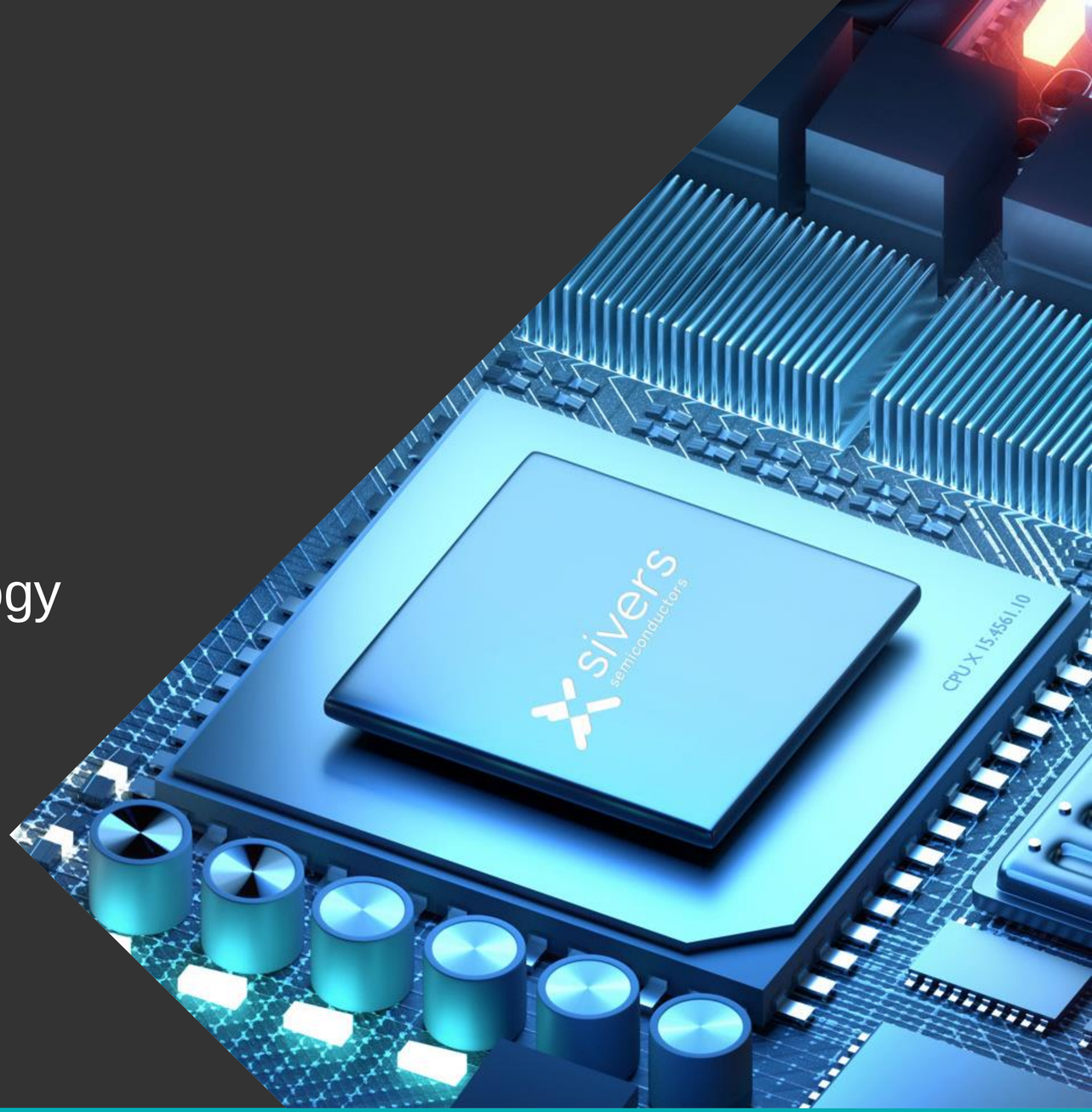
Emerging Semiconductor Trends

Case Study #1 – Fab and end-user co-development

sivers
PHOTONICS

Outline

1. Introduction to Sivers Photonics
2. Sivers InP100 Platform
3. Photonics in AI Networks
4. Advanced DFB Laser Array Technology
5. Summary



About Us

The most advanced supplier of custom III-V semiconductor photonic devices

UK-based design and manufacturing, located in Glasgow, Scotland

100mm wafer fab with capacity of 5,000 wafer starts per year (700m² class 50 facility)

ISO 9001 Certification

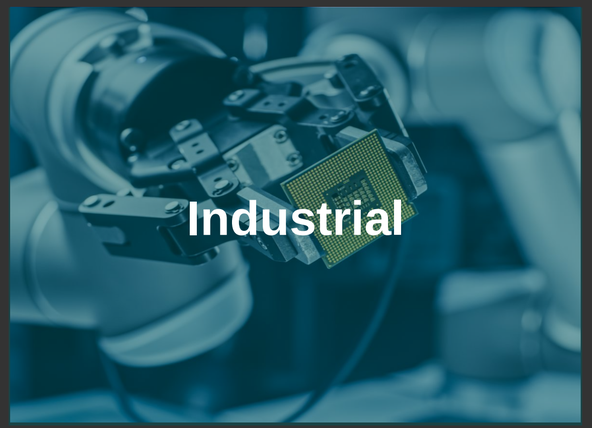
20 year history designing and manufacturing III-V photonic devices

End-to-end chip solutions from design to volume manufacture

Over 80 staff and growing rapidly

Key strategic supplier to many Fortune 100 and Silicon Valley customers

Enabling Next Generation Applications Across a Wide Range of Growth Markets



In-House Design and Manufacturing Capabilities

DESIGN

- Library of epitaxy designs for high-power, high-speed lasers
- Advanced chip design with focus on reliability and performance

PROTOTYPING

- Fully qualified InP100 manufacturing platform
- Design for hybrid silicon photonics
- Etched facet technology with on wafer optical coatings

