SWTEST 2026 CONFERENCE

35th ANNIVERSARY

High Volume Silicon Photonics Testing with a Fully Integrated ATE Solution

MARVELL

TERADYNE

TECHNOPROBE

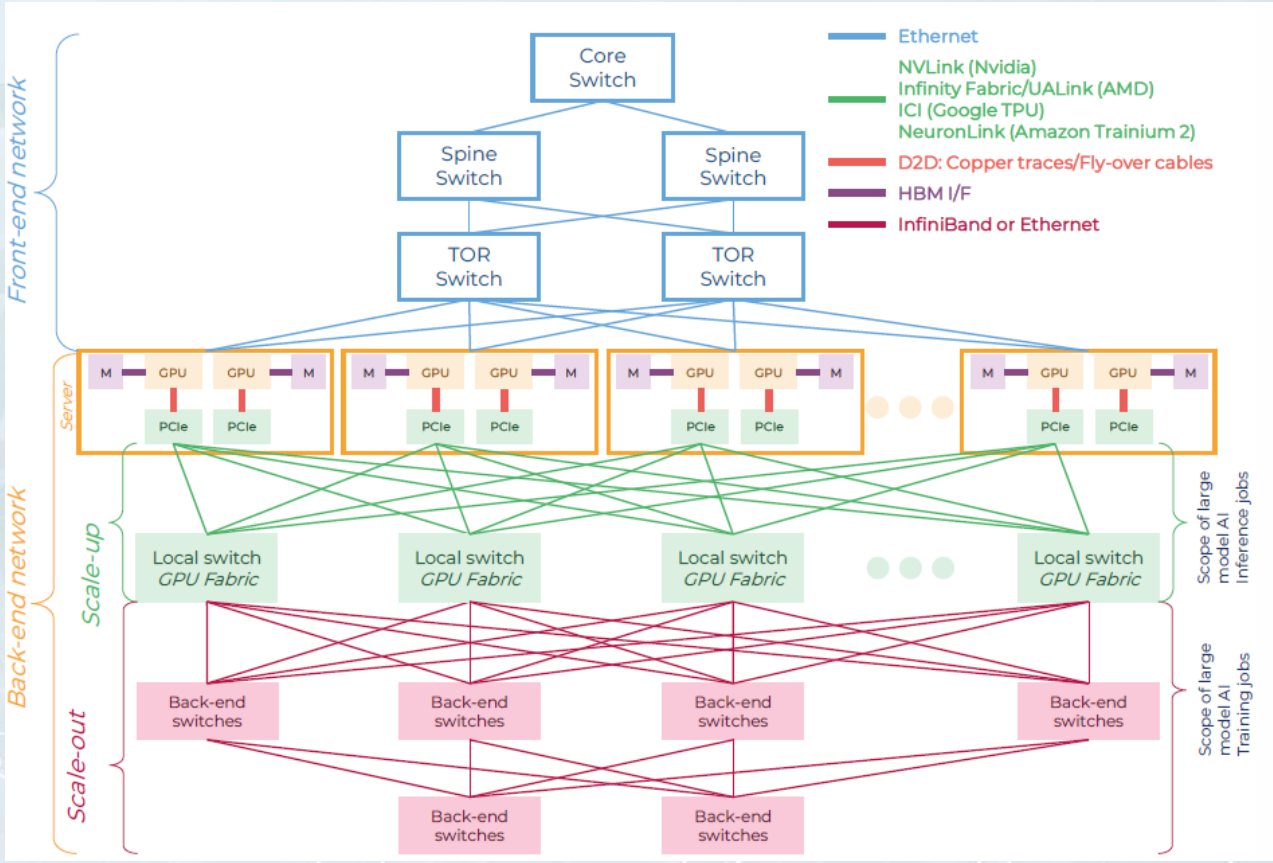
Amit AGNIHOTRI, Andy CHANG (Marvell)
Lakshmi-Anusha CONDON, Monica DAVIS, Ethan DWYER (Teradyne, Inc.)
Alessia GALLI (Technoprobe)

Agenda

- **Introduction**
- **Volume test needs and challenges**
- **Meeting challenges with a fully integrated and automated SiPh wafer test cell**
  - Technoprobe EclipsePhotonic alignment technology with integrated microcontroller
  - Teradyne Photon 100 with fully integrated optical instrumentation
- **Automated alignment and test**
- **Results / Summary**

Why do we need Silicon Photonics and Co-Packaged Optics?

- AI has shifted the system bottleneck from compute to data movement
- Optical interconnect demand is growing exponentially
- Silicon Photonics is the enabler of next-gen optical interconnects
- Networking consumes 5-20% of power budget for data center
- Moving to CPO-based networking is expected to reduce networking power



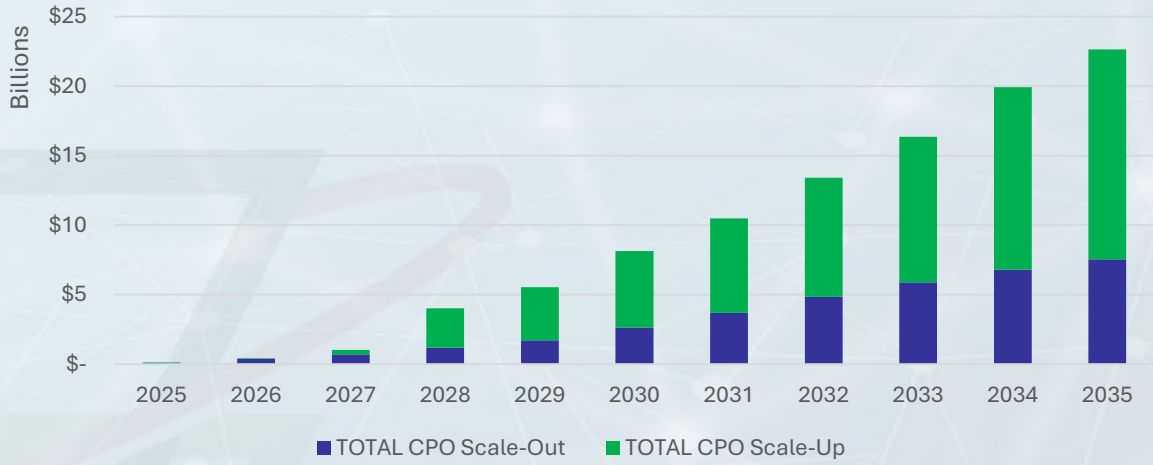
Source: Yole CPO for Data Centers 2025

Optical Testing is Exploding

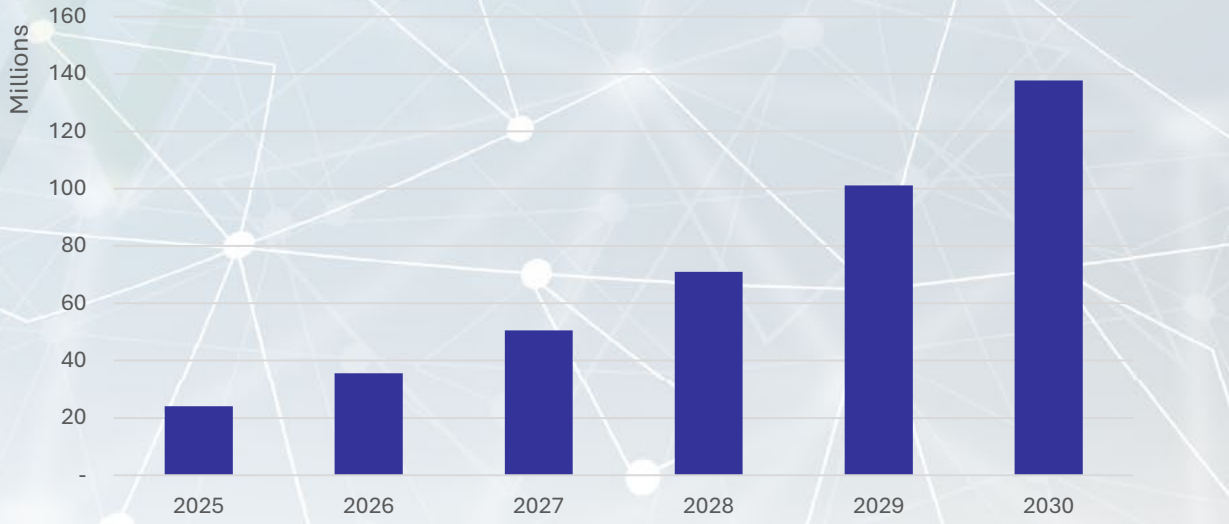
Driven by the rise of silicon photonics and co-packaged devices for datacom

