

EPIC 2023

Introduction of Silicon Photonics and Emerging Applications

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Ack. : SPPD team



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Outline

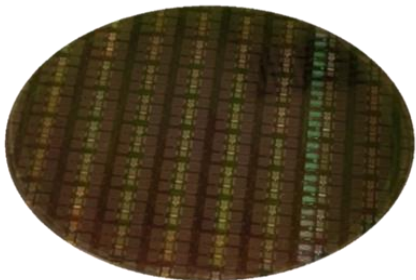
- Silicon photonics
 - Intel Silicon Photonics
- Emerging Applications
 - AI-Infrastructure: Optical Compute Interconnect (OCI)
 - Sensing: 3D Sensing (3DS)

Intel SPPD for EPIC23

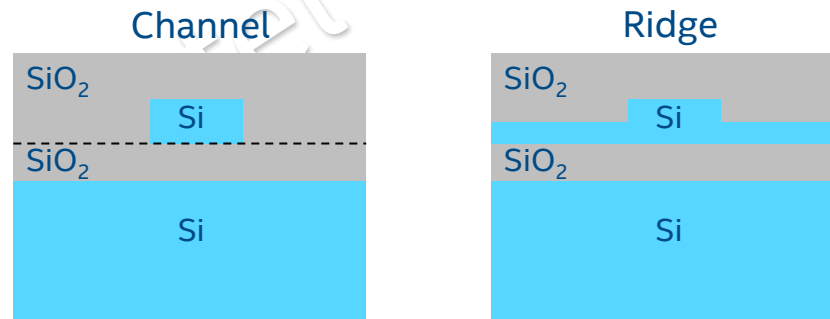
Silicon Photonics (SiPh)

- SiPh is a technology that combines the fields of optics and electronics by using silicon as a medium to generate, manipulate, and detect light.
 - SiPh leverages the capabilities of semiconductor materials, particularly silicon, to create integrated circuits that can process and transmit data using photons (particles of light) instead of electrons.
- Merits: Using mature CMOS process for photonics, Lower cost, Enables guiding, modulation, and detection of light ...
- Challenges of Conventional SiPh: Si is not suitable for lasing; High volume manufacturing (HVM); Integration...

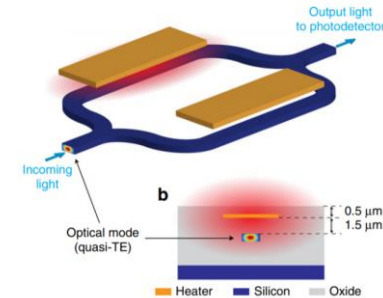
SiPh wafer



SiPh waveguides

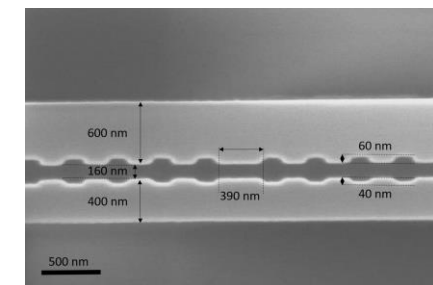


Mach-Zehnder



SiPh devices

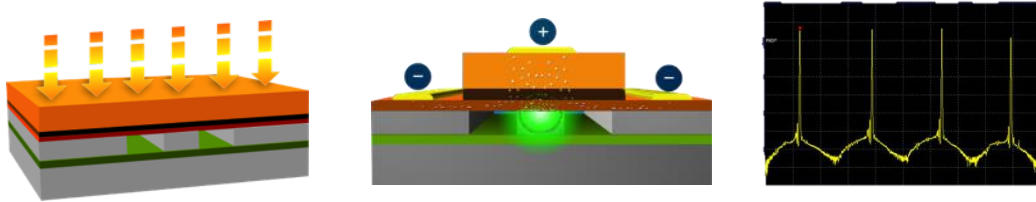
Add/drop coupler



Fainman UCSD, <https://www.unogroup-ucsd.com/silicon-photonics.html>

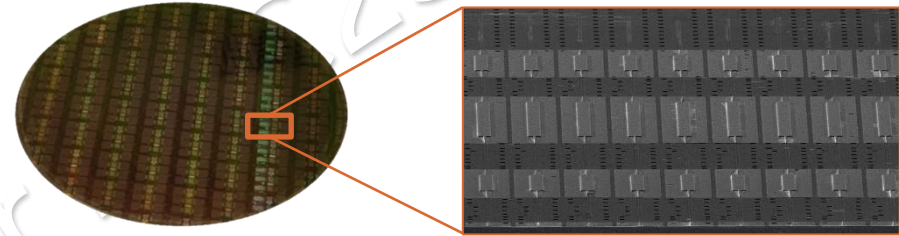
Intel Silicon Photonics

IPs and INTEGRATION: Heterogeneous III-V



- Most integrated optics approach, enabled by Intel's hybrid laser technology with >90% coupling efficiency
- Capable of multiple optical wavelengths and integration of multiple optical components

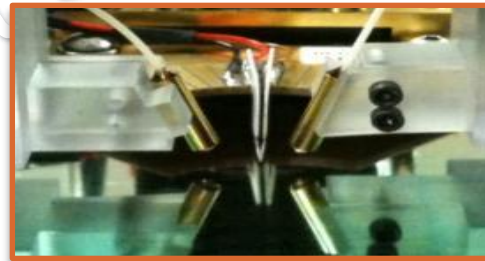
SCALE: Best-in-class manufacturing and reliability



- Industry's highest SiPh volume with industry-leading quality and reliability
- Advanced CMOS manufacturing process at Intel fabs on 300mm wafers

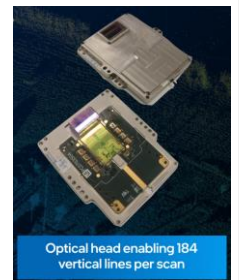
BACKEND and One Stop Shop Services

- High-volume wafer-level testing
- Comprehensive on-wafer optical, electrical, and high-speed test capabilities
- Electronic IC and packaging



LEAD in Emerging Applications

- Unique IPs such as hybrid III-V are ideal for AI and Sensing. SOAs with > 100mW output power
- Leader in OCI and 3D Sensing (3DS). FMCW LiDAR and OCI demo 'ed.



Silicon Photonics: Integration and trend

Photonic Integration enables smaller size, lower power, higher-yield and lower cost...