QUALIFICATION / VOLUME PRODUCTION

- 100mm/4” wafer processing
- High yield with proven reliability
- Automated test, singulation and inspection
- High-volume test capacity (>2M lasers/month)
- In house qualification and reliability testing - GR468 and beyond

Technology Expertise

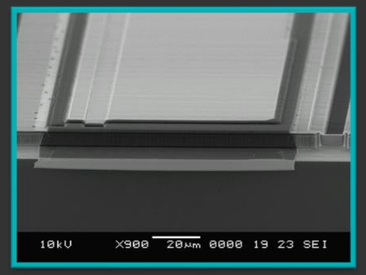
- Integrated design and manufacturing services for a broad range of photonic devices - **FP & DFB lasers, SOAs, RSOAs, Detectors**
- Key player in the Silicon Photonics ecosystem
- Advanced 4” indium phosphide product platform (InP100)
  - Multiple commercial users
- Established volume supplier, shipping over 1 million lasers per month
  - > 45 million lasers in the field to date

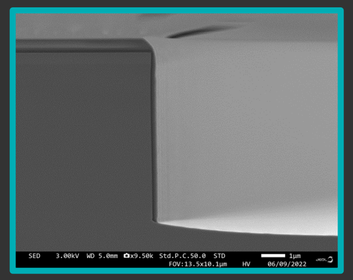
InP100 Product Platform

A common design and manufacturing framework for InP photonics devices that uses standardised process modules to produce a broad range of device types on 100mm wafers.

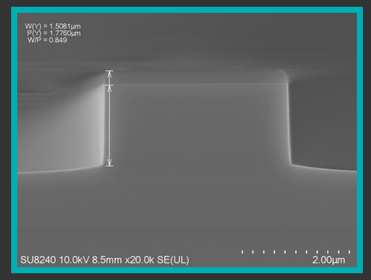
- Multiple device types fabricated using a common set of qualified process modules and design rules
- High yield, proven reliability
- 100mm wafer size, up to 125,000 die sites
- Scalable to high volume
- ***Optimised device architecture for SiPh flip-chip bonding***

