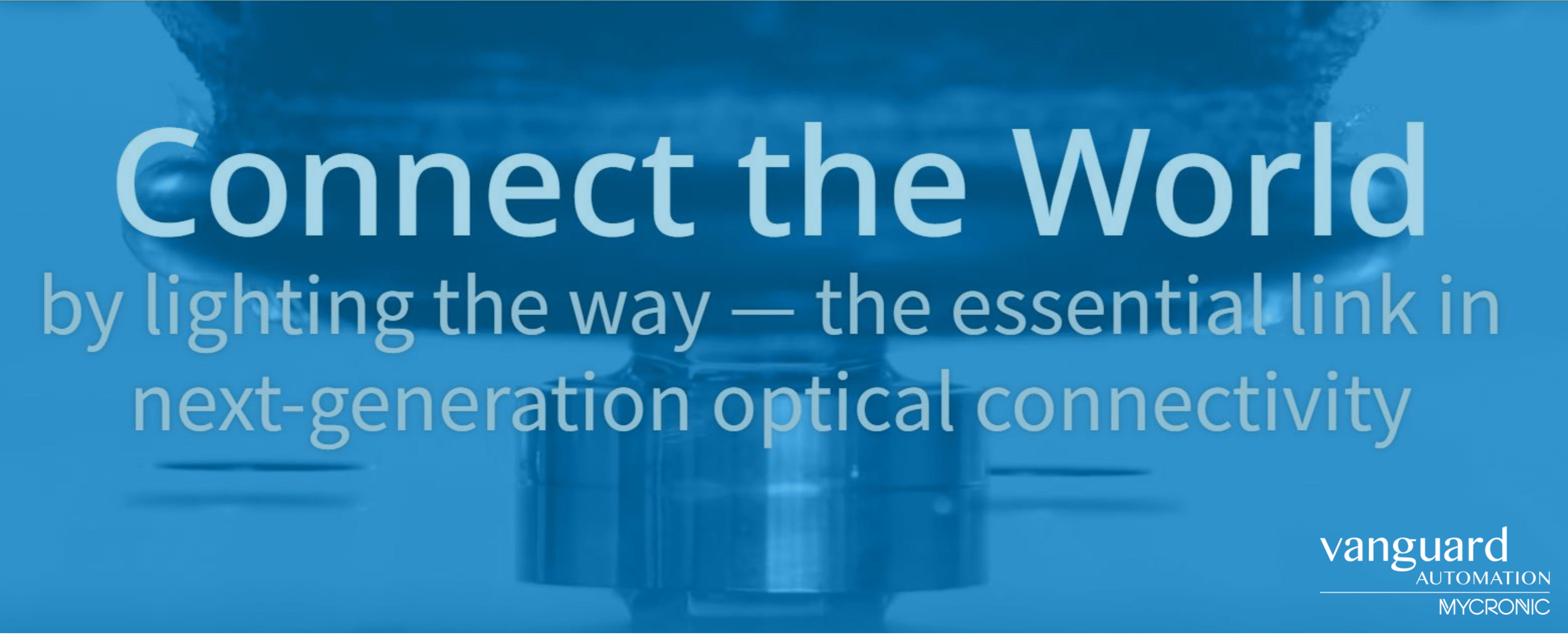
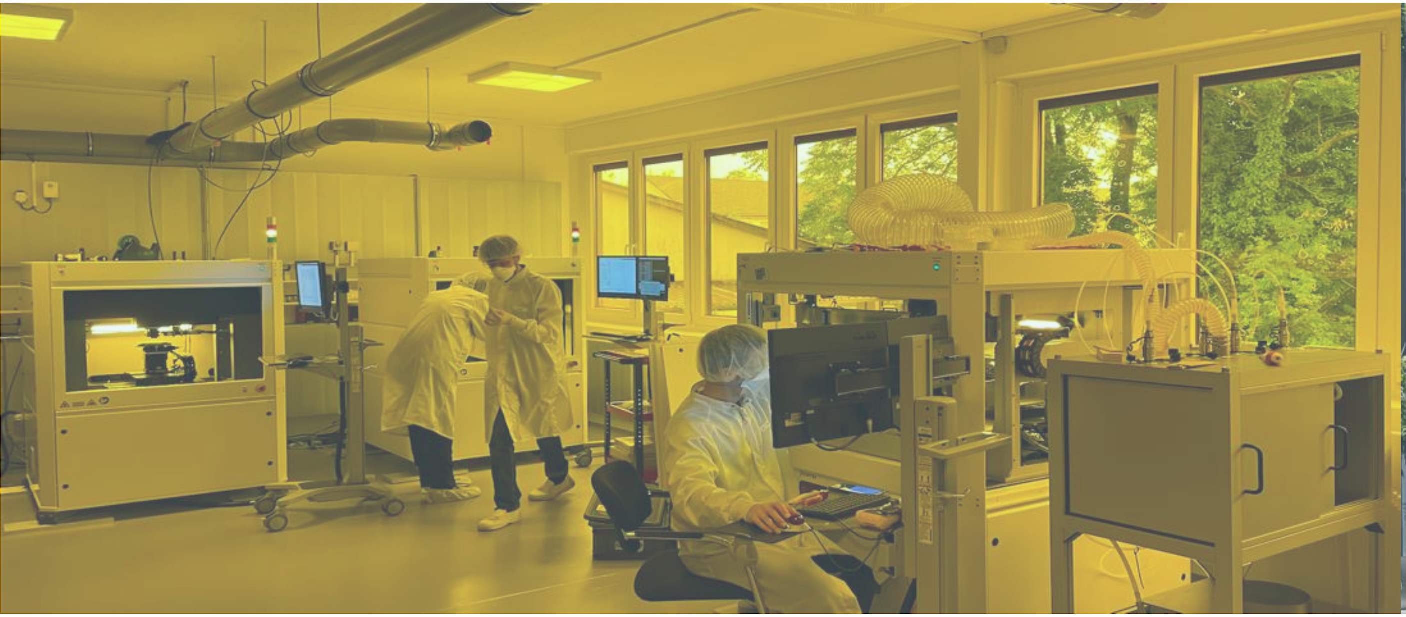


3D Lithography is lighting the path toward scalable and reliable processes for integrating active components into PICs

Thorsten Mayer | CEO - Vanguard Automation

Vanguard Automation on a Page

Unique IP and Fully Automated Tool Chain for Photonic Interconnects



2018
Joint Venture between KIT Spin-Off and ELAS Technologies GmbH – headquartered in Karlsruhe, Germany

2024
Joined Mycronic AB (publ) Swedish high-tech group

MYCRONIC

Unique IP
Growing patent families in the field of 3D lithography and photonic packaging

