Next Generation Miniaturised Freeform Optics from **Facet-Attached Micro-Lenses (FaML)** to **Photonic Wire Bonding (PWB)**

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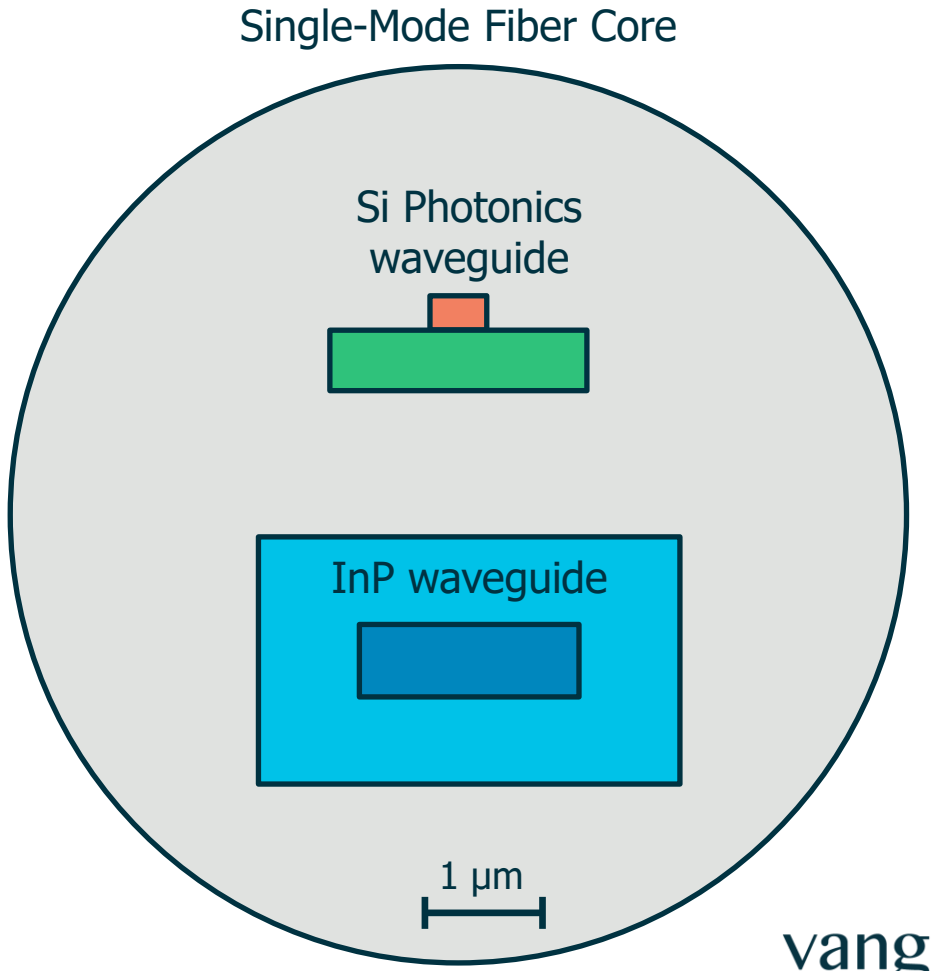
Today's Packaging and Assembly **Challenges**

Different Mode Field Sizes and Heterogenous Material Platforms

- Mode field matching
- High-precision assembly alignment
- Fast and reproducible packaging
- Reliable under various conditions

Over 70% of the cost of photonic integrated systems are generated by the packaging process



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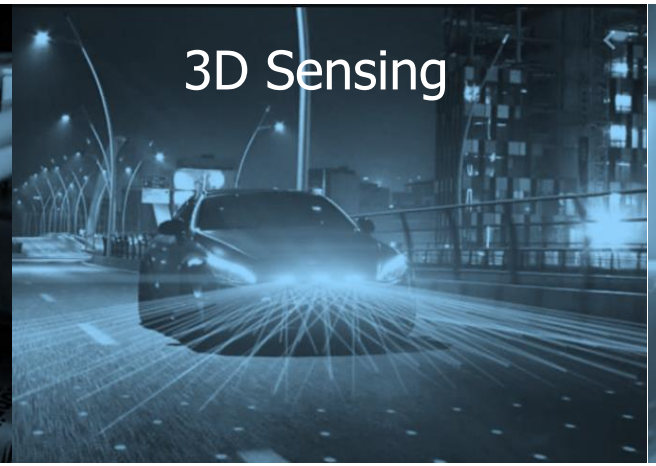
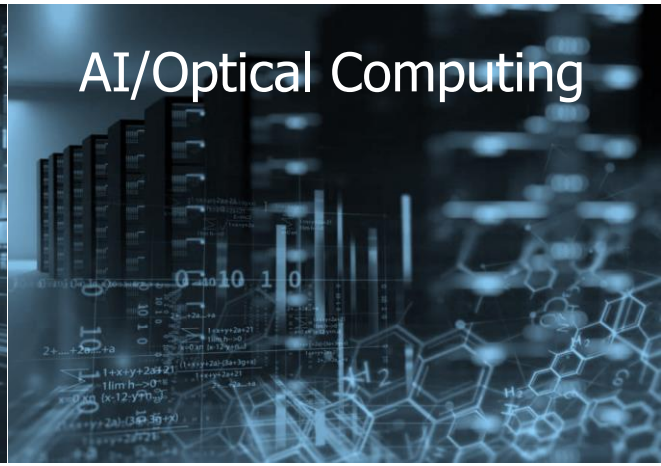
Photonic Integrated Circuits are Growing Rapidly