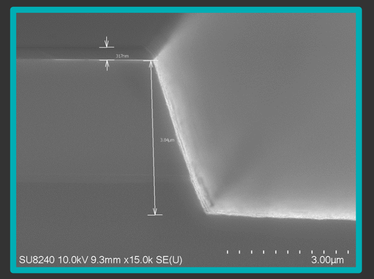
Straight and Angled Etched Facets



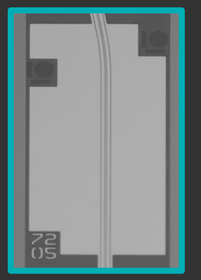


Vertical and angled etched profiles
Accurate vertical alignment surfaces

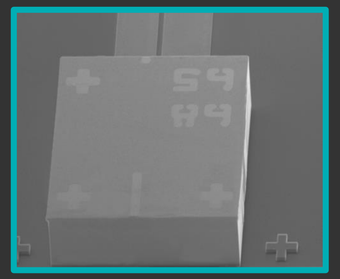




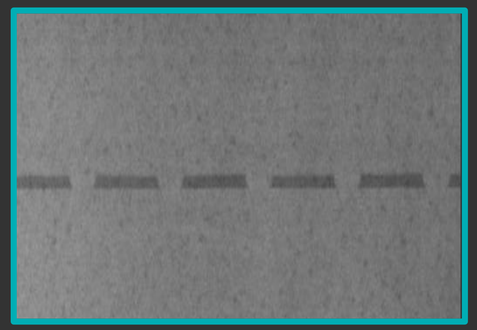
Self-aligned front-side fiducials



Back-side alignment fiducials and chip IDs

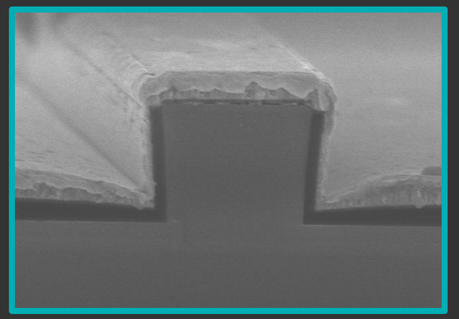


InP100 Product Platform

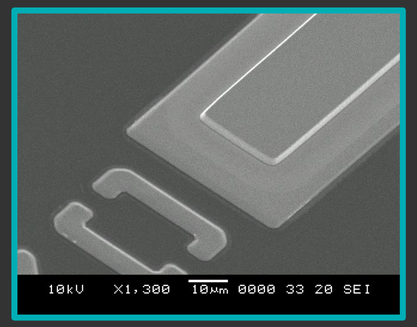


Buried gratings

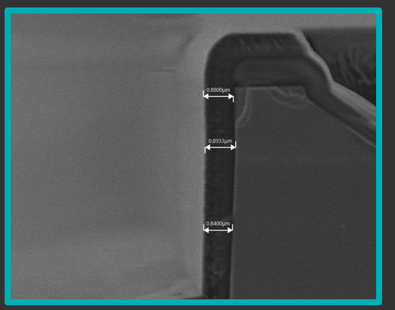
Co-planar contacts



Optimised low resistance metal stack



AuSn solder on III-V



On-wafer optical coatings

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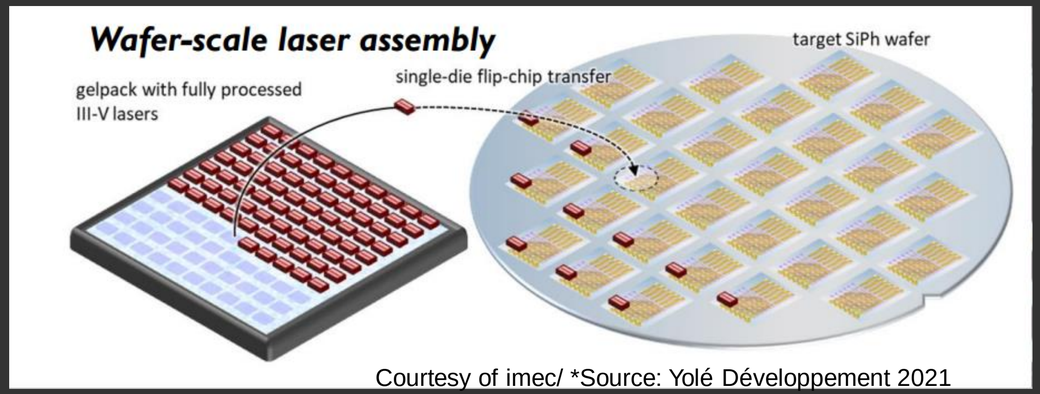
Accelerating Hybrid Integration of InP with SiPh

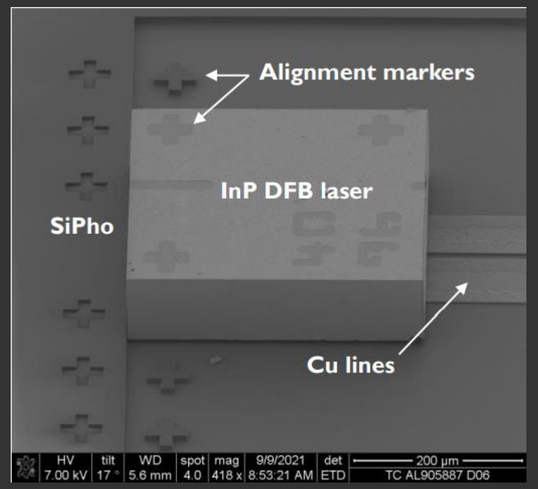
JDP collaboration with world-leading microelectronics institute, imec and ASM Amicra

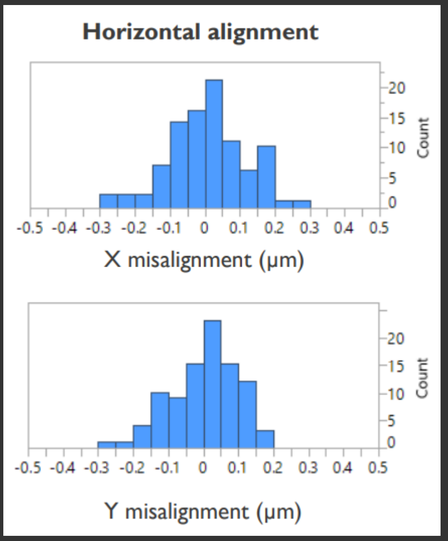
Initial results from first bonded InP dies:

- Single InP DFB lasers at wavelength ~1550nm
- Optical Power up to 40mW coupled into SiN waveguide
- High-Precision (≤0.3um) Laser Assisted FC Bonder Tool
- High mechanical stability with epoxy underfill process
- Coupling efficiency of 1.5±0.5 dB achieved
- FC-bonding of 4- and 8-channel O-band RSOA arrays (with 200GHz channel spacing) underway



Courtesy of imec/ *Source: Yolé Développement 2021





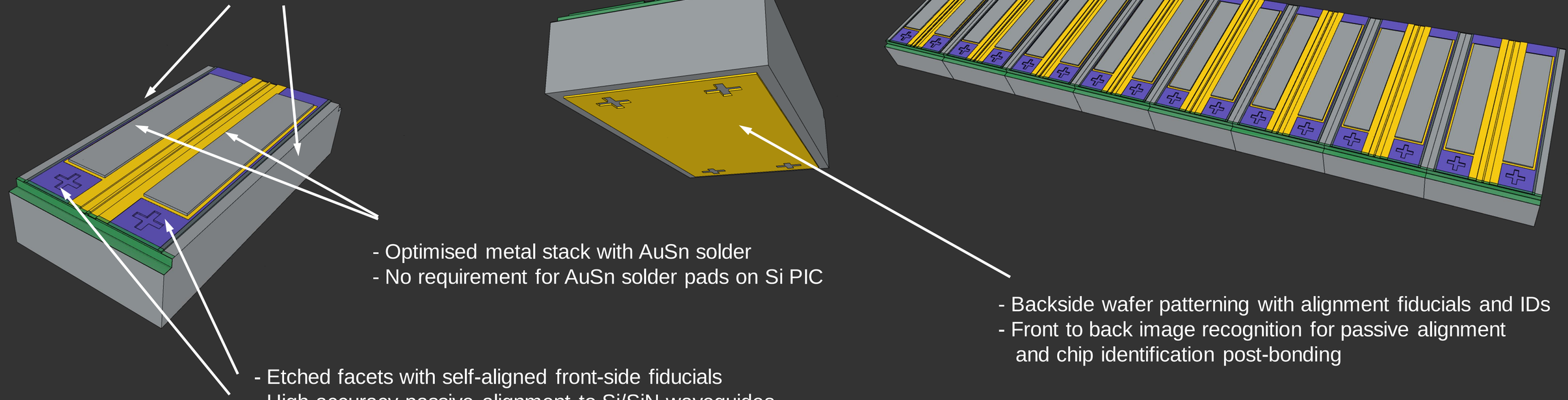
A. Marinins et al., "Wafer-Scale Hybrid Integration of InP DFB Lasers on Si Photonics by Flip-Chip Bonding With sub-300 nm Alignment Precision," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 29, no. 3: Photon. Elec. Co-Inte. and Adv. Trans. Print., pp. 1-11, May-June 2023, Art no. 8200311, doi: 10.1109/JSTQE.2022.3223641.