Products
Process technology incl. Systems, Software, Consumables, related Support and Services

50+
Employees (17 nationalities)

vanguard AUTOMATION

MYCRONIC

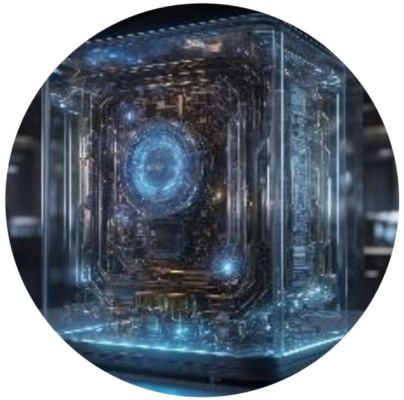
Photonic Integrated Circuits are Growing Rapidly

Telecom/
Datacom

AI/Optical
Computing

Sensing

Quantum
Technologies



Space & Defense

Mission

"Building upon unique IP and expertise in photonics packaging, we empower research and industry to design and manufacture next-generation optical devices through automated solutions that overcome design, performance and scalability challenges."

vanguard AUTOMATION
MYCRONIC

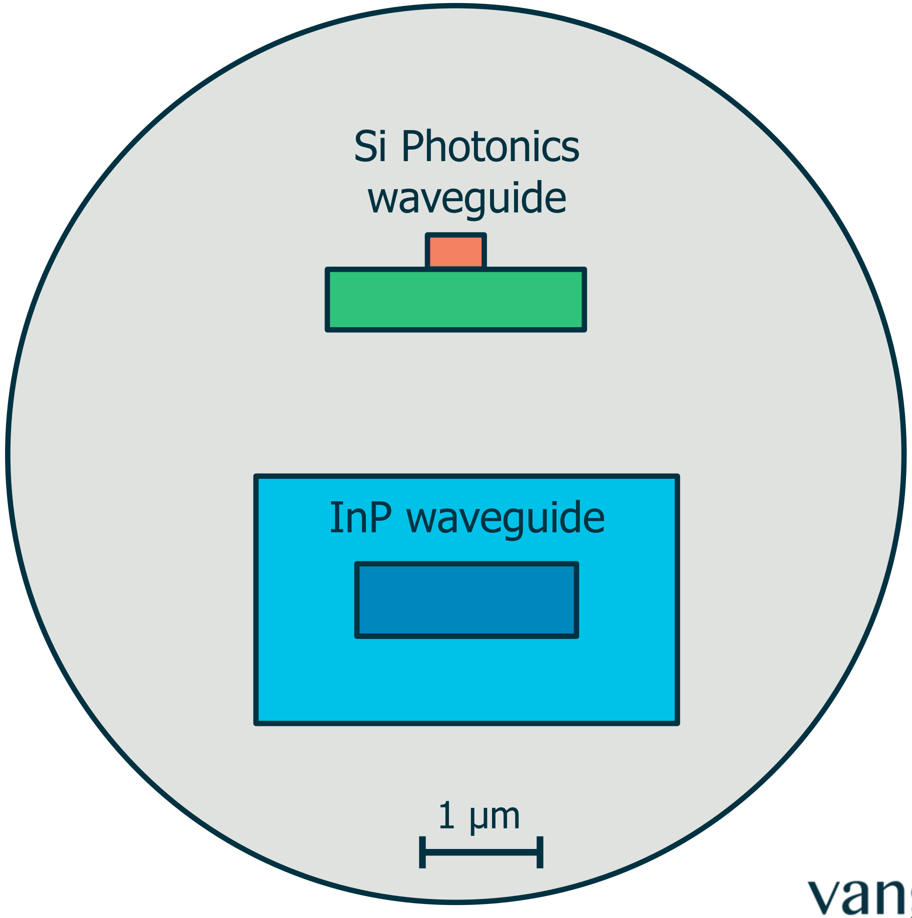
Today’s Packaging and Assembly Challenges

Different Mode Field Sizes and Heterogenous Material Platforms

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

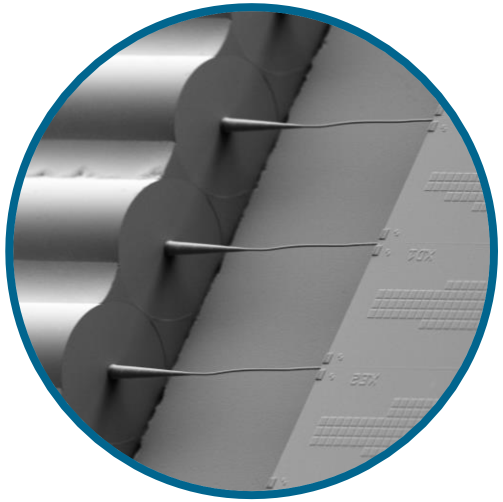
About 80% of the cost of photonic integrated systems are generated by the packaging process

Single-Mode Fiber Core

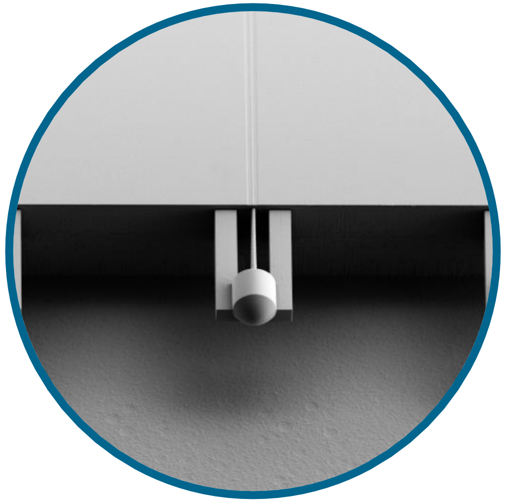


Enabling Next Generation **Photonic Integration and Packaging**
Solutions with **3D Laser Lithography Solutions**

Photonic Wire Bonding (PWB)



Facet-Attached Micro-Lenses (FAML)



Low loss connections to arbitrary mode fields

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

Reliable connections under various conditions

High interconnect density (compact modules)

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

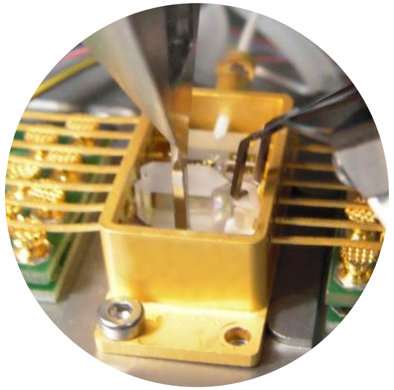
vanguard AUTOMATION

MYCRONIC

Unique Solution to Photonic Packaging and Integration

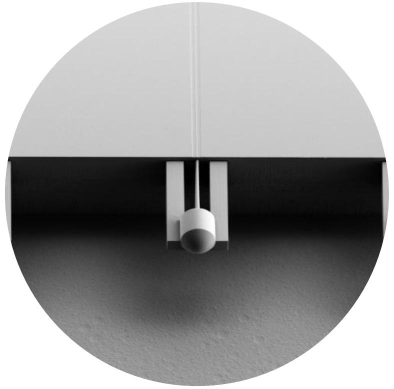
Industry-Grade 3D Nano-Printed Photonic Interconnects

