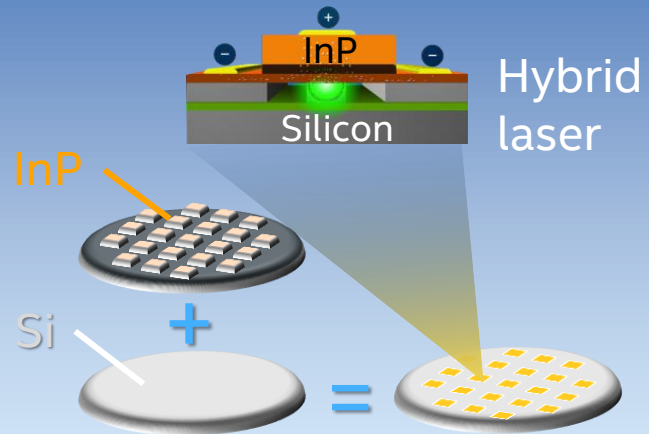


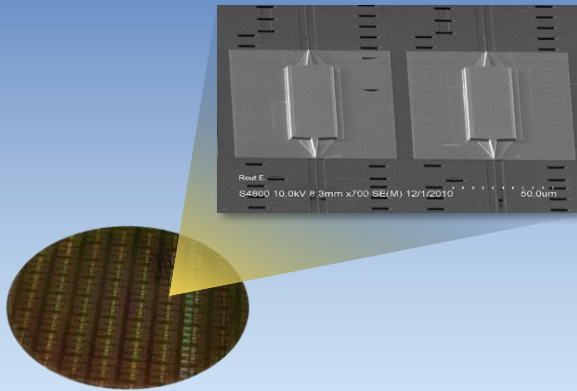
Intel® Silicon Photonics: Optics at Silicon Scale

Silicon Integration



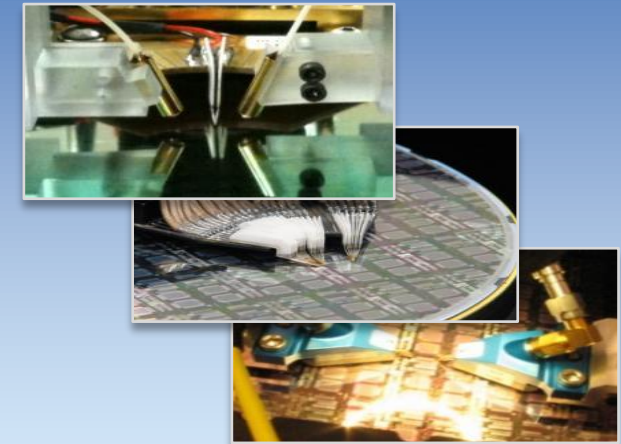
Integrated Optics, Enabled by Intel's Hybrid Laser Technology
InP for lasers, SOAs, PDs