- Device volumes increasing from millions to 100s of millions
- Fiber count per device under test increasing from 10s to hundreds or thousands
- CPO service challenges due to integration of optical engines and xPUs increases need and importance of optoelectric test coverage at all test insertions

CPO Optical Engine Revenue[1]



Silicon Photonics Unit Volume[2]



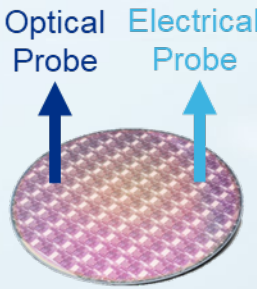
1 Yole, Co-Packaged Optics for Data Centers, 2025
2 LightCounting, Silicon Photonics and Co-Packaged Optics May 2025

Identifying Known Good Die early reduces downstream manufacturing and test costs

Wafer | Optical Engine | Packaged Module

INSERTION 1

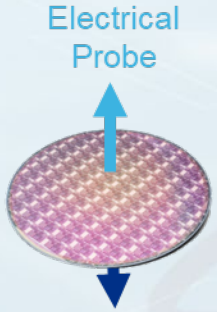
PIC or PIC+EIC



&/or

INSERTION 2

PIC+EIC



INSERTION 3

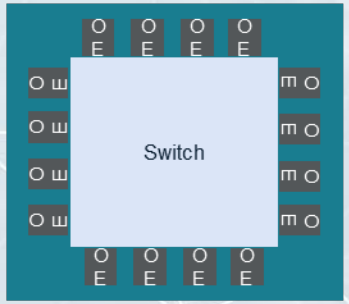
Individuated OE on interposer or packaged with fiber connectors

Fiber alignment &/or *Connector automation*

INSERTION 4

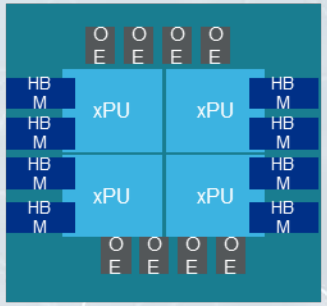
High value Switch or XPU integrated with surrounding co-packaged optical engines

Switch



&/or

AI Accelerator



Device value, cost of scrap, and test complexity increases at each insertion

Identify Known Good Die and Known Good Devices before integration with high value switch or XPU. Shift test left.

Insertion Loss
Photodiode Responsivity
Heater/Modulator Tuning

At speed functional transceiver test: E/O & O/E
Multi-site and/or loopback test: O/O

Functional / Mission Mode Test
Full functional validation
Multi-site and/or loopback

Addressing High Volume Silicon Photonics Wafer Test

Strategic Lever	Primary Focus	Operational Benefits	Business Impact
Standardized & Flexible Equipment	Modular platforms and reusable architectures	Reduced complexity, faster NPI, easier maintenance	Lower CapEx, improved engineering efficiency
Maximize Overall Equipment Effectiveness (OEE)	Setup (short first-time alignment and indexing), calibration, and debug reduction	Higher uptime, increased throughput, stable operations	Lower cost per unit, higher output
Multi-site Test Enablement	Replicable solutions and centralized control	Consistent quality, scalable capacity, faster ramp	Global consistency, reduced operational risk

Critical technical challenges

- **Light Input/Output From Device**
  - Optical alignment efficiency
  - Optical power consistency
- **OSAT Friendly**
- **Parallel Testing – Testing Time**

Fully integrated automated Insertion1 Test

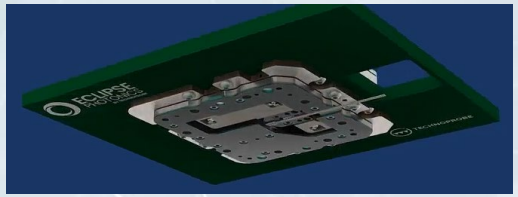
The Photon 100 integrates with Technoprobe EclipsePhotonic to enable single-sided wafer test at scale

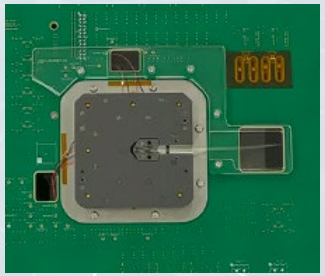
Teradyne UltraFLEXplus ATE with Photon 100

High volume optoelectric wafer test fully integrated via IG-XL Software Platform

Technoprobe EclipsePhotonic

Optical alignment flexures + piezo electric positioning integrated into probe card





Photon 100 provides

High Power Lasers
Tunable Laser Channels
Optical Power Measurement
Optional Signal Conditioning:
Polarization Control and Switching
Laser Safety