Limited Scalability | **Performance, Scale, Design Flexibility** | **Complexity**



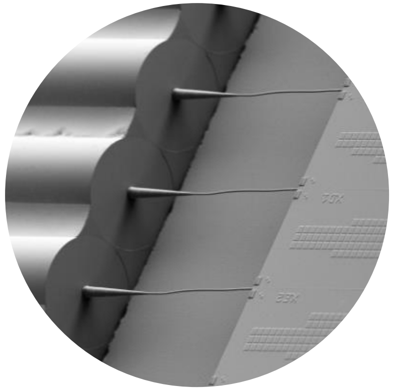
Lens Active Alignment

Current devices are built with active alignment**. Limits miniaturization and increases overall package size.**



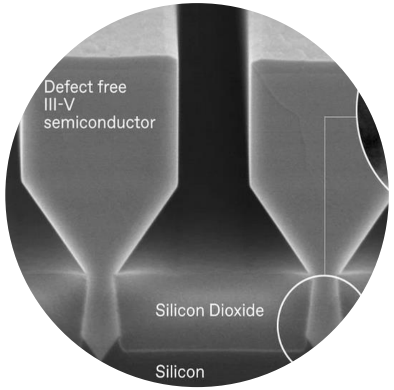
GT-PI
Micro-Optical Lenses

3D in-situ nano-printed lenses allow parallel optical connections in a much smaller form factor. **Improves coupling efficiency and increases Yield**



GT-PI
Photonic Wire Bonds

Fast, low loss connections between known-good components**. No alignment, no lenses, smaller packages, enabling new designs.**



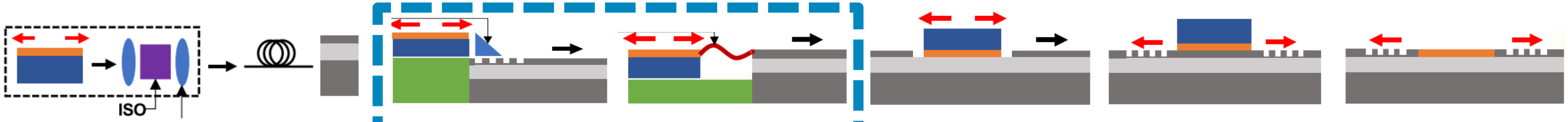
Heterogenous Integration

Direct laser integration on silicon SOI wafer. **Locked into specific components, long development times, lower yields.**

Image sources: ficonTEC, Vanguard Automation, IMEC

PPA Metrics: Techniques for **Integrating a Laser into a Silicon PIC**

S. Sekhar, W. Bogaerts, L. Chrostowski, et al., Roadmapping the next generation of silicon photonics, 2024

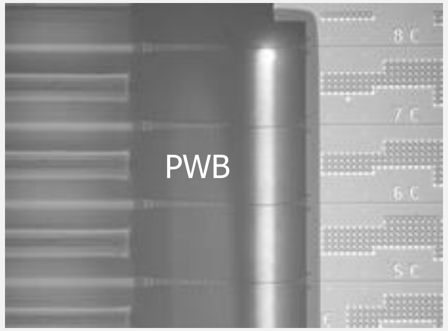


Integration	**Conventional** LD-ISO-FAU-PIC	**Hybrid 2.5D** FSO→**FaML**	**Hybrid 2.5D** PWB	**Hybrid 3D** Flip Chip/TP	**Heterogenous** Dir. Bonding/TP	**Monolithic** Heteroepitaxy
Coupling loss	> 2 dB	**0.3 dB**	**0.5 dB**	1 dB	1 dB	Few dBs
Output power	High	High, **1 W**	High, **500 mW**	Medium	Medium	Low
Pol. ctrl.	Needed	Needed	No need	No Need	No Need	No Neeed
Therm. mngt.	Easy	Easy	Easy	Medium-Difficult	Difficult	Medium
Linewidth red.	N/A	Good-**Best**	Good-**Best**	Good	Best	Good
Assembly size	Large	Medium-**Small**	Medium-**Small**	Small	Smallest	Smallest
On-chip	No	No-**Yes**	No-**Yes**	Yes	Yes	Yes
Pckg. style	KGD	KGD	KGD	KGD	All or nothing	All or nothing
Test	Die	Die-Wafer	Die-Wafer	Die-Wafer	Wafer	Wafer

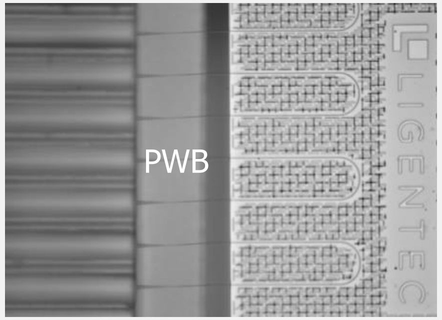
PWBs and FaMLs

Towards Standardized **Process, Application, and Manufacturing Design Kits**

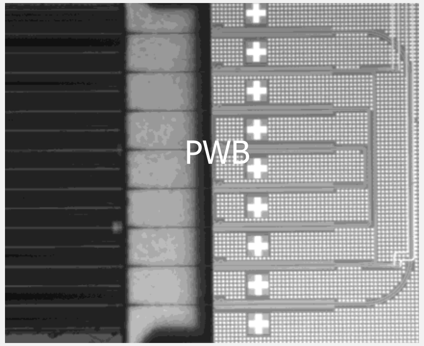
Silicon (AMF)



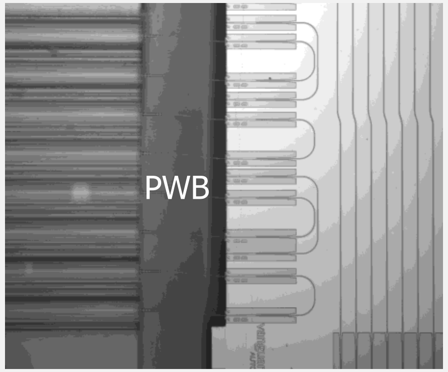
Silicon Nitride (Ligentec)



