SWTEST
PROBE TODAY, FOR TOMORROW
2025 CONFERENCE

Wafer-Level Testing of Photonic Devices

Keystone photonics

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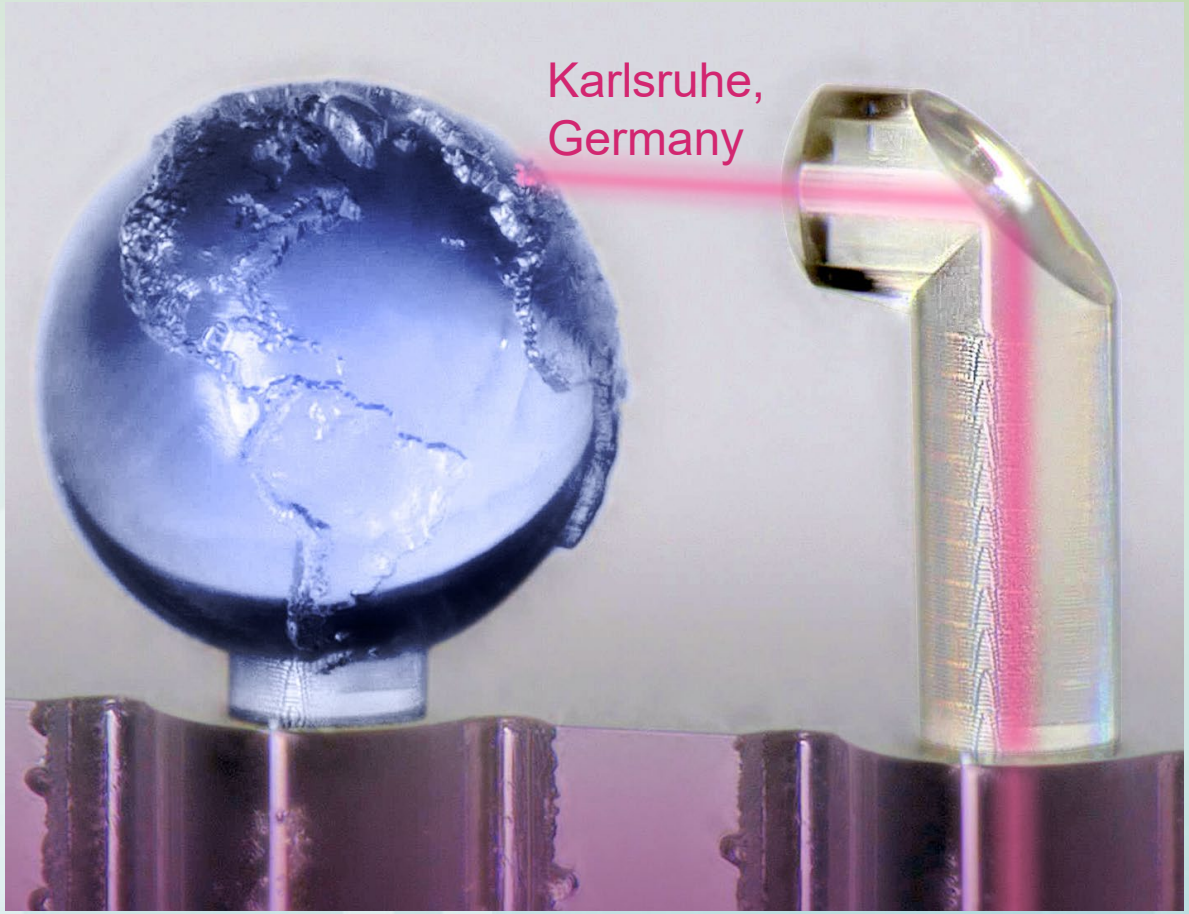
Keystone Photonics

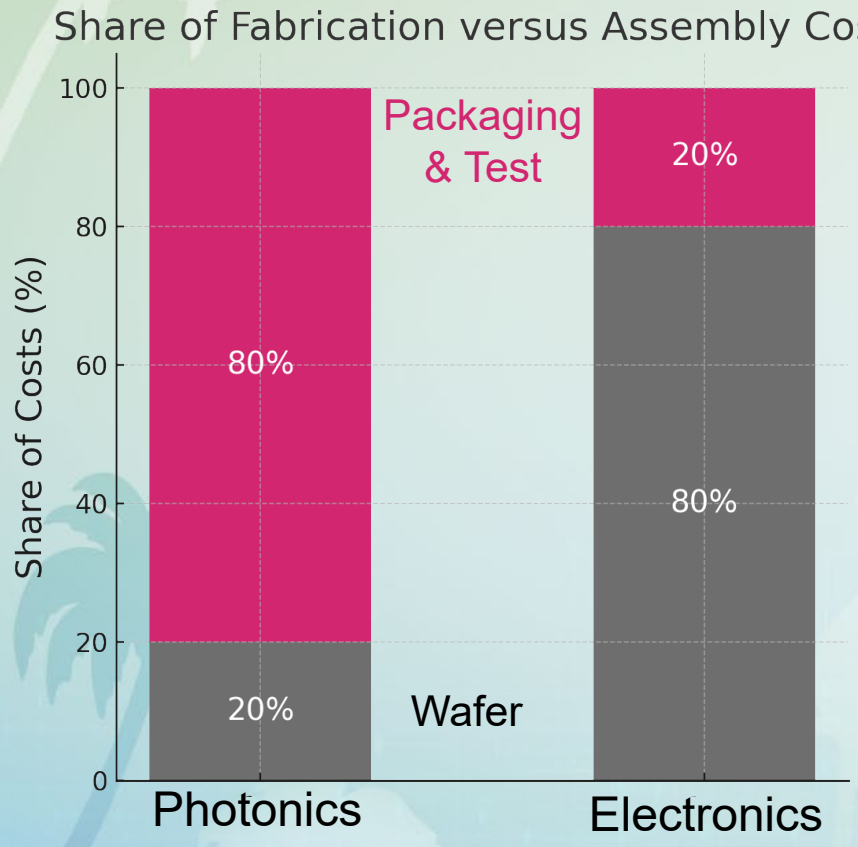
Content

- Relevance and challenges of photonic wafer-level testing
- In-situ printed micro-optics
- Comparison to other testing approaches
- Reproducibility
- Production-readiness
- Challenges

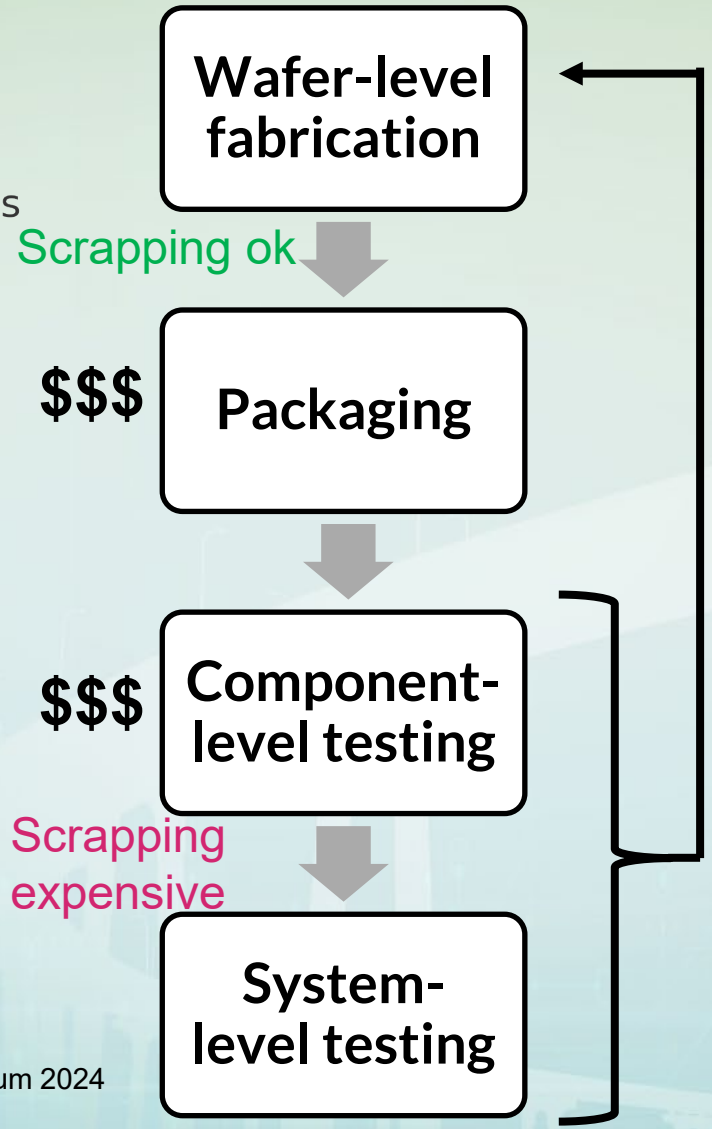


Test After Singulation is Too Late!

Test (and packaging) is the larges cost-driver in integrated photonics



Fuchs et al. 10.1109/JLT.2011.2159260;
Gregg Barlett, Global Foundries at Global Photonic Economic Forum 2024
https://youtu.be/H0_H9M0i7Og?si=nPdJyWC5KYMoJ8TR

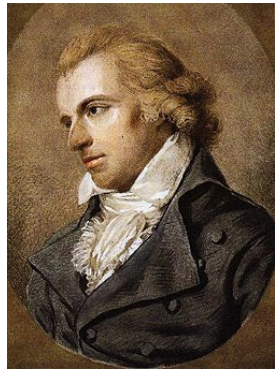


Key Takeaway:

Packaging in photonics is a major cost driver + testing can be automated at wafer-level
=> Test before packaging

"Drum **prüfe**, wer sich ewig bindet, Ob sich das Herz zum Herzen findet!"

"**Test** who binds themselves for eternity, whether heart meets heart in unity."

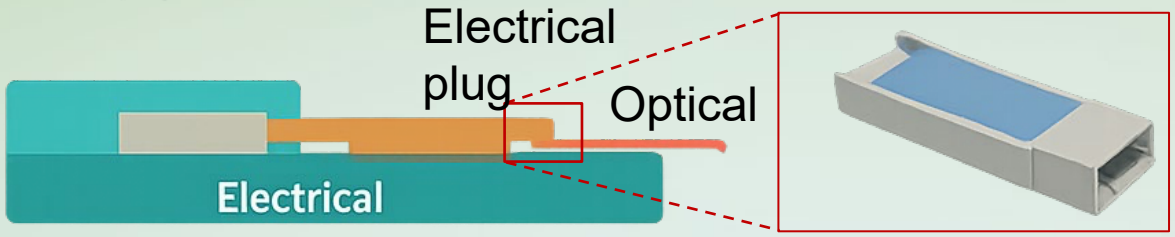


Friedrich Schiller, 1799

What has to be tested?

Pluggable
Will grow for 5y; **Arista** claims still ok for 1600.