Optical Blind Mate

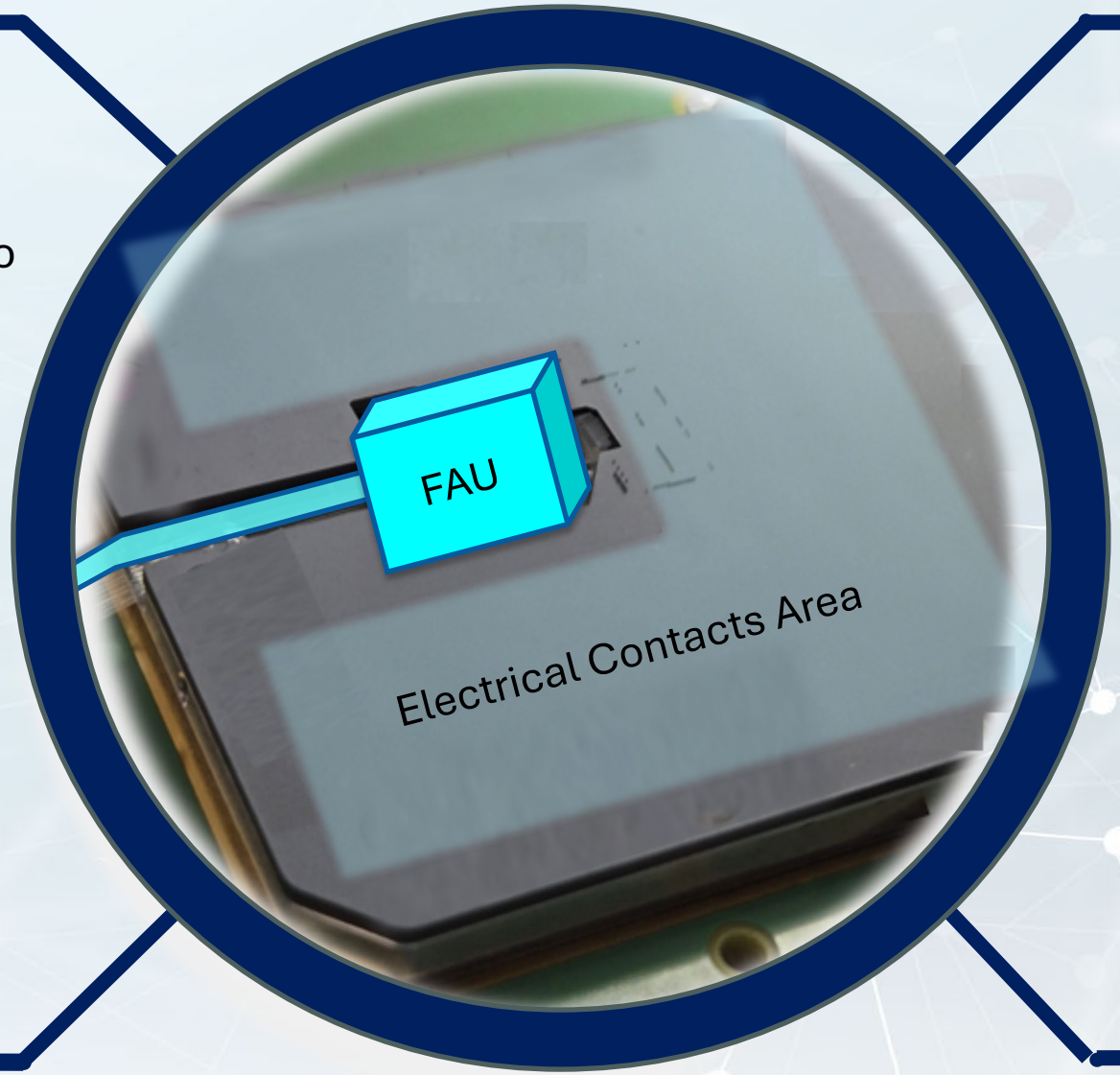
between UltraFLEXplus test head interface and probe card enables fully automated wafer test with the user's choice of

Industry Standard Prober

EclipsePhotonic alignment technology

- **FAU**

Complete FAU integration into the Probe Head



- **Electrical Contacts**

Wide portfolio of vertical needles available, including RF solutions.

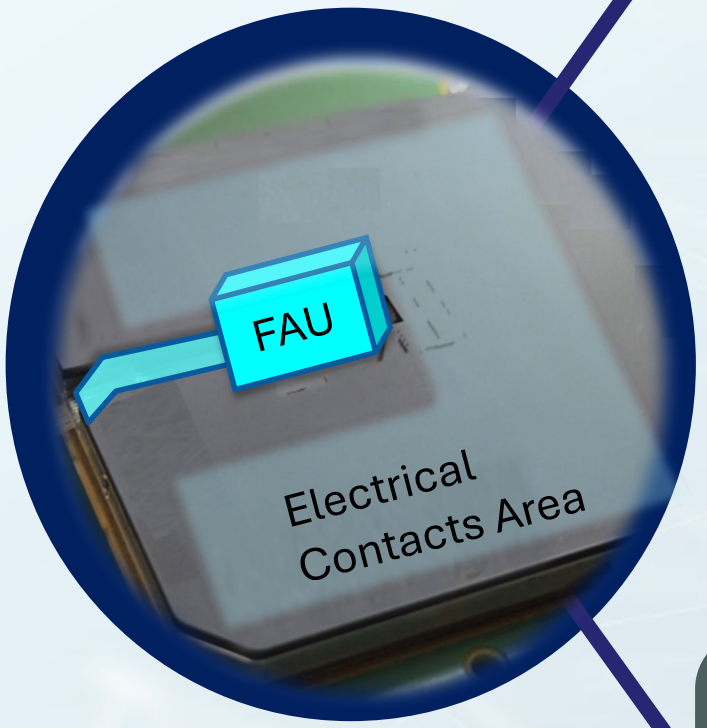
- **High-accuracy Positioner**

Eclipse features positioner actuation with 150 nm accuracy

- **Positioner control**

Actuation control is embedded into the PCB, featuring a dedicated MCU

EclipsePhotonic alignment technology



Top side Coupling

- Multiple algorithms available for grating coupler alignment, evaluated in terms of alignment time, accuracy, repeatability and FAU safety.
- Gradient Scan , Raster scan, ..

Edge Side Coupling

- A dedicated algorithm has been developed for side coupling, mostly evaluated in terms of alignment speed and FAU safety.

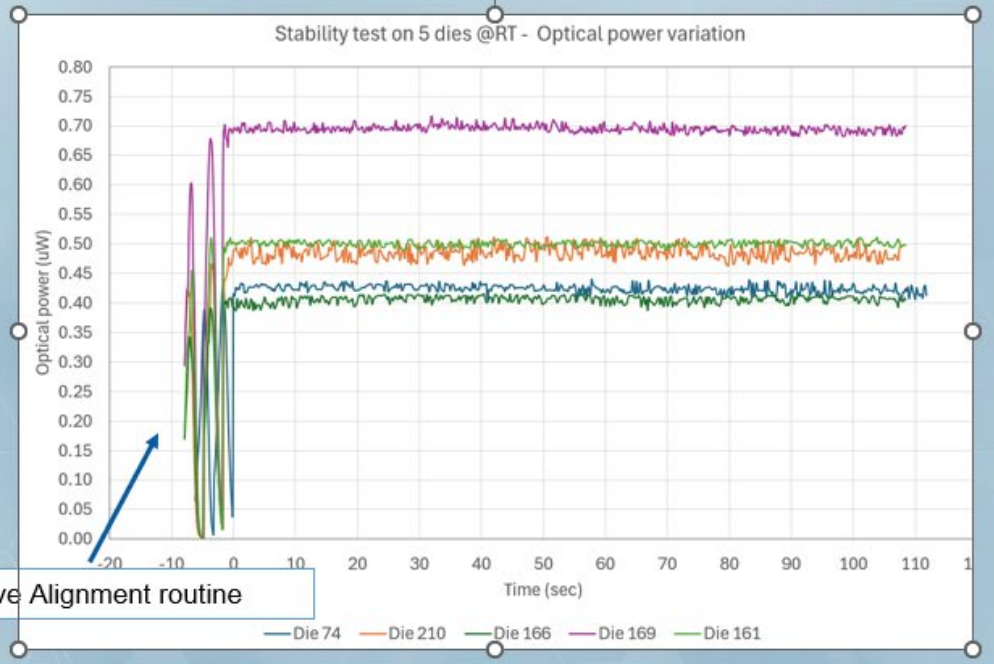
Establish electrical probe alignment and continuity