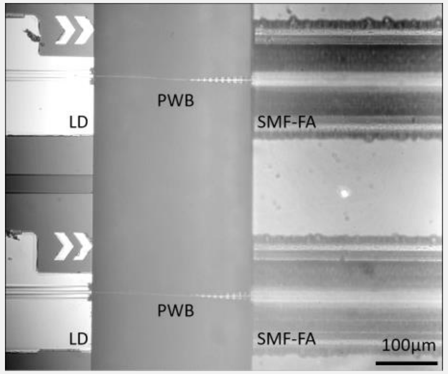
Silicon Nitride (AIM)



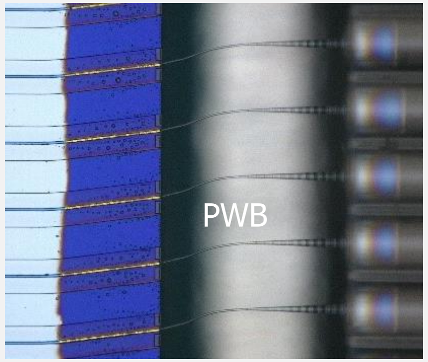
TFLN (CSEM)



InP (Mentech)



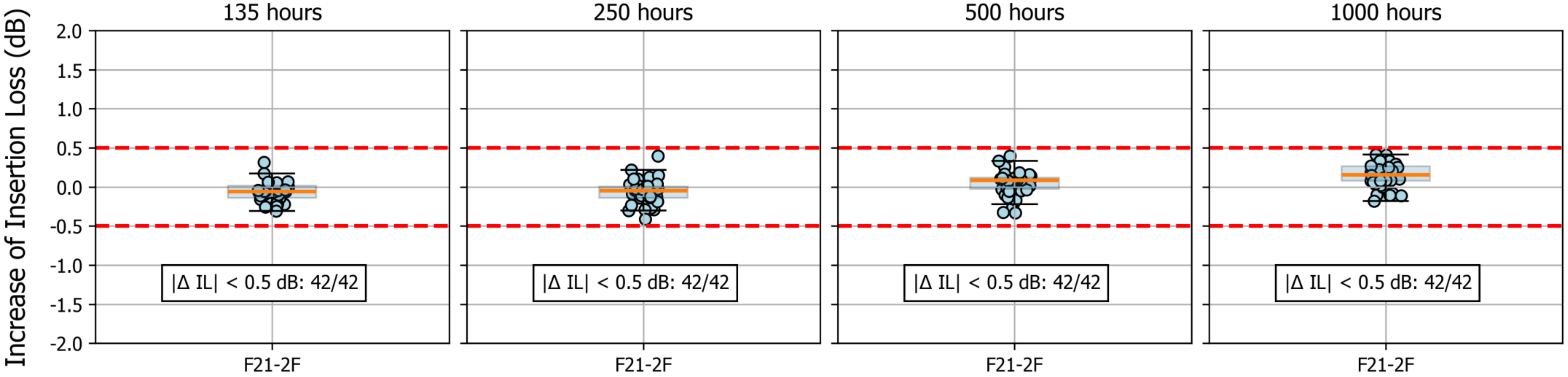
InP (HHI)