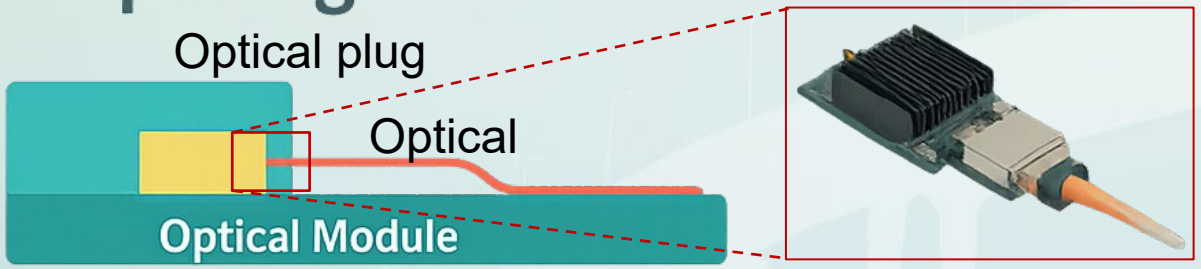
Pluggable Transceiver



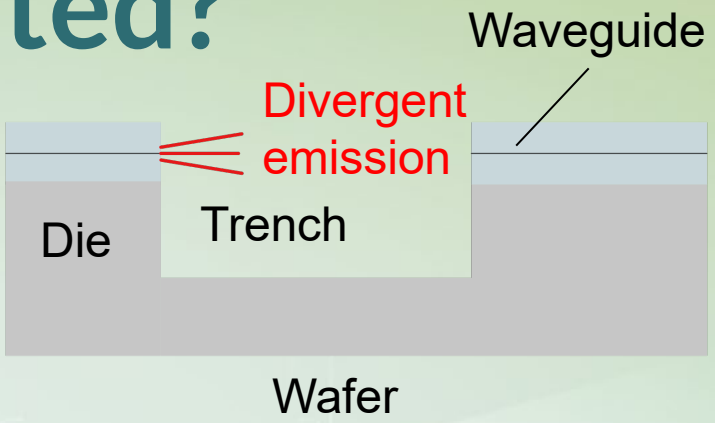
Laser + Fiber interface

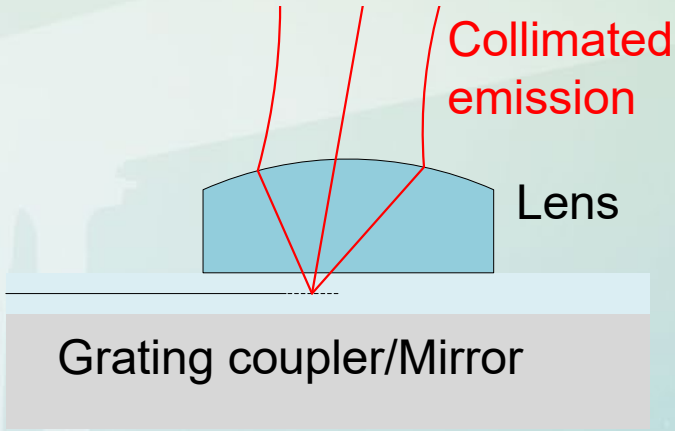
CPO: Nvidia/TSMC COUPE, will ramp soon!

Co-packaged



Fiber only, laser is separate

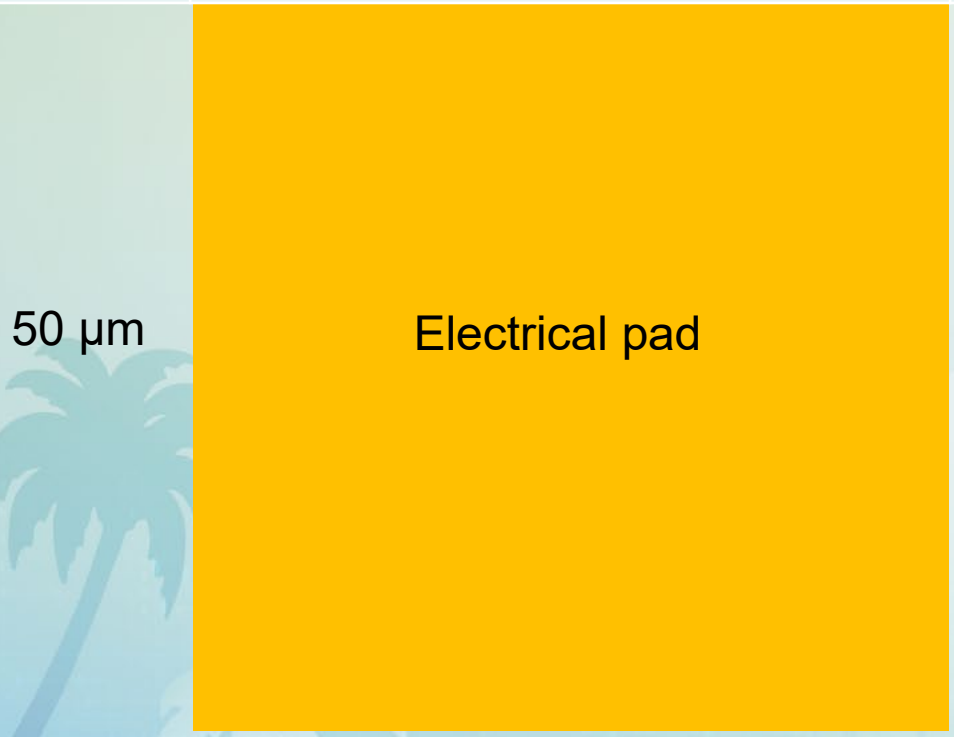


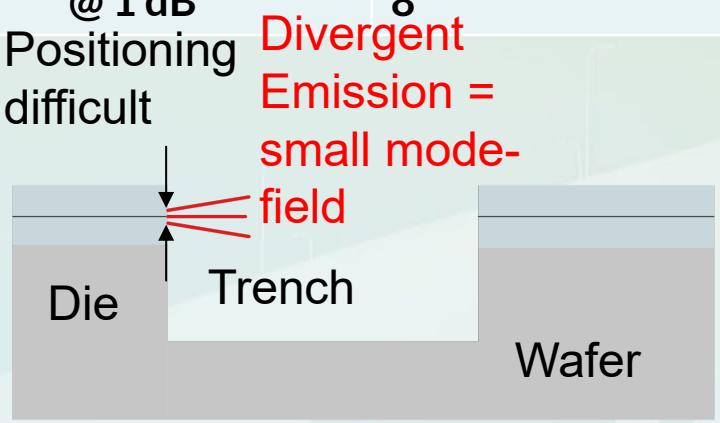


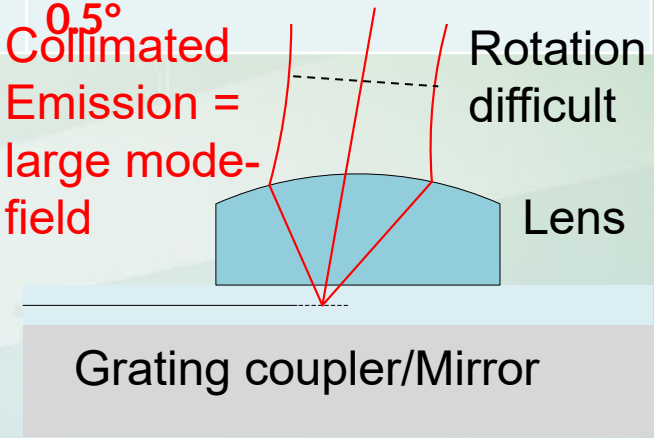
Key Takeaway: There are two competing architecture. Electrical pluggable with "more" electrical signal and mostly trench-coupling and CPO with "more" optical signal and mostly surface coupling.

How is Optical Testing Different?

	Electrical	SMF interface	High RI interface	Optical plug
Size	50 µm	10 µm @ 1/e²	2.5 µm	40 µm
Position	20 µm	2 µm @ 1 dB	0.5 µm	8 µm
Angular	-	2° @ 1 dB	8°	0.5°







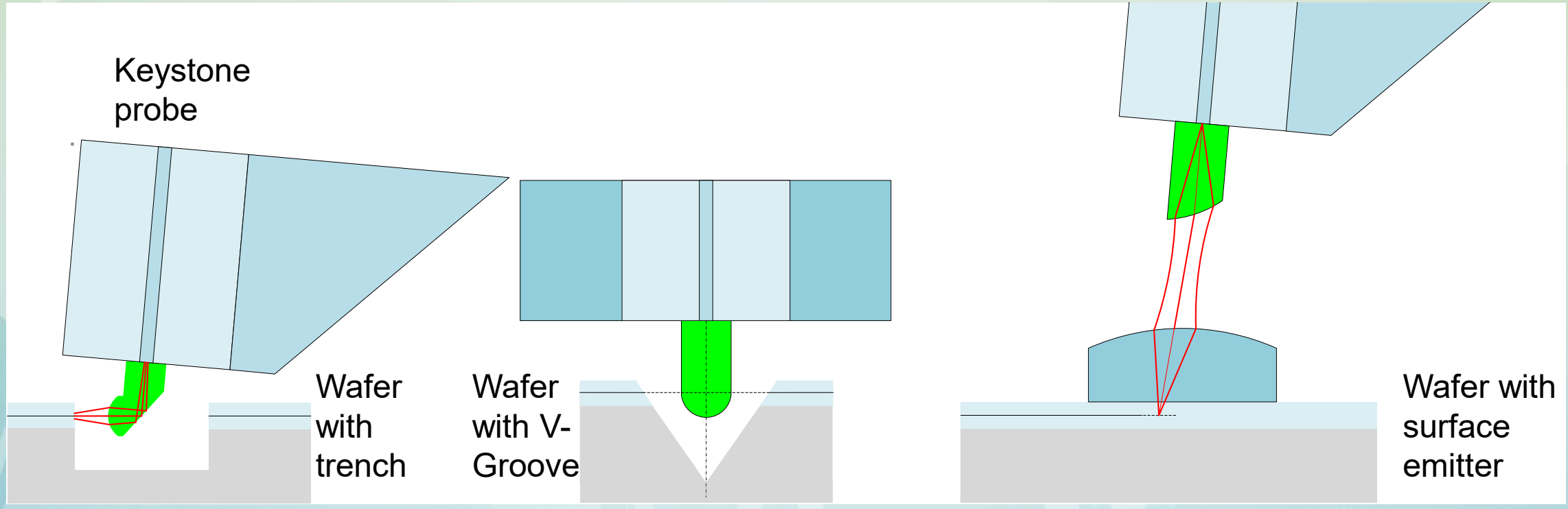
Key Takeaway: Optical testing always has high alignment requirements – either translational or angular.

Micro-Optics for Coupling

Trench for „pluggable“

V-Groove for „pluggable“

Surface coupling for „CPO“



Key Takeaway: Can adapt to all relevant coupling interfaces.

