From Lab to Line: Enabling Efficient PIC Testing for Mass Production

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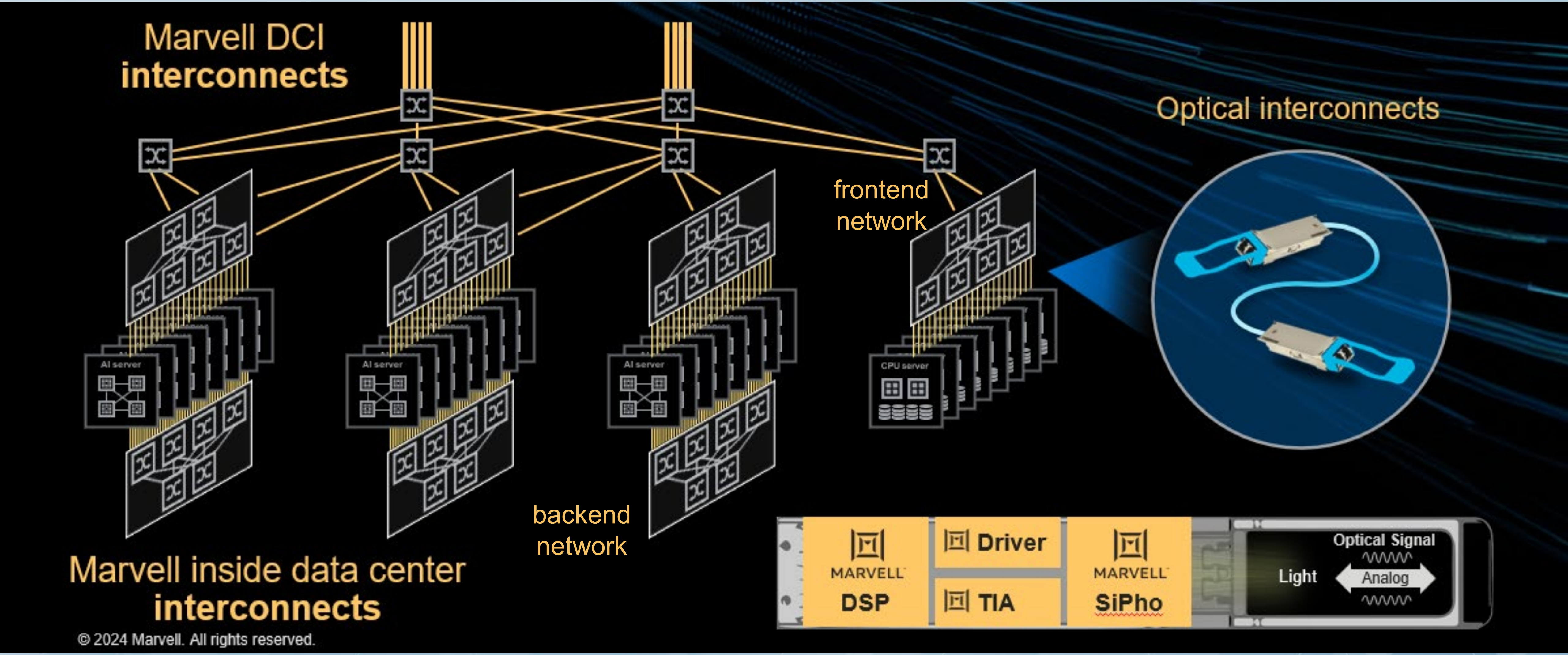
Marvell optical connectivity solutions

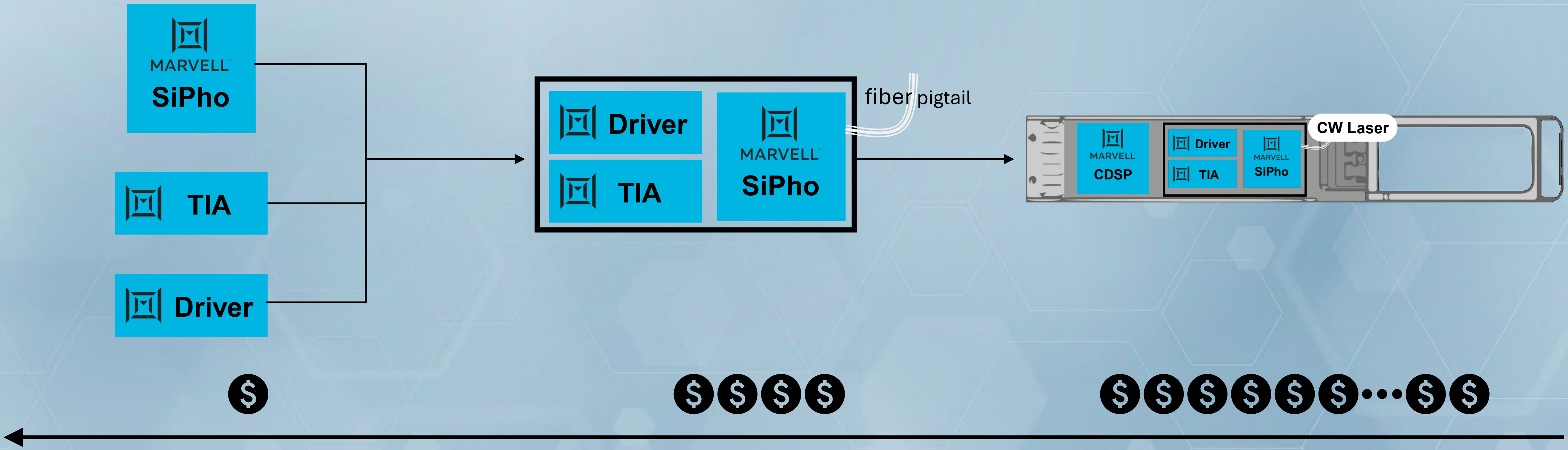


COLORZ 800G ZR silicon photonics module

	CDSP	**Orion™ 5nm:** SerDes, error correction, telemetry, interoperability
128Gbaud Optical Light Engine	Driver	Amplifies electrical signal from DSP to drive modulator
	TIA	(Transimpedance amplifier) Amplifies electrical signal from detector
	SiPho	(Silicon Photonics) converts electrical signal to light and vice versa
	CW Laser	Continuous wave (CW) laser source