Intel 100 Gb CWDM4 optical transceiver, 2019

Ciena 10 Gb optical transceiver, 2005

<https://www.ciena.com/insights/articles/Coherent-optical-turns-10-Heres-how-it-was-made-prx.html>

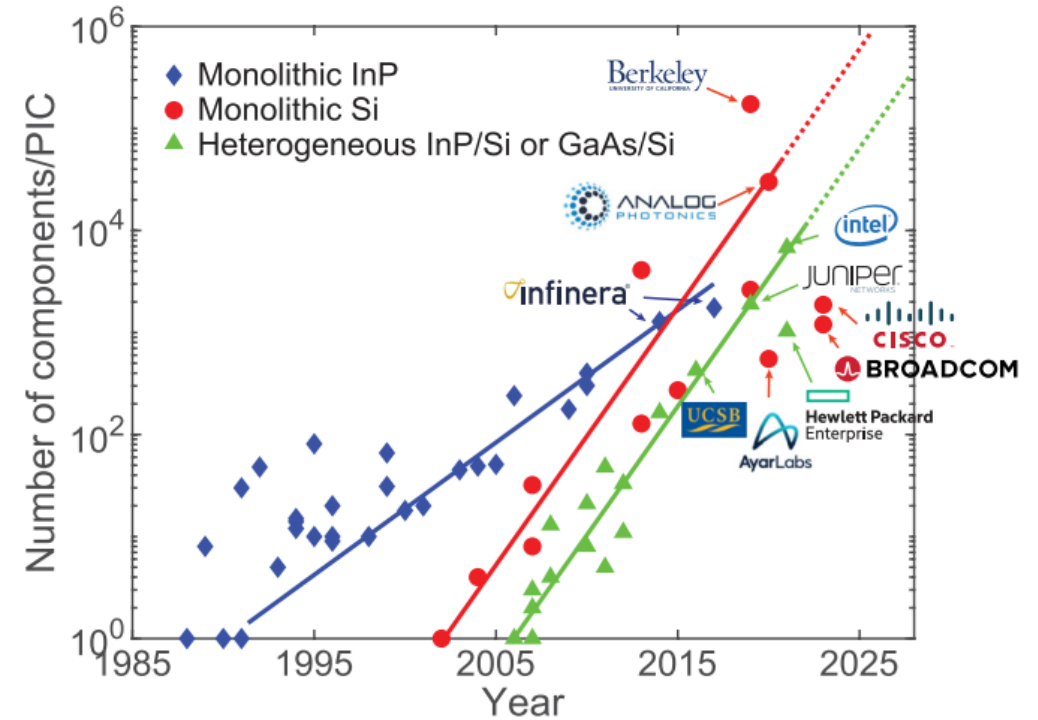


FIG. 5. The number of photonic components integrated on a single waveguide over time for three photonic integration platforms: InP substrate with integrated lasers, Si substrate without integrated lasers, and Si substrate with integrated lasers.

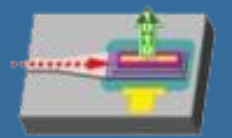
Intel: Silicon Photonic integration

ACTIVES

Hybrid laser and SOA
Electrons generate photons



Ge Photodetector
Photons generate electrons



Si Modulator
Electrons control photons



PASSIVES

MUX/ Demux



Coupling I/O



Optical Filter



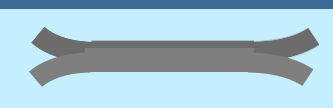
Interferometer/Switch



Splitter/Combiner

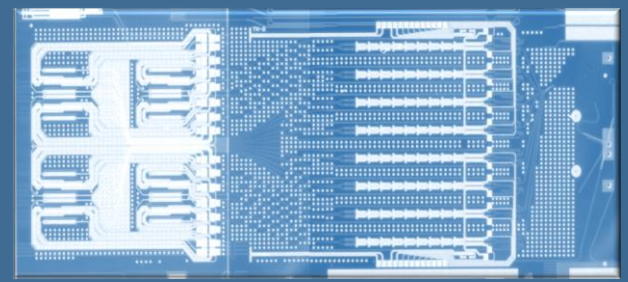
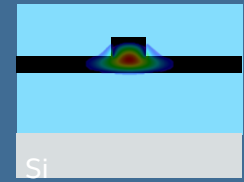


Polarization Diversity

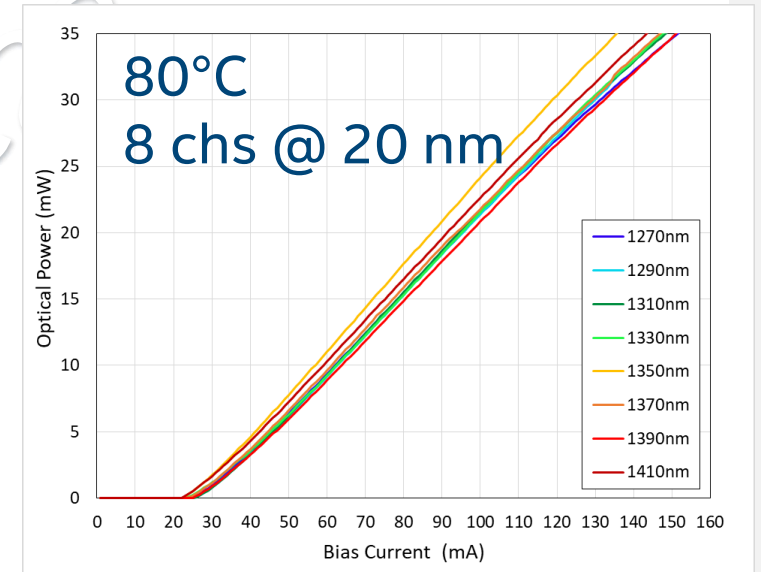
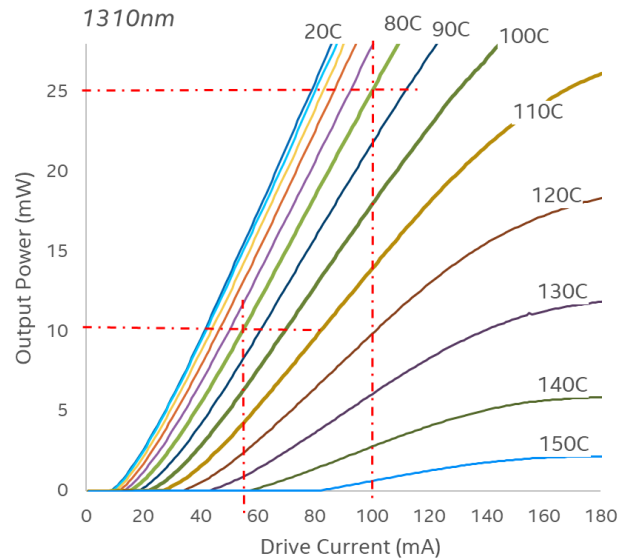
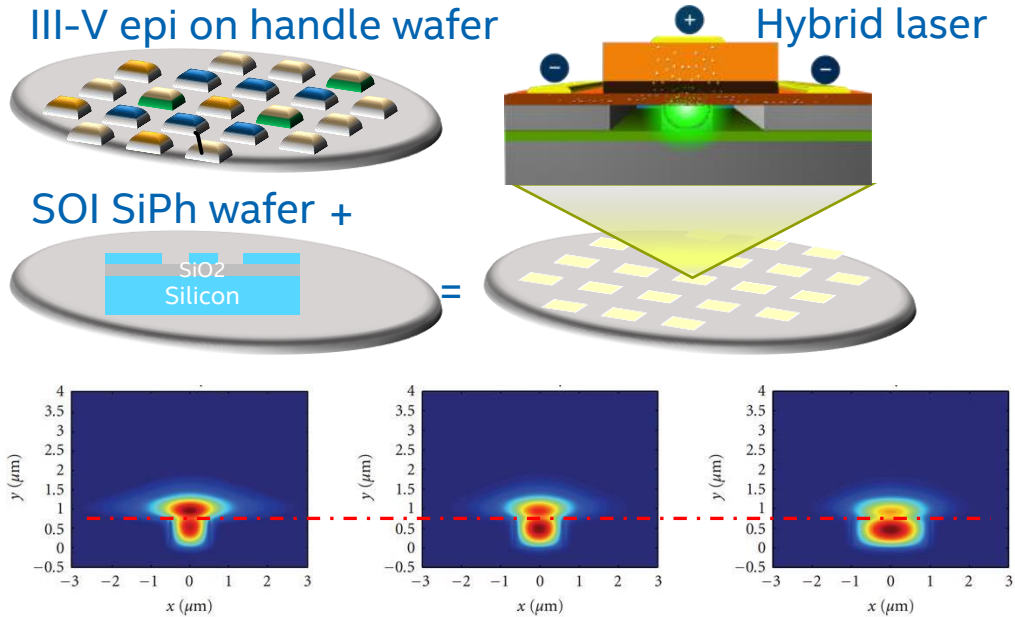