Our Mission

Advance Photonic Packaging and Assembly by providing scalable 3D nano-fabrication solutions for prototyping and manufacturing

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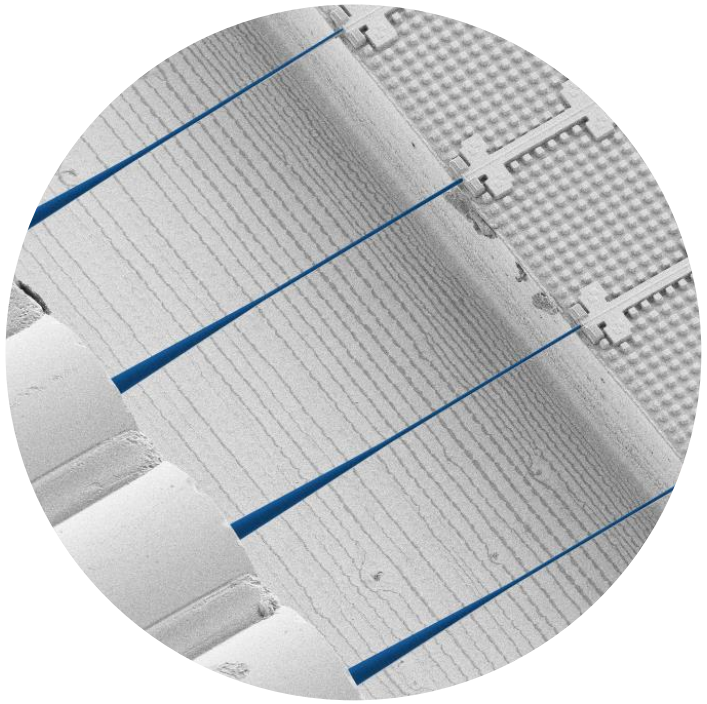
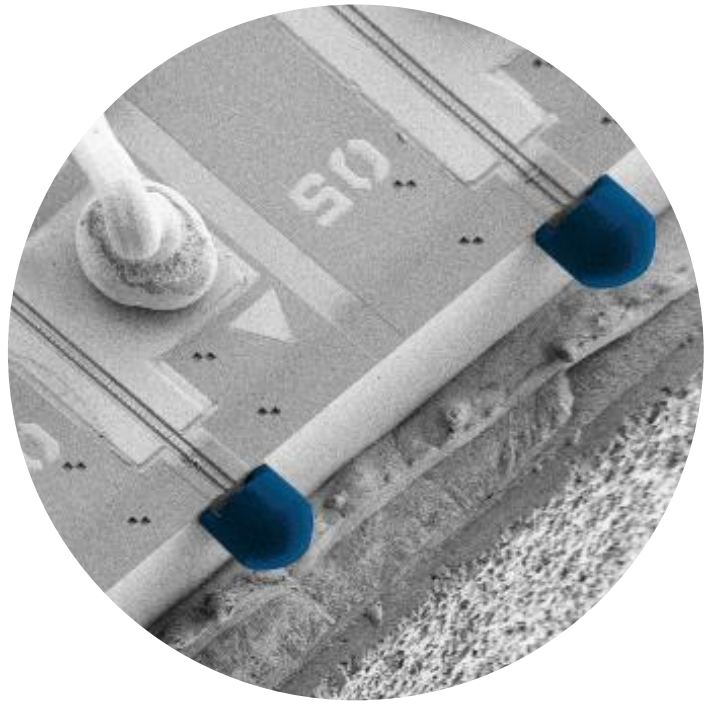
Enabling Next Generation **Photonic Integration and Packaging** Solutions with **3D Laser Lithography Solutions**





Photonic Wire Bonding (PWB) and **Facet-Attached Micro-Optical Lenses (FAML)**

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Micro-Optical Elements for **industrial** applications

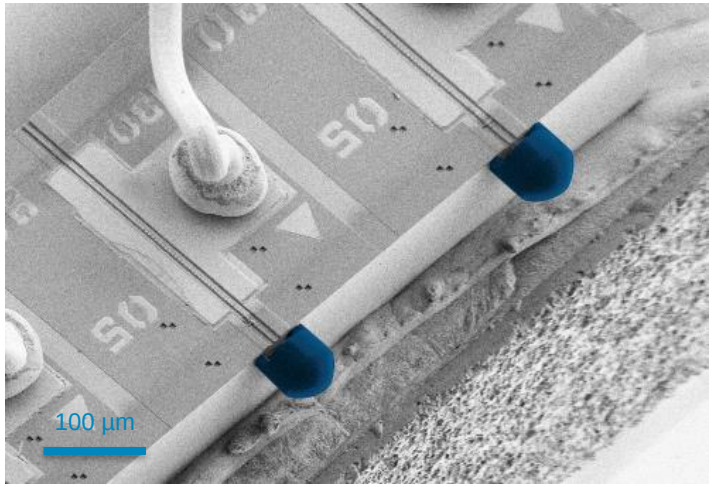
Compatible components
- Laser (DFB and other)
- PIN and APD diodes
- SMF, PMF and MMF fiber arrays
- PIC: SOI, SiN, InP, LiNb and more