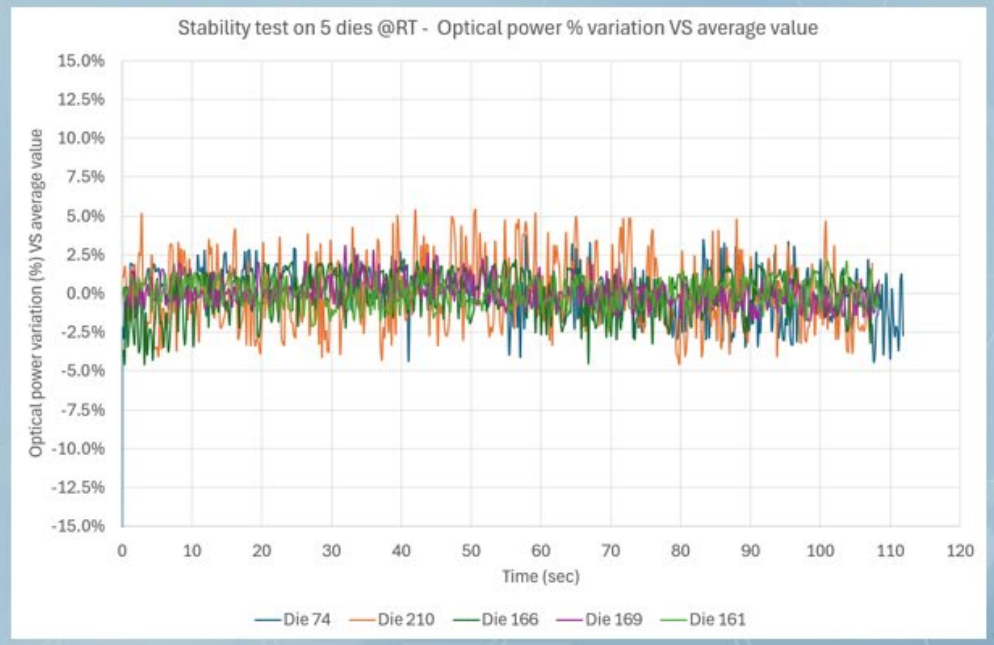
Exploit the power transfer loopback available with DUT with the algorithm to find peak optical power

Test the DUT through ATE electro-optical instrumentation, index to next die and active align if required

Stability Test: Bench-level performance

- Technoprobe selected five DUTs to conduct a stability test, measuring the Power meter output over 110 seconds following the Eclipse alignment routine. DUT in contact at OT=80µm. Sampling period = 200msec



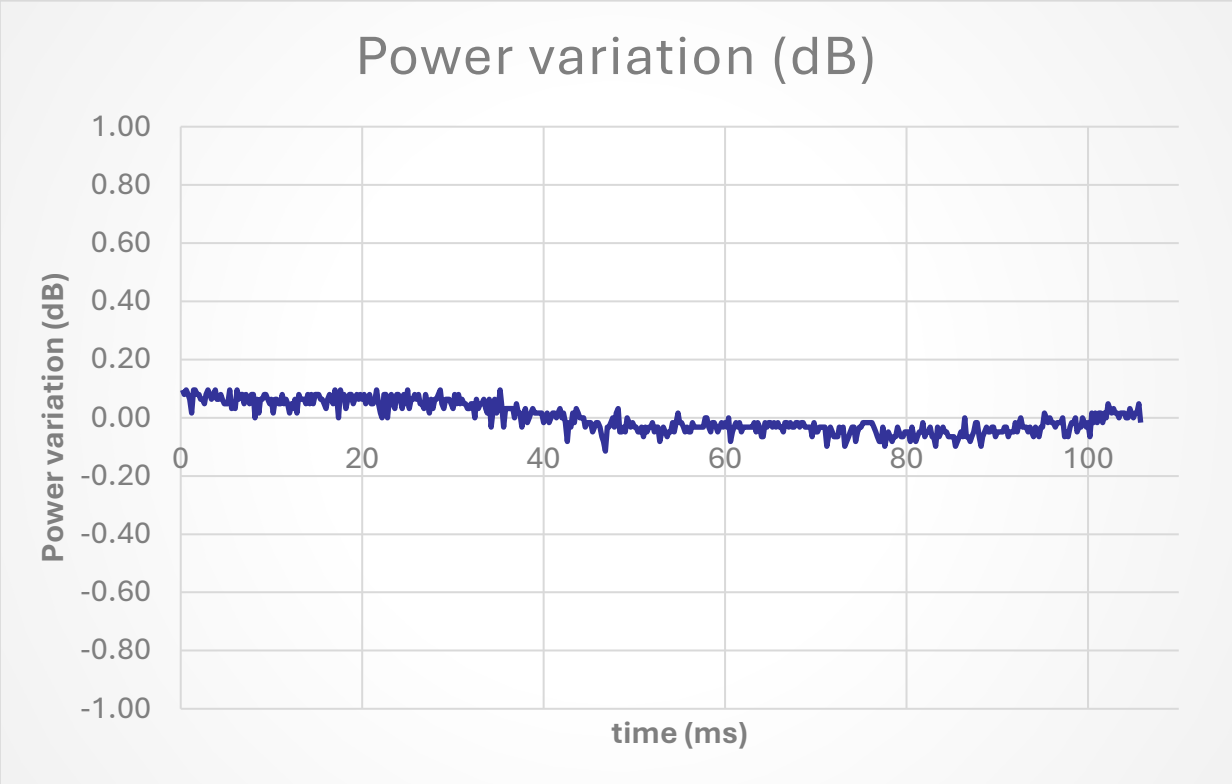


Conclusion: The detected power is stable over time, with only slight variations of about ±0.25 dB around the average.

SWTestAsia 2025: Walter Contrata and Alessia Galli

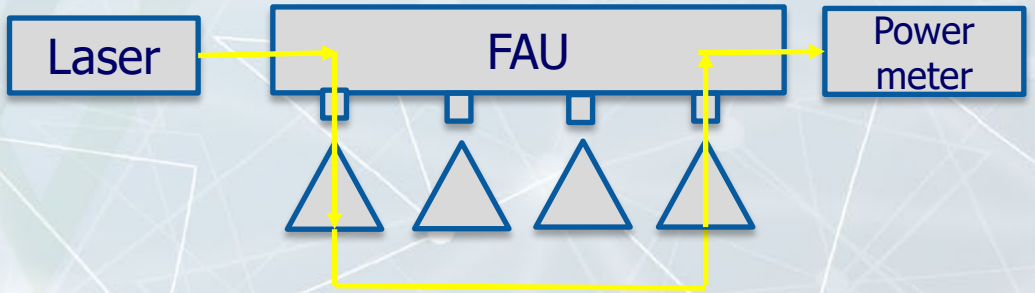
Stability Test: Bench-level performance

- The same test was repeated in the same environment but using **FAU #2,** featuring a mode field diameter (MFD) better tuned to the device under test (DUT) .
- The results showed a significant improvement in stability data, with variation of ± 0.1 dB around the average value.



Setup Information:

- Optical Path: Complete loopback involving two Grating Couplers:



Stability test

- Sampling rate: 200ms
- Total time: 100 s
- Total Power variation : 0.2 dB
- Power variation/GC : 0.1 dB

Teradyne Photon 100 provides a turnkey solution for silicon photonics test

Teradyne UltraFLEXplus enables Opto-electric Silicon PhotonicTesting at Scale

Photon 100

Integrated optical instruments: laser sources, optical power meters, signal conditioning