WAVEGUIDE INTEGRATION

Large-scale PIC & On-chip Interconnects



Heterogeneously integrated lasers

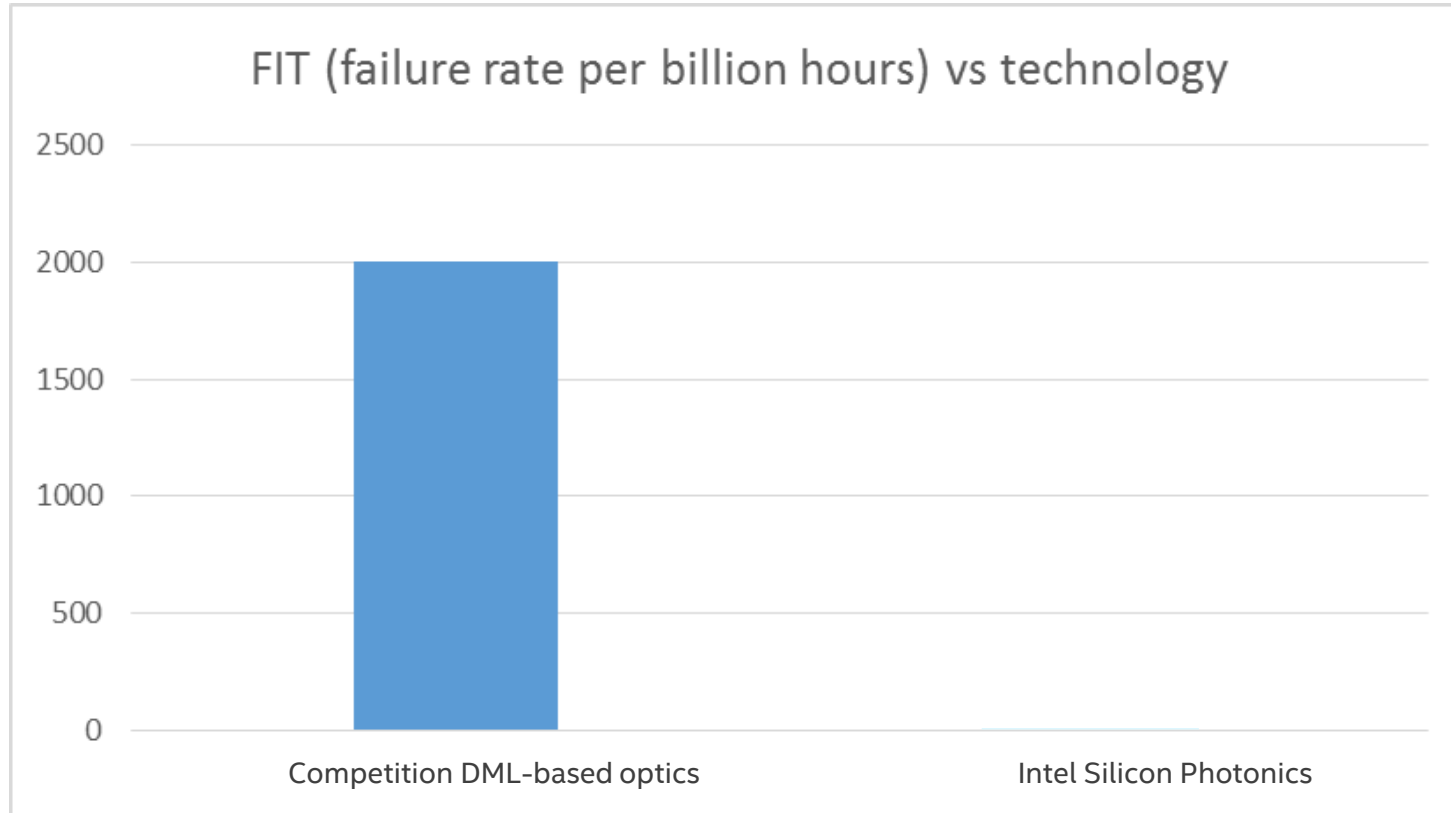


P. Doussiere, "Laser integration on silicon," Jeffrey Driscoll, et al, "First 400G 8-Channel Group IV Photonics, 2017

Jeffrey Driscoll, et al, "First 400G 8-Channel CWDM Silicon Photonic Integrated Transmitter", Group IV Photonics, 2018

- 300 mm wafer bonding
- Tight CMOS process control
- Design of InP die can be optimized on different regions PIC and / or wafer => WDM lasers, SOAs, etc.