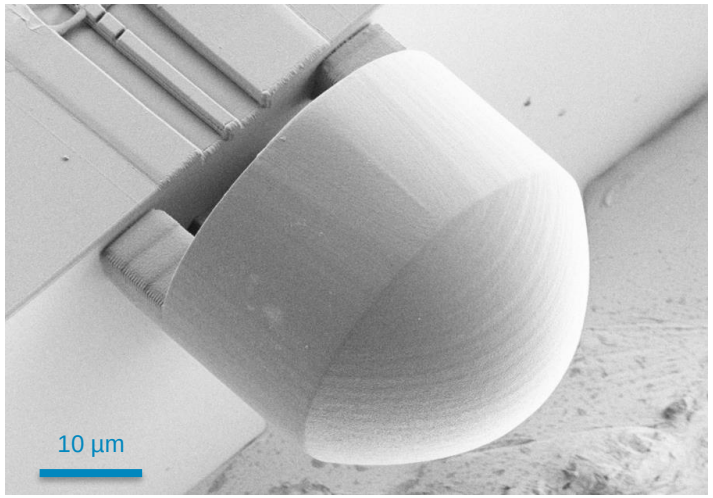
Standard building blocks:
- Lenses with focal length up to centimeters and mode-field diameters of 2.0 µm to 100 µm (@1/e² intensity)
- Total-internal-reflection mirrors
- 3D-printed mode-size converter

Coupling, depending on laser and chip
- Laser-to-Chip: 0.6 to 2.5 dB
- Chip-to-Fiber: 1.5 to 2.5 dB

Alignment tolerances @ 1 dB penalty:
- ±1.5 µm (single lens on one component) to ±15 µm (beam expander)

Tested operational range
- 530 nm to 2000 nm





Reproducibility
- Below σ = 0.2 dB coupling variation
- Below 10% mode-field and focus length variation/deviation

Accuracy
- Below σ = 50 nm detection accuracy
- Below ±100 nm shape accuracy
- Less than 10 nm RMS-roughness

Reliability testing
- > 4000 h 85°C/85% rel. hum
- > 250 cycles -40°C to 85°C
- Reflow soldering, 3 cycles, 270°C
- Die bonding, 310°C

Shock testing
- Acceleration of up to 1500 g
- Vibration, 20g, all axis

High power operation
- >1 W @ 1550 nm

Cryogenic operation
- > 10 cycles 4K to room temperature

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Industry proven **reliability** and mechanical shock testing

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Connect with Innovation

HB-CDM module

"Low Insertion Loss 128-Gbaud HB-CDM with 3D Printed Spot Size Converter Integrated InP-based Modulator",(2023)
Y. Mizuno et al., 2023 OFC, San Diego, CA, USA, 2023, pp. 1-3

First demonstration of commercial optical modules benefitting from 3D printed optical components integrated InP devices

Improved coupling efficiency with spot size converter lens- reducing mode conversion losses by **1.5dB per lens**

Relaxed alignment tolerances to 1.6µm with 1dB penalty

InP-Chip becomes **25% smaller** as coupling structures for mode field matching become redundant.

Telcordia GR468 qualified

Reliability testing
- 500 cycles -40°C to 85°C
- Reflow soldering, 3 cycles, 270°C
- Die bonding, 320°C

Shock testing
- Acceleration of up to 1500 G
- Vibration 20-2000 Hz

High power operation
- 200 mW optical output

up to 3000 h

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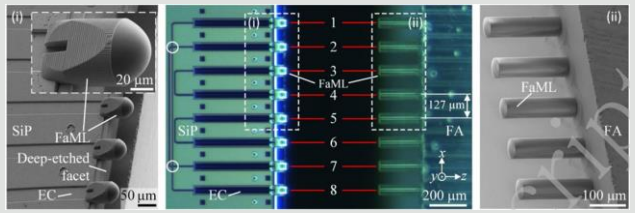
Use Cases – 3D-printed lenses

Relaxed Alignment Tolerances | Maximize Coupling Efficiency | Low Back reflectance

"3D-printed facet-attached microlenses for advanced photonic system assembly",(2023)
Xu et al., 2023. Light: Advanced Manufacturing, 4 (3). doi:10.37188/lam.2023.003

Alignment tolerance ± 14.4 µm with a 1 dB penalty

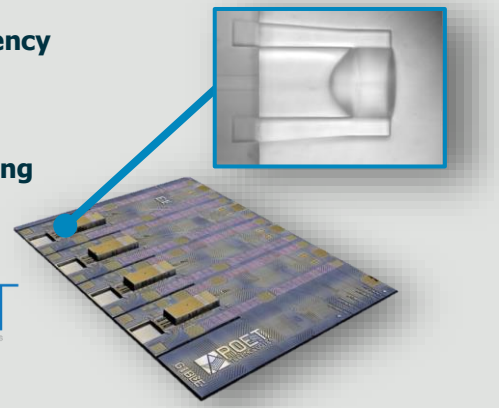


Collaboration to incorporate 3D-lithography technology into POET's Optical Interposer™ platform.