Optimised Lasers for Hybrid Silicon Photonic Assembly

The best lasers on the market for hybrid flip-chip integration onto all the main Si, SiN platforms

- Array output format, individually addressable ports
- Wide tunability range

- Vertical alignment surfaces
- ±5nm height accuracy to optical mode centre



- Optimised metal stack with AuSn solder
- No requirement for AuSn solder pads on Si PIC

- Backside wafer patterning with alignment fiducials and IDs
- Front to back image recognition for passive alignment and chip identification post-bonding

- Etched facets with self-aligned front-side fiducials
- High accuracy passive alignment to Si/SiN waveguides

Photonics in AI Networks

Legacy Copper-Based Technologies Cannot Support Explosive Growth in AI

Optical I/O is the Solution for the Generative AI Era

Today's Copper Wire Technology Cannot Support Growing Energy Needs

The energy required to move increasing volumes of data between GPUs in an AI cluster with electrons in copper wires will **exceed the energy available to process the data**

Data Centers Use 5% of Total Energy Production, Growing to 50% by 2050

Sivers is the solution

Using photons instead in small or long fibers will **reduce energy by up to 90% with lower latency and remove all copper interconnect bottlenecks**

Sivers Creates Significant Power Efficiency Using Light

10X
Lower Latency

8X
More Power Efficient

5X
Higher Data Rate

90%
Cost Reduction

$12B+
Ecosystem Investment

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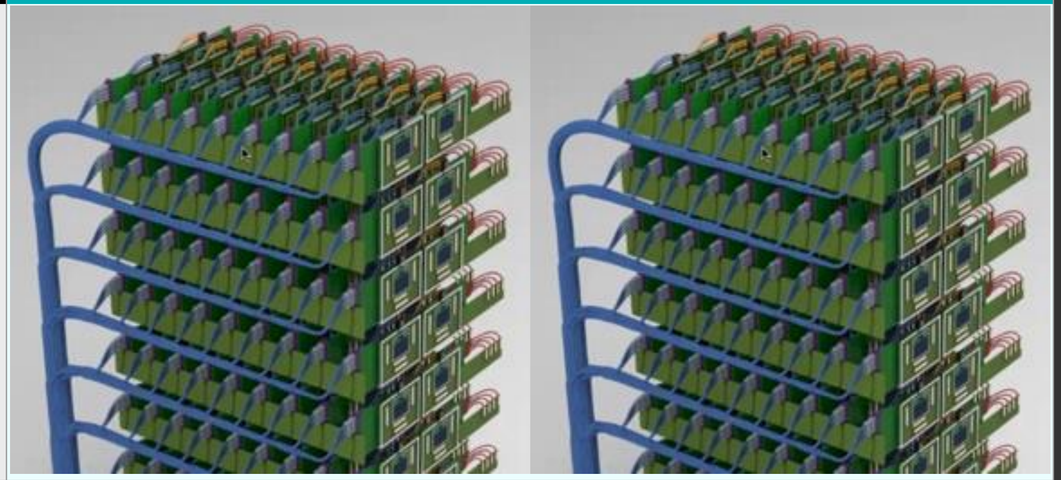
Sivers is Enabling GPU Superclusters for Generative AI

	Legacy Approach *NVIDIA HGX AI Supercomputing Platform*	**Sivers Photonics Solution** *Enabling GPU Super Clusters*
		
Connection Type	Electrical	All-Optical
Max Bandwidth	1,800 Gbps	8,000 Gbps
Linking	512 GPUs	100,000 GPUs
Energy Usage	100% (50 pJ/b)	10% (5 pJ/b)

Data Center: Sivers Laser Array Powering Ayar Labs Optical I/O Solution

Socket – Socket
Board – Board
Rack - Rack

data

Ayar TeraPHY™ CMOS Optical I/O Chiplets

GPU/CPU/FPGA

Sivers Photonics' Laser Array has **ASP of $50-100**

Ayar SuperNova™ multi-port, multi-wavelength light source

laser

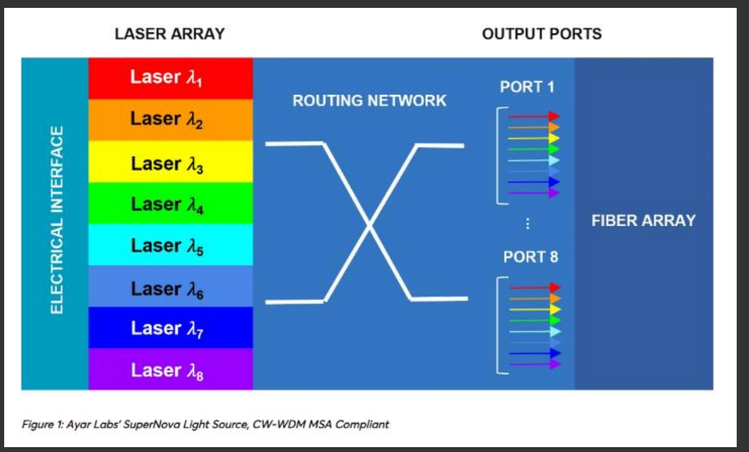


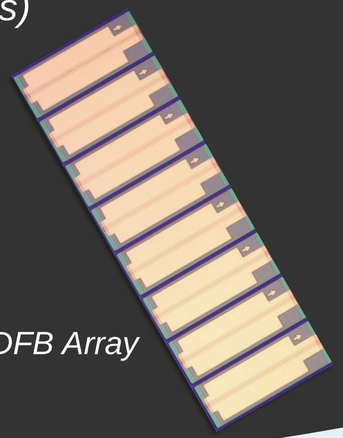
Figure 1: Ayar Labs' SuperNova Light Source, CW-WDM MSA Compliant

8λ O-band CW DFB Laser Array

Siver's SAM Reaching $2.5 Billion per Year

Market Opportunity for Sivers

($ Billions)