In-situ printed micro-optics

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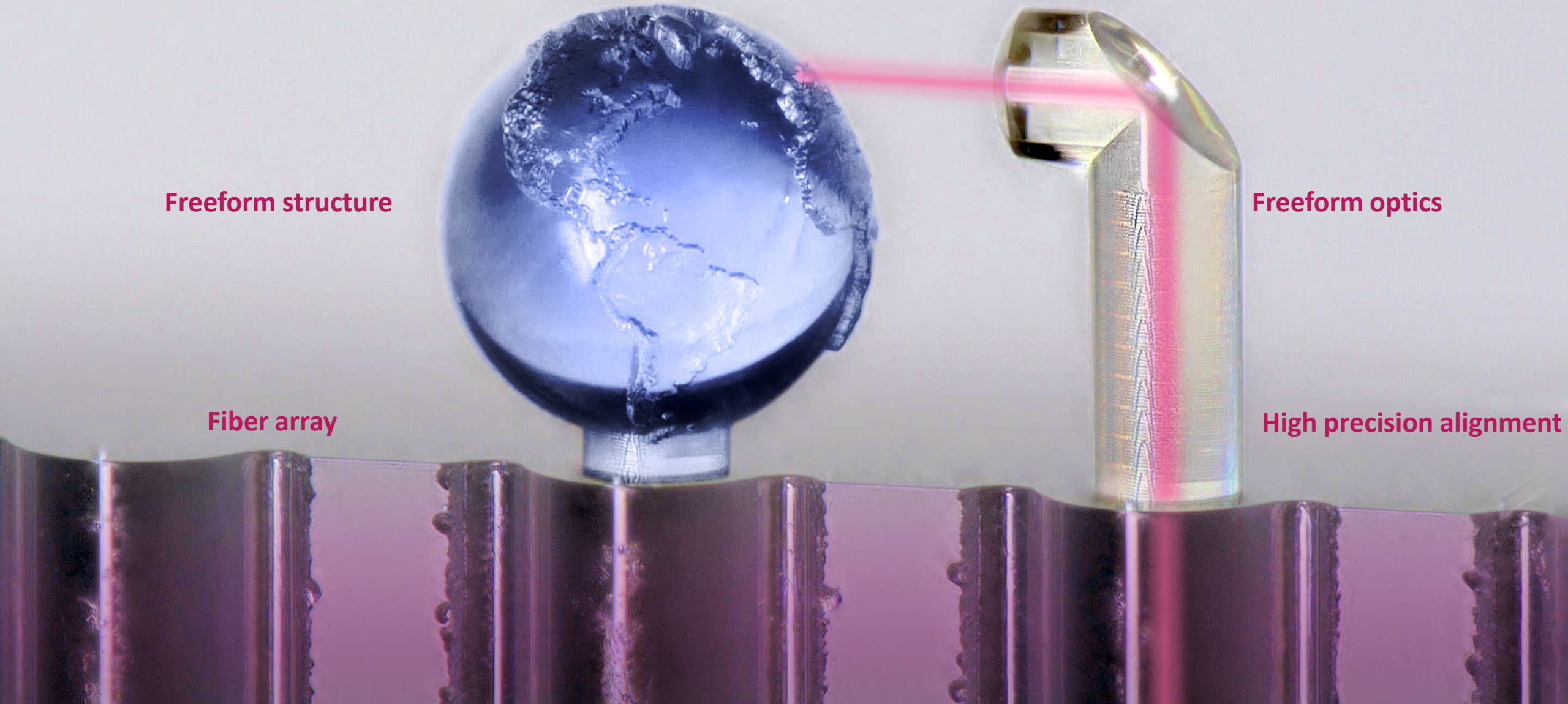
Make photonic interfaces
accessible at wafer-level



Freeform structure

Freeform optics

Fiber array

High precision alignment

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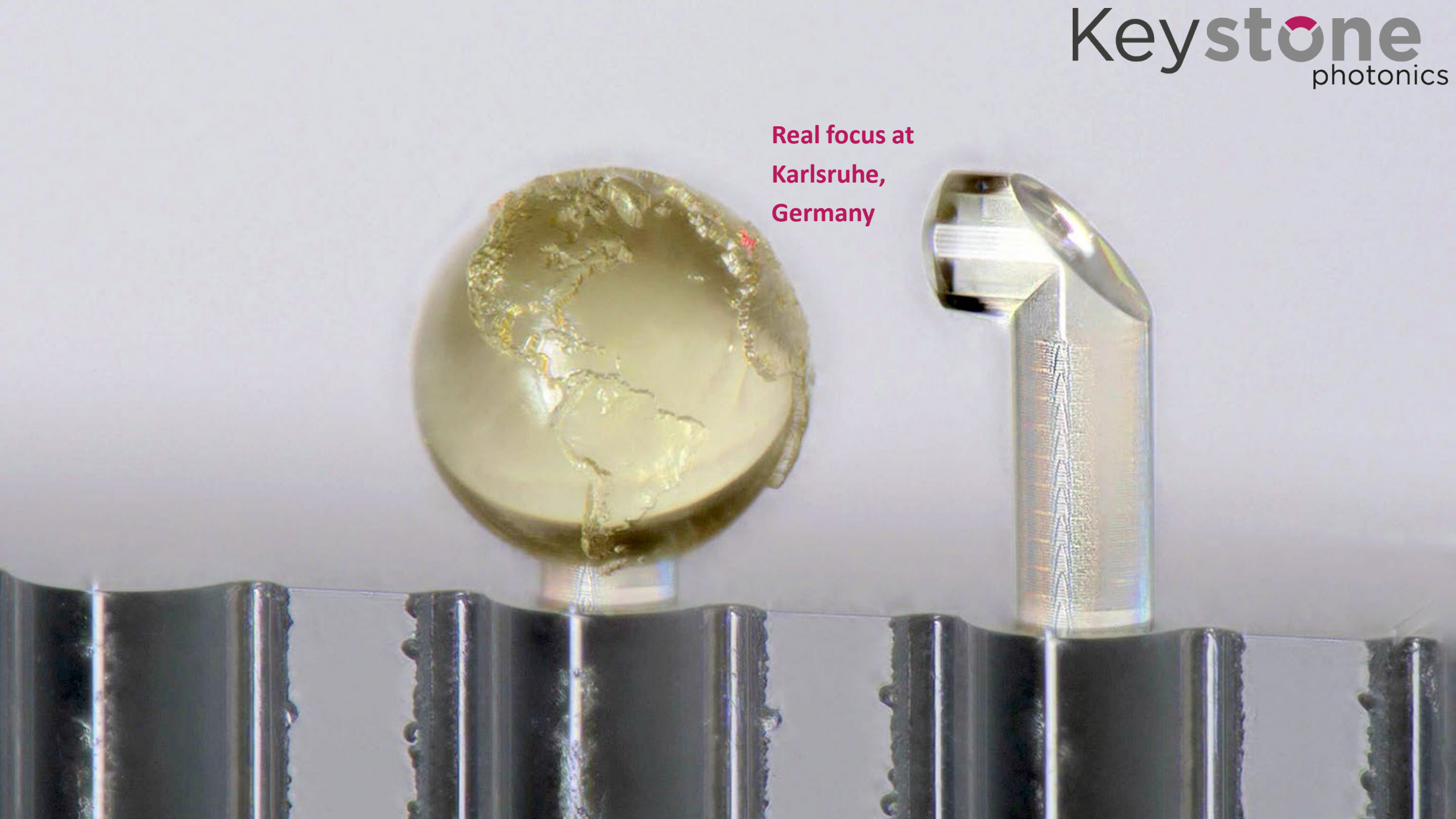
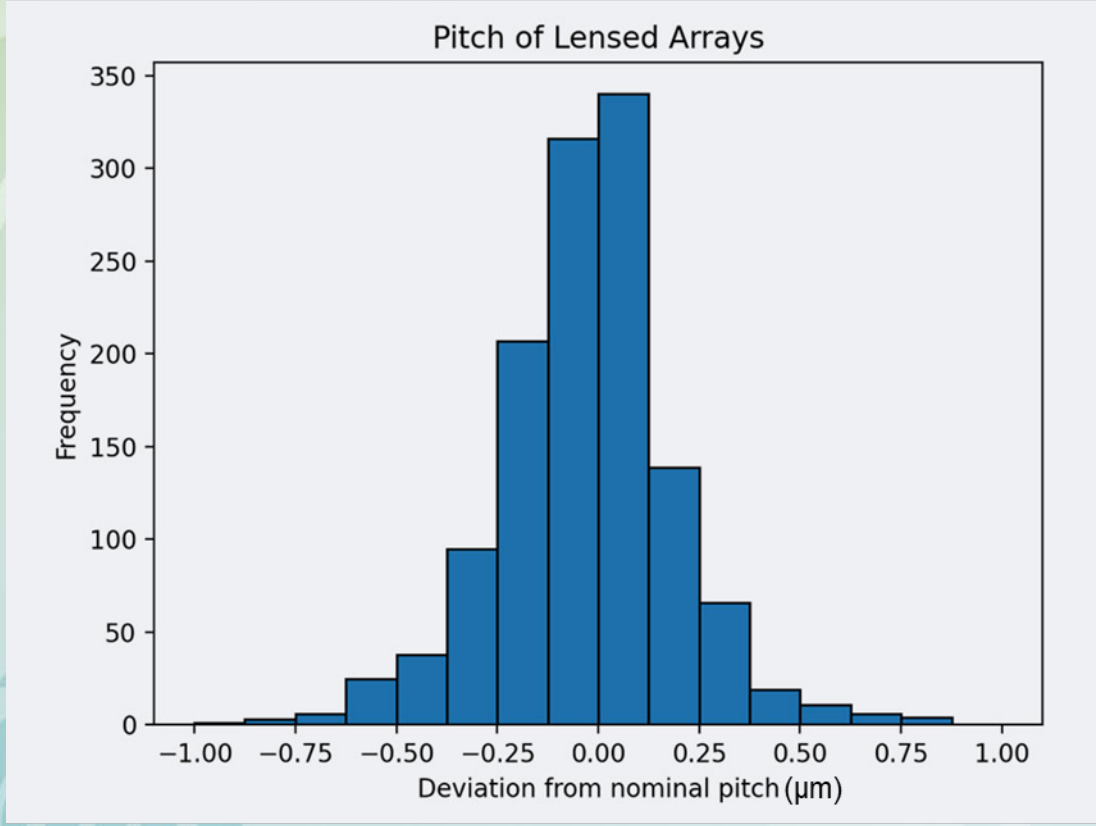
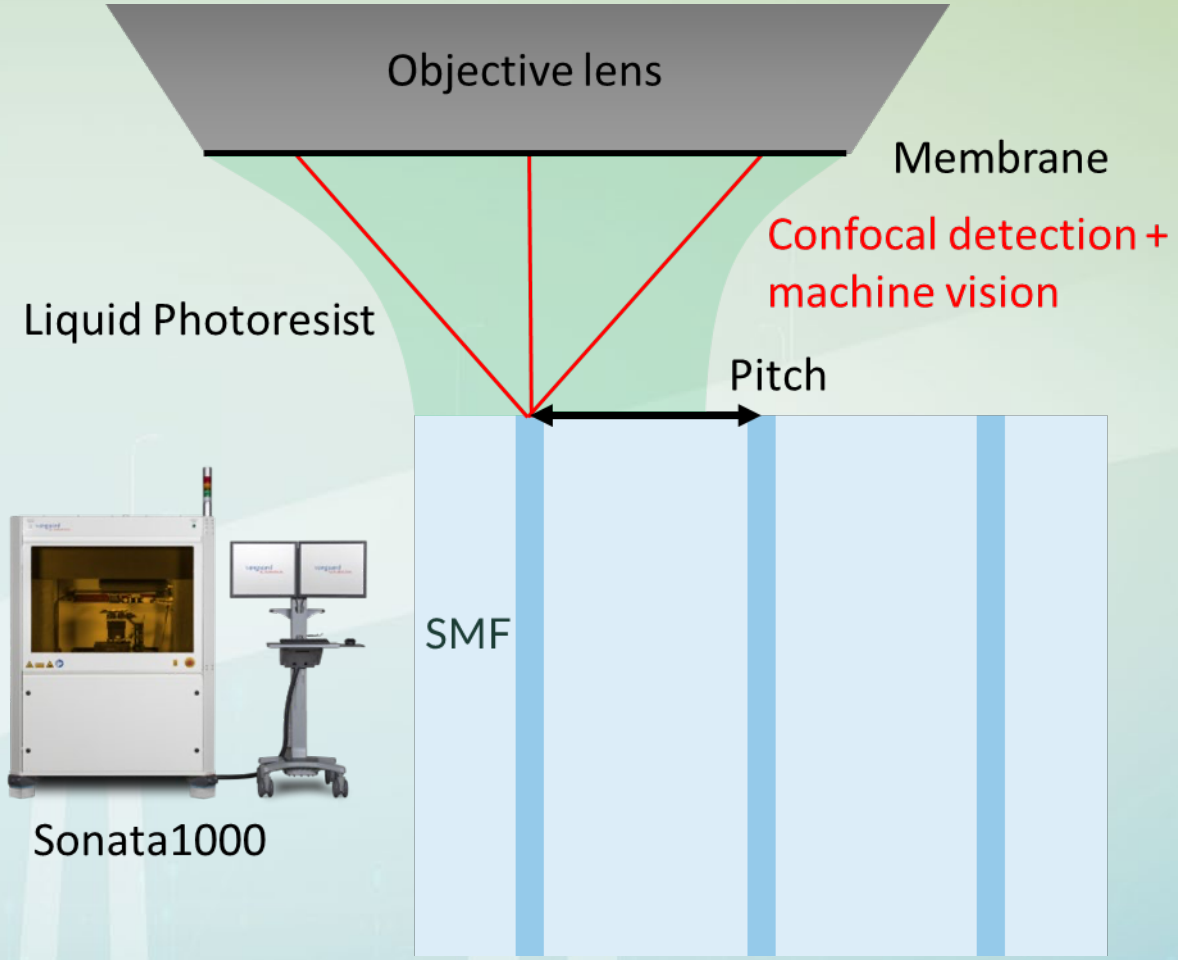