Increased Efficiency

Cost Reduction

Wafer level scaling

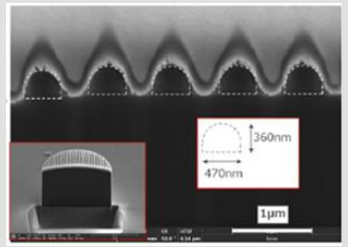


"3D-printed aspherical lens with moth-eye anti-reflection structure",(2024)
Y. Mizuno et al., Proc. SPIE 12898, Advanced Fabrication Technologies for Micro/Nano Optics and Photonics XVII, 128980R

Reflectance on the lens surface was reduced to **0.005%**

Coupling efficiency to fiber is improved to **-0.33 dB**

Structure size 360 x 470 nm



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Quantum Applications

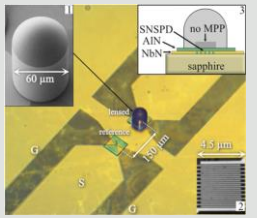
Cryogenic temperatures | No degradation | Broadband working range 530 – 2000 nm

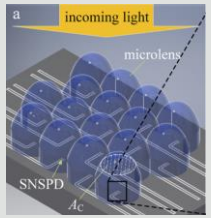
"Superconducting nanowire single-photon detector with 3D-printed free-form microlenses", Opt. Express 29, 27708-27731 (2021)

The paper demonstrates FaMLs operating at **cryogenic temperatures** down to **4.6K**

Assemblies undergo **10 cool down cycles**

Karlsruhe Institute of Technology

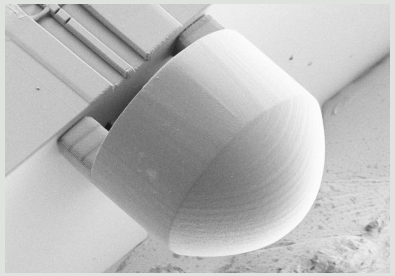




Path to Implement Photonic Integration with 3D Lithography

Step 1- 3D printed elements

3D printed elements



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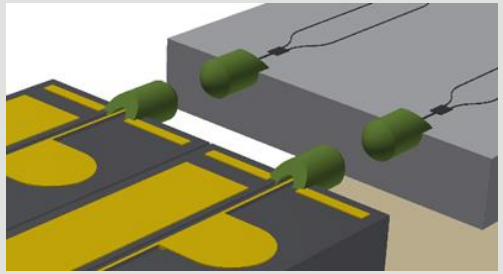
Active alignment

- improve coupling and yield
- No major changes to production process steps

Step 2- passive alignment

FaML



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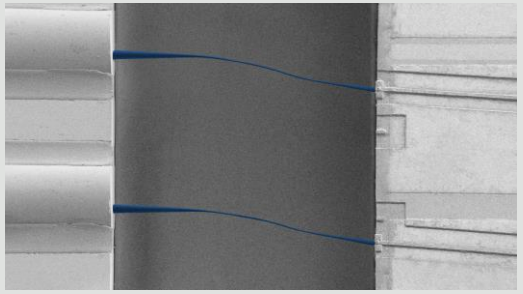
Passive alignment (±15µm)

- passive assembly is a viable process

Step 3- PWBs with relaxed alignment tolerances

PWBs



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Relaxed Pick & Place (±30µm)

- ensuring compact coupling
- high yields
- high package density

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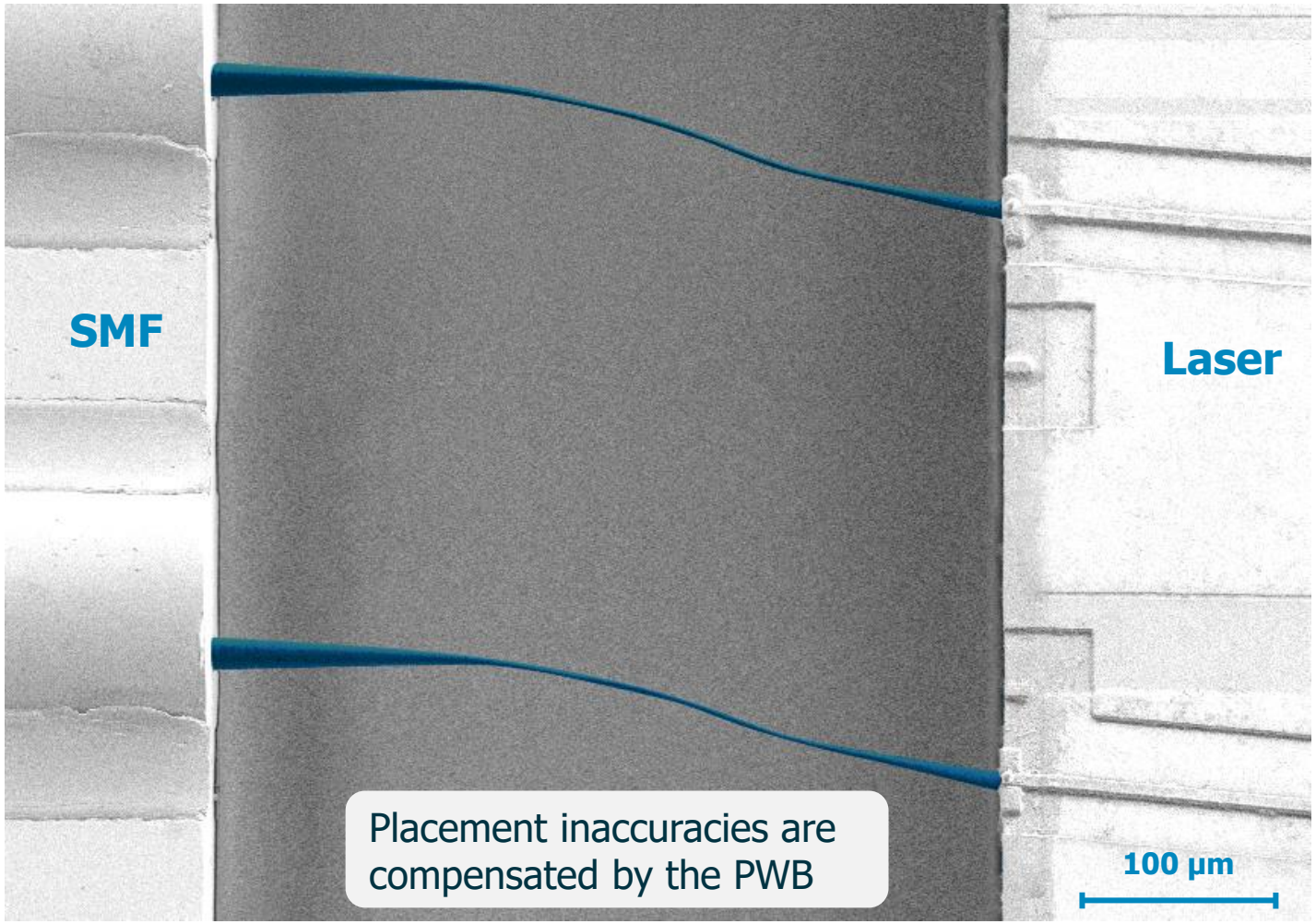
Photonic Wire Bonding: The Benefits