Intel Silicon Photonics Field Reliability

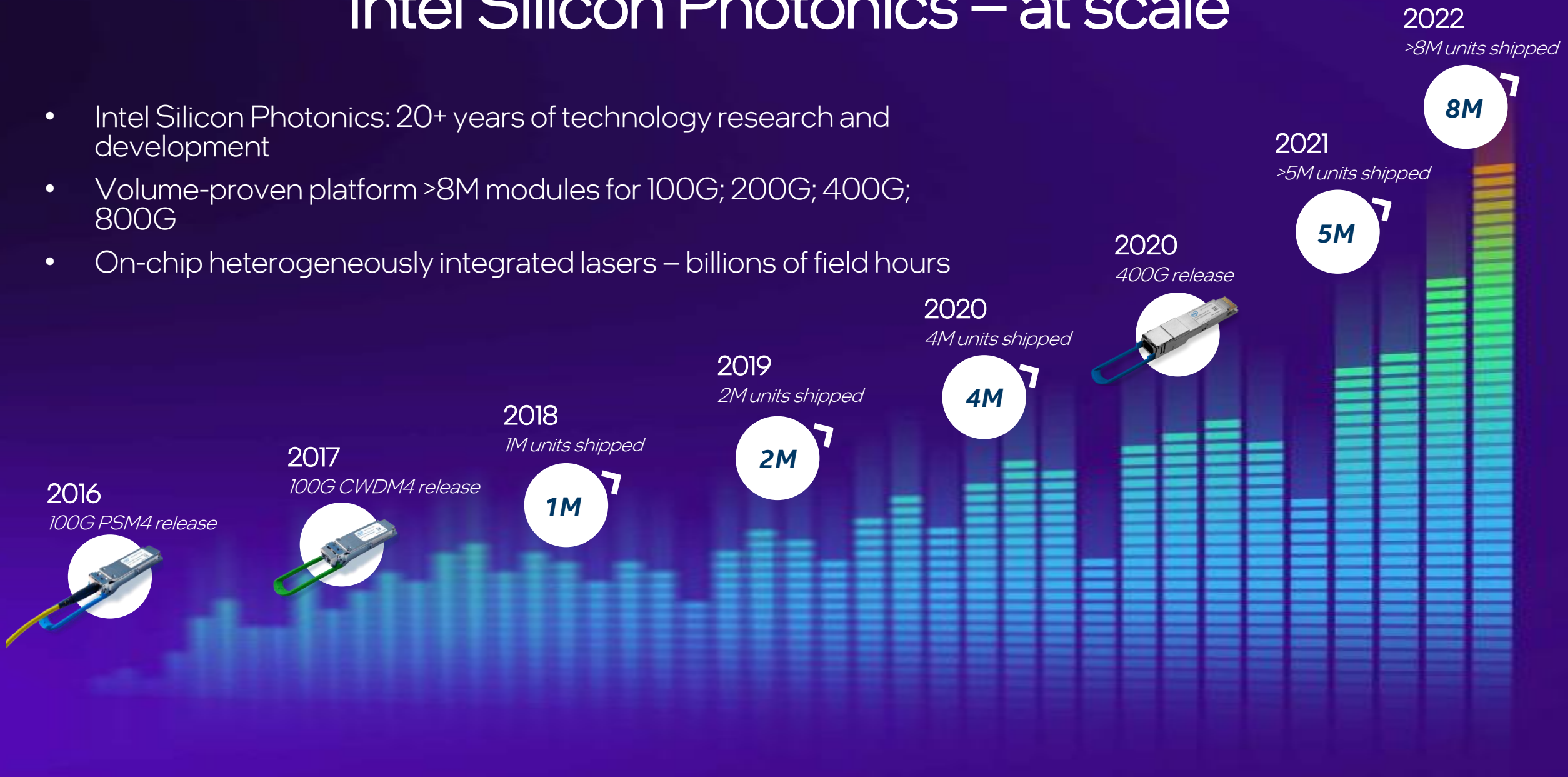


Meta publicly-presented data
(ECOC/JEDEC/EPIC) from 100G optics data
center production deployment

- Field data demonstrates Intel silicon photonics reliability orders of magnitude better than traditional optics
- Fundamental silicon photonics laser reliability better due to
 - Lack of facet failure mechanisms
 - No InP substrate or regrowth
 - Lower current density of silicon photonics integrated laser
- Higher levels of integration and fewer process steps in silicon photonics translate to better product quality and reliability

Intel Silicon Photonics – at scale

- Intel Silicon Photonics: 20+ years of technology research and development
- Volume-proven platform >8M modules for 100G; 200G; 400G; 800G
- On-chip heterogeneously integrated lasers – billions of field hours



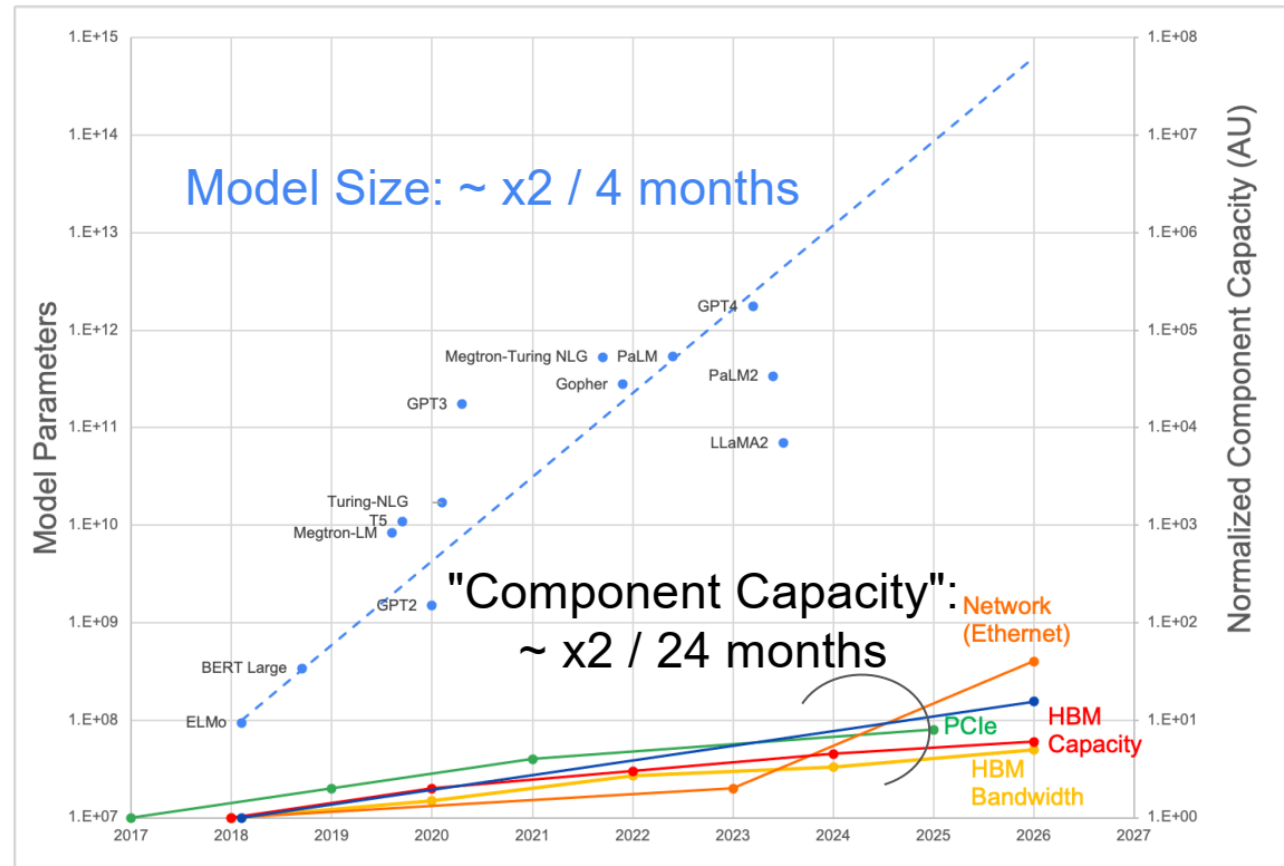
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Intel SPPD for EPIC23