Need to shift yield to the left

Wafer-level KGD | **Optical light engine** | **Optical module**



Low(er) yield scrap cost

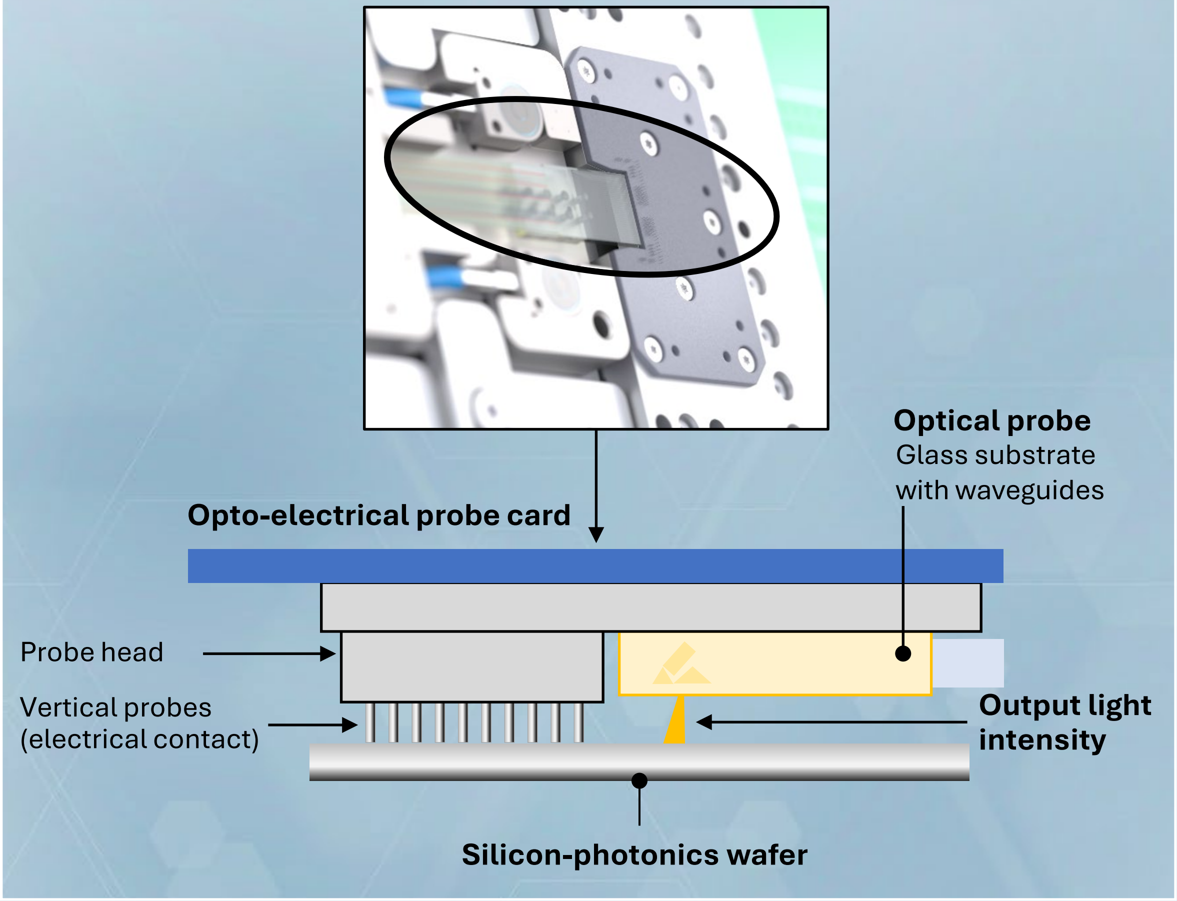
High test capacity

High yield scrap cost

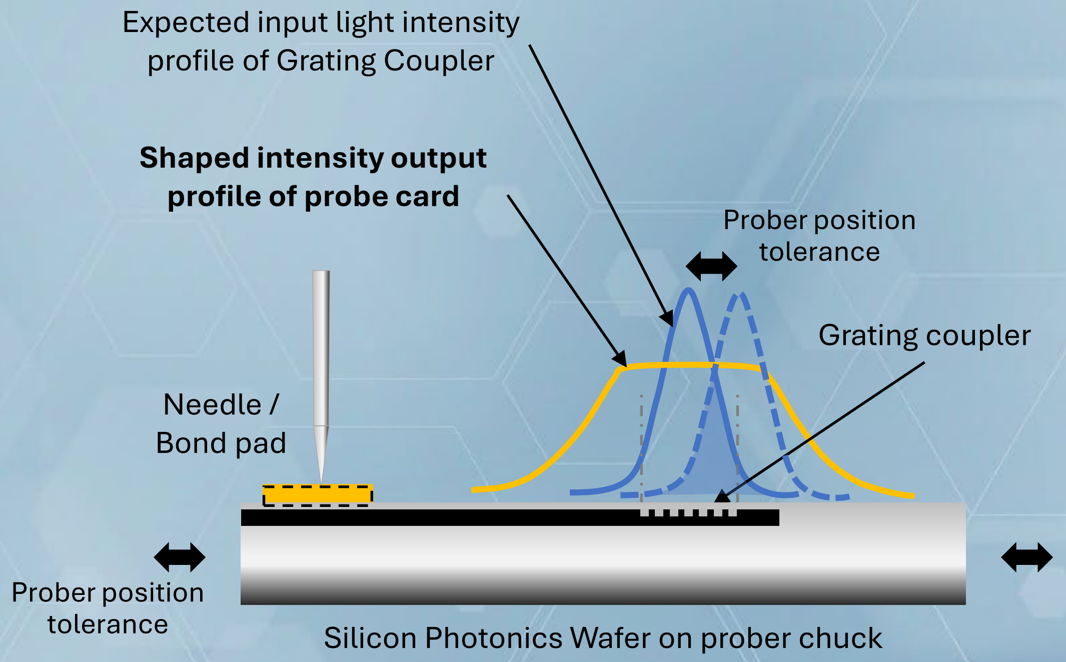
Lower test capacity

UFO probecard – working principle

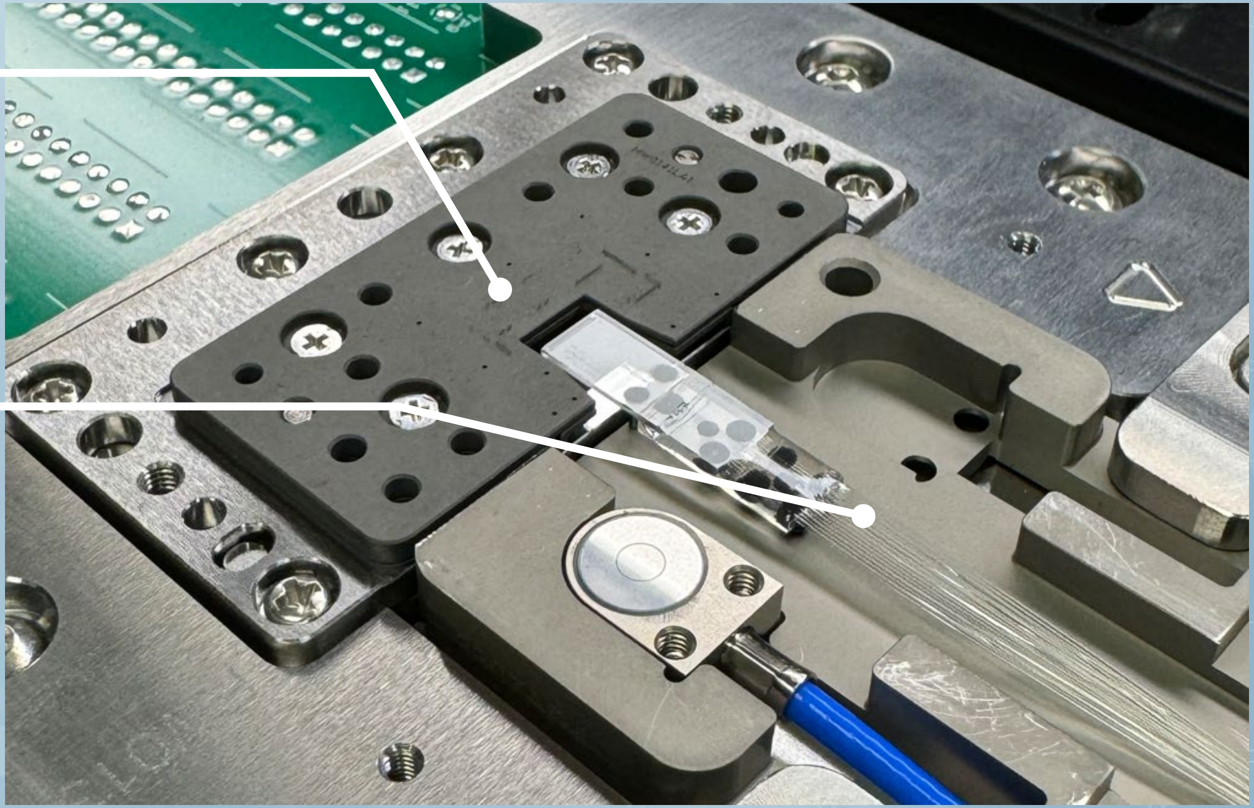
Alignment insensitive test solution for PIC wafer-level test