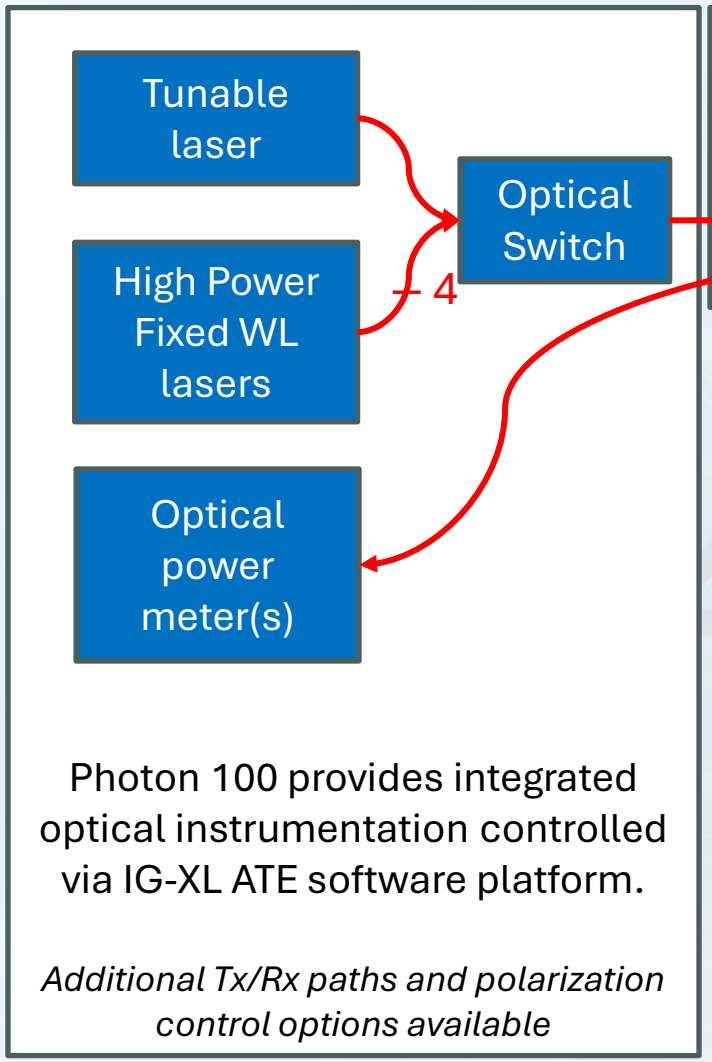
Scalable optical fiber count with calibrated performance at the FAU

Digital: UltraPin 2200

Power Management: UltraVI264

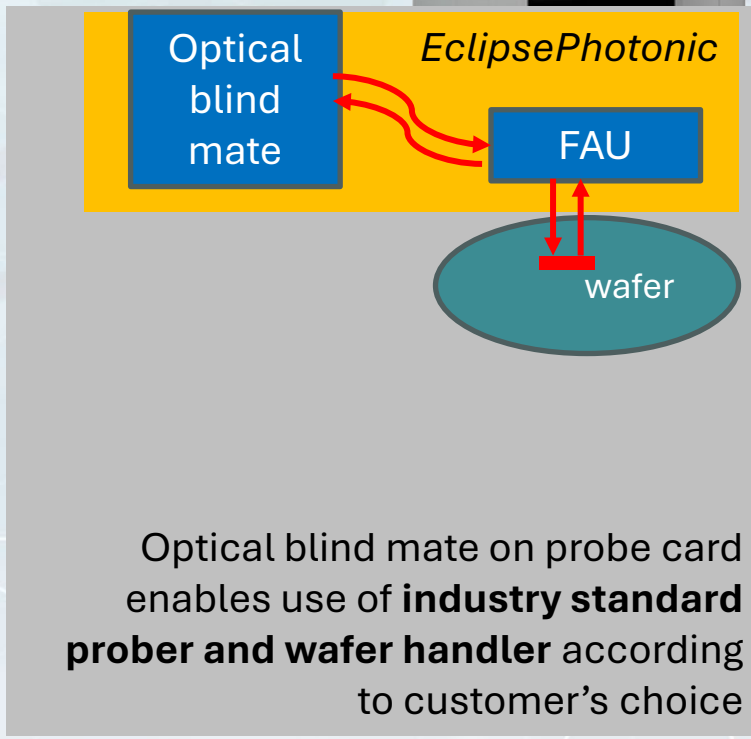
Full integration with IG-XL Software Platform

A fully integrated, easily deployable, silicon photonics ATE solution

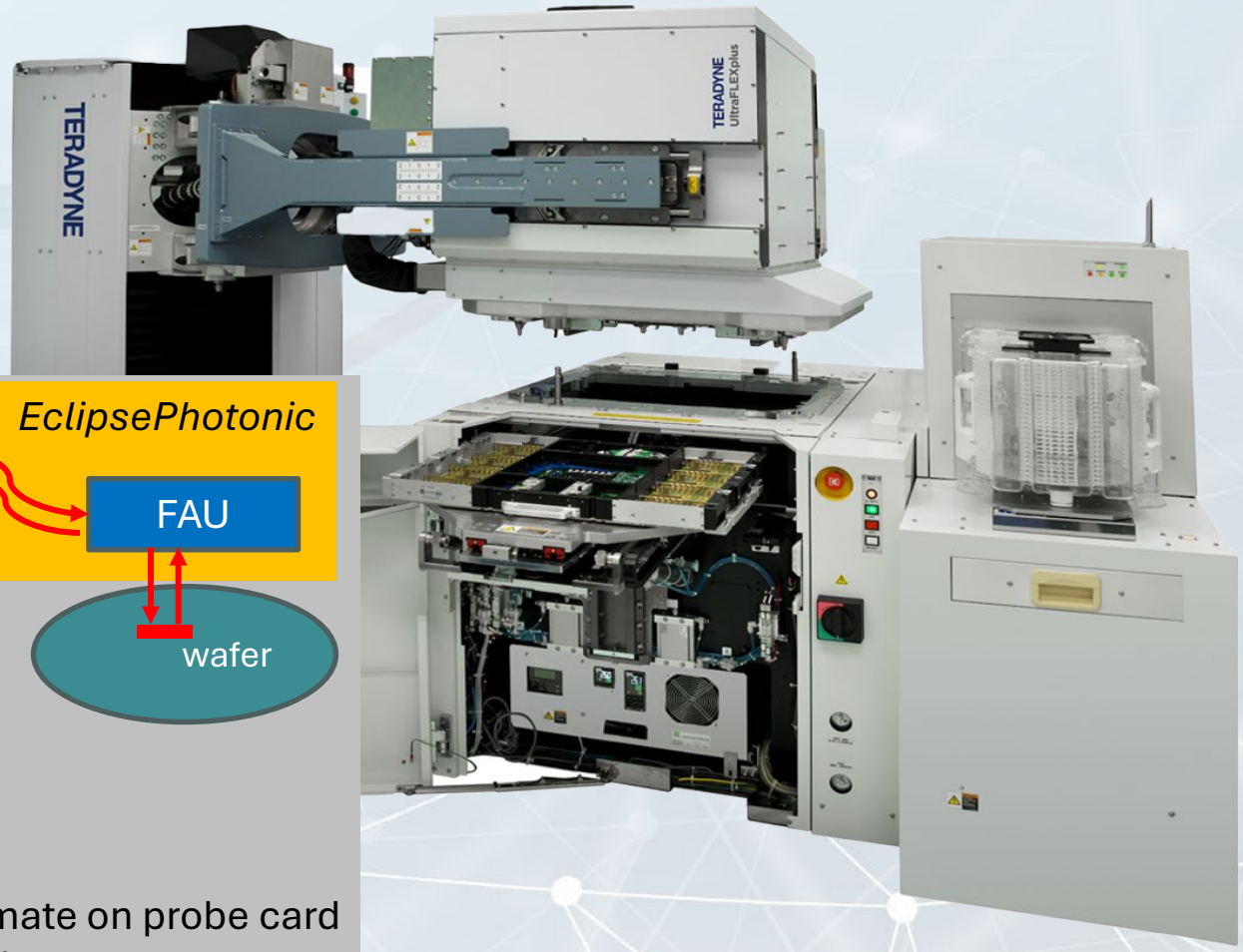


Photon 100 provides integrated optical instrumentation controlled via IG-XL ATE software platform.