Laser by Freedom Photonics LLC

Low loss connection to arbitrary mode fields

Automated, **reproducible** and **fast** processes

Reliable connections under various conditions

High interconnect density (compact modules)

High degree of **design flexibility** for hybrid multi-chip integration

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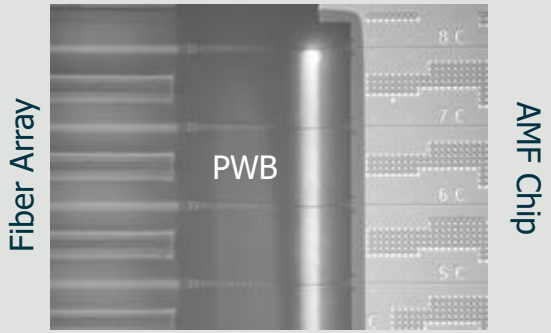
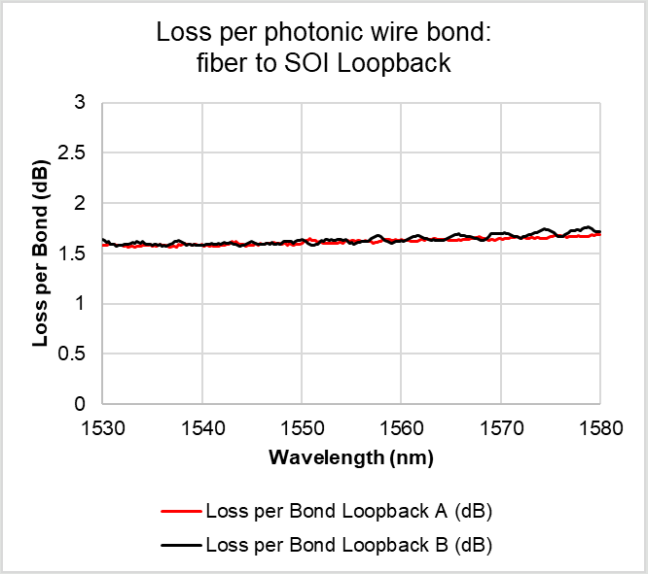
Compatibility with material platforms/foundries

Silicon (**AMF**, Singapore)

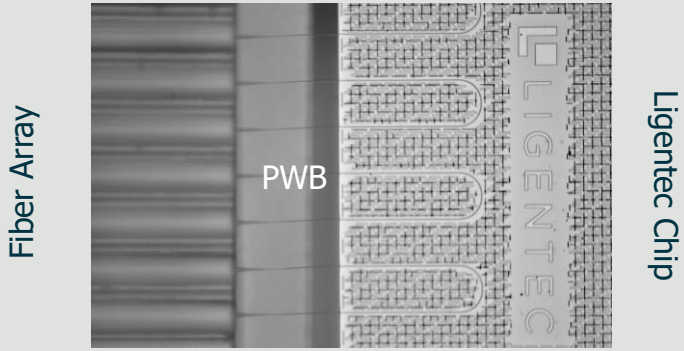
- **~1.5dB loss**

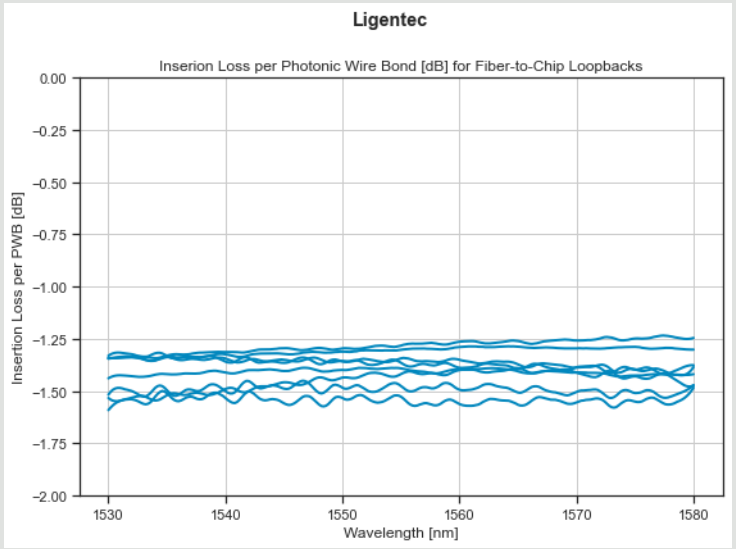




Silicon Nitride (**Ligentec**, Switzerland)