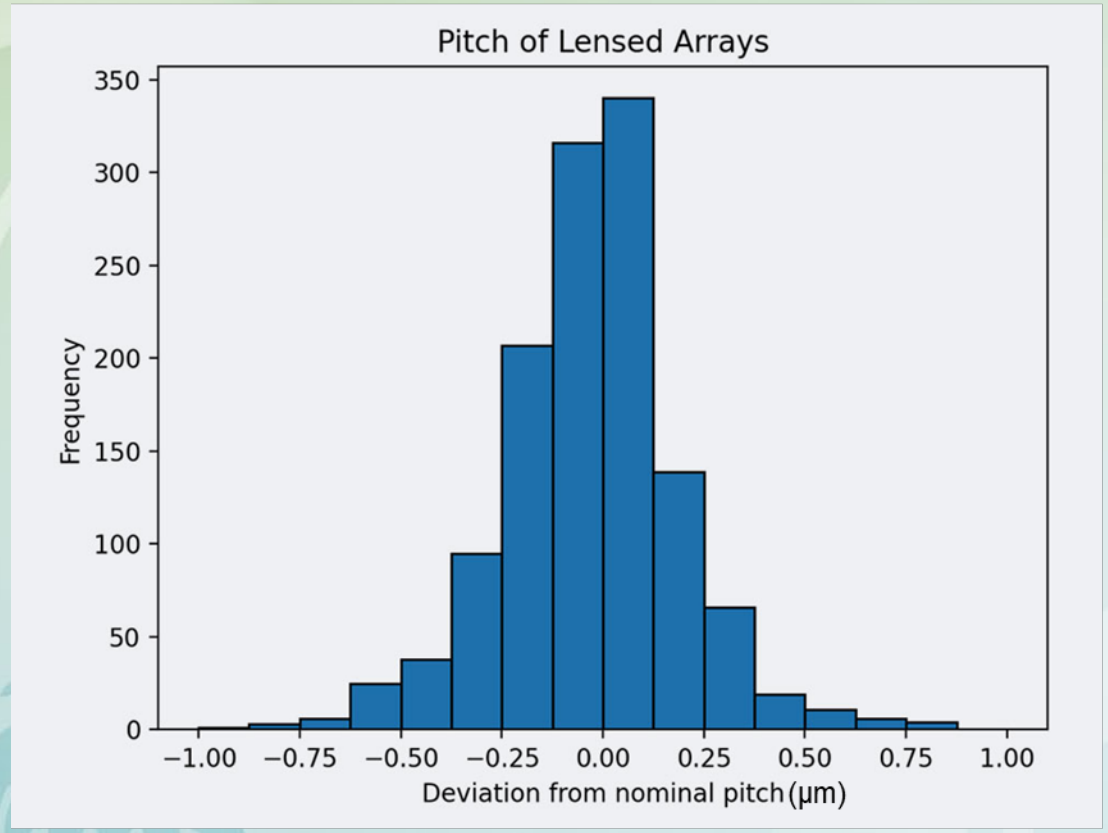
Fabrication

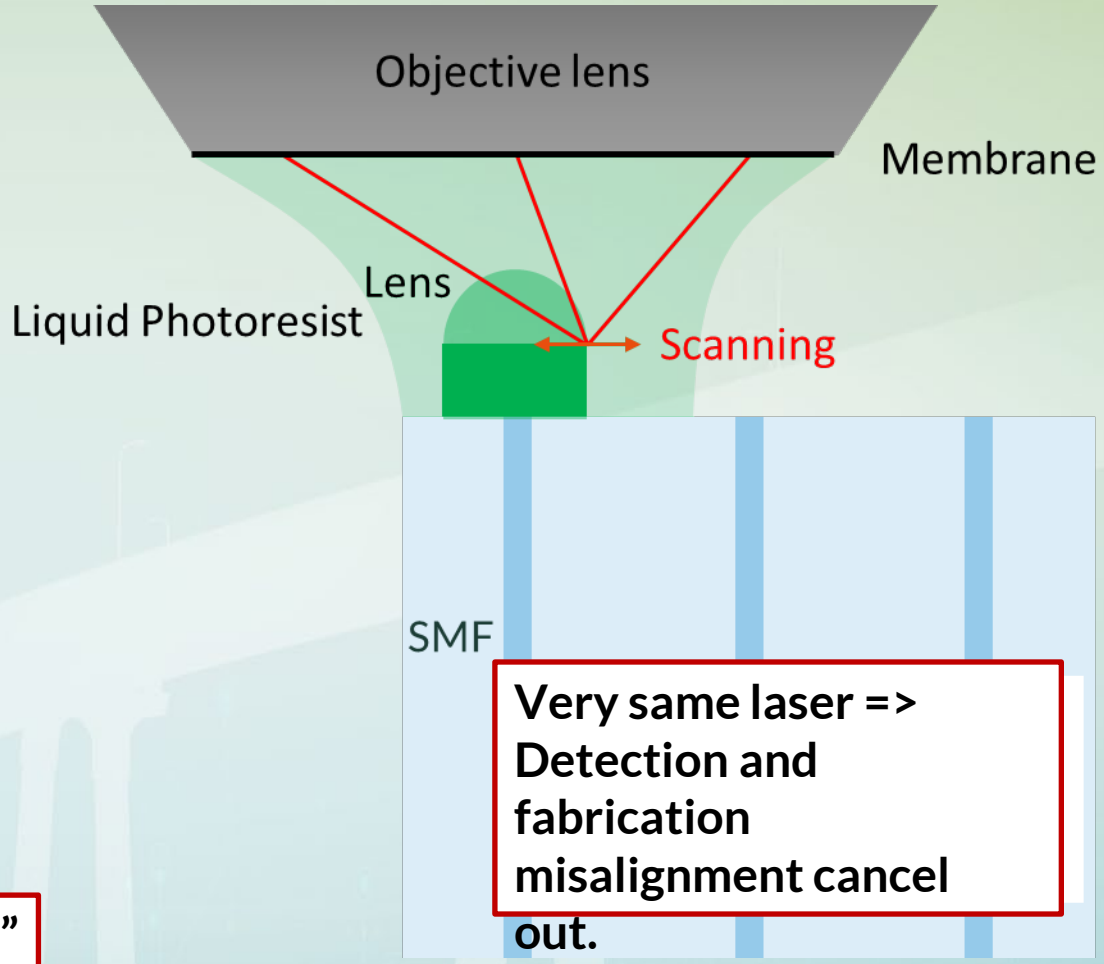




Key Takeaway: Fabrication inherently does in-line inspection.