Silicon Manufacturing



Advanced CMOS Mfg Process at Intel Fabs On 300mm Wafers

Silicon Scale

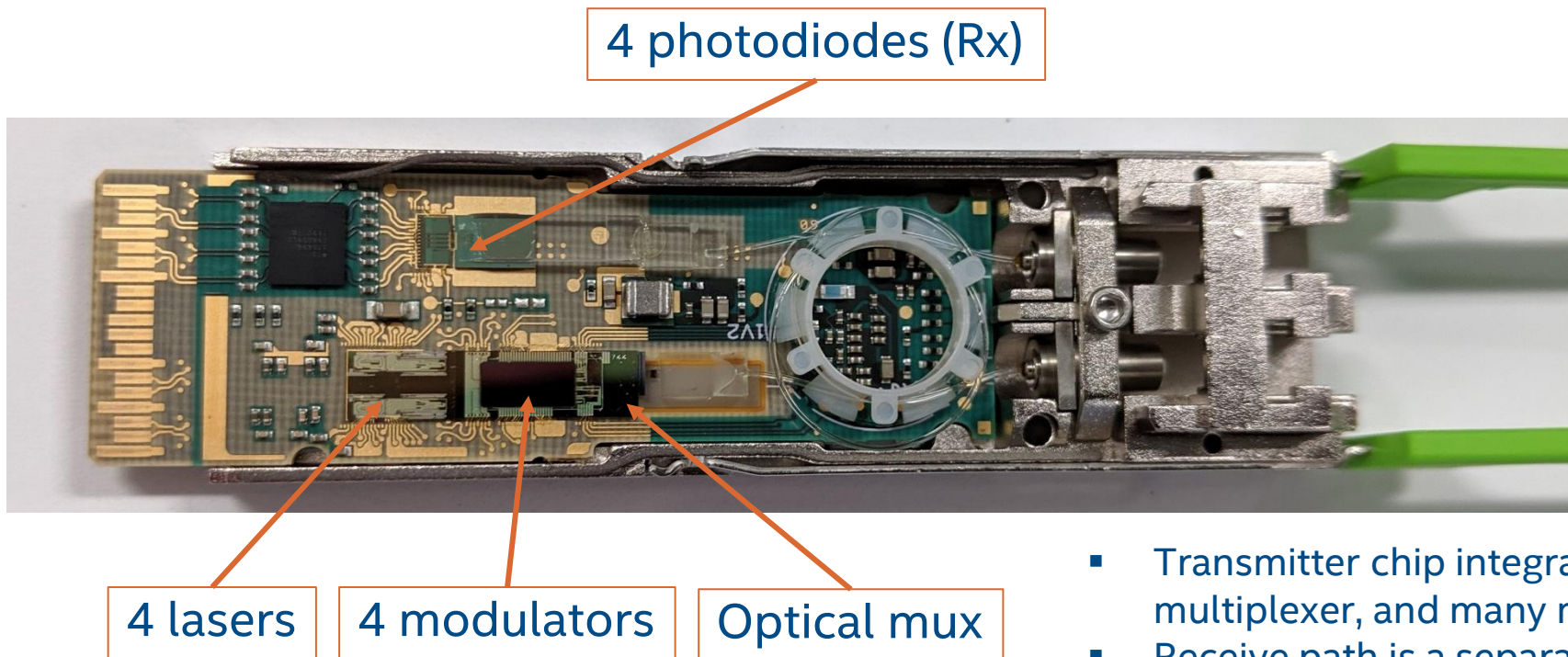


Automated On-wafer Optical, Electrical, and High-speed Test
Wafer-level burn-in

Differentiated platform through hybrid laser approach

CWDM4 transceiver: 4M+ units shipped since 2017

Non-hermetic packaging; -40°C to 85°C operation; leading reliability



Award Winning  **First High Volume Integrated Silicon Photonics Transceiver**

- Transmitter chip integrates 4 lasers, 4 modulators, optical multiplexer, and many monitoring PD's on a single die
- Receive path is a separate chip with 4 high speed photodiodes
- Data center operation or industrial temperature range (-40°C to 85°C)
- Industry-leading reliability and quality: ~2 FIT for laser; ~30dppm for module

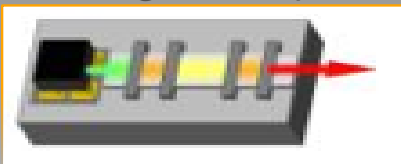
Robert Blum, "Integrated silicon photonics for high-volume data center applications," Proc. SPIE 11286, Optical Interconnects XX (Photonics West 2020)

Silicon Photonics Integration

Large Component Library of Active and Passive Devices

ACTIVES

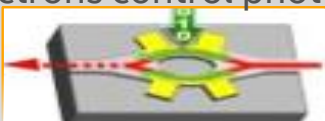
Hybrid lasers + SOAs
Electrons generate photons



SiGe/InP Photodetectors
Photons generate electrons



Si Modulators
Electrons control photons

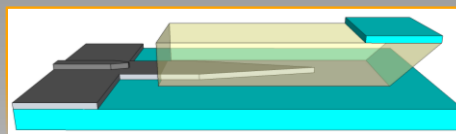


PASSIVES

MUX/ Demux



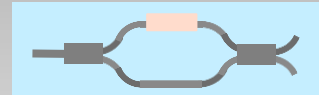
Coupling I/O



Optical Filter



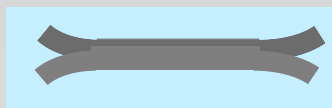
Interferometer/Switch



Splitter/Combiner

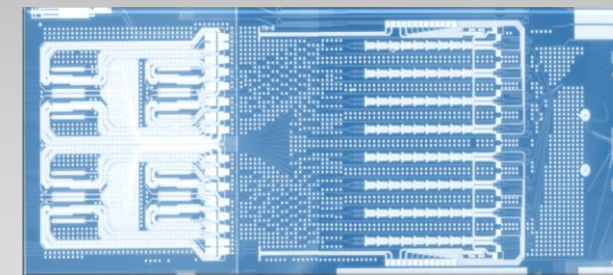
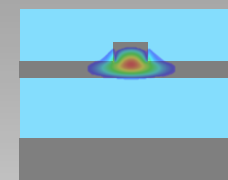