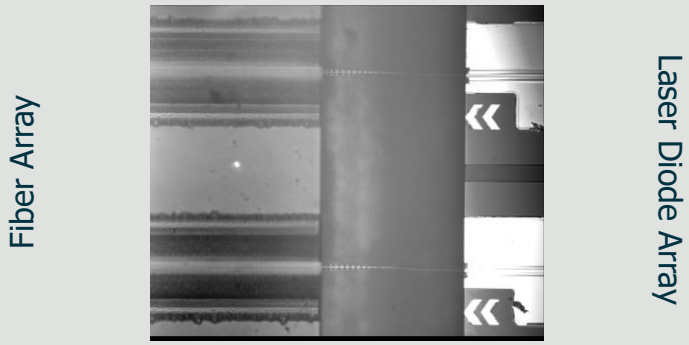
- **~1.5dB loss**

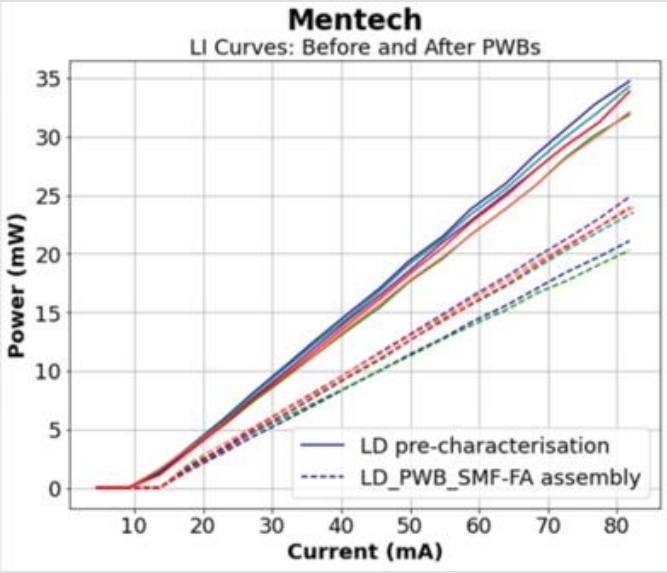




Indium Phosphite (**Mentech**, China)

- **~1.5dB loss**





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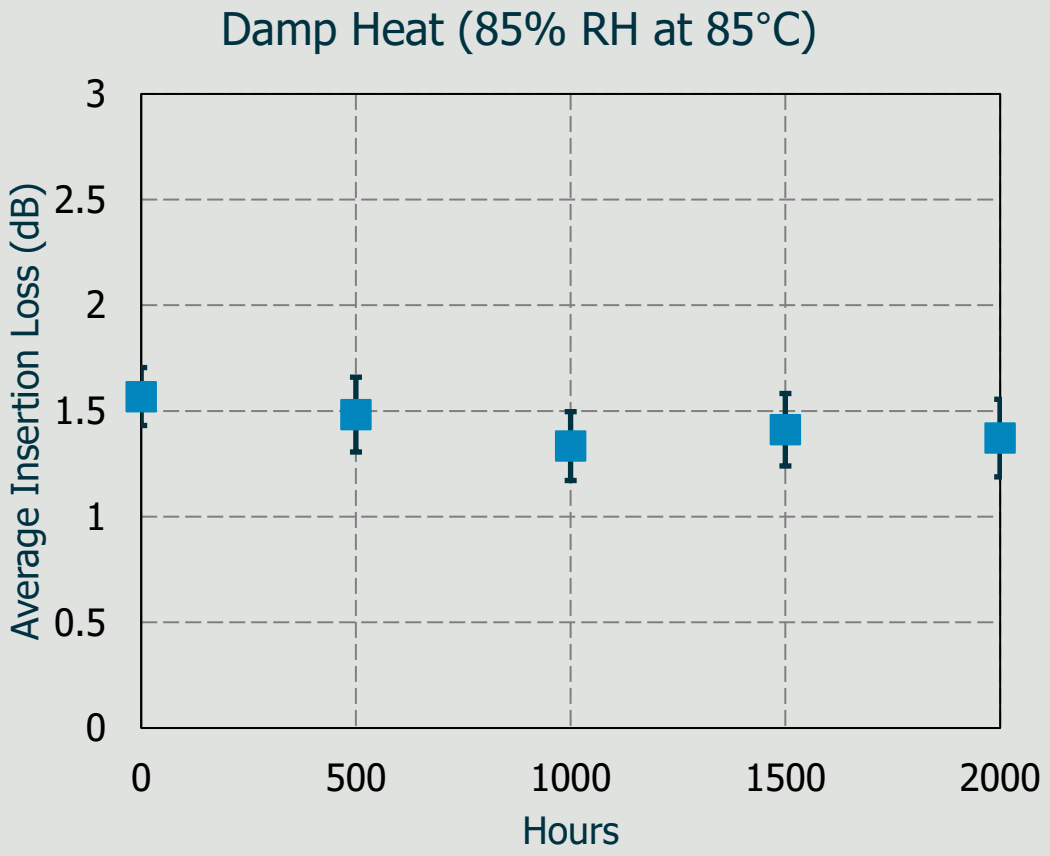
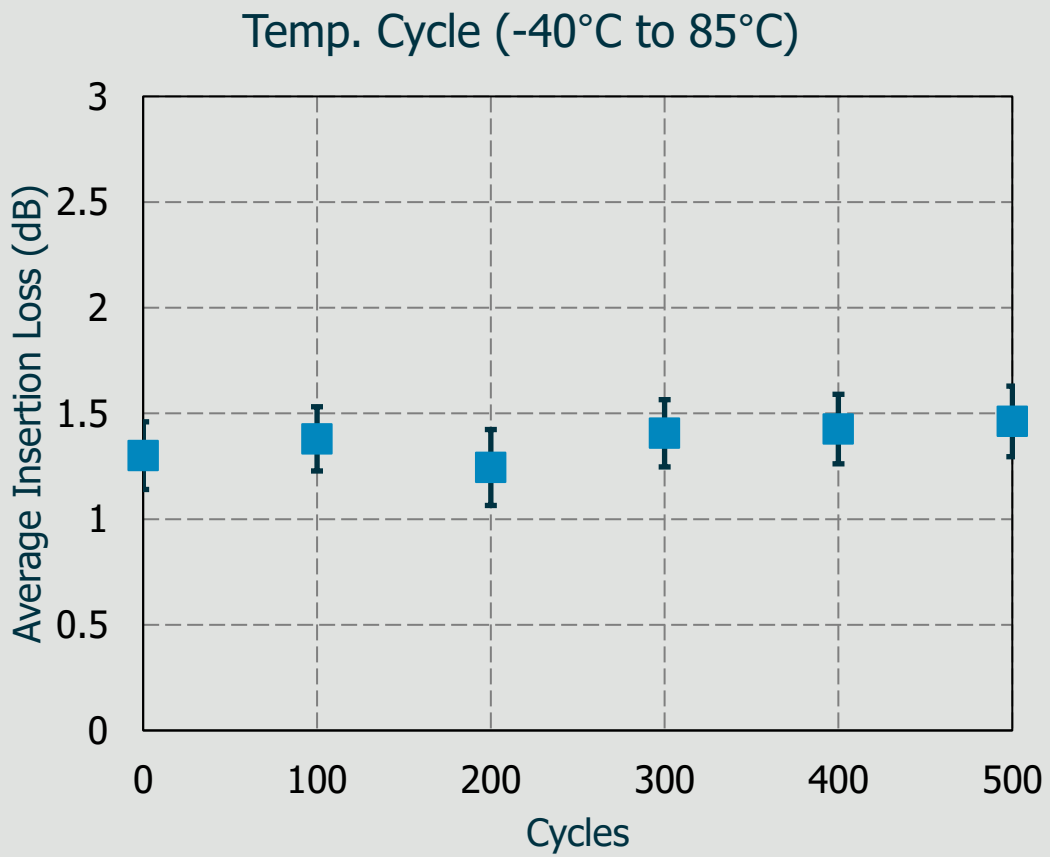
Reliability - Insertion Loss in Damp Heat and Temperature Cycling