Fabrication

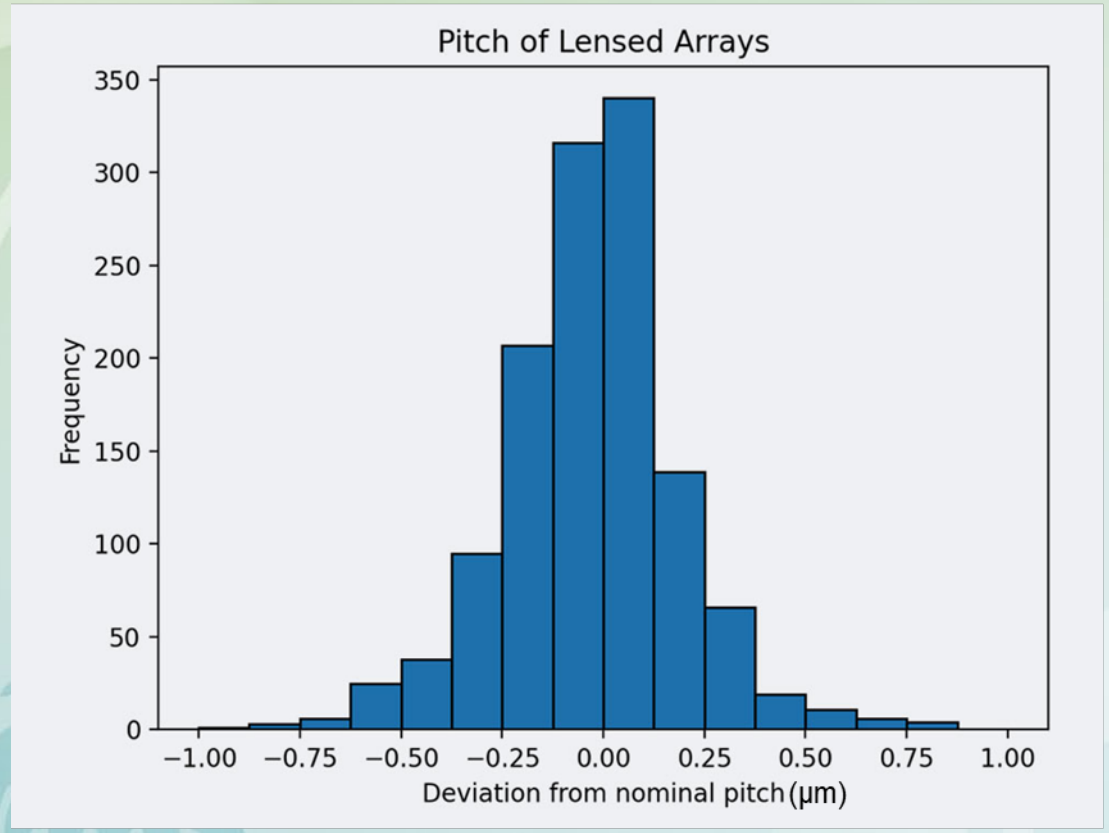


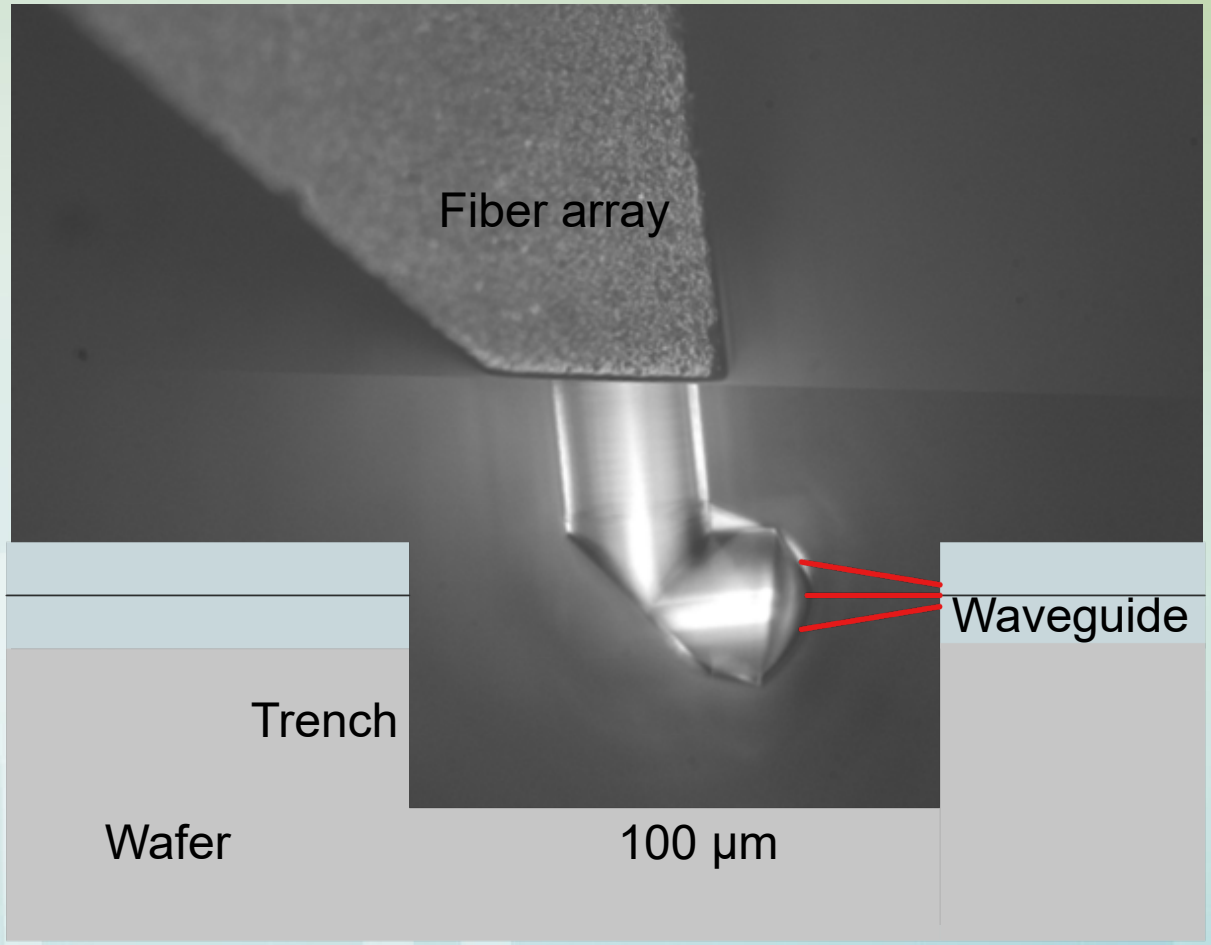


Very same laser => Detection and fabrication misalignment cancel out.

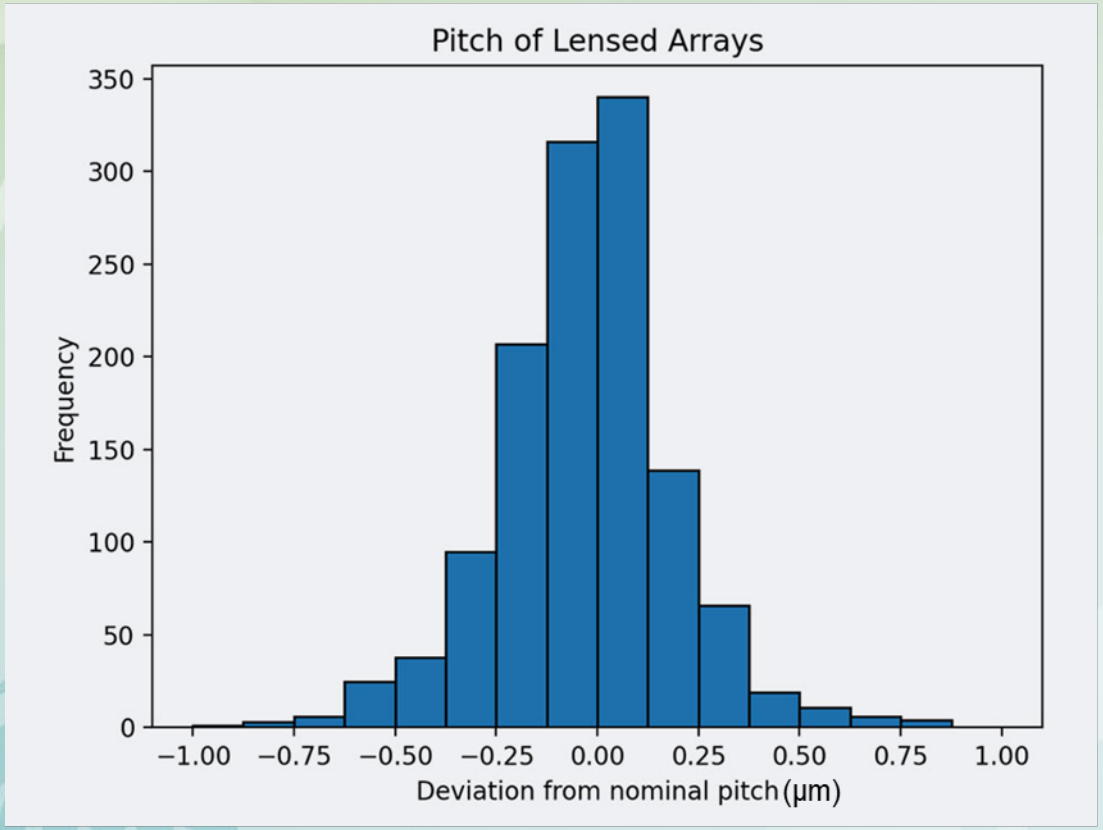
Key Takeaway: Fabrication can happen on "anything" including interposer, optical probe cards etc.

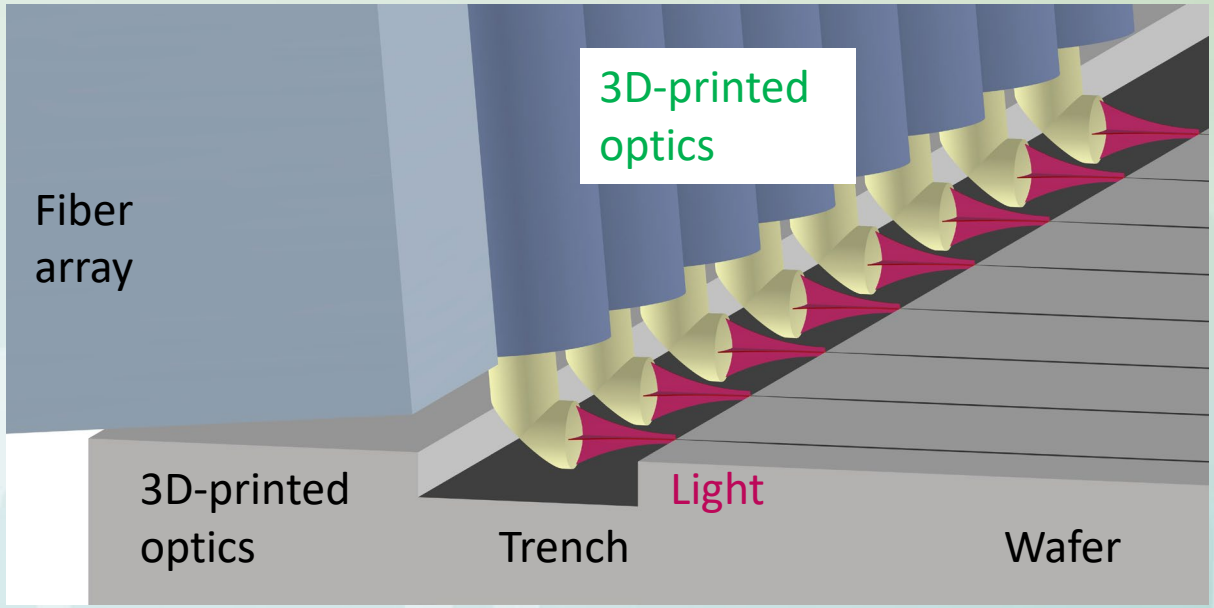
Fabrication





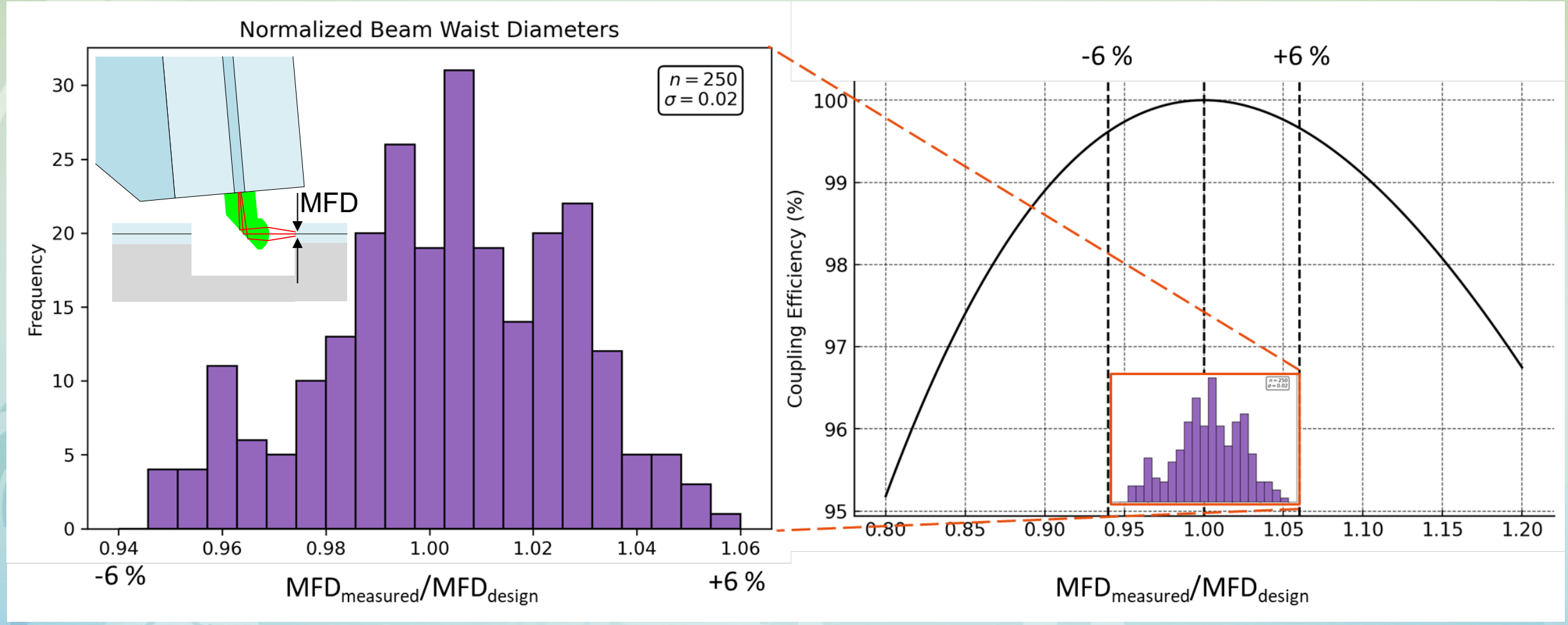
Multi Channel





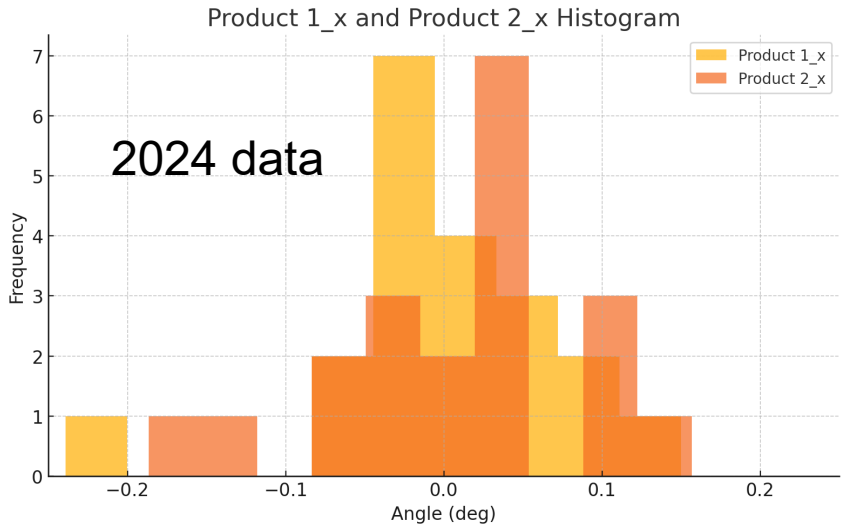
Key Takeaway: Pitch accuracy is sufficient for arrays.