AI-Infrastructure: Problems in IO Scaling

IO Protocol & Component Scaling is far behind AI Model Size Scaling

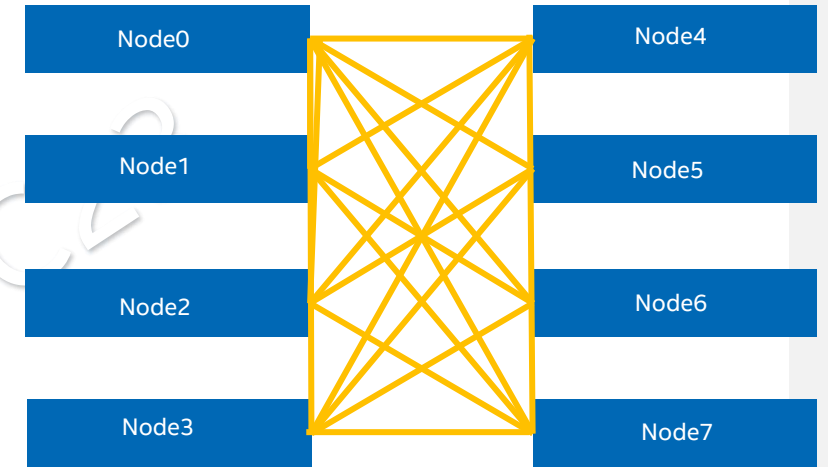


Ref: Meta

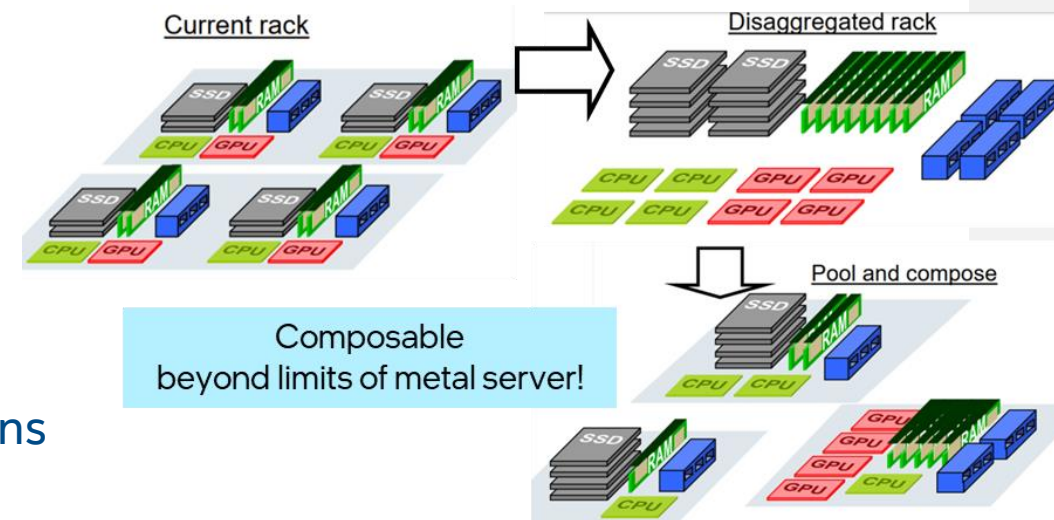
Optical Compute Interconnect (OCI)

- Explosion in bandwidth requirements for AI/ML infrastructure
 - Node-to-node or cluster network
- Resource disaggregation and composable systems
- Co-packaged Optical Compute Interconnect (OCI) designed for compute fabric and resources

Bandwidth density – Tbps/mm
Low power – 2-3pJ/b
Some use cases latency sensitive - ~10ns
Cost and scalability

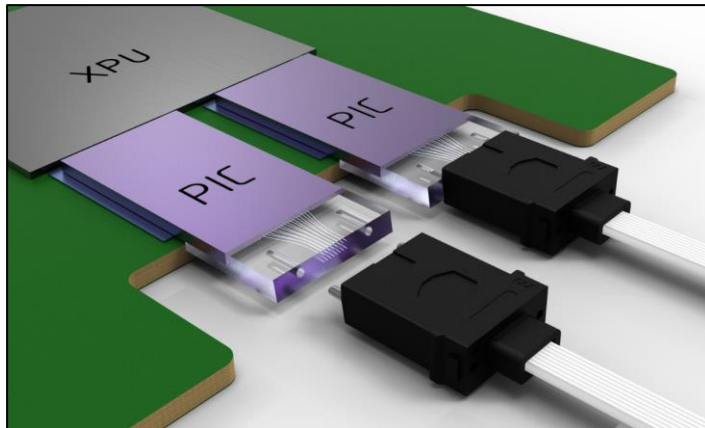
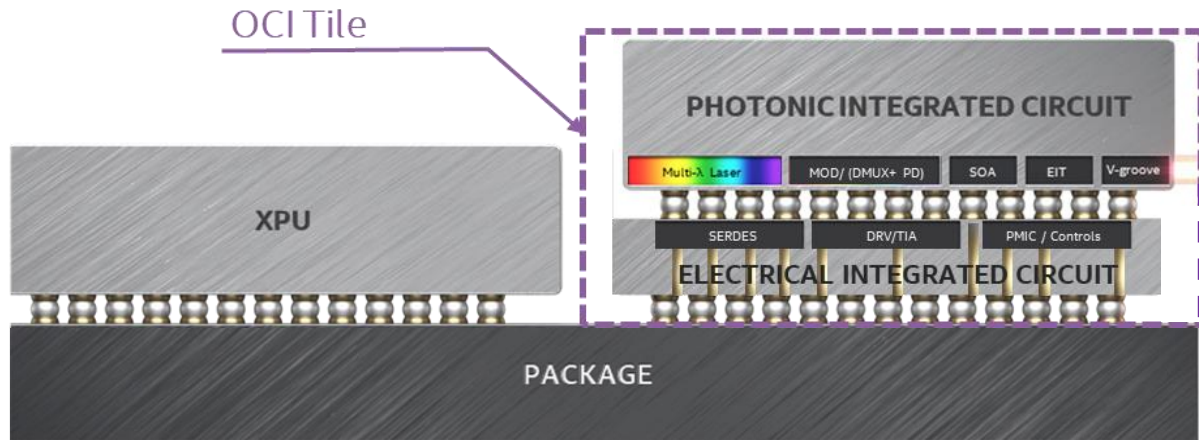