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Vanguard **SYMPHONY 1000**

Machines

SONATA 1000

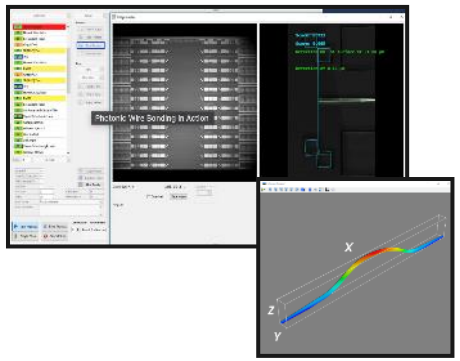
Automated 3D Lithography-based Nano Printing

REPRISE 1000

Automated Pre- and Post-Processing: Development and Encapsulation

Software

Composer and BrightWire3D



Software for Machine Control, Process Development and Management

Additional Products and Services

VanCore, VanClad, …

Materials for the Production of PWBs and Micro Optical Lenses

Professional Services

- Training
- Process Development
- Feasibility Studies
- Development Support
- Maintenance Services

The Full Suite: SYMPHONY 1000

"Photonic integration and packaging with Photonic Wire Bonding and facet-attached micro-optical elements", PIC Magazine, September 2023

"As PIC Production Ramps Up, Fabricator Eye Alignment Options", Photonics Spectra, June 2022

"Photonic Wire Bonding: Using Lasers to Integrate Lasers", Photonics Spectra, August 2022

"Integrated photonics for quantum applications", Laser Focus World, September 2022

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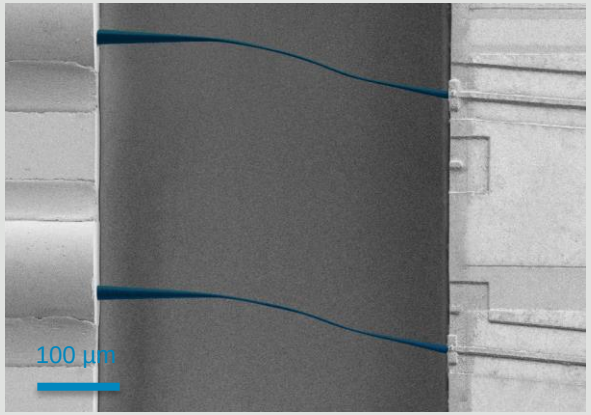
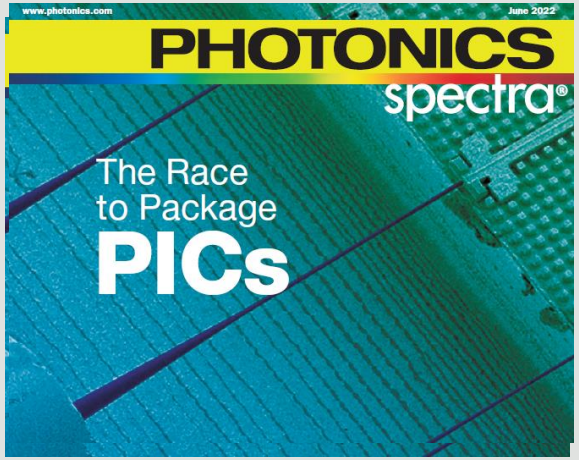
Most Flexible 3D Printing Solution for Optics and Photonics

