fF) | 35 GHz *(20fF) | 47GHz *(20fF) |

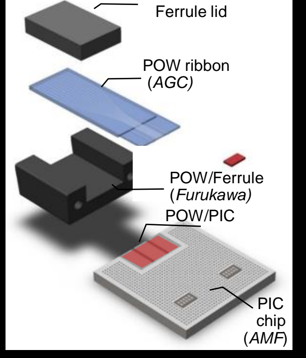
- RF-grade CMOS FETs integrated with SiPh
- Dense high speed channel integration
- Reduced packaging costs
- ESD elimination further reduces input capacitance
- Significant TIA bandwidth due to low input capacitance

*courtesy of GF*
*source IBM-GF :*
*CPO Webinar Sept16,2020*

# Compliant Polymer interface – Dense Single mode coupler



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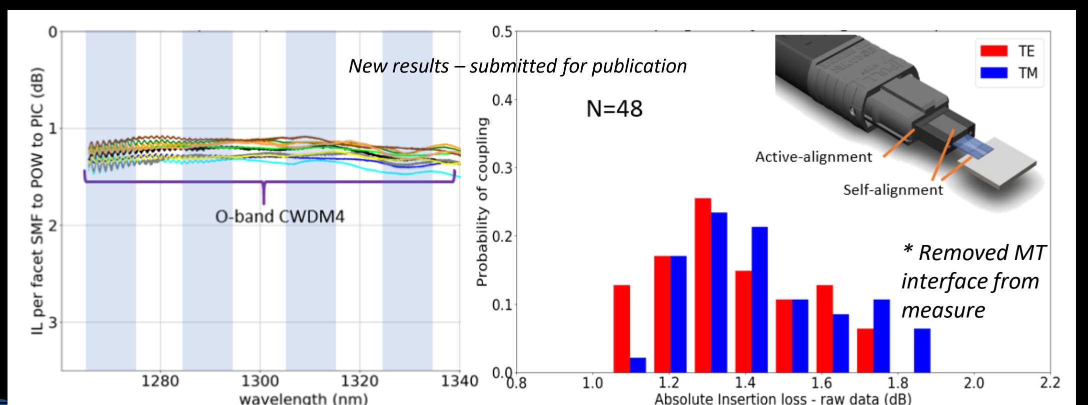


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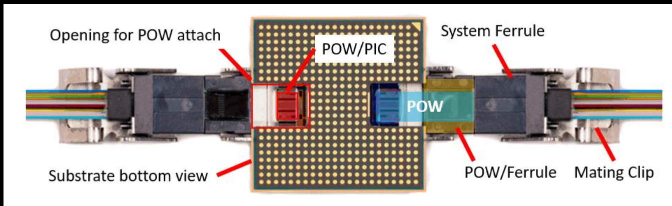
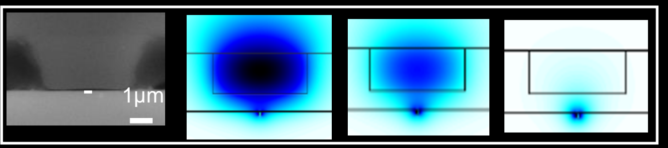
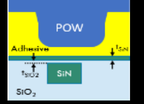
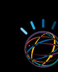


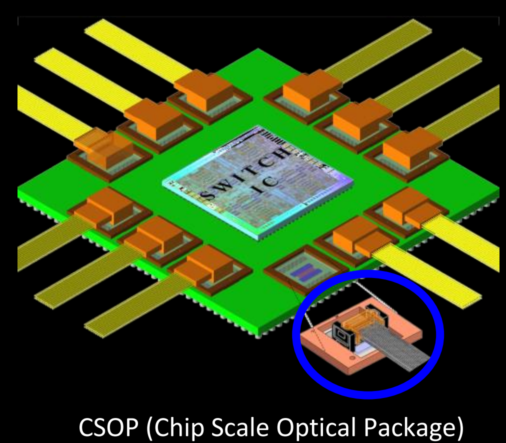





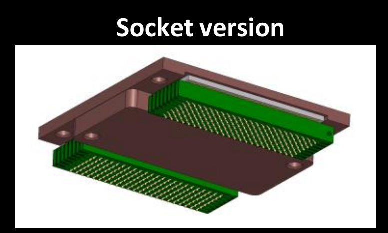
# ARPA-E Enlighten: Motion – VCSEL co-packaging

Multi-wavelength Optical Transceivers Integrated On Node

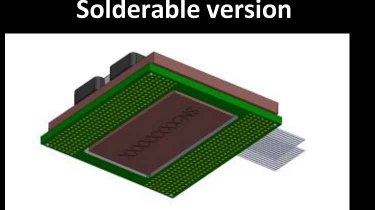



CSOP (Chip Scale Optical Package)
56Gbps NRZ (16Tx + 16Rx)

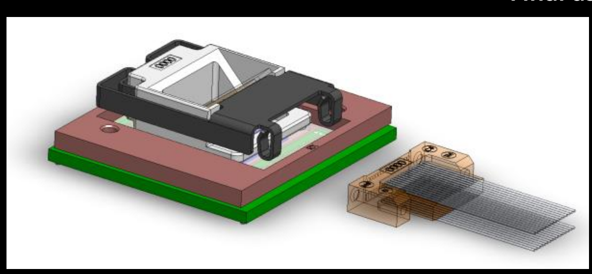
Socket version

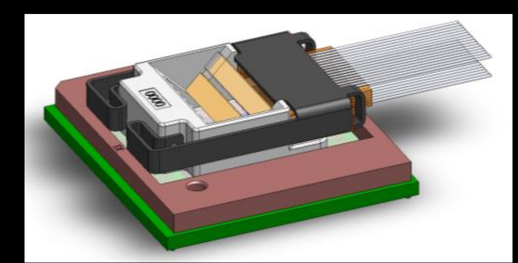


Solderable version



Final assembly





# ARPA-E Enlighten: Motion – VCSEL co-packaging

Cu Heat Spreader

Glass Carrier

SAFE ICs, VCSELs, PDs

Keel

(Lenses / fiber clipping not shown)

**VCSELs / PDs arrays**
- Au/Sn
- Optically clear UF

**SAFE ICs**
- Sn/Ag - Cu pillar
- Structural UF

C4 landing pads for glass substrate

+ =

**Glass substrate**
- Sn/Ag
- Structural UF