Optical concept compensates prober alignment tolerances

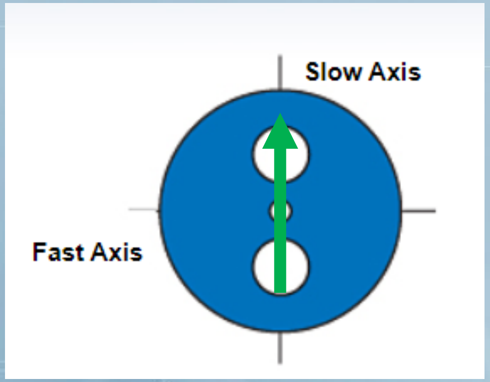


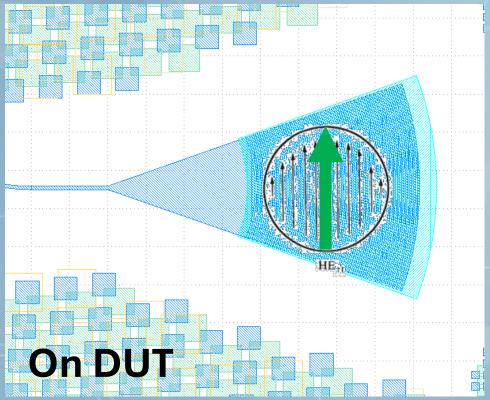
What’s new in this UFO probecard?



Vertical Pin Probe Head with lower support cutout. Co-developed with probe partners (previous: cantilever)

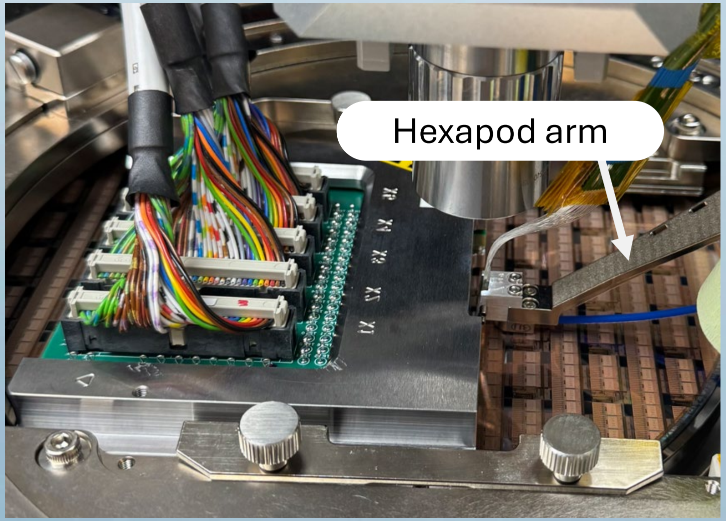
Polarization Maintaining Fibers. No polarization controller or polarization optimization required.
(previous: single-mode fiber)



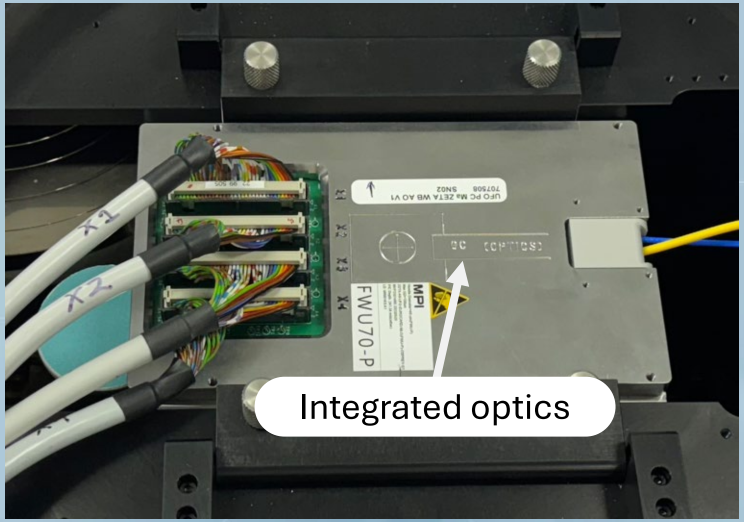


Lab versus line setup

Engineer and technician setup and alignment

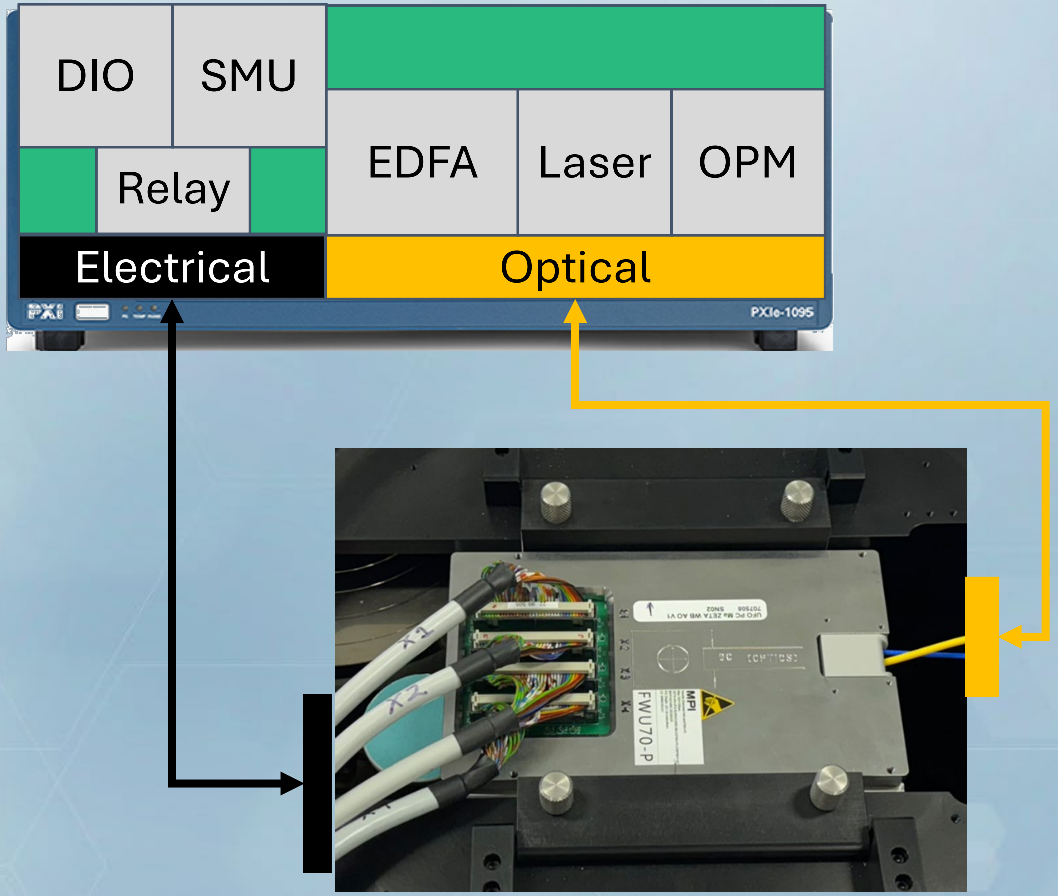


Plug & play deployment, test engineer did not travel



Engineering lab		Production line
Marvell Engineering Lab	**Test location**	US-based OSAT
Active, separate hexapod optics	**Optical alignment**	Passive, integrated probecard optics
SMF/PMF mode	**Optical mode**	Expanded mode
MPI Engineering Prober	**Prober**	Accretech UF200
Engineering PXI	**Tester**	Production PXI