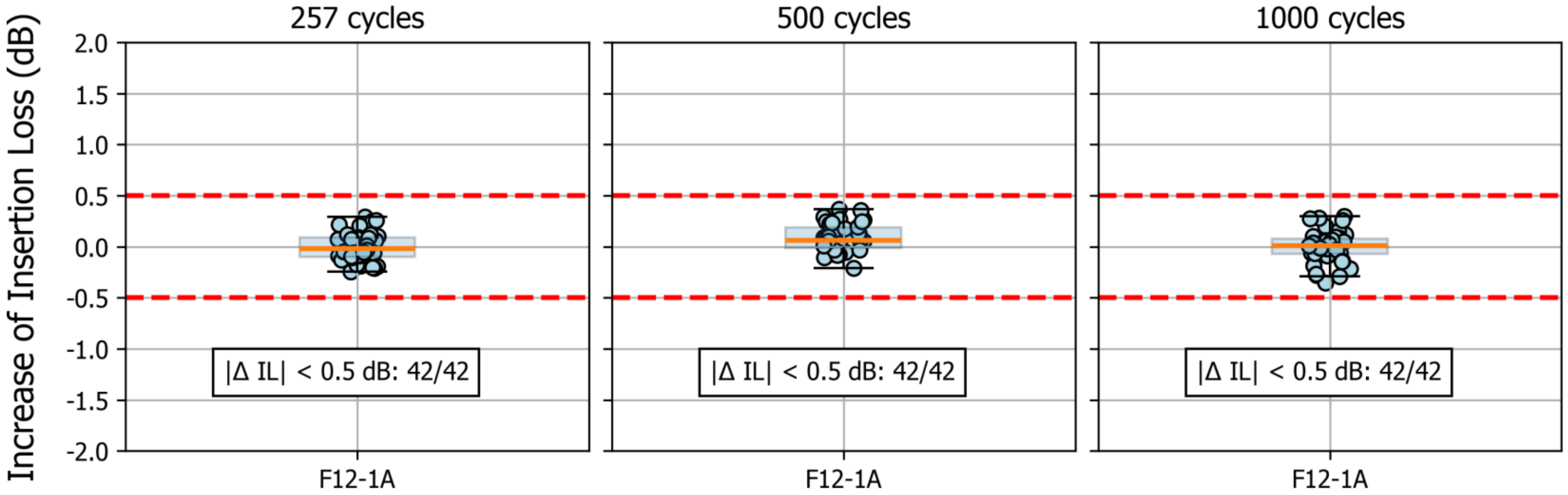
Initial Insertion Losses ~ 1.5 dB

Reproducibility & Reliability: **Photonic Wire Bonding**

Damp Heat 85°C and 85% RH



Temperature Cycle -40°C to +85°C



vanguard AUTOMATION
MYCRONIC

Industry Proven **Photonic Integration and Packaging**

Fully Automated Solutions with **3D Laser Lithography**

Wafer Level & Batch Processing for Photonic Integration

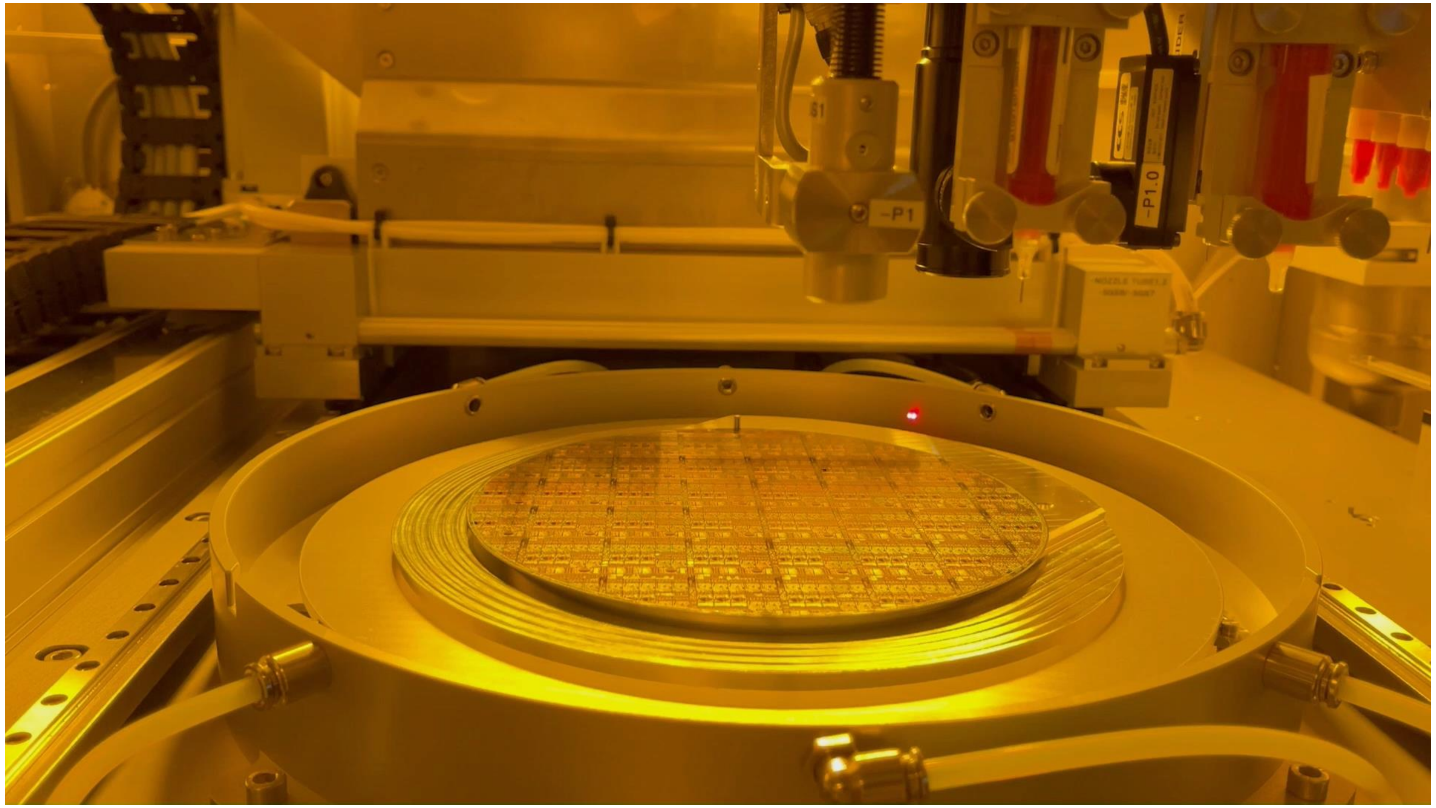
Active Device Integration

High Reliability & Yield

Mode-field-matching

Relaxed Pick & Place

Tolerances



vanguard AUTOMATION

MYCRONIC

3D-printed aspherical lens with moth-eye anti-reflection structure

SUMITOMO ELECTRIC

Connect with Innovation

"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 from 4.4% to 0.005% at 1550 nm wavelength

Coupling efficiency to fiber is **improved** from -0.52 dB to -0.33 dB

Structure size 360 x 470 nm

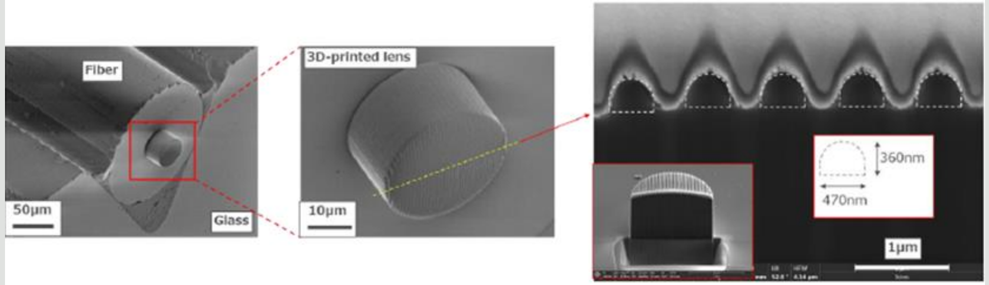


Figure 4 (a) SEM image of the aspherical lens on fiber (b)Cross-sectional SEM image of stripe moth-eye structure

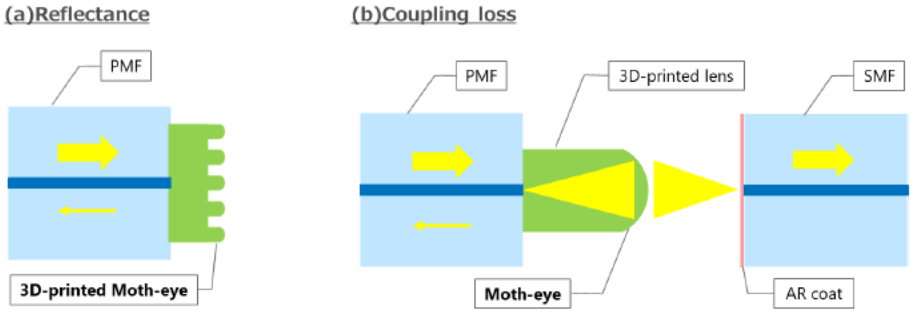


Figure 5 Measurement method for (a)Reflectance of Fresnel reflection (b)Coupling loss of lens

Table 1 Measurement result of reflectance and coupling loss

	w/o moth-eye	w/ moth-eye
Reflectance	4.4% (-14dB)	**0.005% (-43dB)**
Coupling loss	0.52dB	**0.33dB**

vanguard AUTOMATION

MYCRONIC

Recent **Quantum Applications** from Ecosystem Partners & Users

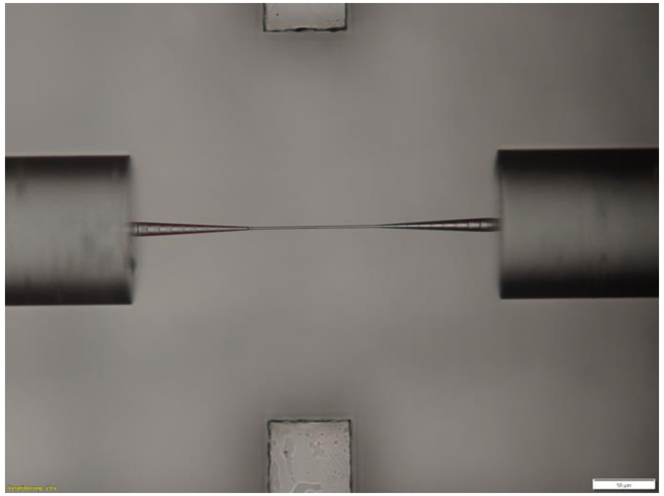
SPOC - Scalable Packaging for All-Optical CV Quantum Computing