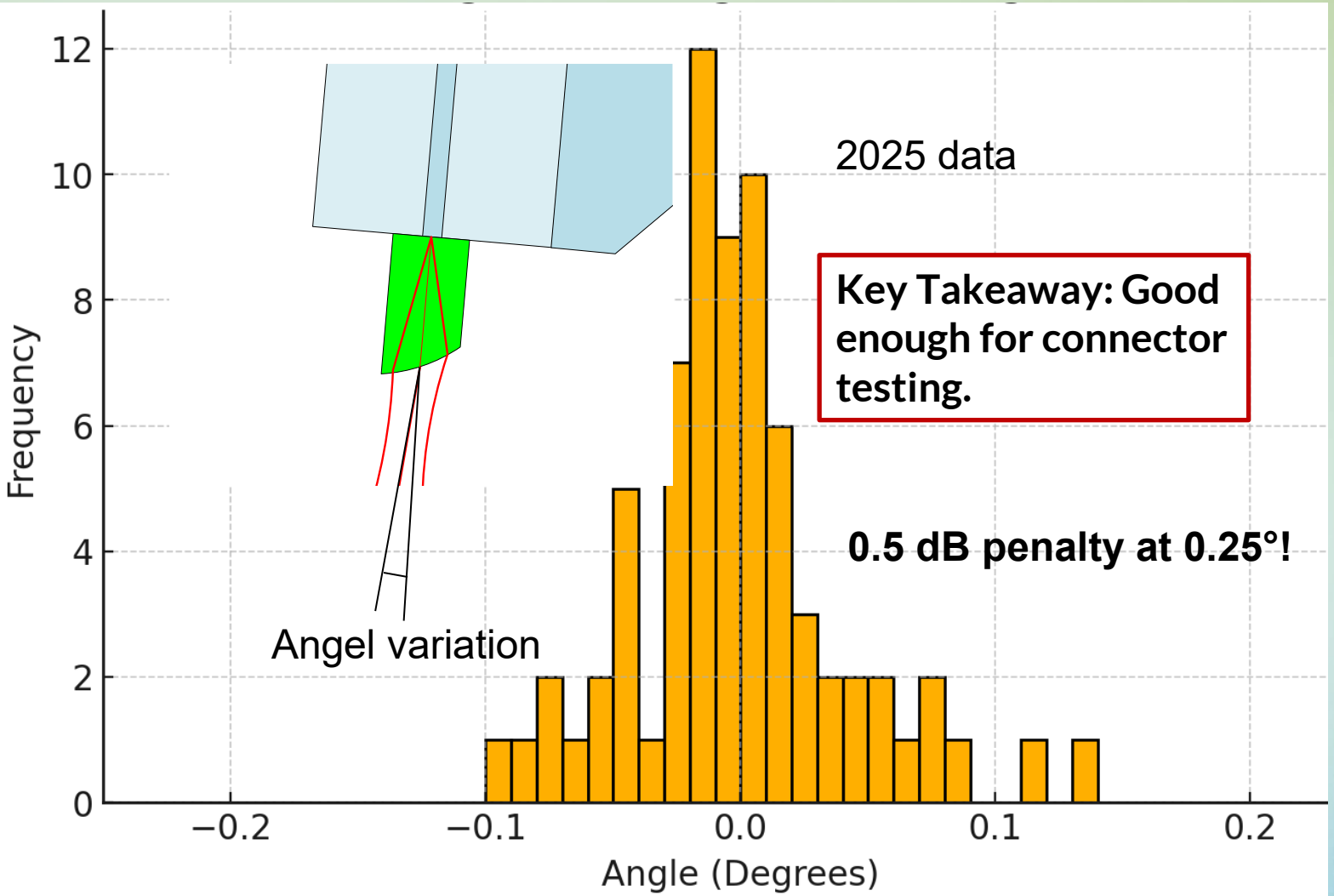
Mode-Field Size Reproducibility



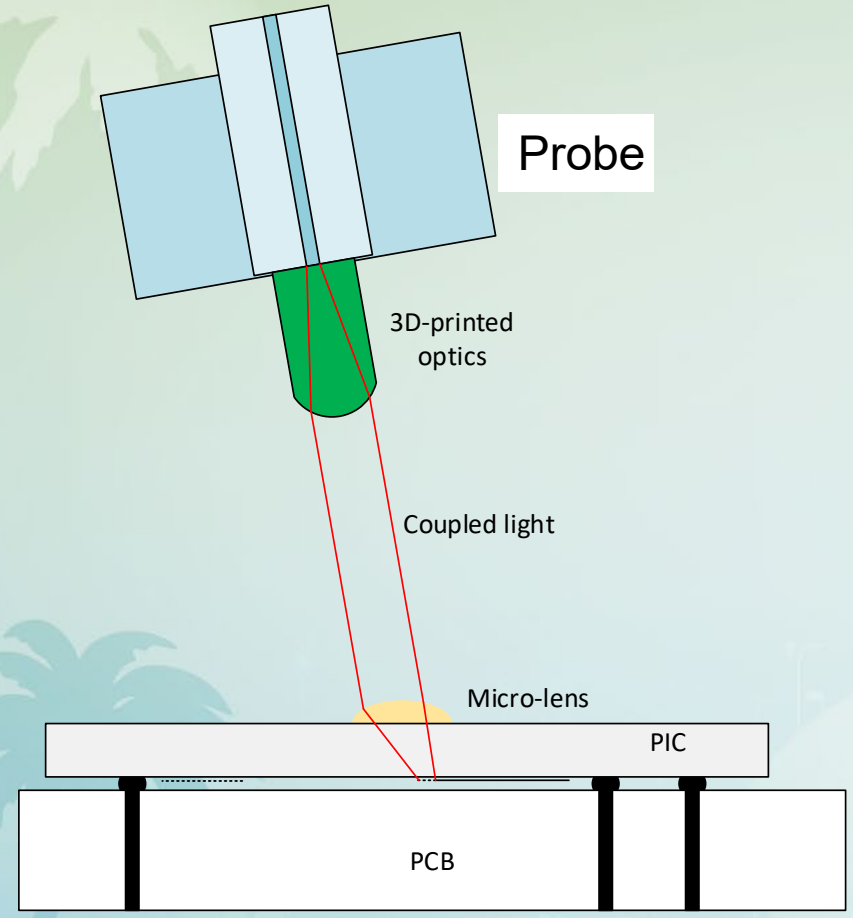
Key Takeaway: There is "no" mode-field variation.

