

CONNECTING THE PHOTONIC INTEGRATED CIRCUITS COMMUNIT

Routing Photonic Integration to the Next Dimension

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Industry proven Photonic Wire Bonds and Facet-Attached Micro-Optical Elements: from Telecom/Datacom to Quantum Applications

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## PIC INTERNATIONAL CONFERENCE

#### Photonics Integrated Circuits are Growing Rapidly

25.9% CAGR (source: MarketResearchFuture.com)



#### **Mission**

Advance Photonic Packaging and Assembly by providing scalable 3D lithography solutions for prototyping and manufacturing



#### Today's Packaging and Assembly Challenges

Different Mode Field Sizes and Heterogenous Material Platforms



- $\rightarrow$  Mode field matching.
- $\rightarrow$  High-precision assembly alignment.
- $\rightarrow$  Fast and reproducible packaging.
- $\rightarrow$  Reliable under various conditions.
- → Over 70% of cost of photonic integrated systems are caused by the packaging process



# Industry Proven Photonic Integration and Packaging Solutions with 3D Laser Lithography

Samples by PIXAPP (Photonic Packaging Pilot Line)



# Mode field matching & angled facets High interconnect density Design flexibility & alignment offsets

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



Laser by Freedom Photonics LLC

#### PWB: Compatibility with material platforms/foundries

#### Silicon (AMF, Singapore)

> ~1.5dB loss

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Silicon nitride (AIM, USA) ≻ ~1.7dB loss





Indium phosphide (Mentech, CN) ≻ ~1.5dB loss







## Passing Standard Reliability Tests for Tele/Datacom





## Micro-Lens Use Case in Tele/Datacom



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

(a)Reflectance (b)Coupling loss



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



#### Photonics West 2024



## Photonic Wire Bond Use Case in Quantum

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

**Passive alignment** of **single-photon sources** to optical fibers via **PWB** 

Measurement of **single-photon emission** source from a **quantum dot** (QD) in a waveguide

Julius-Maximilians-

Assemblies cooled to **1.6K** for more than **1 week**.

**UNIVERSITÄT** 

**WÜRZBURG** 





## Micro-Lens Use Case in Quantum

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

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

Assemblies undergo 10 cool down cycles. **No degradation or delamination** observed

Broadband working range 530 – 2000 nm





Karlsruhe Institute of Technology



#### Most Flexible 3D Printing Solution for Optics and Photonics

# **Photonic Wire Bonds** 100 µm Laser by Freedom Photonics LLC PHOTONICS spectra<sup>®</sup> The Race to Package PICs PIC by Institut für Mikroelektronik Stuttgart

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#### **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 Extensionσσσ<tr

Design by Moveon Technologies Pte Ltd.



#### vanguard-automation.com

#### Vanguard SYMPHONY 1000

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#### Software-Defined Fabrication of PWBs and Micro-Optical Lenses



"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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#### **Ecosystem Partners, Academic and Industrial Users**









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Accelerating PIC Adoption in Established Markets 17th April 2024 12:10

Scaling photonic integration & packaging of hybrid multi-chip assemblies using 3D lithography