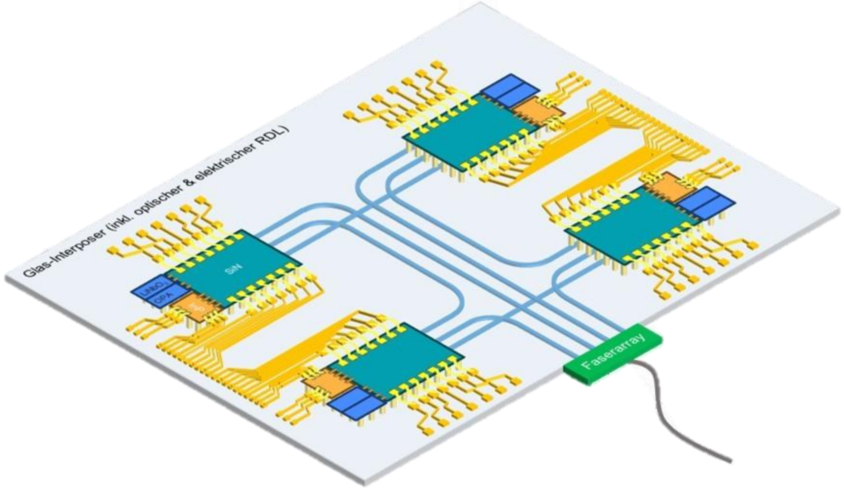
https://www.izm.fraunhofer.de/en/news_events/tech_news/spoc.html

Glass-based fully optical **quantum processor**.

Photonic integration of optical chips and fibers by **photonic wire bonding**.

Increased coupling efficiency by **50%**.





Fraunhofer IZM

AKHETONICS

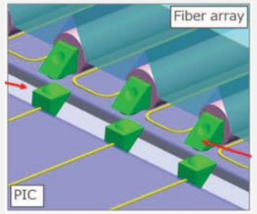
vanguard AUTOMATION

MYCRONIC

Use Cases – 3D-Printed Lenses

Relaxed Alignment Tolerances | Maximize Coupling Efficiency | Low Back Reflectance

"3D-printed Beam Expanding Lens for Chip to Fiber Vertical Coupling",(2024) Y. Mizuno et al., 2024 IEEE 74th (ECTC), Denver, Colorado, USA)

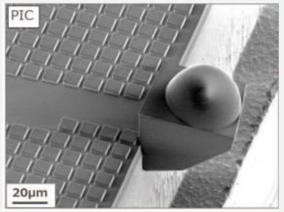


Vertical coupling

Wide bandwidth (1260 to 1575 nm)

Relaxed alignment tolerance ±10μm

1.2dB coupling efficiency



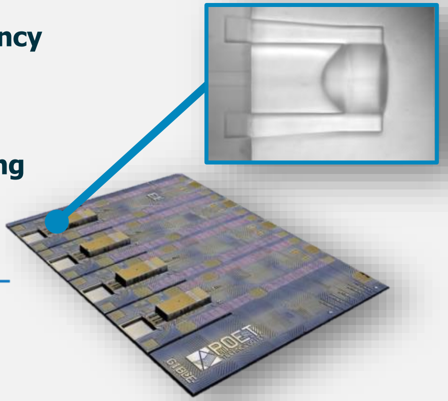
SUMITOMO ELECTRIC
Connect with Innovation

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

Increased Efficiency

Cost Reduction

Wafer level scaling



POET Technologies

vanguard AUTOMATION

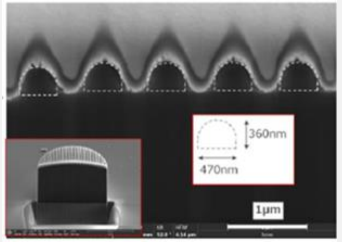
MYCRONIC

"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



SUMITOMO ELECTRIC
Connect with Innovation

Quantum Applications

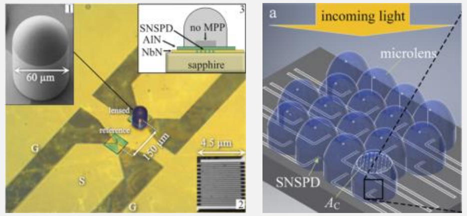
Cryogenic temperatures | No degradation | Broadband working range 530 – 2000 nm

"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**

KIT
Karlsruhe Institute of Technology



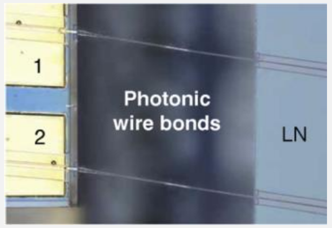
Use Cases – Photonic Wire Bonding

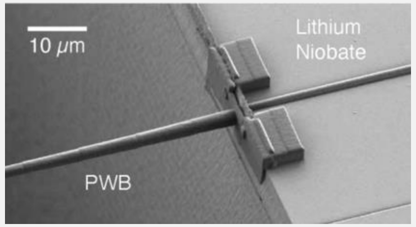
Active Device Integration

Multi-Chip Hybrid Integration | Passive alignment process | Mode-field-matching | Relaxed pick and place tolerances of ± 30 µm

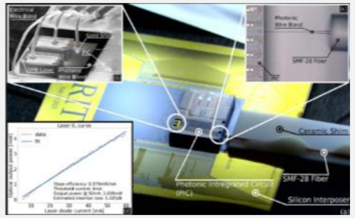
HARVARD School of Engineering and Applied Sciences | MESA+ INSTITUTE FOR NANOTECHNOLOGY | FREEDOM PHOTONICS | RIT Rochester Institute of Technology | UBC | vanguard AUTOMATION MYCRONIC | DREAM PHOTONICS

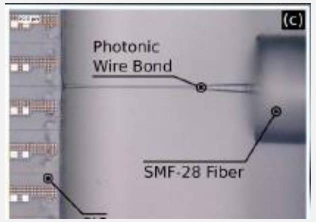
"High-power and narrow-linewidth laser on thin-film lithium niobate enabled by photonic wire bonding", Franken et. al. APL Photonics 1 February 2025; 10 (2): 026107