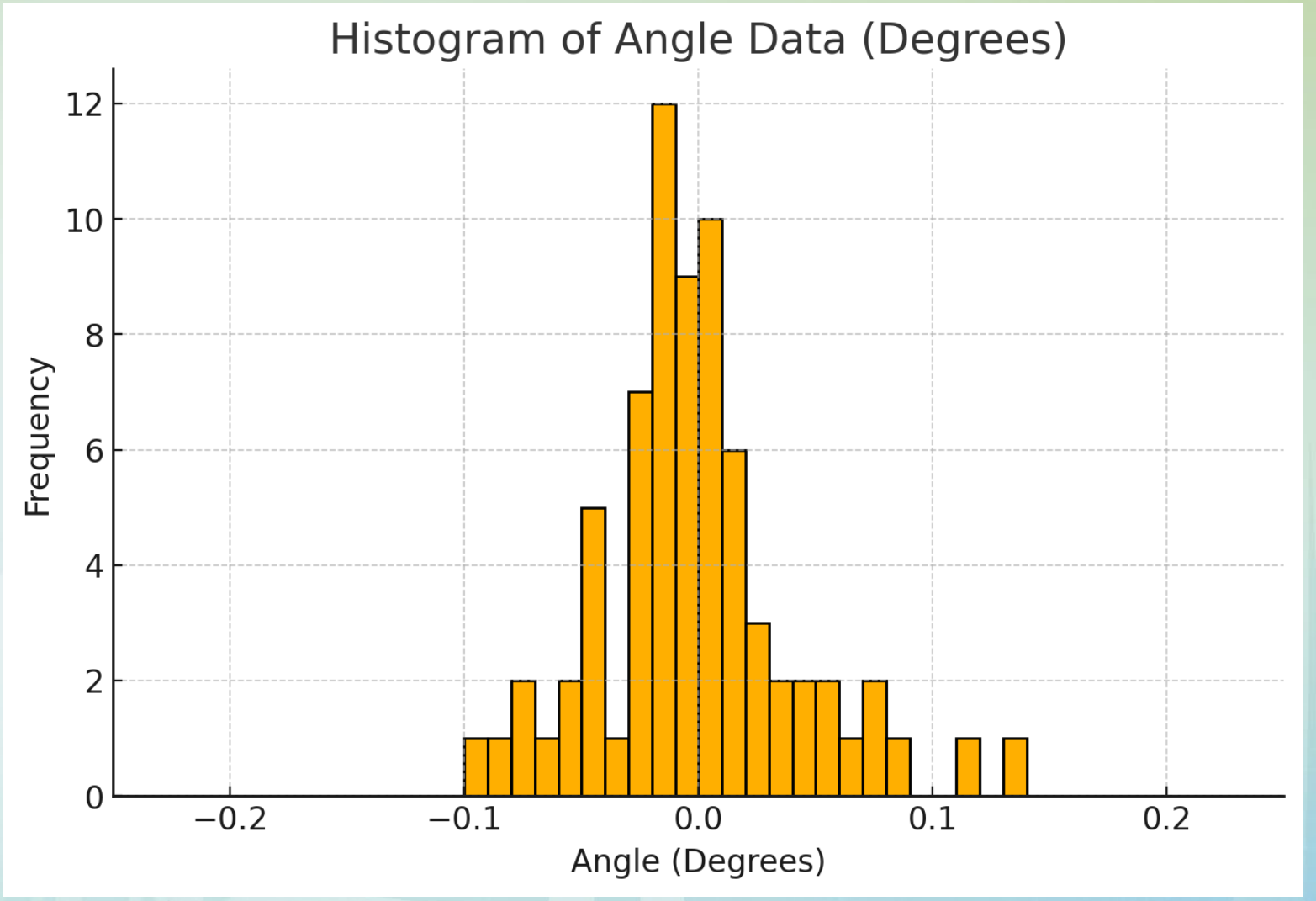
Angular Accuracy



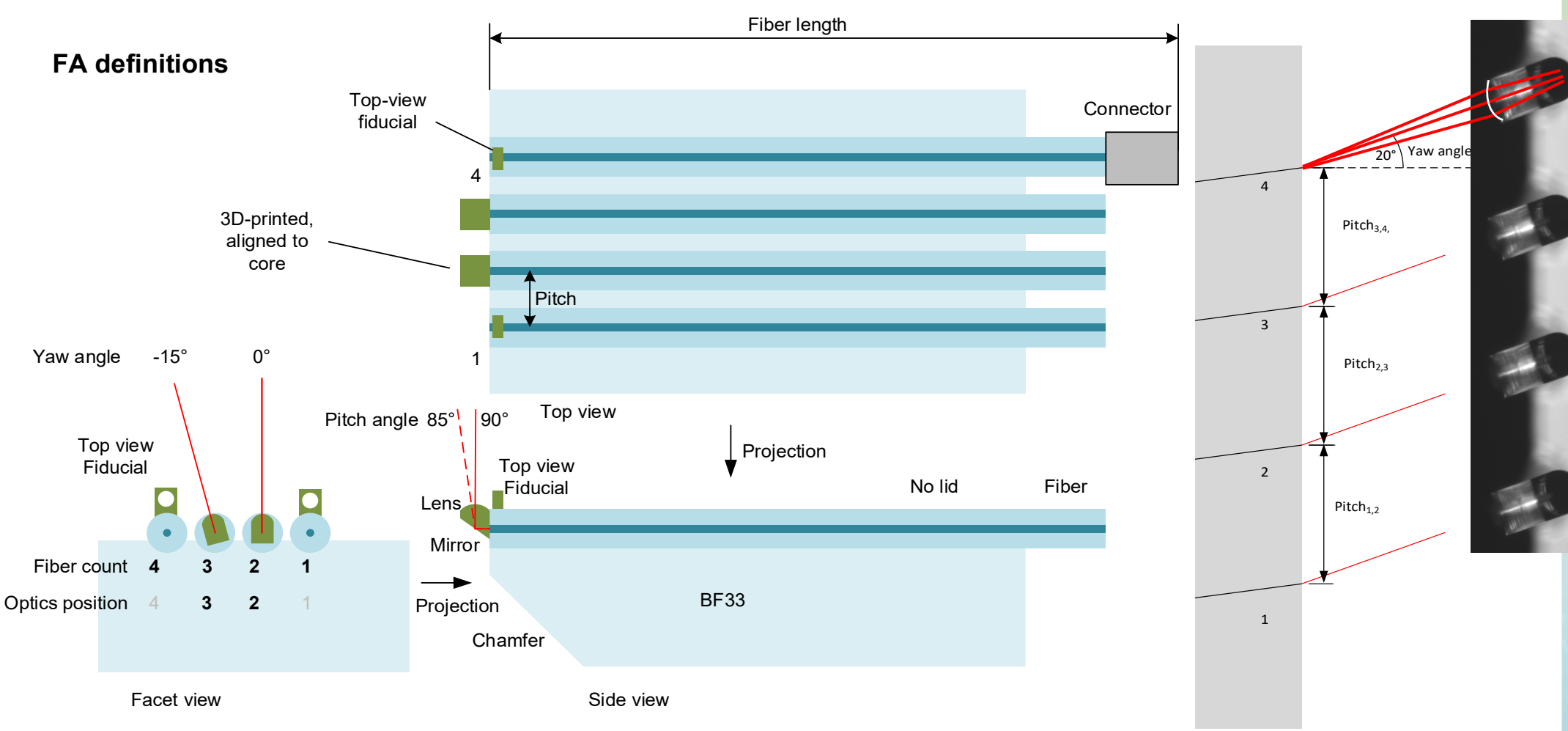


Suitable for Double-Sided Testing





Adapting to a Non-Standardized World

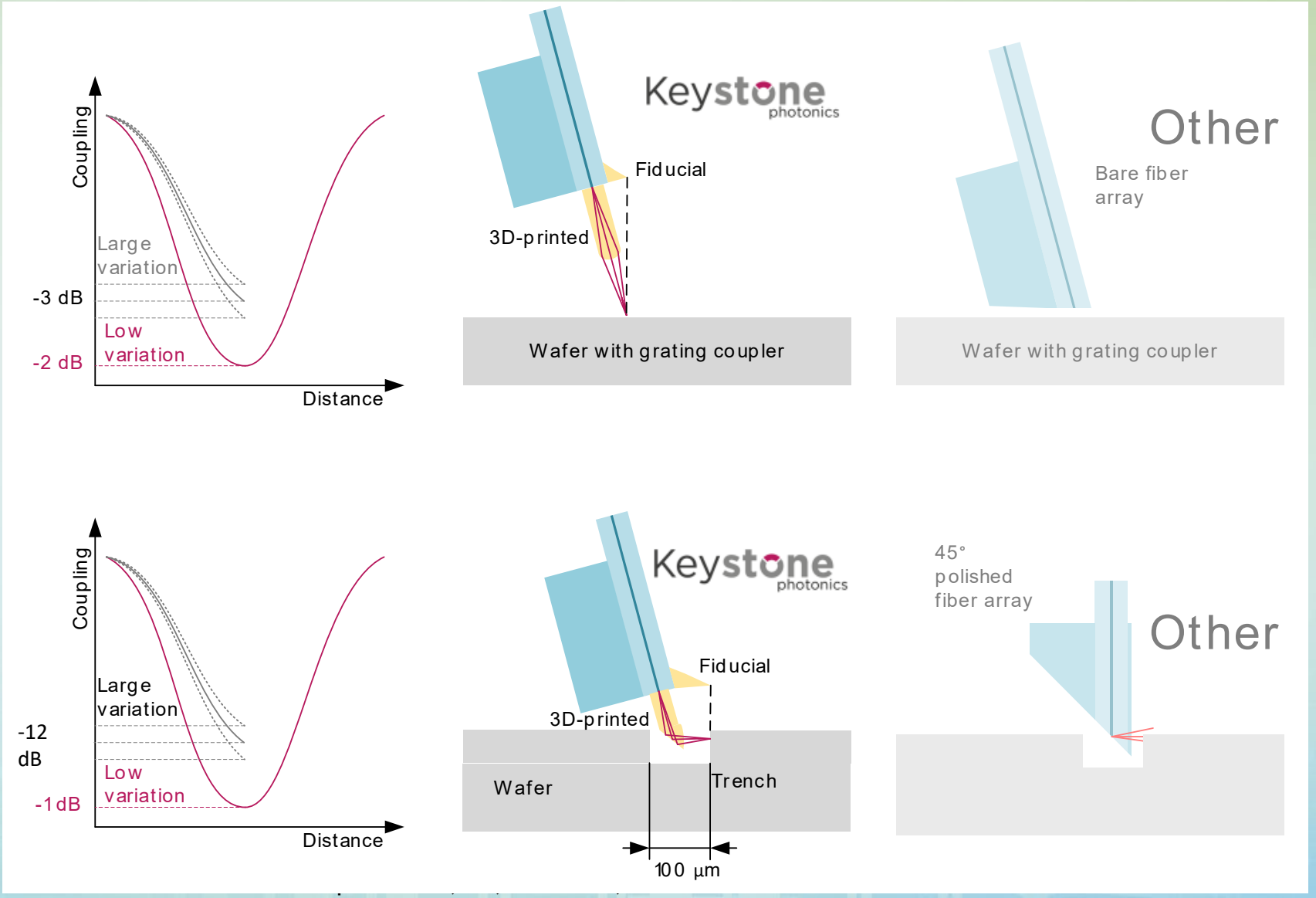


Key Takeaway: Can adapt to most optical interfaces

Comparison to Fiber Only Testing

Keystone Probes	Advantage
Reproducible	Detect device variation
Multi channel	Fast
Good coupling	BER testing
Fiducial	Simple alignment
Adjustable angle	Detect emission angle variation
PM-Option	No Pol alignment
Large working distance	Robust testing method
Micro optics	Testing of V-Grooves

Takeaway: Order-of magnitude improvement vs. no optics

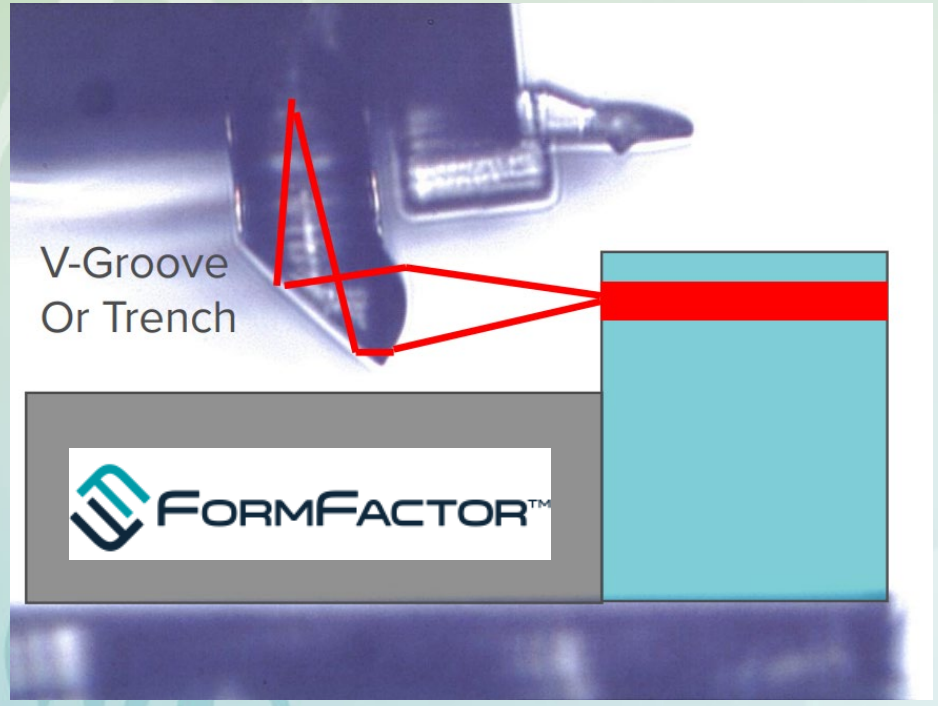


Other Features, see SWTest 2024

- Probe properties
  - High surface accuracy and low surface roughness
  - High-power operation of up to 1W
  - Passes Telcordia tests including damp heat
- Application
  - Can be integrated in existing prober using fiducials
  - Pitch conversion down to 20 µm
  - Available on customer-specific metal carrier