Polarization Diversity



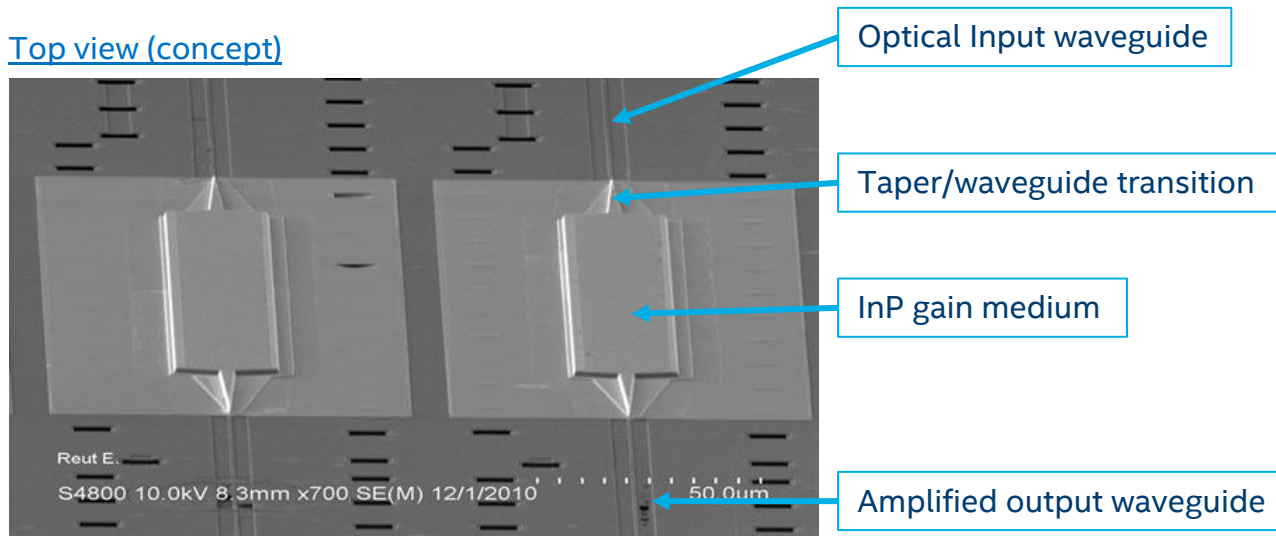
WAVEGUIDE INTEGRATION

Large-scale PIC &
On-chip Interconnects

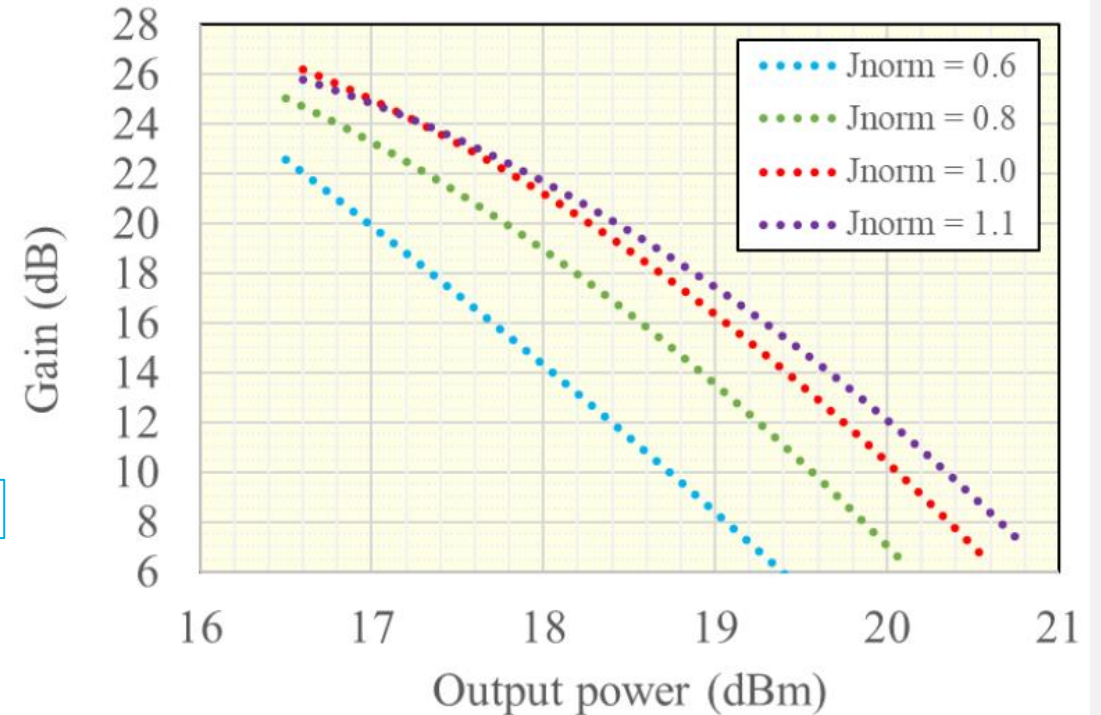
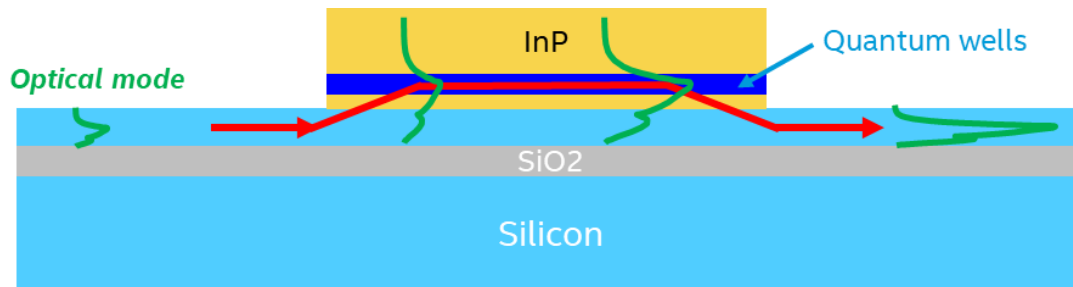