Production line test setup



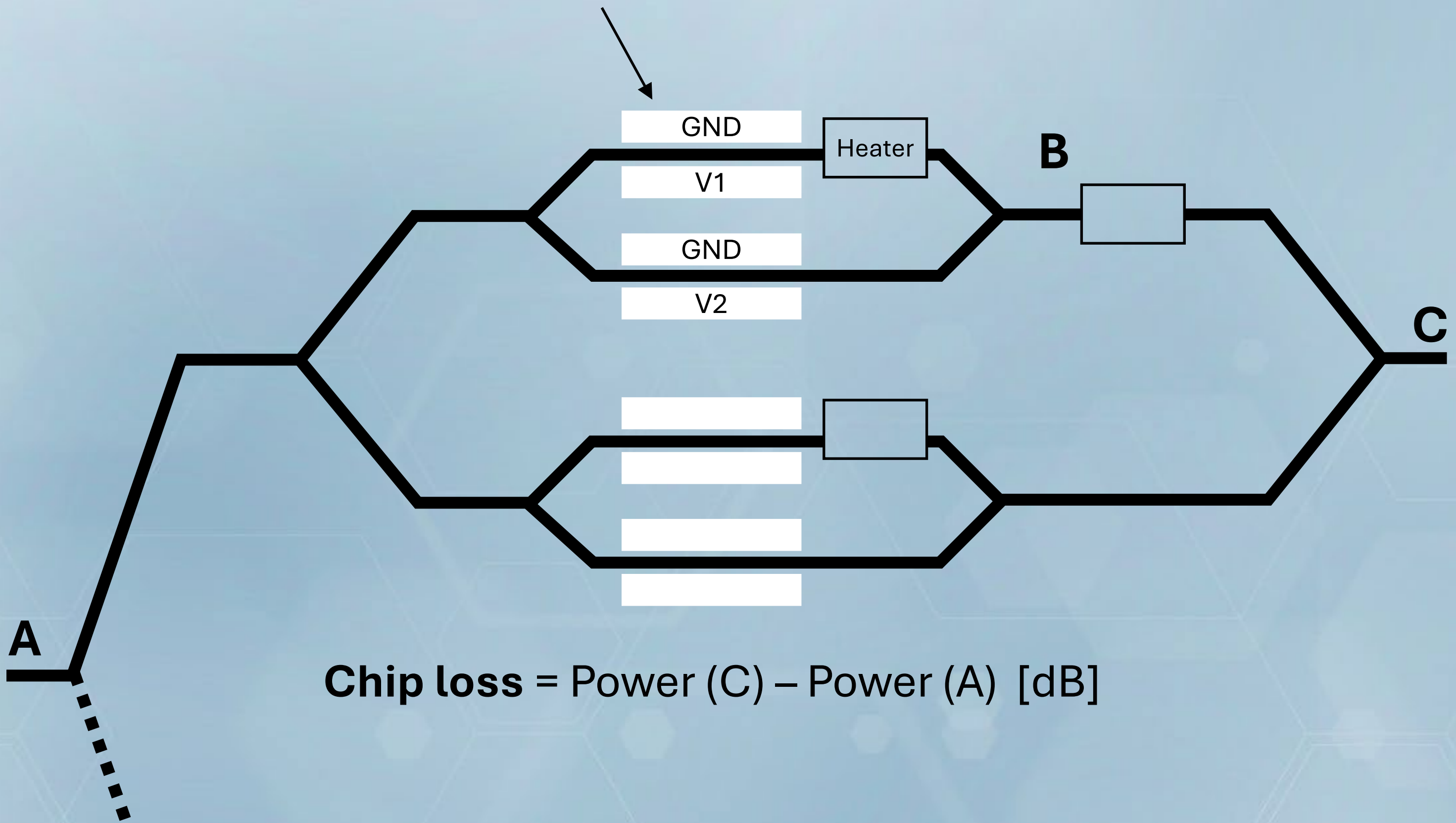
UF200 prober

- Relatively low pin-count device – only 119 non-GND electrical signals
- PXI is highly customizable – can mix and match DC, optical and RF instruments
- Lower CAPEX and maintenance costs
- Leverages existing Marvell PXI infrastructure

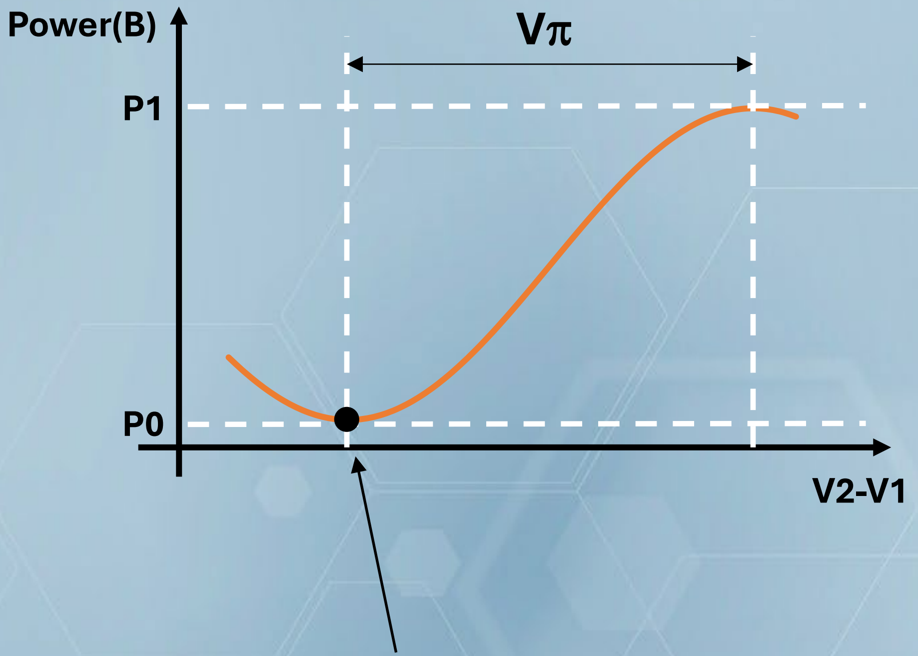
Measurements definition

Vπ = halfwave voltage of Mach-Zehnder modulator [V]

Extinction Ratio (ER) = 10*log10(P1/P0) [dB]



Chip loss = Power (C) – Power (A) [dB]