Additional Tx/Rx paths and polarization control options available

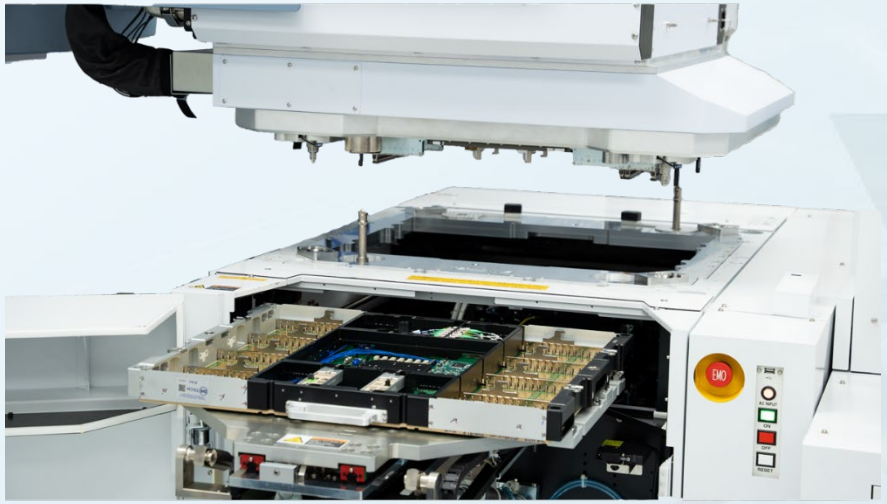


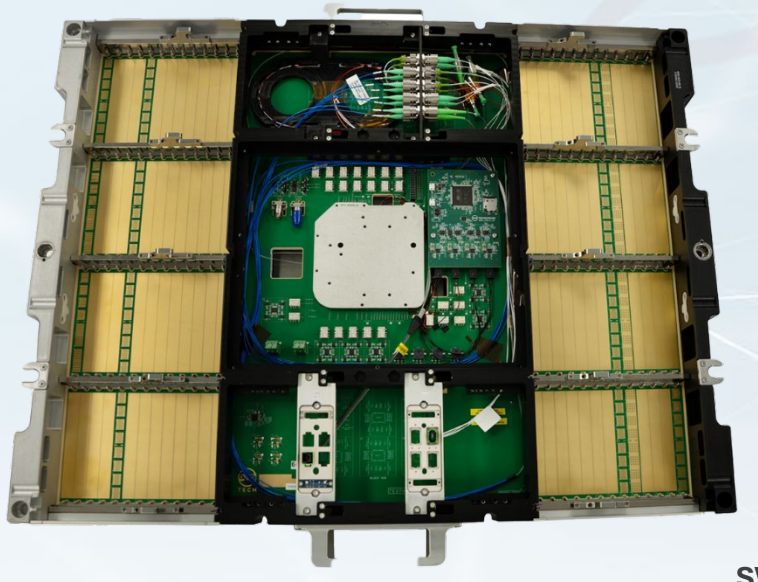
Optical blind mate on probe card enables use of **industry standard prober and wafer handler** according to customer's choice



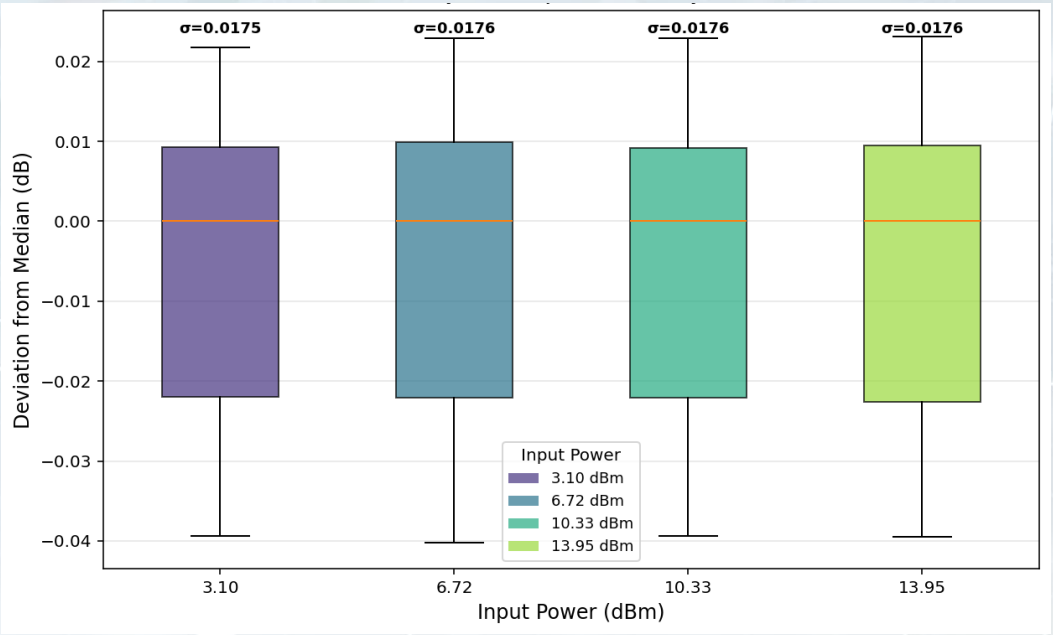
Self-contained modular approach ensures compatibility across OSATs and foundries

Repeatable optical blind mate enables robust operation

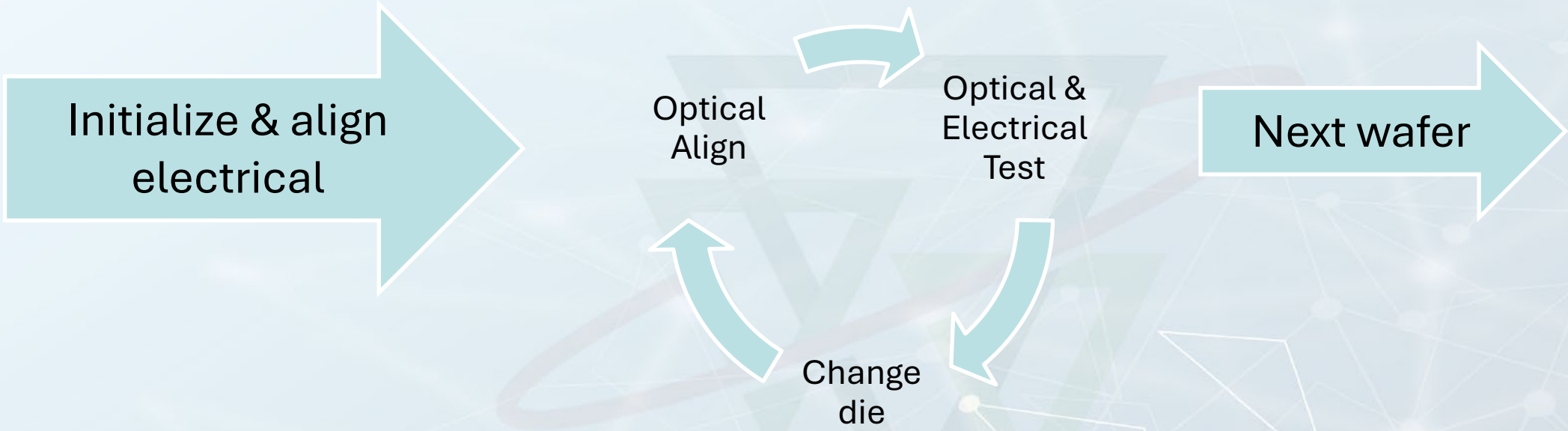




- Industry standard optical connectors are integrated into the test head and probe card
- Measurement across 100 cycles with a fiber loopback confirms consistent optical performance with σ = 0.0175 dB at 1310 nm (±3σ = 0.0525 dB)