Sivers CW DFB Array

	2025E	2026E	2027E	2028E
Data Center GPU Units Sold (Millions)	14.8	17.1	18.8	20.5
Laser Arrays per GPU	4	4	4	4
Addressable Laser Arrays (Millions)	59.0	68.2	75.0	81.8
Sivers Content per Laser Array ($ Actual)	$50 – $100	$50 – $100	$50 – $100	$50 – $100
Total Addressable Market ($ Billions)	**$3.0 – $5.9**	**$3.4 – $6.8**	**$3.8 – $7.5**	**$4.1 – $8.2**
Illustrative Optical Penetration	***1.0%***	***5.0%***	***15.0%***	***30.0%***
Serviceable Addressable Market	**$30M – $60M**	**$171M - $341M**	**$564M – $1.1BM**	**$1.2B - $2.5B**

Key Drivers

Support for large GPU clusters

Size: 5-50k GPUs per cluster

- 16Tb/s bi-directional connectivity per GPU-GPU link,
- Four (2x Up + 2x Down) Supernova (8Tb/s) modules are required per GPU

Sivers DFB arrays volume pricing $50-$100 per array depending on volumes

⇒ Significant portion of BOM costs

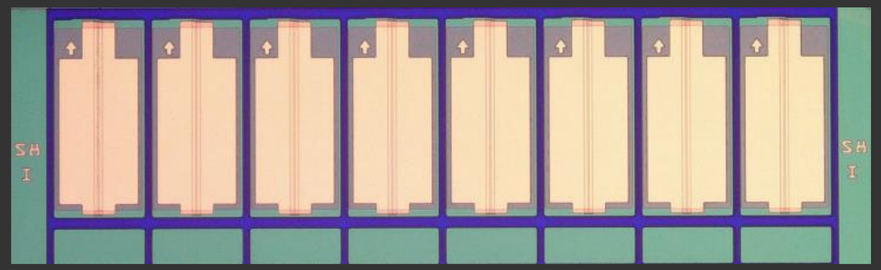
An annual deployment of up to 5 large clusters gives TAM up to $150M per annum -> 250,000 GPUs

InP100 Platform
DFB Laser Arrays

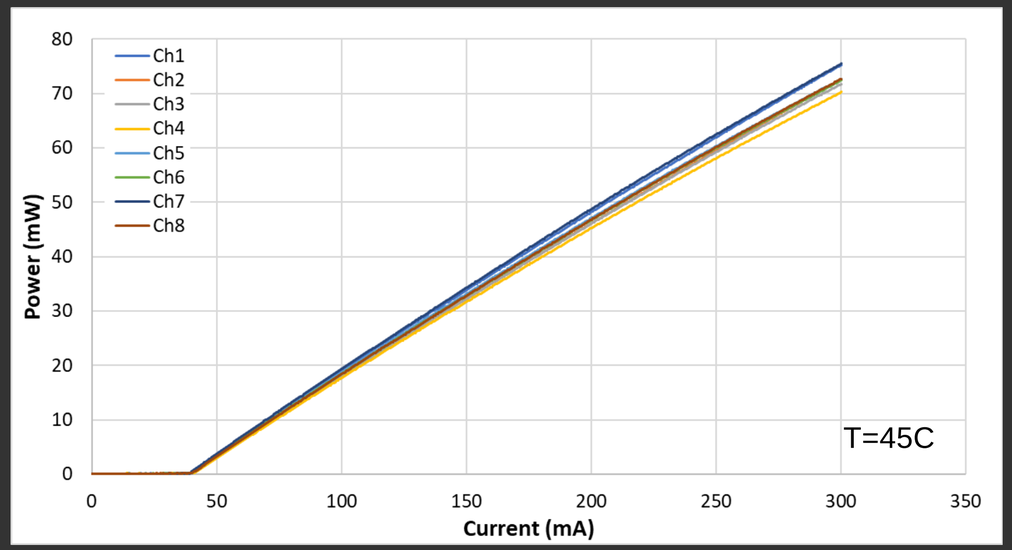
DFB laser diode arrays designed for use in CW-WDM MSA compliant applications

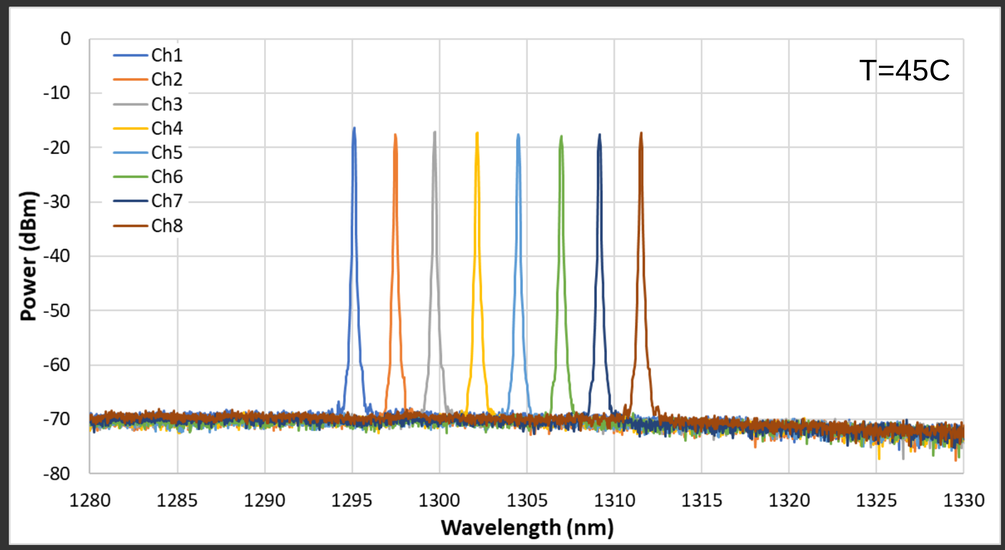
Key features

- > 50mW per channel CW operation
- 400GHz channel spacing around 1300nm
- Operating temp 20°C - 70°C
- AlInGaAs MQW active region
- Proven high reliability - GR468 qualification
- Suitable for non-hermetic applications