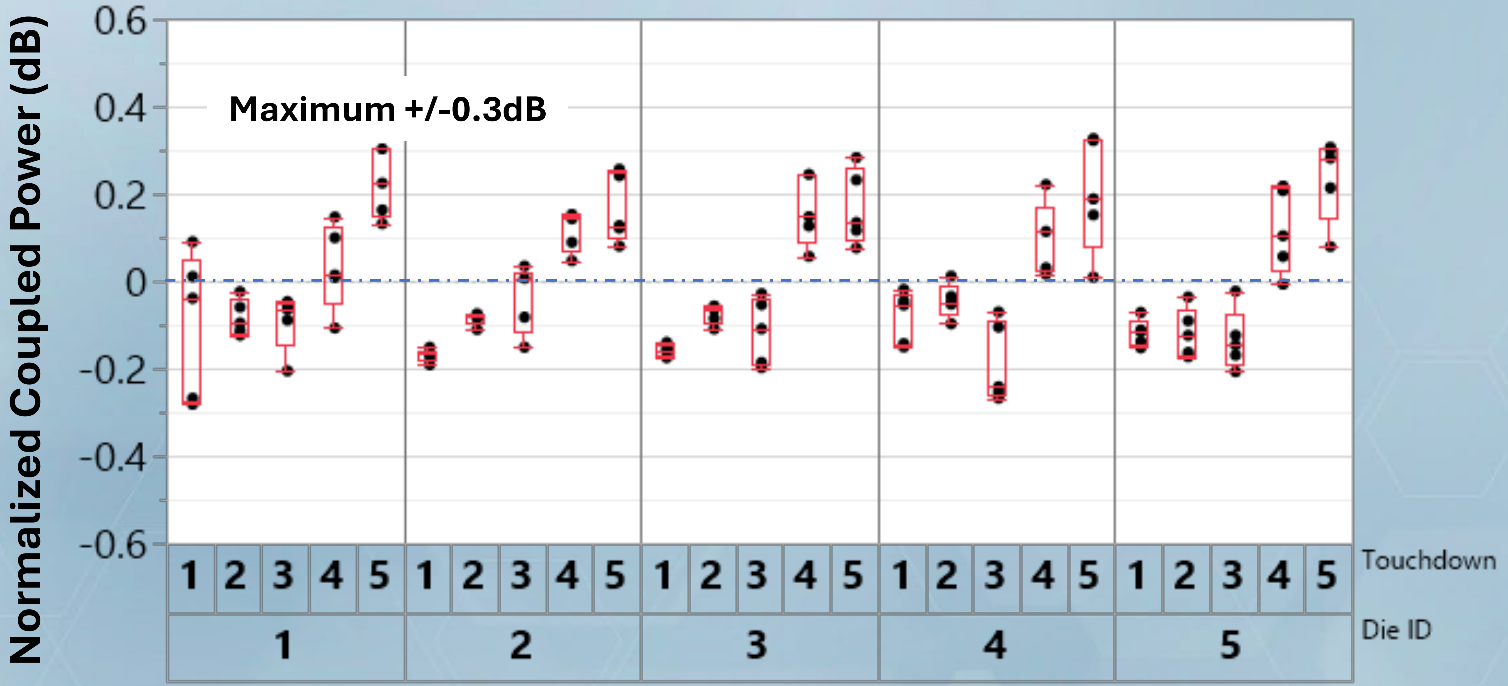


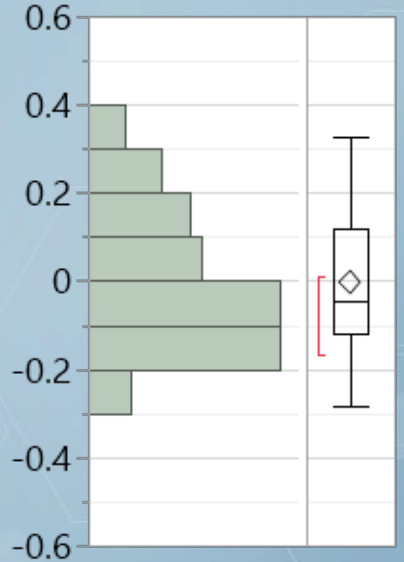
Bias point = Phase of null bias from zero heater power [deg]

Phase tuning rate = Heater Power for 2π phase shift [mW]

Production line: Optical coupling

Repeatability: 5 die x 5 touchdowns/die x 5 runs/touchdown

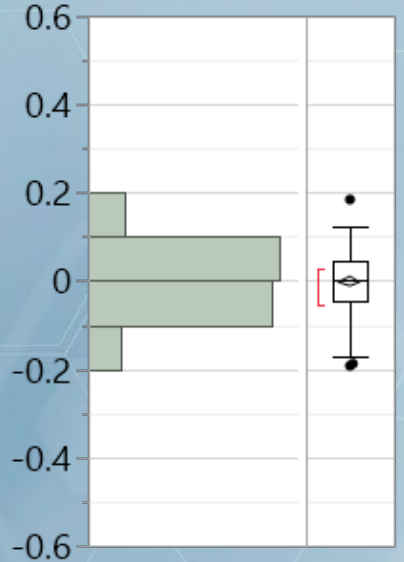




By die

σ_{total} = 0.15dB

→ $\sigma_{touchdown}$ = 0.13dB



Within touchdown

σ_{meas} = 0.07dB

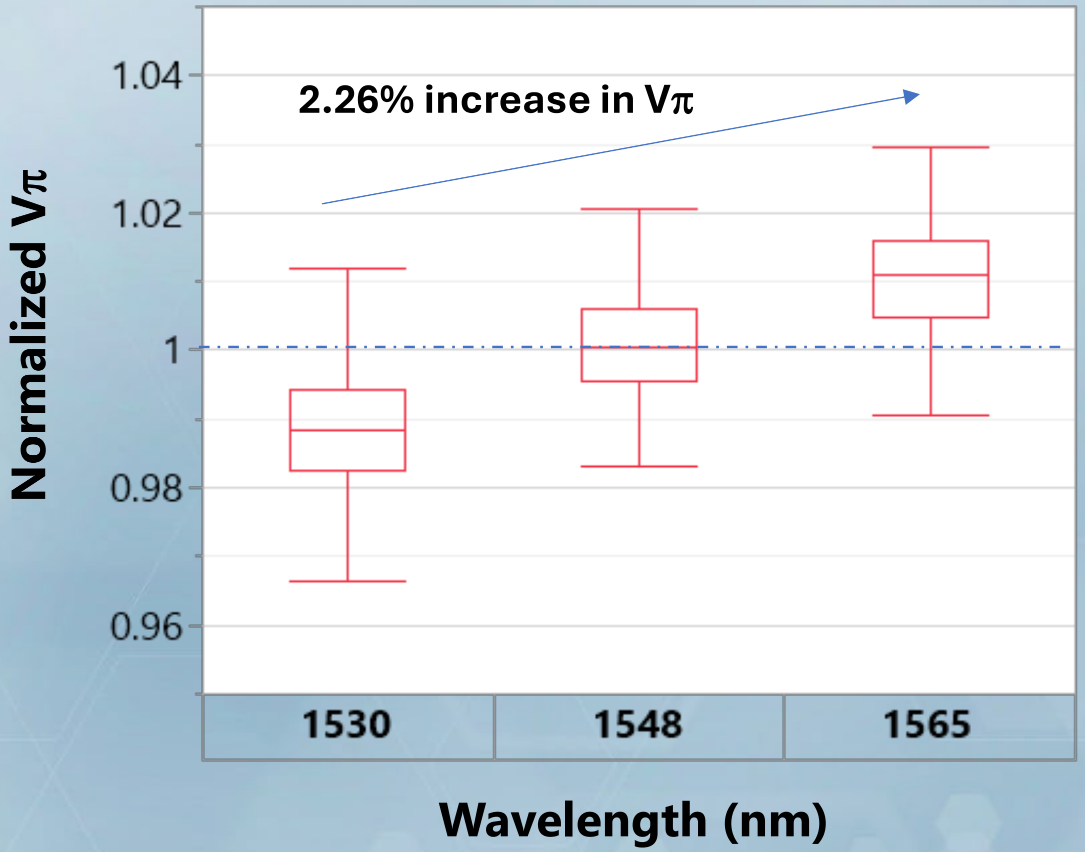
Good coupling repeatability on UF200 prober: Similar to published results