Application: Wafer-Level Testing in Manufacturing

Coupling loss is 1.47dB/facet



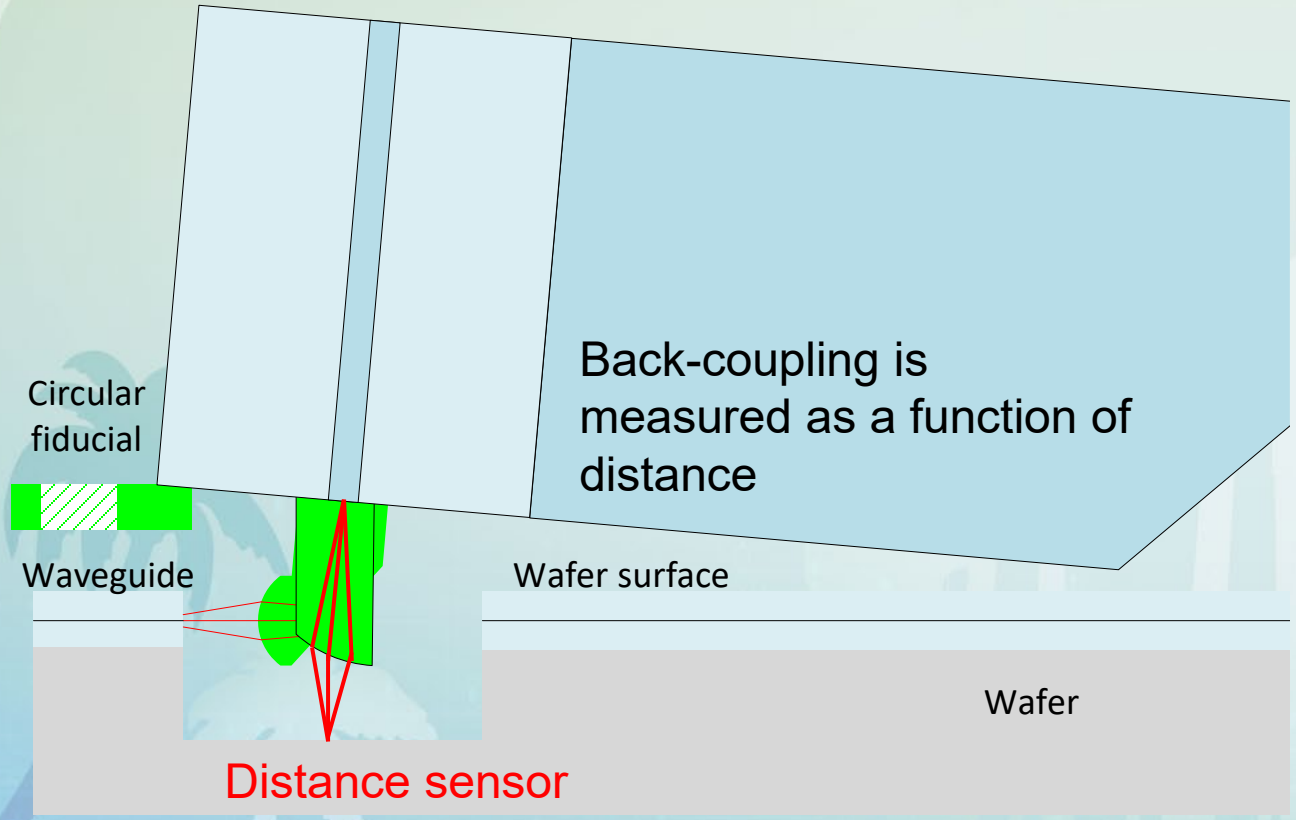
Available from Formfactor

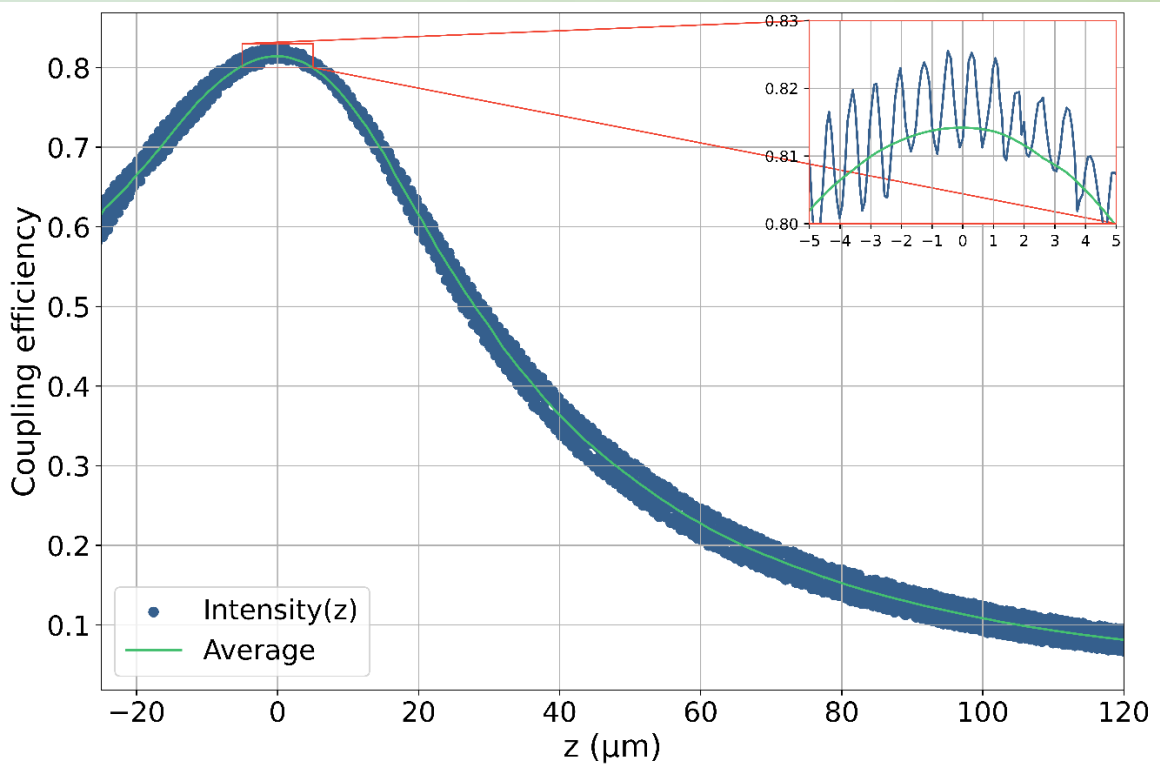
www.formfactor.com/sales-service/contact-sales/

https://www.formfactor.com/download/fully-automated-integrated-silicon-photonic-wafer-test/?wpdmdl=82376

Wafer-Level Distance Sensor for Thin Wafer

Using additional channels for distance sensing based on a confocal principle





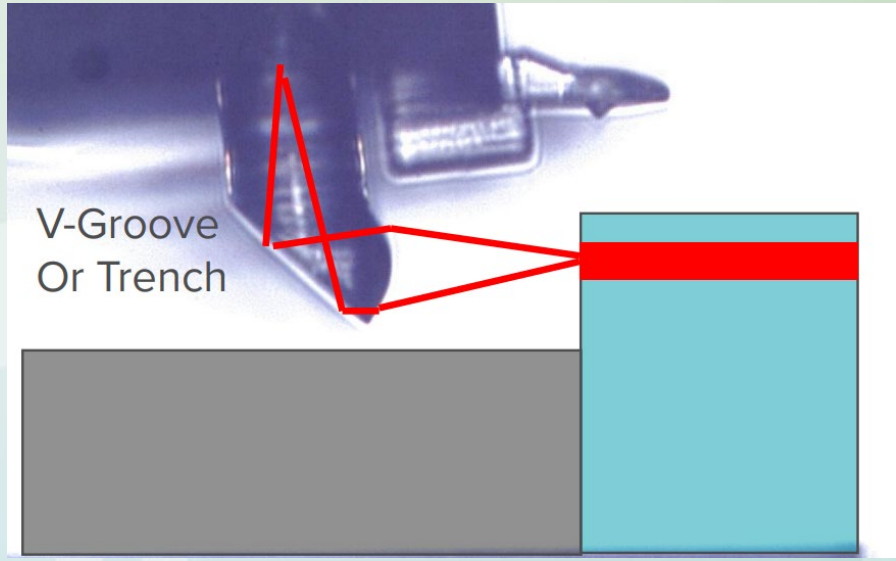
Measured at flat surface

Track Record

- Based on >10 years of research, basic functionality available since 2015
- First industry customer 2018
- Used in production environment since 2021
- Several thousand probes shipped
- More than 90% industry customers
- Available directly from Keystone or via most testing companies

Formfactor OFC Release 2025

+TEL
+Advantest

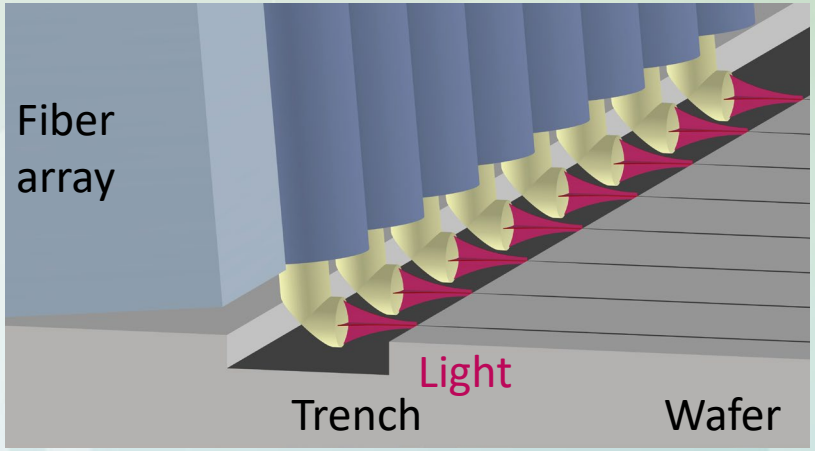


Available from Formfactor

https://www.formfactor.com/blog/2025/pioneering-high-throughput-wafer-testing-for-silicon-photonics-with-triton/

Ficontec OFC 2025 Release

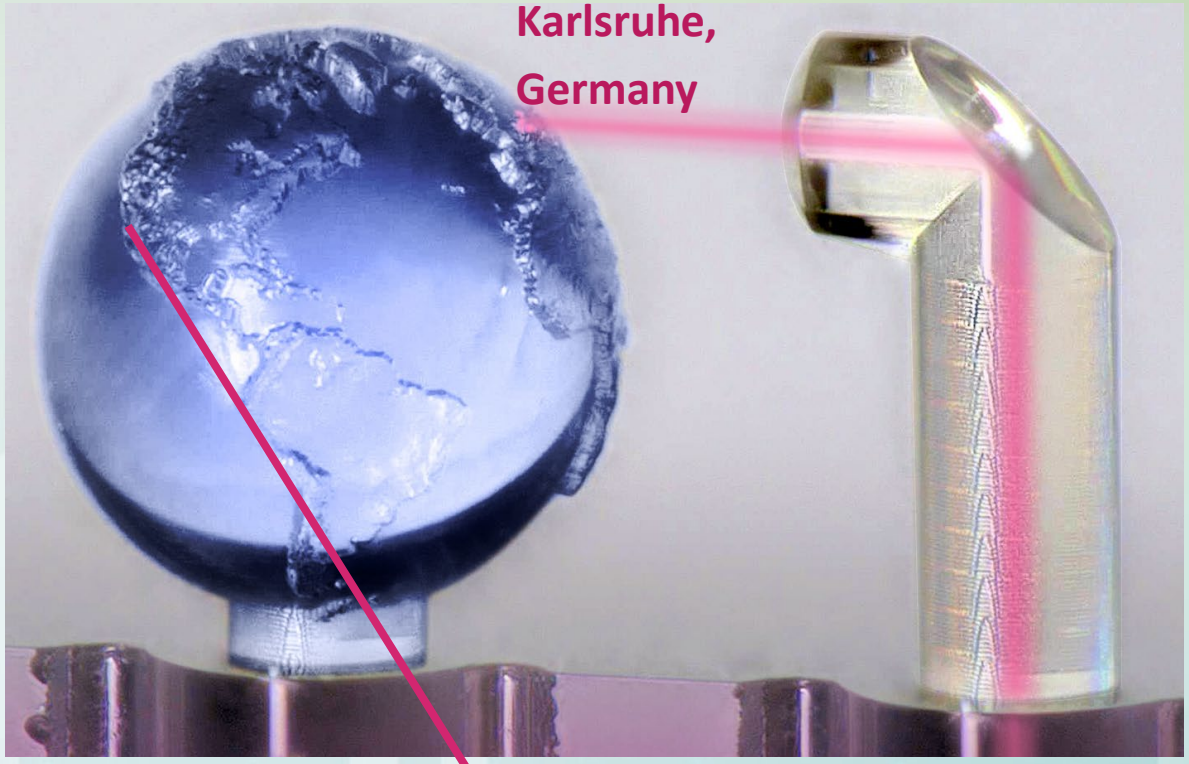
+ Teradyne



Sources; Top: Formfactor, SWTest 2024 and OFC 2025, Bottom: Ficontec, OFC 2025

Key Takeway

- Wafer-Level Testing plays a crucial role in photonics manufacturing
- Optical Testing always has high accuracy requirements - either angular or translational
- Keystone Photonics can provide a versatile solution for production



Booth 103