- Channel Counts
  - 8, 16 and 32 wavelengths
- Grid Spacings
  - 400, 200 and 100GHz

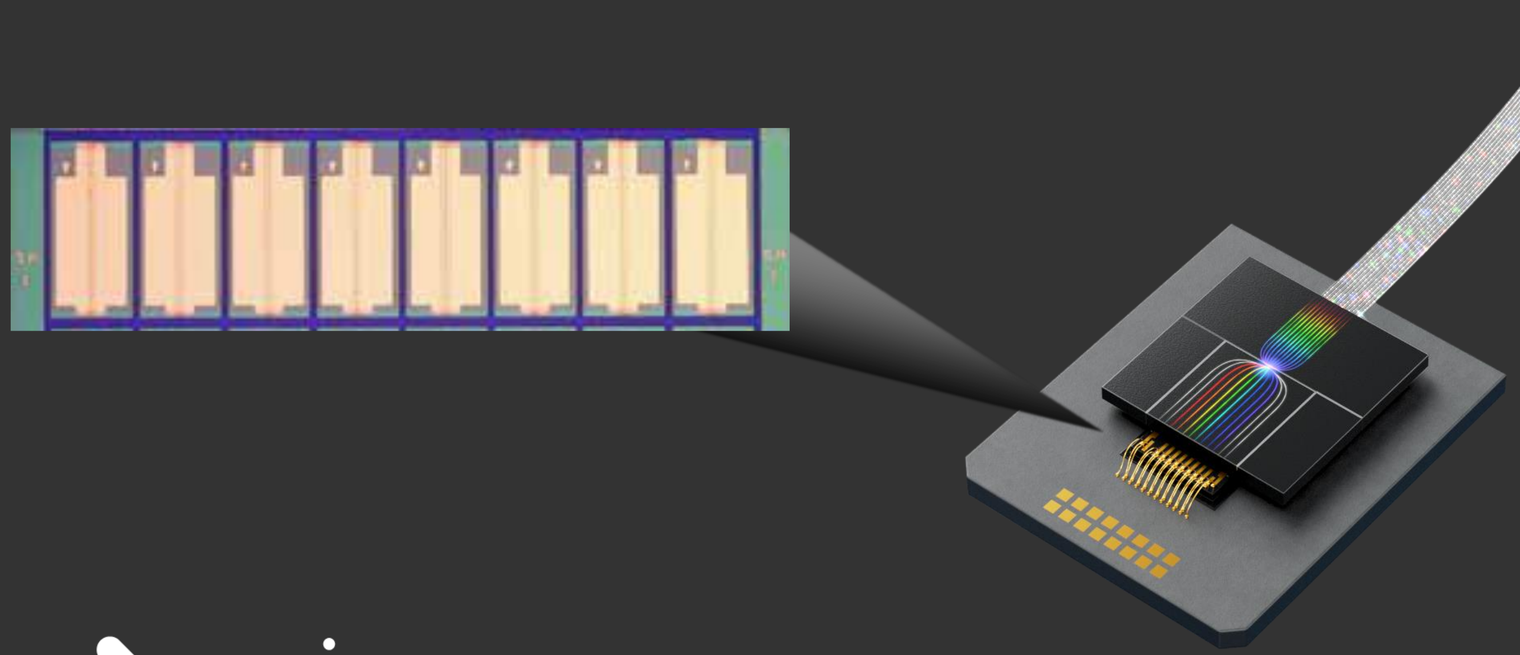




Ayar Labs SuperNova™ Multi-Wavelength Optical Source with Sivers Photonics DFB Laser Array Technology Inside