Fully automated test flow

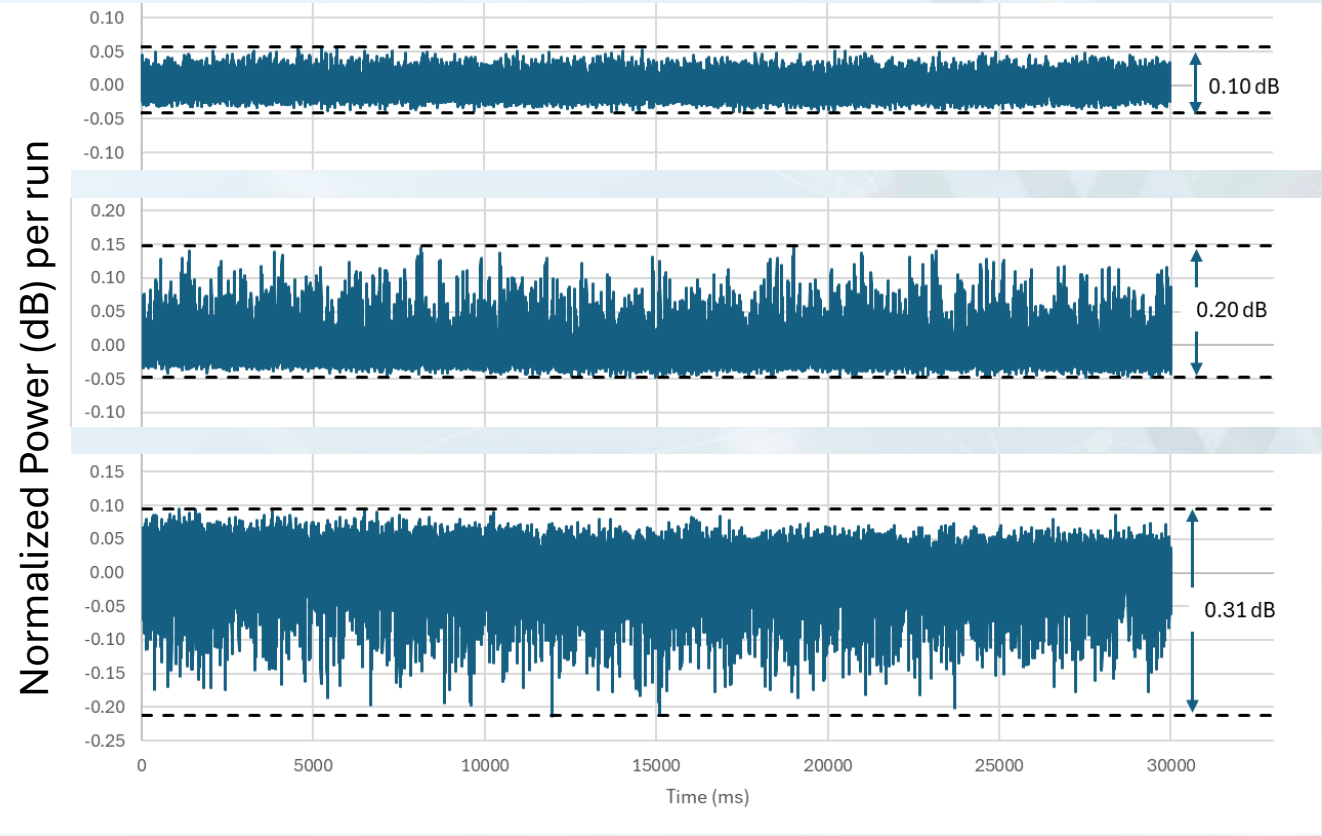


Initialization of the system for electrical alignment follows standard ATE protocols
Optical alignment occurs once the electrical initialization is complete

- Tester provides 5V power supply to probe card daughter board
- SPI commands to control Eclipse Photonic are sent through the support board

Stability Test: ATE-level performance – single die

Optical stability was measured at wafer level using the UltraFLEXplus with Photon 100
Loopback power was measured over 30 s with 1 ms sampling rate, 1 ms integration time

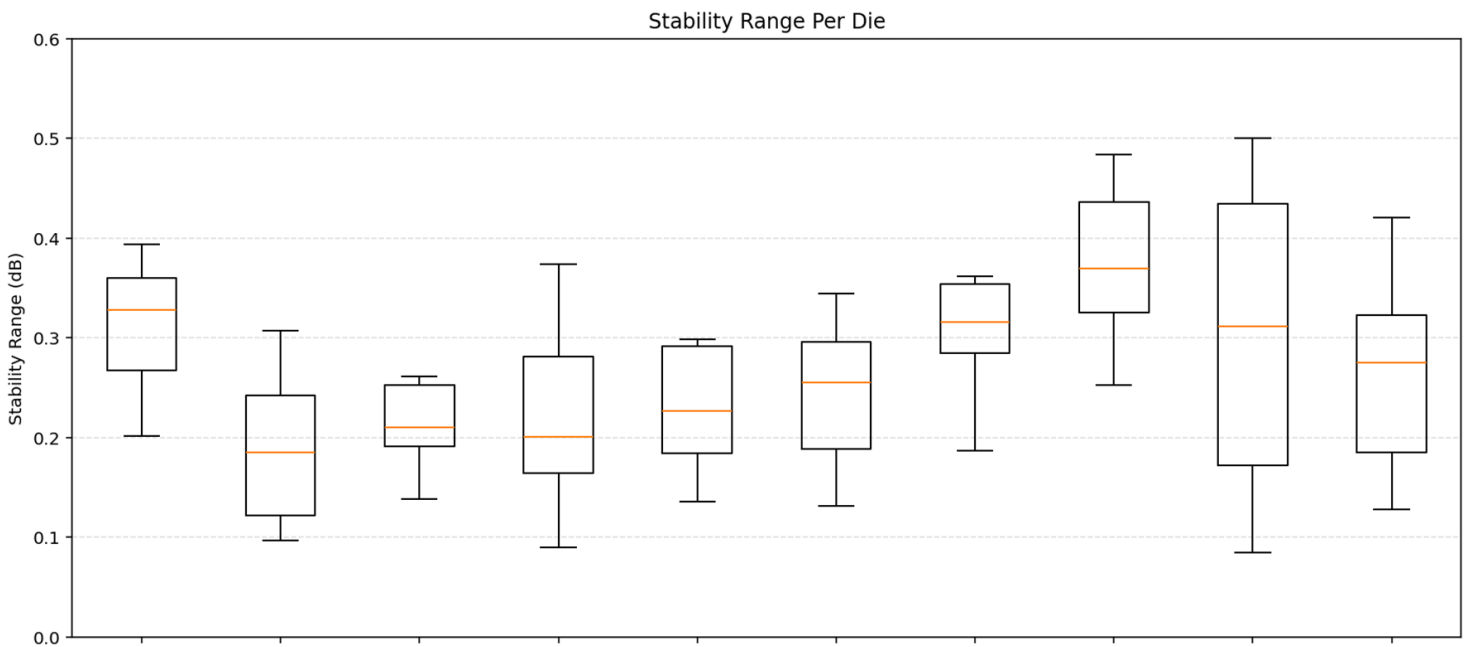


Example results shown for 1 die, 3 runs:

- Each trace represents a discrete alignment event
- Power variation range as low as only 0.1 dB is observed over the 30 s sampling period
- Other runs show a slightly higher range of power levels

Stability Test: ATE-level performance – multiple die

Optical stability was measured at wafer level on 10 die, 10 times each using the UltraFLEXplus with Photon 100
Loopback power was measured over 30 s with 1 ms sampling rate, 1 ms integration time.
Stability Range is calculated as Max Power – Min Power over the 30s measurement period