Optical repeatability summary

	Engineering lab: Hexapod	Production line: Jenoptik probecard		
Parameter	σ_{total}	σ_{total}	σ_{meas}	$\sigma_{touchdown}$
Vπ	0.78%	0.76%	0.55%	0.52%
Chip loss	0.054 dB	0.030 dB	0.019 dB	0.023 dB
Bias point	1.80°	1.50°	0.41°	1.44°
Phase tuning rate	0.50%	0.29%	0.14%	0.25%

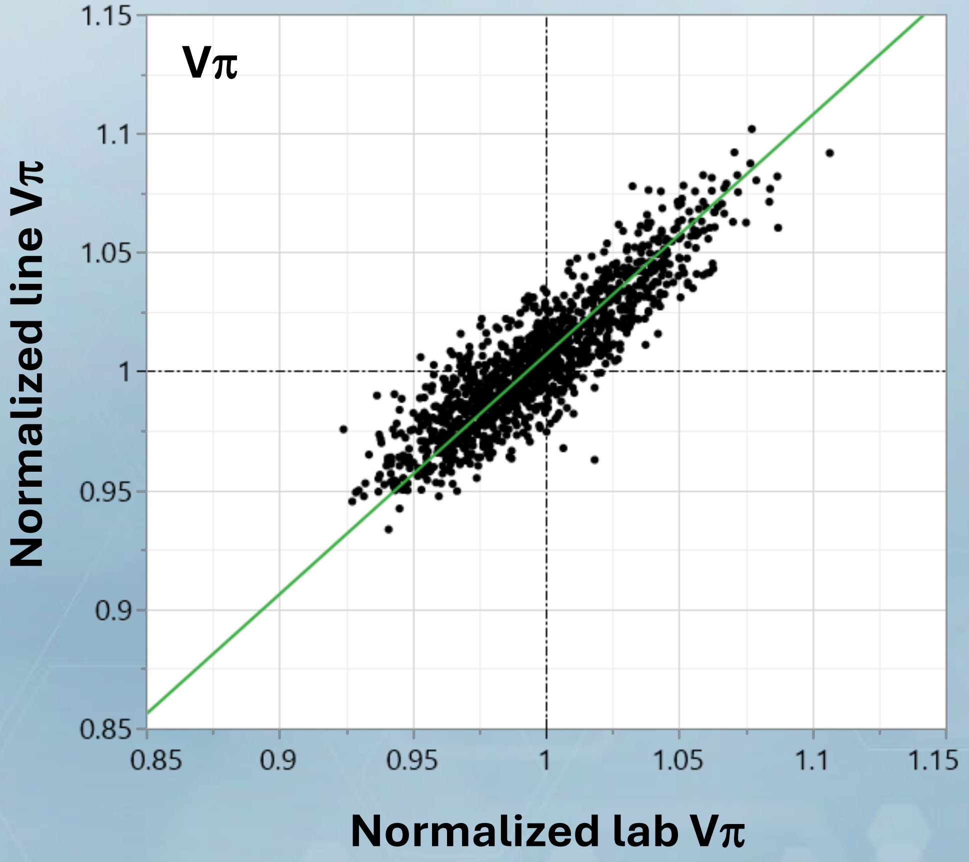
Excellent measurement repeatability for key parameters versus active alignment

Production line: Vπ versus wavelength



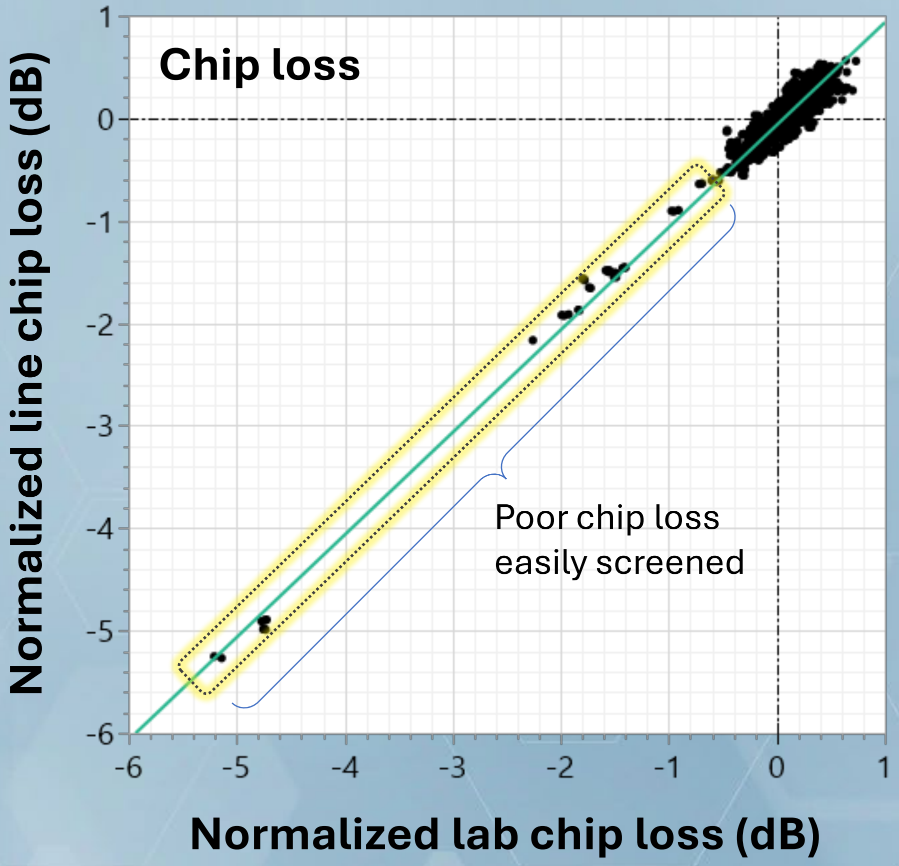
- Clearly observe expected Vπ shift with wavelength due to wavelength scaling versus a fixed-length modulator
- Closely matches expected 2.29% theoretical increase from 1530 to 1565nm