The Industry's First Product based on the CW-WDM MSA Specification

LIVE DEMONSTRATION
SIVERS BOOTH #615



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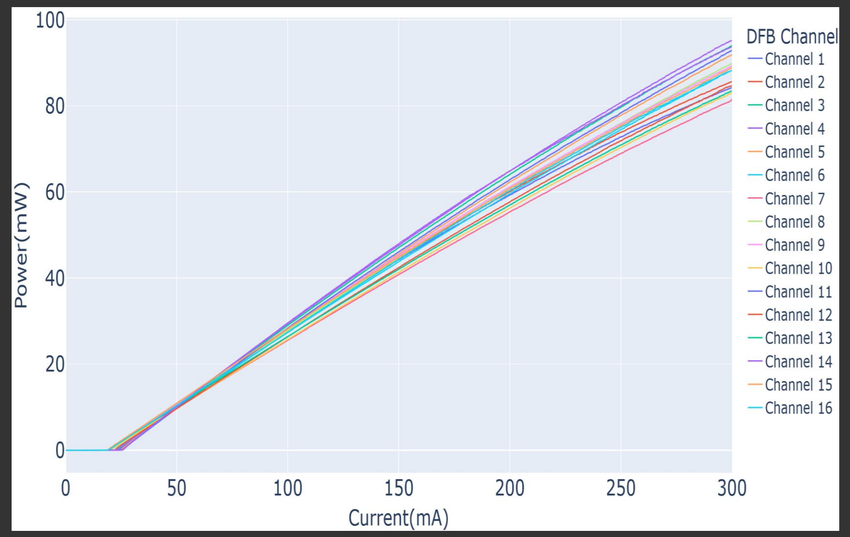
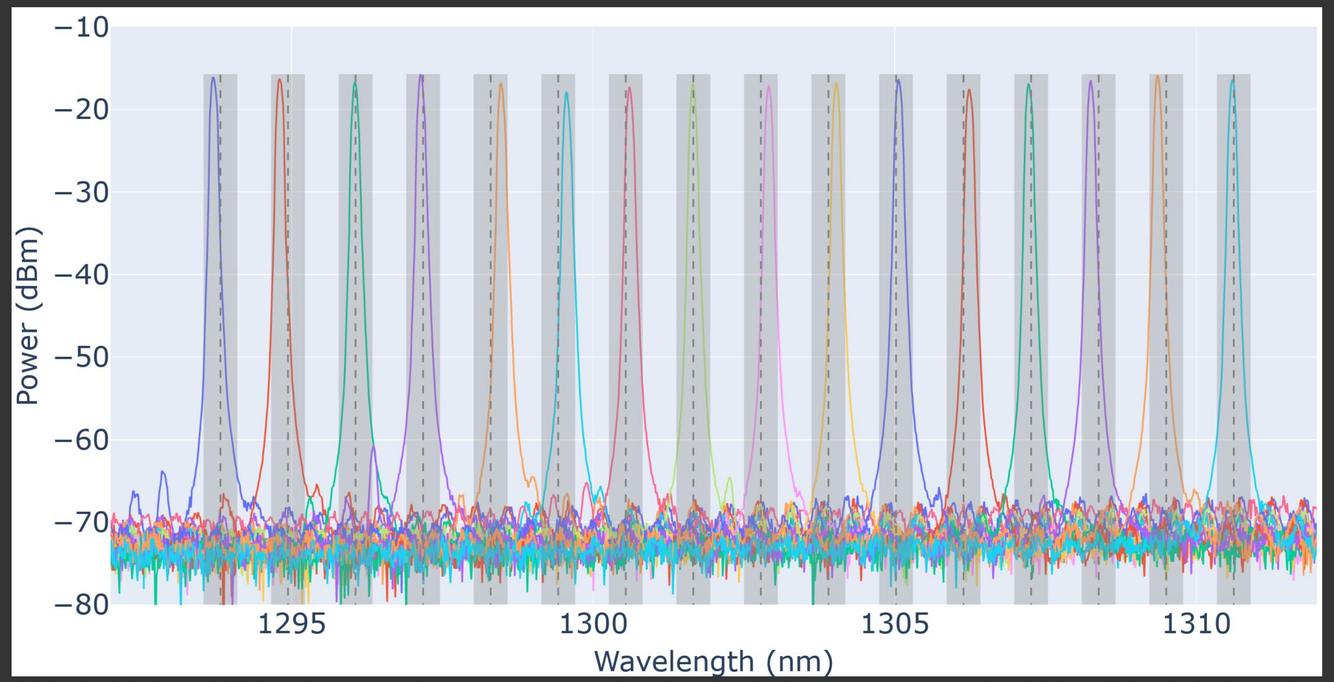
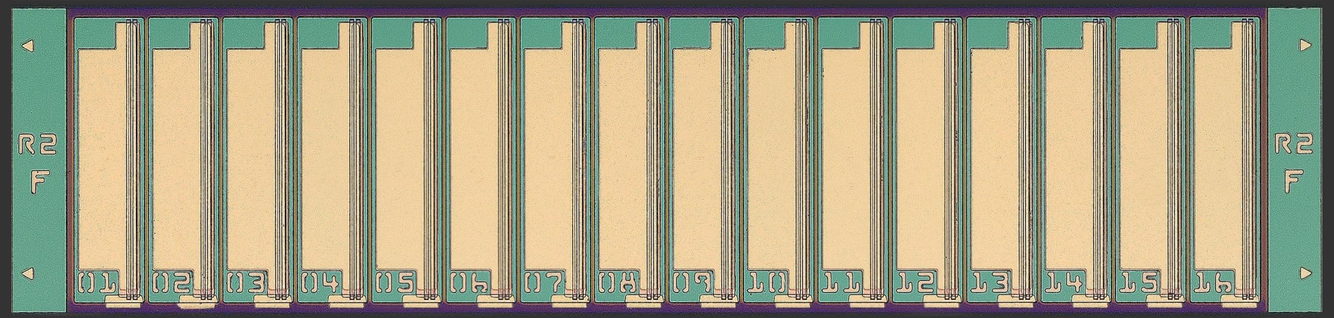
16 Element DFB laser diode arrays

- 16 Element DFB Array
- Ridge waveguide design
- Buried gratings with MOCVD regrowth
- Channel spacing target 200 ± 50Ghz
- >40db SMSR per channel