Each box plot represents repeat measurements on a single die

- Best runs exhibit stability with <0.1 dB net power variation
- Optical power across multiple die is stable to within 0.5 dB, comparable to the ± 0.25 dB reported at bench level with the same wafer and FAU #1

Conclusions:

- Optical stability with ATE is comparable to or better than lab data
- Levers are available for further improvement

Automated Test

- Automated test is conducted according to customer specific need for KGD testing
- Example photonic performance parameters evaluated include:

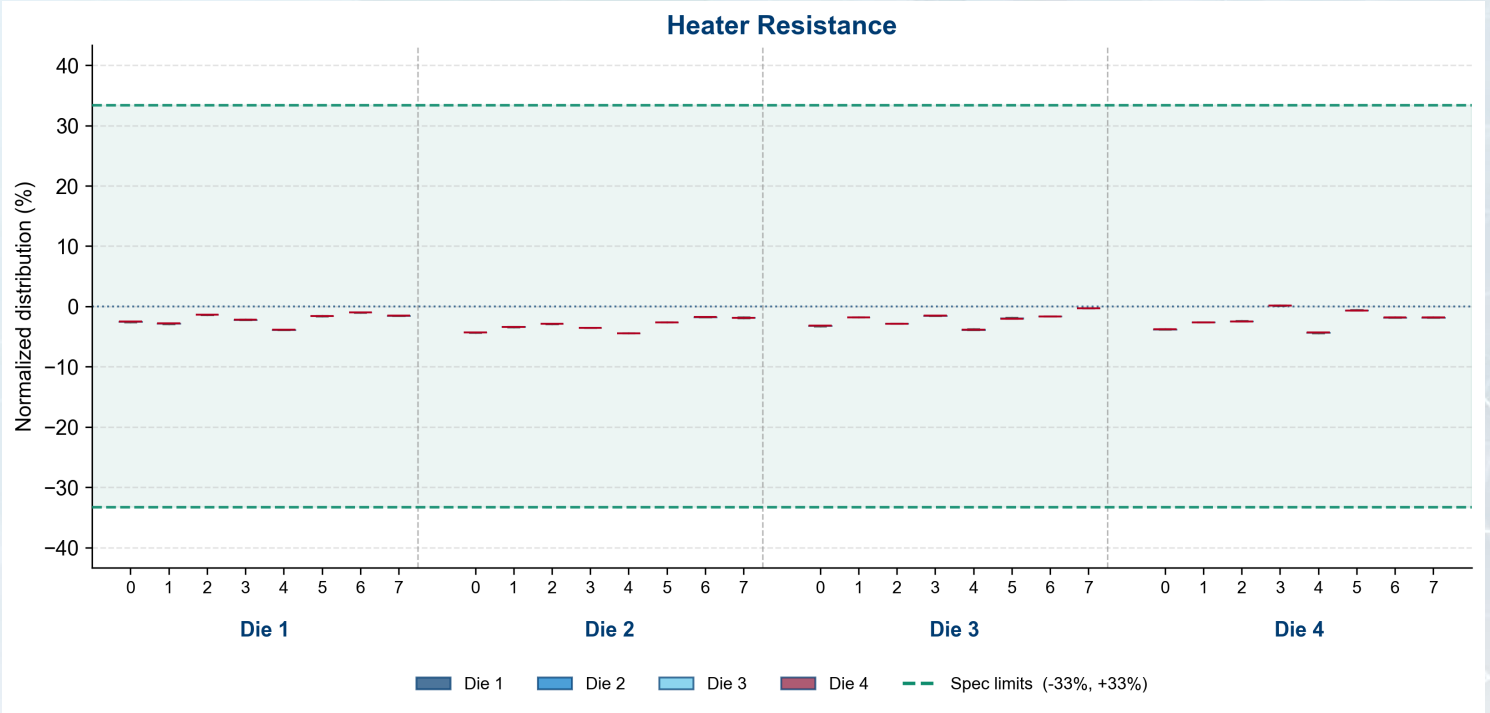
Test	Parallel* vs Sequential	Concurrent**
Insertion Loss	-	-
PD Dark Current	Parallel	-
Heater Resistance (Ω)	Parallel	Yes
V_π (V)	Parallel	-
Extinction Ratio (dB)	Parallel	Calculated from V_π sweep
Termination Resistance (Ω)	Parallel	Yes

*Parallel ≡ all channels can be tested simultaneously
**Concurrent ≡ multiple tests can be run at the same time

- Test time per die for customer selected tests has been improved by approximately a factor of two compared to bench-level tests, before additional optimization.

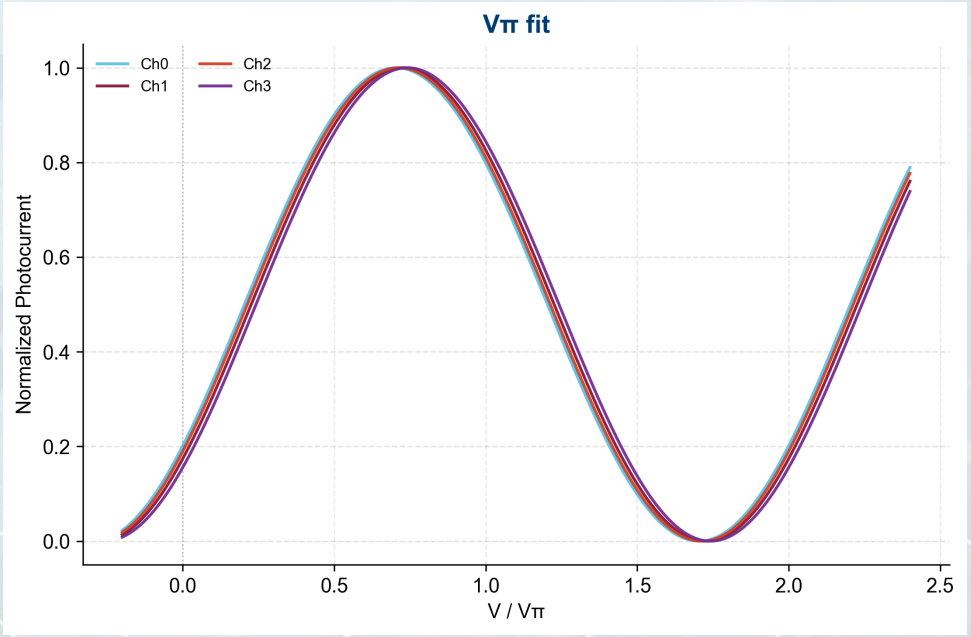
Modulator performance – Heater resistance

- Heater resistance determines the thermal tuning operating point for every Mach-Zehnder interferometer
- To measure R = V/I, the tester forces a known current through the on-die heater and measures the voltage drop



Modulator performance – measurement of Vπ

- V_π is the voltage swing required to shift the modulator's optical output from peak to null transmission; the headline figure of merit for modulator drive efficiency
- ATE successfully measures and reports V_π per die and per channel within die



Summary

- EclipsePhotonic probing has been successfully integrated into ATE using the Teradyne UltraFLEXplus with Photon 100
- Optical blind mate integrated into the test head and probe card enables fully automated operation
- Integrated MCU on the probe card enables rapid optical alignment for efficient KGD screening at first test insertion
- System provides coupling consistency and stability appropriate for design
- This solution can scale with the volume manufacturing needs supporting AI growth

Future work

- Move additional degrees of freedom from lab to full implementation on ATE, improving optical coupling control and increasing range of motion
- Further optimize FAU designs exploring tradeoffs between performance and speed
- Integration of edge-coupled solution with ATE
- Deploy fully integrated systems for high volume test to support industry needs

TERADYNE
Photon 100

Thank you!