Compute Fabric (AI/ML)



Resource disaggregation

Intel: Optical Compute Interconnect (OCI)



Ultra-high bandwidth
~1Tbps per fiber

Reach
>100m, orders of magnitude better than electrical I/O

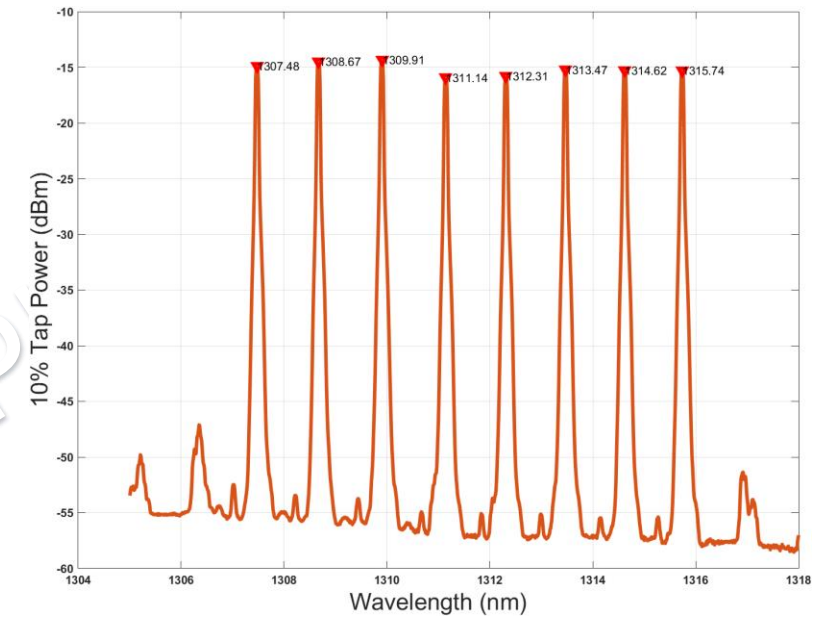
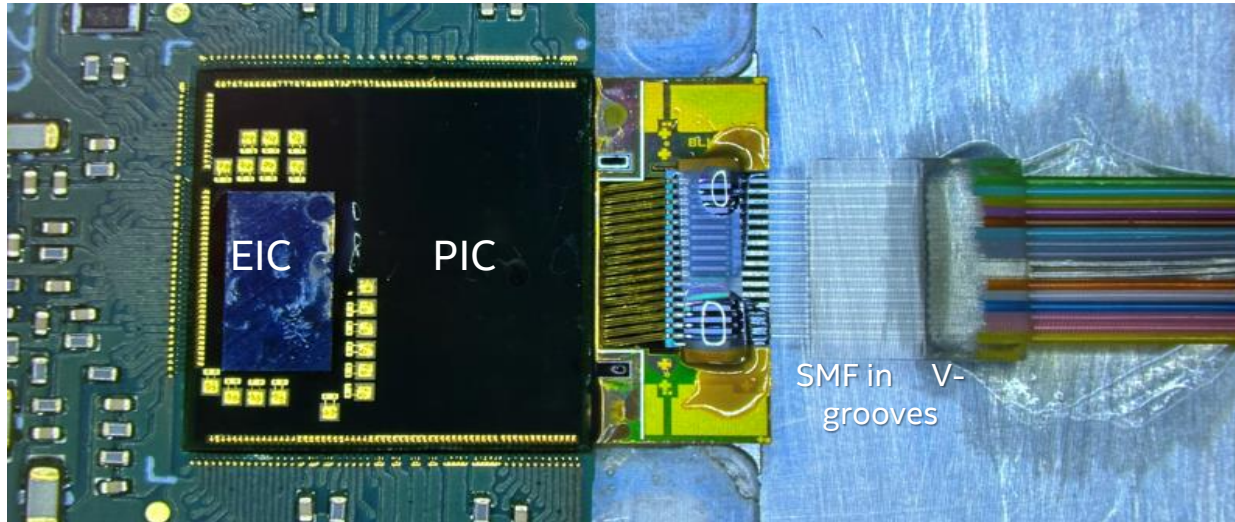
Shoreline Density
>4x improvement over PCIe6

Energy Efficiency
<3pJ/b (65% of PCIe6)

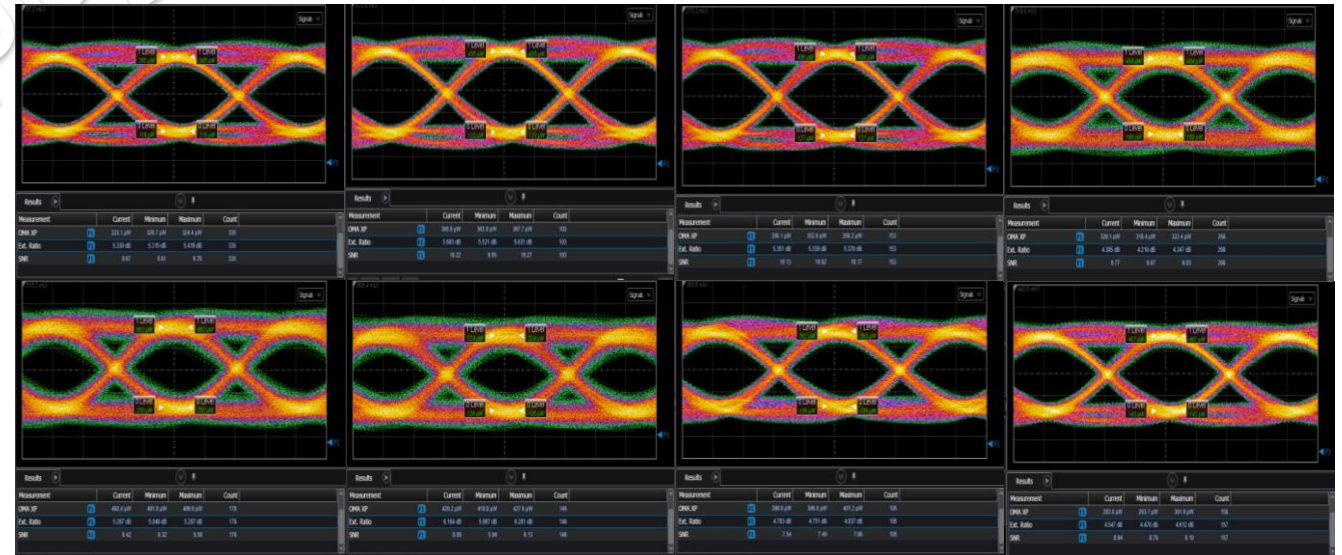
Latency
<10ns + TOF, comparable to electrical I/O

Key elements: integrated laser, EIC with RF TSVs, and detachable optical connector