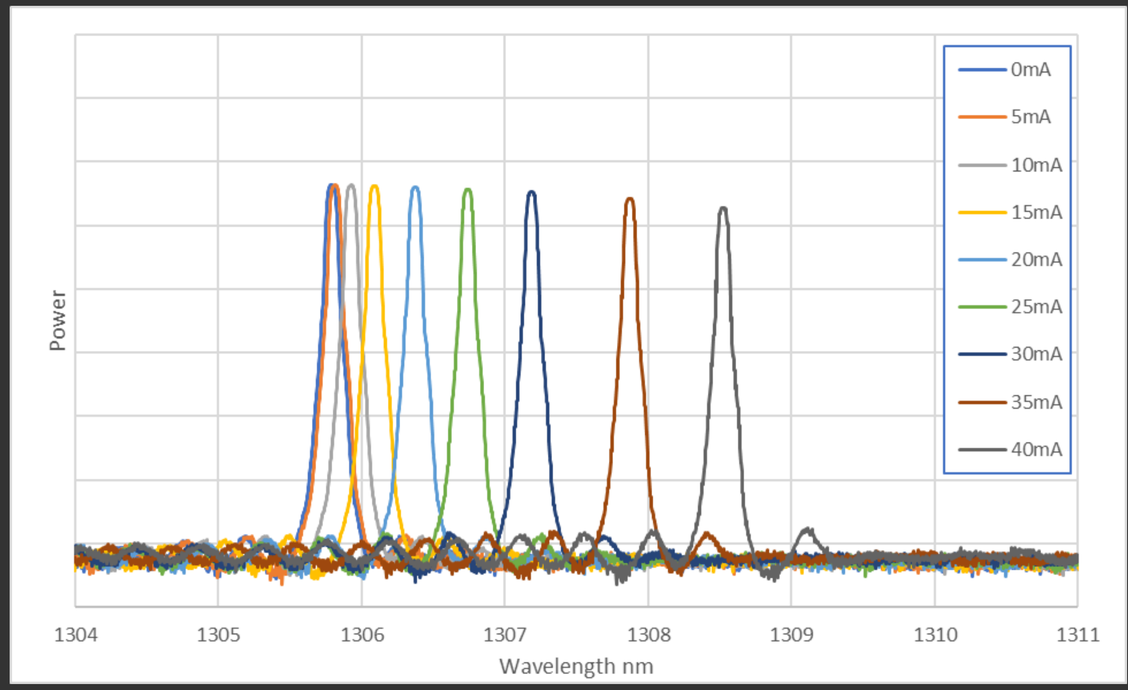


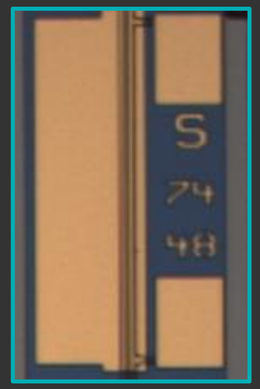


Hitting ± 50GHz bands starting to become a challenge, ***so need tuneability for ± 25GHz***.

Adding Tuneability to the lasers

- Integrated thin film resistors
  - Simple and accurate approach to implement
- Tuning rate around 0.6mW/GHz depending on laser thermal impedance
  - 25GHz tuning requires only 15mW of electrical power
  - Adds <15% to total laser power requirements
- Method of feedback control flexible

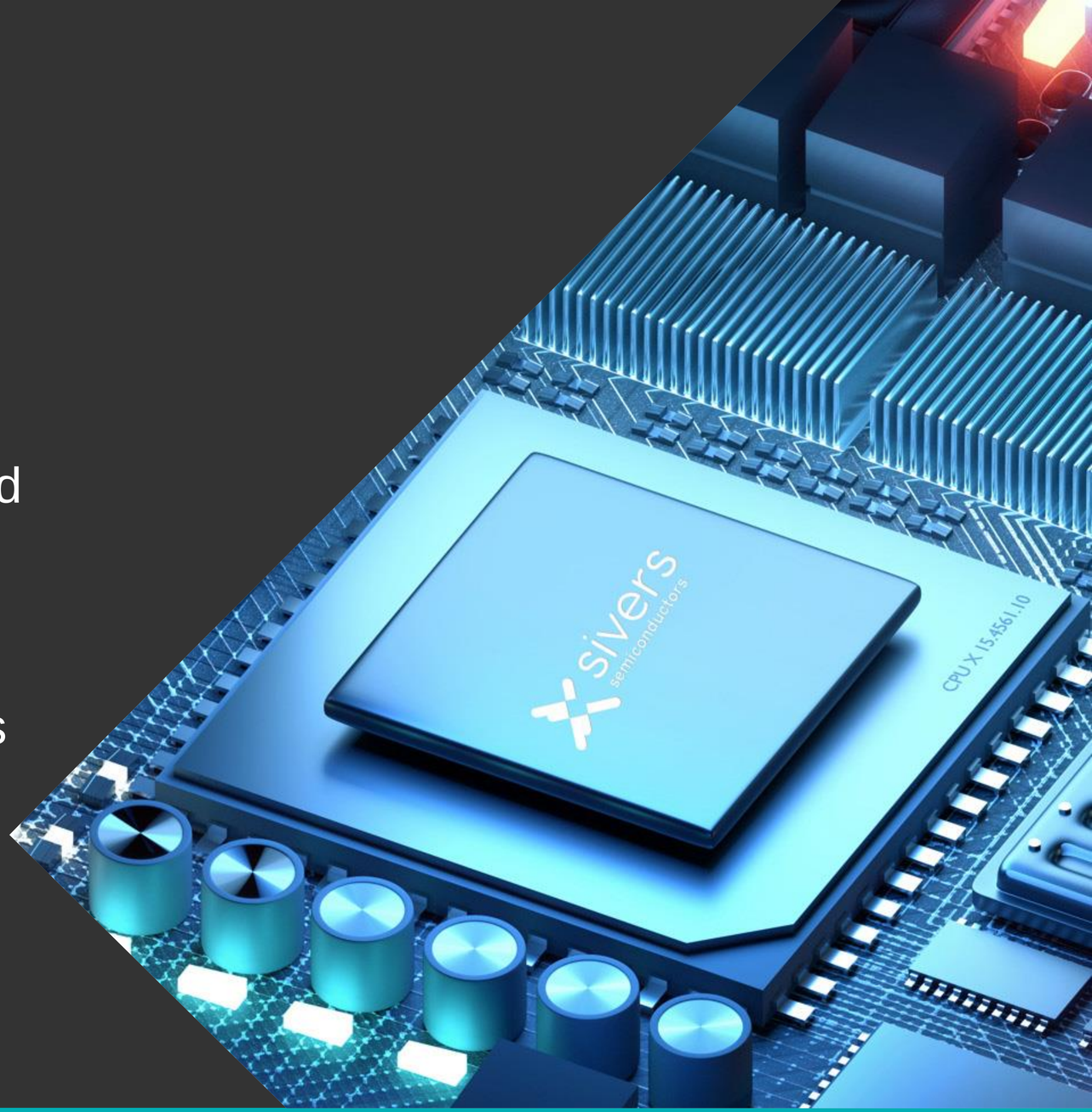




Hitting ± 25GHz bands can be achieved.

Summary

- Sivers Photonics has complete in-house capability for III-V laser design and manufacture
- Our InP100 platform provides most advanced custom III-V DFB Laser Array Products for Next-gen Optical IO applications
- Strong traction with leading Industry partners in the AI Industry



Thank you.

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