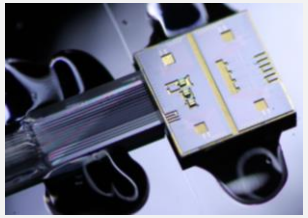


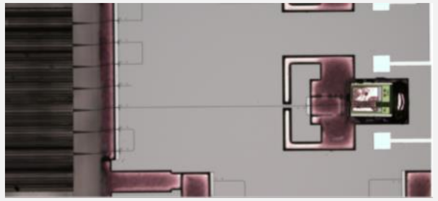
"Packaged Tunable Single-Mode III-V Laser Integrated on a Silicon Photonic Integrated Chip Using Photonic Wire Bonding",(2024) Deenadayalan et al., IEEE 74th (ECTC), Denver, Colorado, USA)





"SiEPICfab: the Canadian silicon photonics rapid-prototyping foundry for integrated optics and quantum computing",(2021)
Darcie et al. , Proc. SPIE 11691, Silicon Photonics XVI



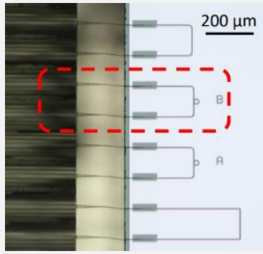


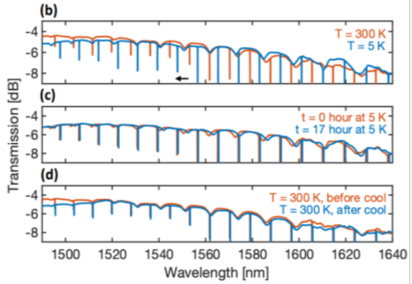
Quantum Applications

Cryogenic temperatures | (IL) < 2dB | No degradation

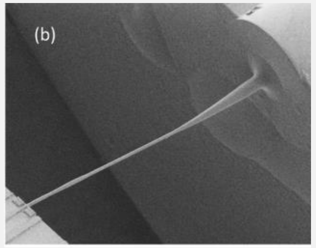
"Cryogenic Optical Packaging Using Photonic Wire Bonds", (2023)
arXiv:2307.07496v1 [physics.optics]

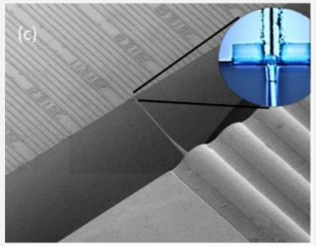
DREAM PHOTONICS | UBC





"Plug-and-Play Fiber-Coupled Quantum Dot Single-Photon Source via Photonic Wire Bonding", Adv Quantum Technol. 2023, 2300227





Julius-Maximilians-UNIVERSITÄT WÜRZBURG | UBC | Carl von Ossietzky Universität Oldenburg

Vanguard **SYMPHONY 1000**

Unique IP and Fully Automated Tool Chain for Photonic Interconnects

Machines

SONATA 1000

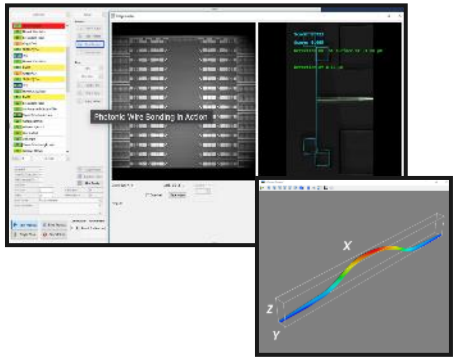
Automated 3D Lithography-based Nano Printing

REPRISE 1000

Automated Pre- and Post-Processing: Development and Encapsulation

Software

Composer and BrightWire3D



Software for Machine Control, Process Development and Management

Materials and Services

VanCore Resist Series

Materials for the production of PWBs and Micro Optical Lenses

Professional Services

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

COMPLETE INDUSTRY READY SOLUTION

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MYCRONIC

Collaborative Ecosystem: Partners and Users

UBC

VE RI TAS HARVARD

University of Delaware

PICadvanced
Think outside the box with us!

SUMITOMO ELECTRIC
Connect with Innovation

University of Stuttgart

C2MI
Centre de Collaboration MiQro Innovation

RIT
Rochester Institute of Technology

Sun Yat-Sen University

GHENT UNIVERSITY

Tyndall
National Institute
Institiúid Náisiúnta

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

VTT

Fraunhofer
IZM

DREAM PHOTONICS

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POET
Technologies

AIM PHOTONICS

Keystone photonics

ficonTEC
photonics assembly & testing

KIT
Karlsruhe Institute of Technology

Nanjing University 1902
南京大學

UESTC 1956

FREEDOM PHOTONICS
a Luminar company

mentech

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Die Universität der Informationsgesellschaft