Site correlation: Vπ and chip loss



Absolute mean value of Vπ Δ = 0.68%

Normalized Vπ RMS Error to fit = 1.38%



Absolute mean value of loss Δ = 0.06 dB

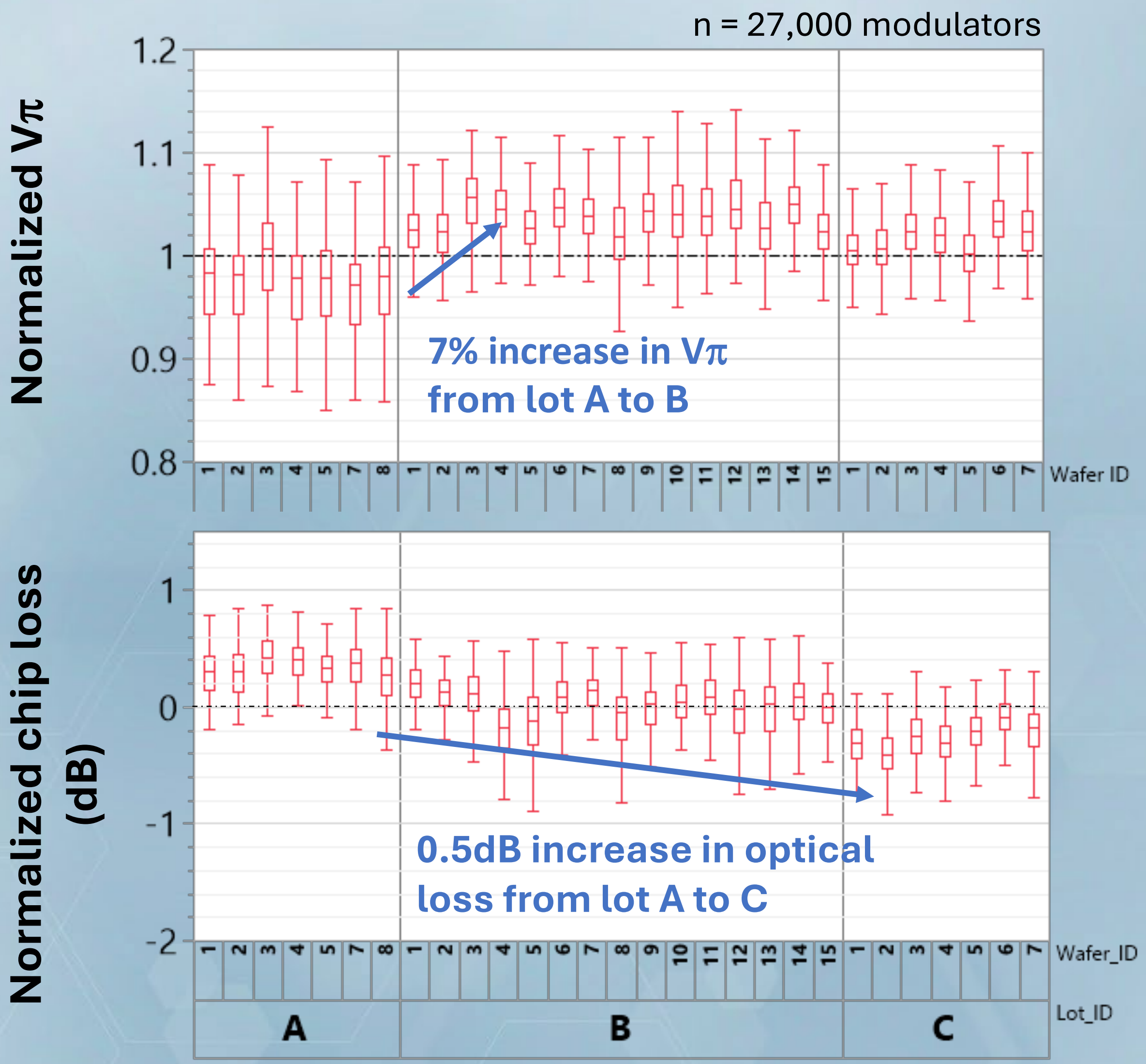
Normalized loss RMS Error to fit = 0.10 dB

Optical site correlation summary

	Engineering lab repeatability	Production line repeatability	Engineering lab to production line correlation		
Parameter	σ_{total}	σ_{total}	**RMSE**	**Absolute mean Δ**	R^2
$V\pi$	0.78%	0.76%	1.38%	0.68%	0.79
Chip loss	0.054 dB	0.030 dB	0.10 dB	0.063 dB	0.95
ER	-	-	2.1dB	1.0 dB	0.52
Bias point	1.80°	1.50°	5.9°	-	0.99
Phase tuning rate	0.50%	0.29%	0.53%	0.10%	0.92

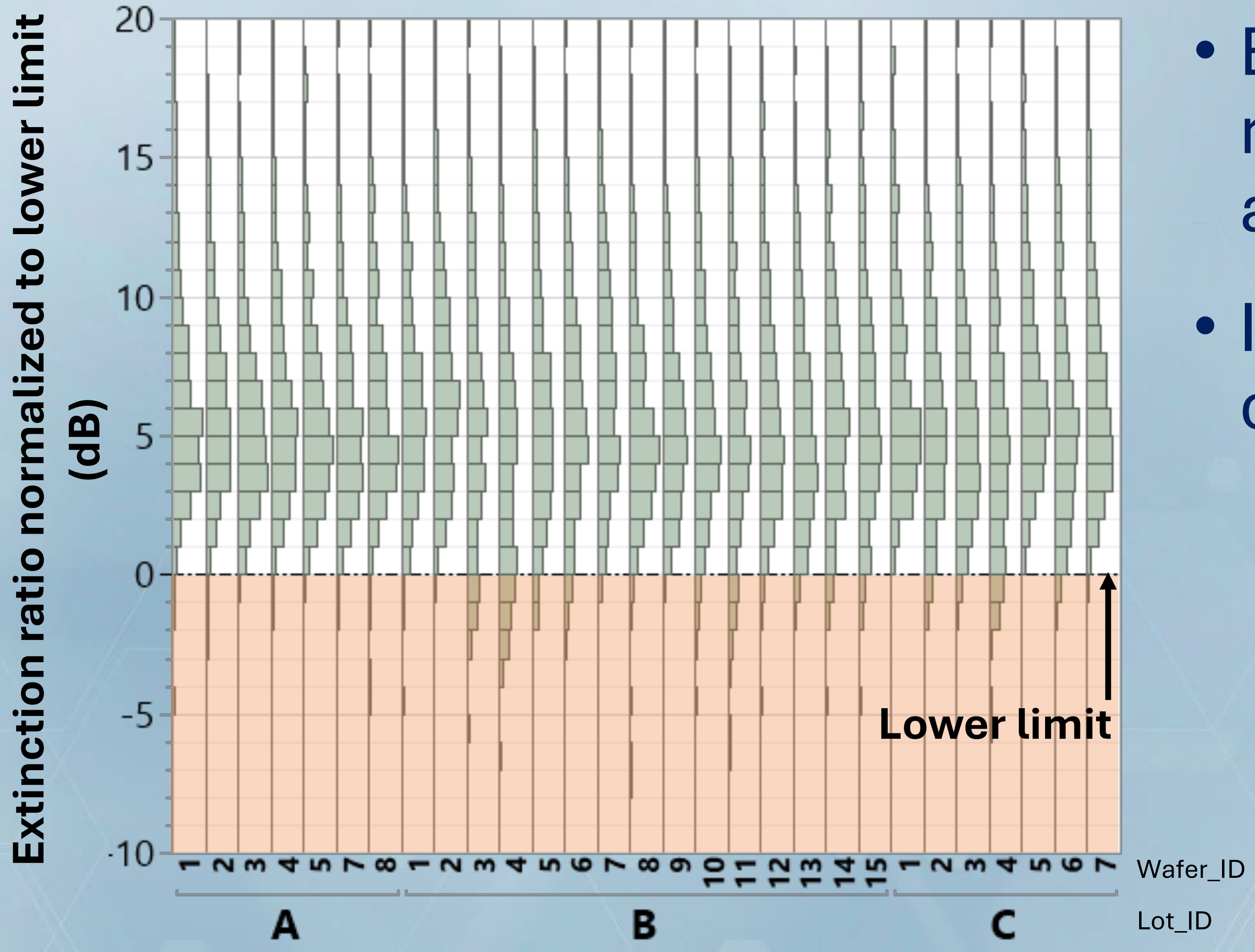
Excellent measurement correlation relative to repeatability between lab and line