OCI Subsystem Demonstration



- 8f x 8λ x 64 Gbaud PIC die-stacked with 8-ch 32 Gbaud EIC testchip
- Tx spectrum and eye diagrams: uniform 200 GHz λ spacing, 8-10 dB SNR
- Tx-to-Rx loopbacks show error-free performance



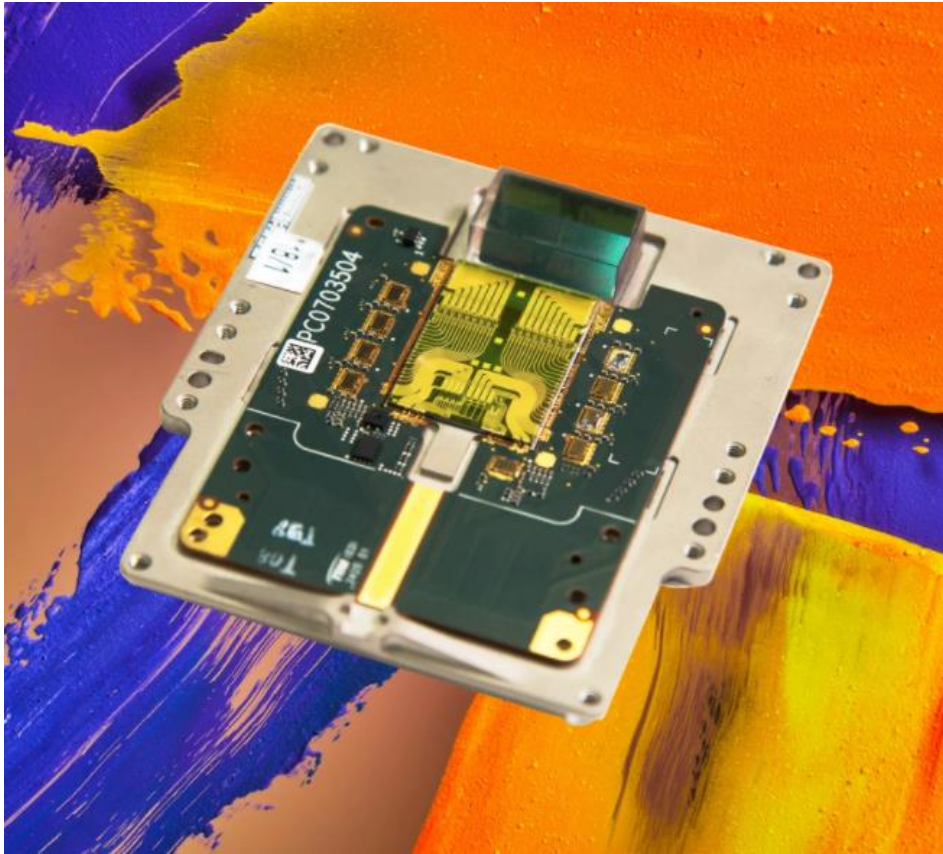
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Intel SPPD for EPIC23

Intel's SiPh FMCW "LiDAR on a chip"

Integrating 6000+ active and passive components on chip for high volume manufacturing



Mobileye CEO Amnon Shashua shows of the company's new lidar SoC prototype.

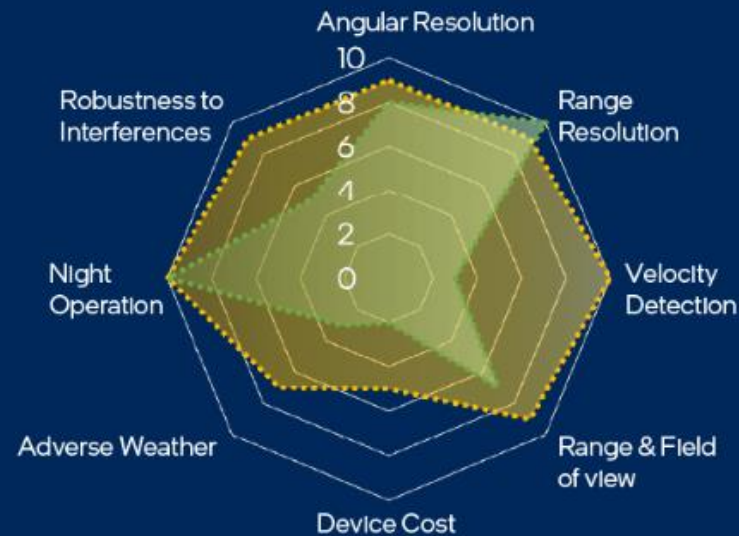
PHOTOGRAPH: MOBILEYE

<https://www.wired.com/story/mobileye-lidar-on-a-chip-intel/>

<https://www.intc.com/news-events/press-releases/detail/1435/ces-2021-mobileye-innovation-will-bring-avs-to-everyone>

SiPh Disrupts 3D Sensing (3DS): FMCW LiDAR vs. ToF

Frequency-Modulated Continuous Wave (FMCW) LiDAR is conducting a coherent detection and uses Doppler effect to measure both range and closing speed while ToF are focused on short bursts and range measurement