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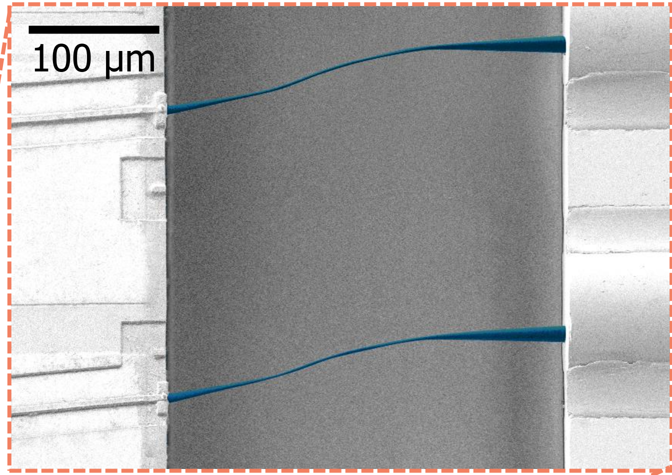
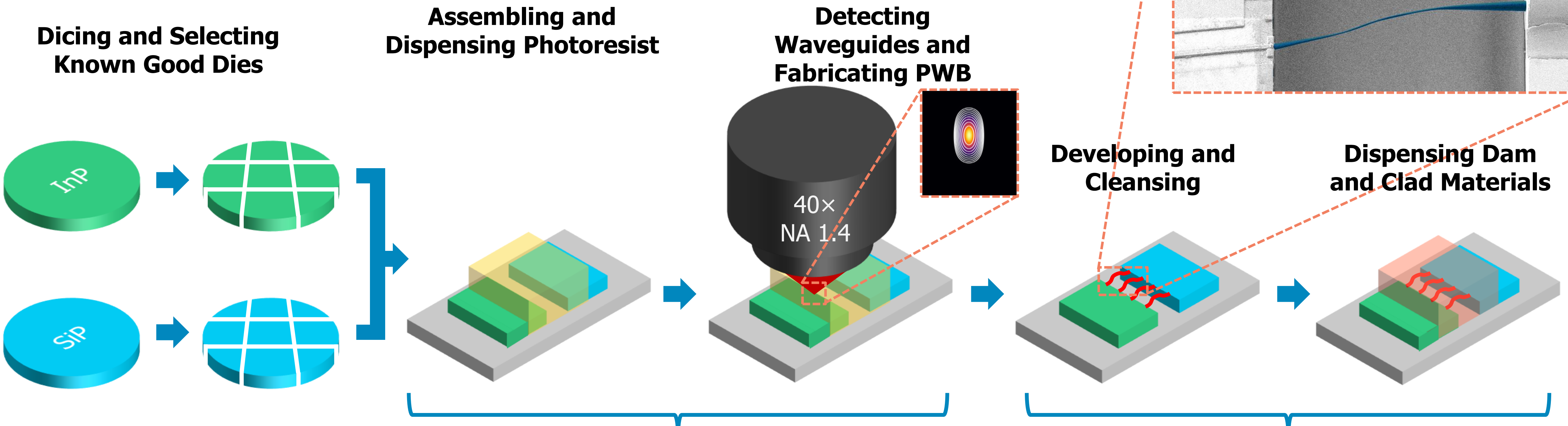
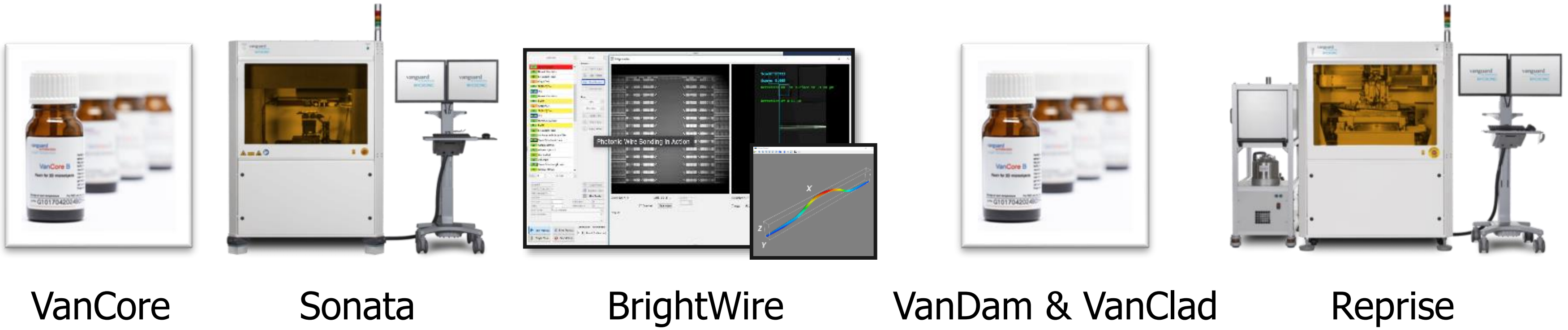
3D Lithography for Photonic Packaging

Strategy 1: PWB for Die-Level Hybrid Integration





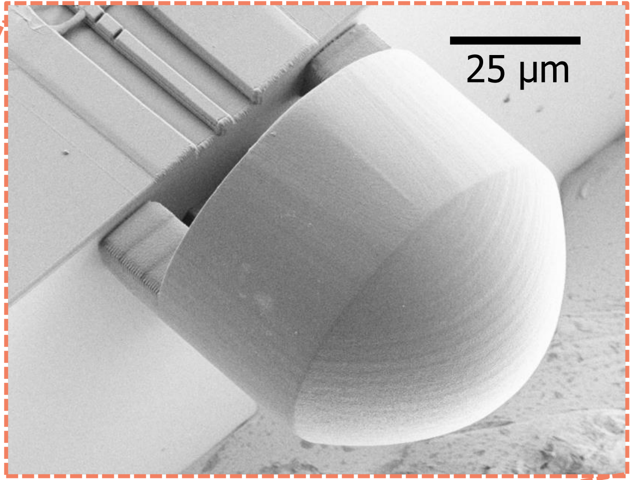


Advantages

- Passive alignment
- Up to ± 30 µm component placement offset (all axes)
- Mode field adaptation and low insertion loss
- High interconnect density

3D Lithography for Photonic Packaging

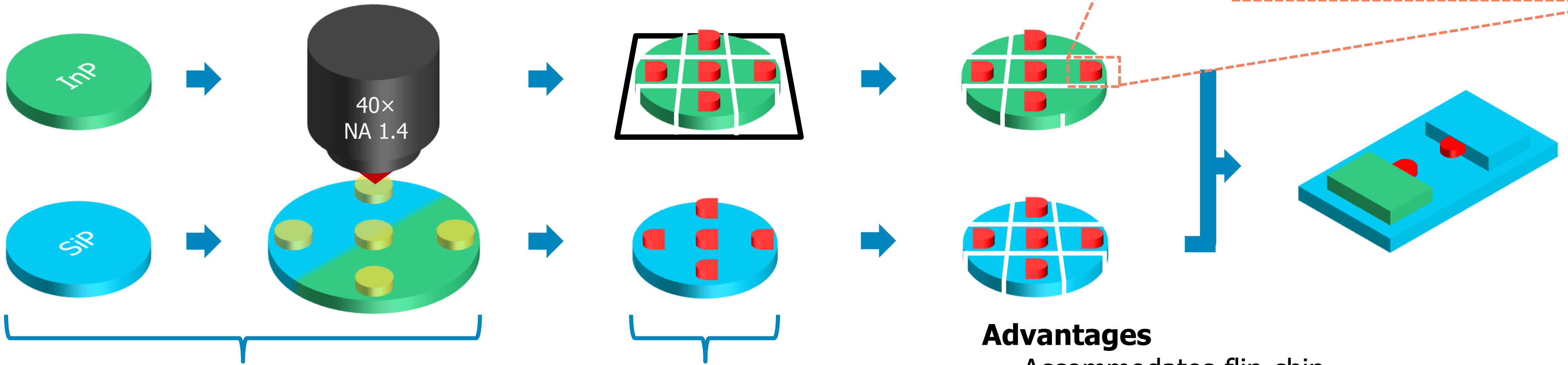
Strategy 2: FaML for Wafer-Level Hybrid Integration



Dispensing Photoresist, Detecting Waveguide, and Fabricating FaML

Developing and Cleansing

Dicing and Selecting Known Good Dies



VanCore

Sonata

BrightWire

Reprise

Advantages

- Accommodates flip-chip approach
- Placement tolerance up to ±15 µm, enabling passive alignment
- Wider distance between components to facilitate bulk optics (e.g., isolator)

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