Production data: Vπ and chip loss



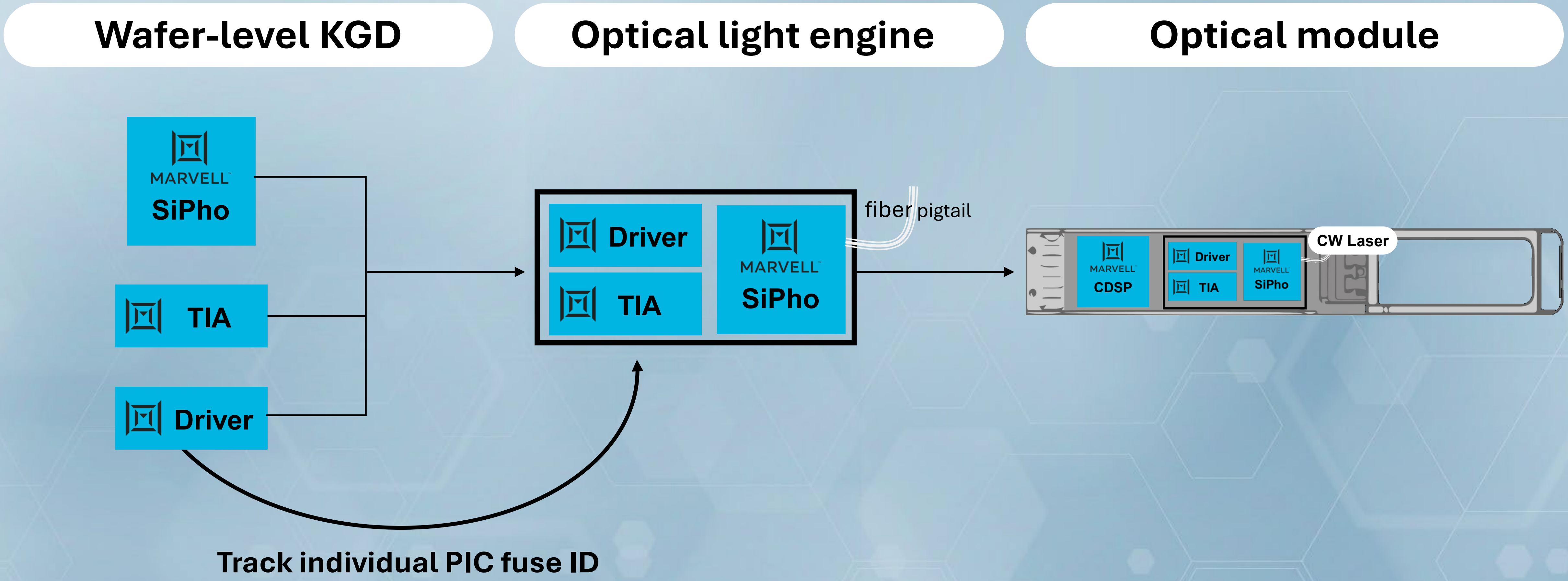
- Clearly characterize Vπ/loss spread and process shifts between different production wafer lots
- Early warning in case of yield crash or maverick lots
- Shorten yield improvement cycle for any process or design changes

Production data: Extinction ratio



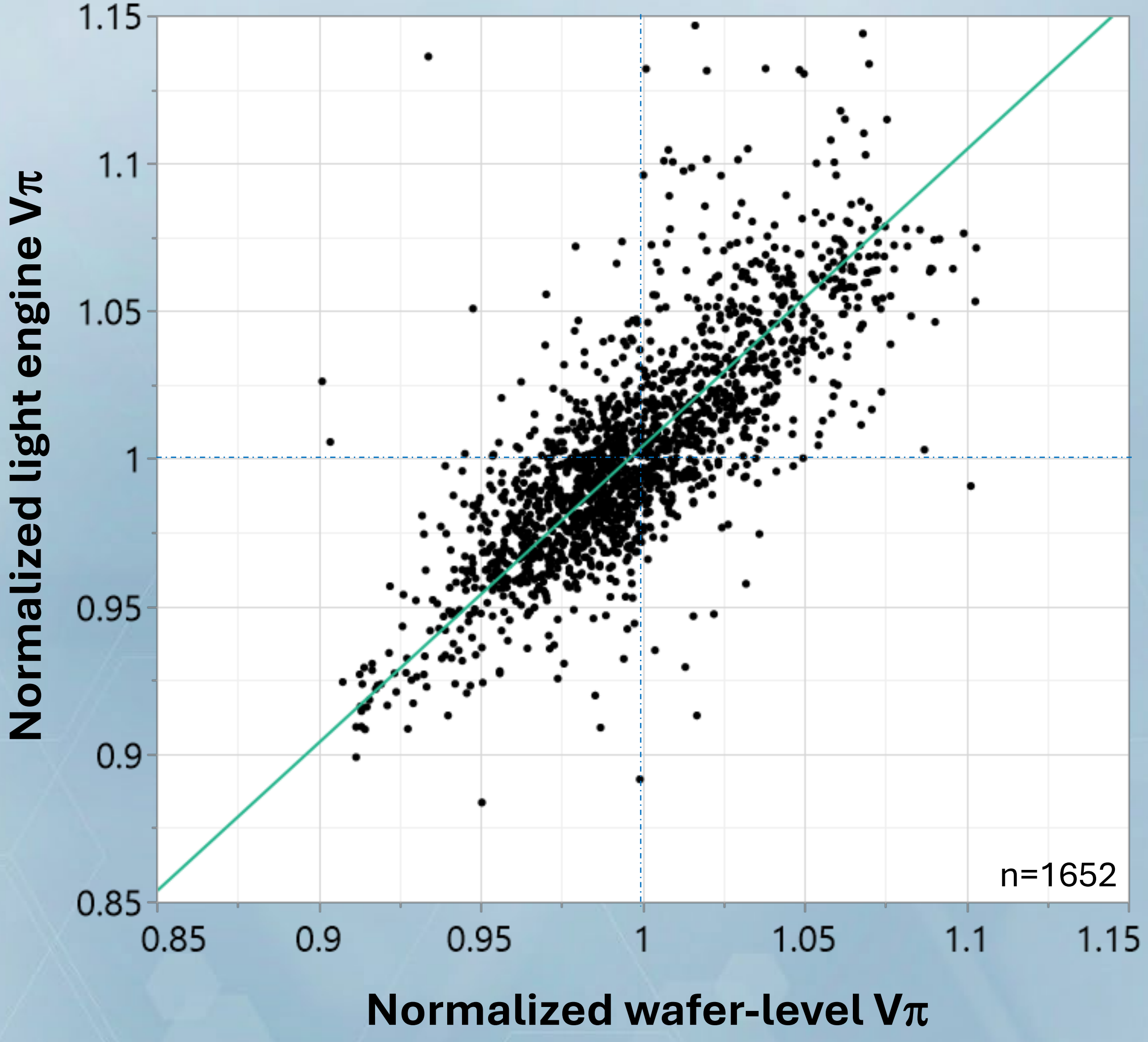
- Eliminate PIC with low extinction ratio before committing TIA, Driver and fiber attach assembly
- Improves final yield on certain optical engine lots by up to 20%

Is there correlation to subsequent assembly?



Track individual PIC fuse ID

Wafer to light engine correlation: Vπ



Parameter	RMSE	Absolute mean ∆	R^2
Lab to line	1.38%	0.68%	0.79
Line to light engine	2.63%	0.44%	0.57

- Wafer-level Vπ measurements predictive of light engine Vπ even after assembly process
- Wafer-level binning used to reduce light engine yield loss

Summary

1. Compared to active alignment, Jenoptik’s monolithic optical probecard has similar measurement repeatability and capability for key PIC optical parameters

2. Excellent measurement correlation between the engineering lab and production line is observed – with plug & play deployment at the OSAT

3. Early warning to wafer-level process shifts and maverick lots shifts yield left to known good die

Future work

1. Large-scale correlation of wafer-level measurements to optical module performance to further shift yield to the left
2. Integrate microwave measurement capability to 67GHz
3. As PICs are rapidly increasing in density/complexity, demonstrate integration of a monolithic optical probecard direct dock solution with a standard ATE tester