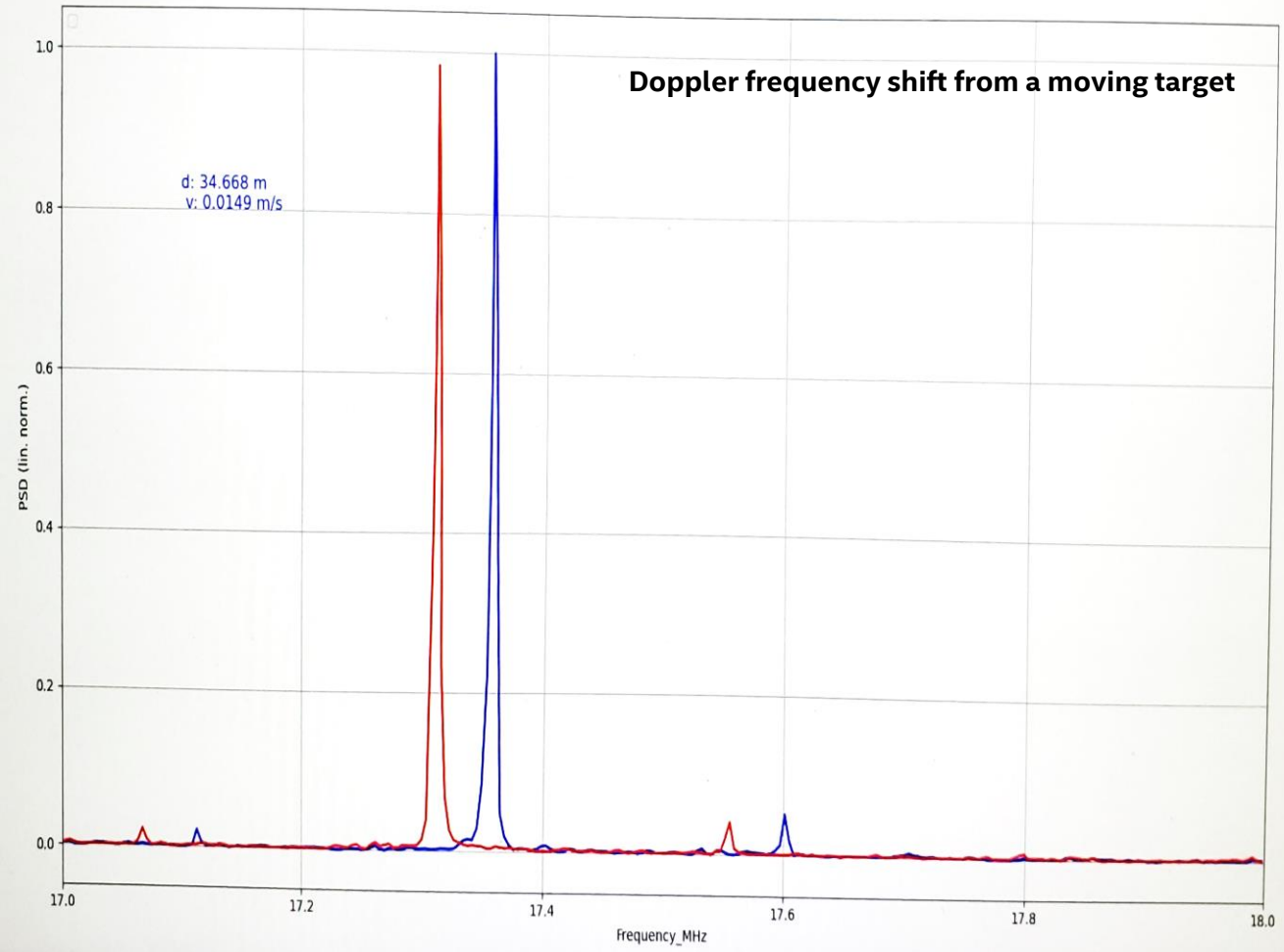
<https://newsroom.intel.com/wp-content/uploads/sites/11/2021/01/Under-the-hood-deck.pdf>
<https://static.mobileye.com/website/corporate/media/radar-lidar-fact-sheet.pdf>

Intel-Mobileye FMCW LiDAR Demo in CES



<https://www.youtube.com/watch?v=DkVezxsZhn0>

Intel SiPh 3DS PIC Demo: Auto, IoT and CE Applications...



Silicon Photonics (SiPh) Sensing: 3D Sensing, Bio...

Various 3D Sensing Application



Facial recognition in Mobile



Mapping in GIS



Detection in Automotive



ADAS in Automotive



Detection in AR/VR



Obstacle avoidance in Drone



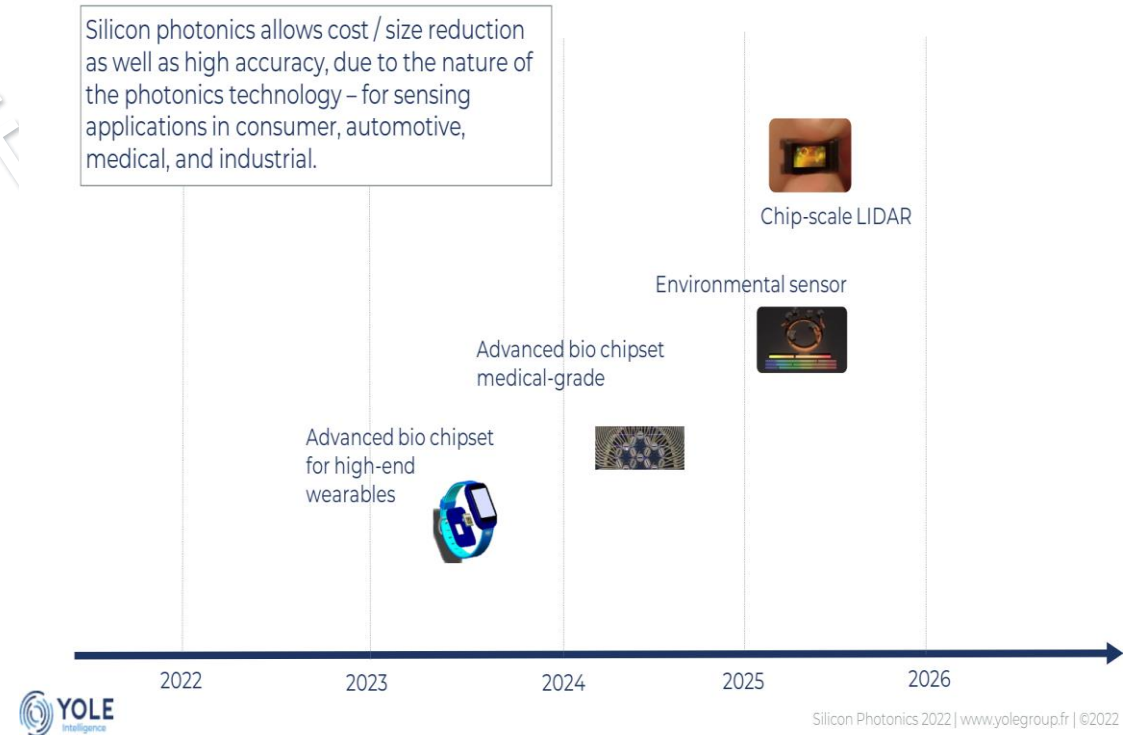
Object recognition in Industrial



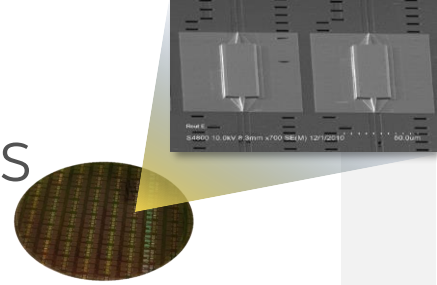
People counting in Surveillance

Various SiPh Sensing Applications

Silicon photonics allows cost / size reduction as well as high accuracy, due to the nature of the photonics technology – for sensing applications in consumer, automotive, medical, and industrial.



Takeaway: Silicon Photonics (SiPh) and Emerging Applications



- **SiPh can address burning issues such as power/BW. Intel SiPh is a unique and mature platform**
 - Intel SiPh: industry's highest production volume with industry-leading quality and reliability; Unique and proven On-chip lasers and SOAs, and huge IP portfolios
- **SiPh enables emerging applications such as AI and Sensing...**
 - Intel pioneers in OCI and 3DS. Demoeed the Best-in-Class FMCW LiDAR and OCI. More to come...
- **Opportunities: Intel opens its unique SiPh platform to strategic customers to develop custom PICs and to co-develop disruptive photonics products for emerging applications**

Thank You!