Photonic Wire Bonds

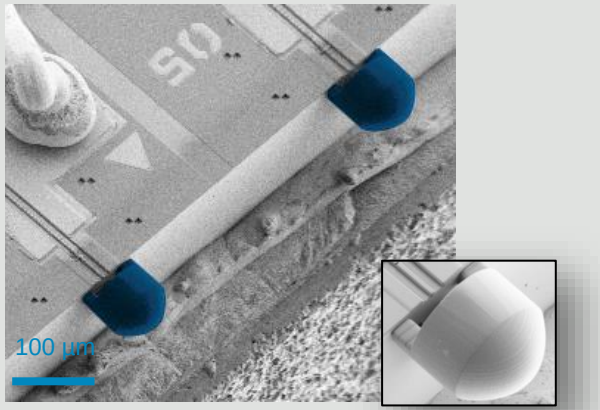


Laser by Freedom Photonics LLC

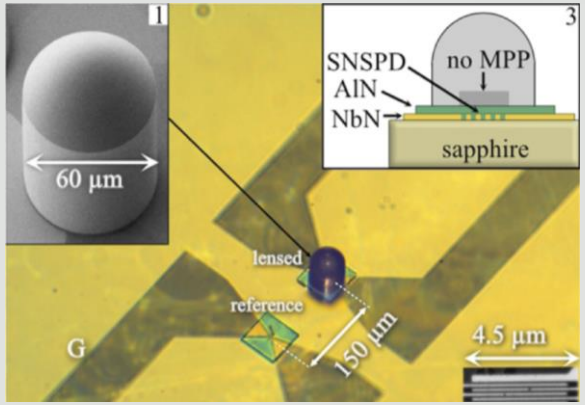


PIC by Institut für Mikroelektronik Stuttgart

Micro-Optical Elements

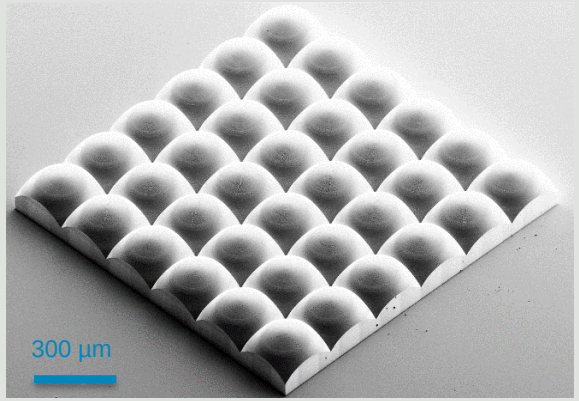


Samples by PIXAPP (Photonic Packaging Pilot Line)

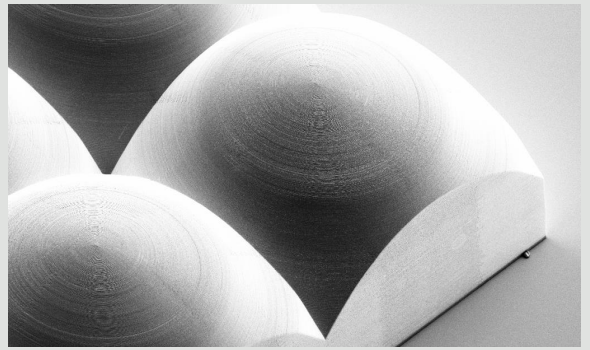


Xu et al., Superconducting nanowire single-photon detector with 3D-printed free-form microlenses, Opt. Expr. 29, 27708-27731 (2021)

Write Field Extension



Design by Moveon Technologies Pte Ltd.



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Meet us at the **50th ECOC exhibition** in Frankfurt

ECOC 2024 FRANKFURT (50th Anniversary)

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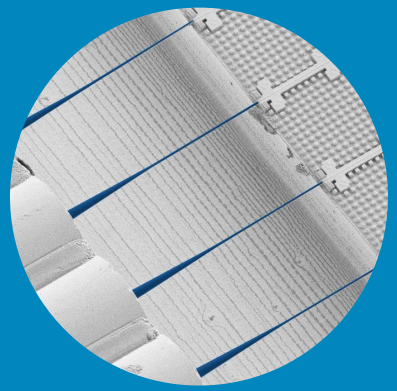

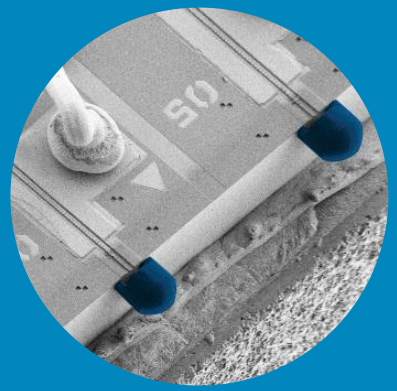

Visit the team at Booth **C104**!

ECOC Exhibit - **Market Focus**
Tuesday 24th September **10:20**

"Next Generation Photonic Integration and Packaging Solutions with ***Photonic Wire Bonding (PWB)*** *and* ***Facet-Attached Micro-Optical Elements"***

Dr. Sebastian Skacel

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Ecosystem Partners, Academic and Industrial Users