Optical On-Chip Amplifiers Enable High Output Power

Top view (concept)



Side view

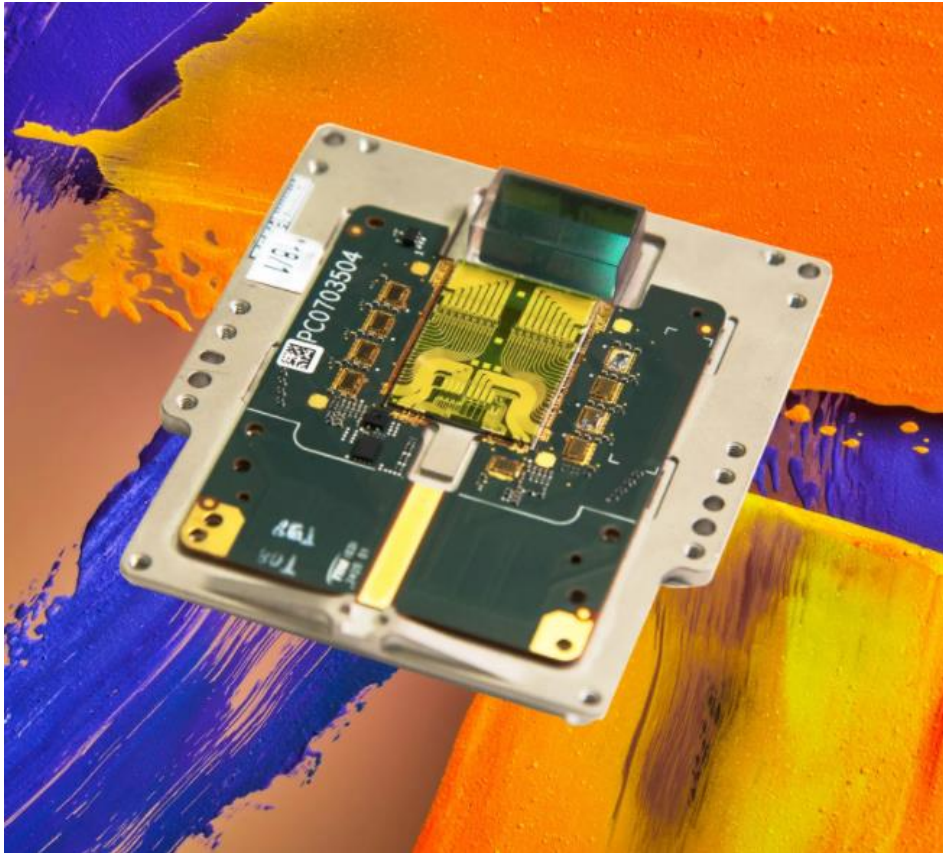


- 100mW (20dBm) output power from semiconductor optical amplifiers (SOAs)
- On-chip SOAs are unique differentiation for Intel hybrid integration platform

J. K. Doyle, S. Gupta, "An overview of silicon photonics for LIDAR," Proc. SPIE 11285, Silicon Photonics XV, (SPIE OPTO/Photonics West 2020)

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.

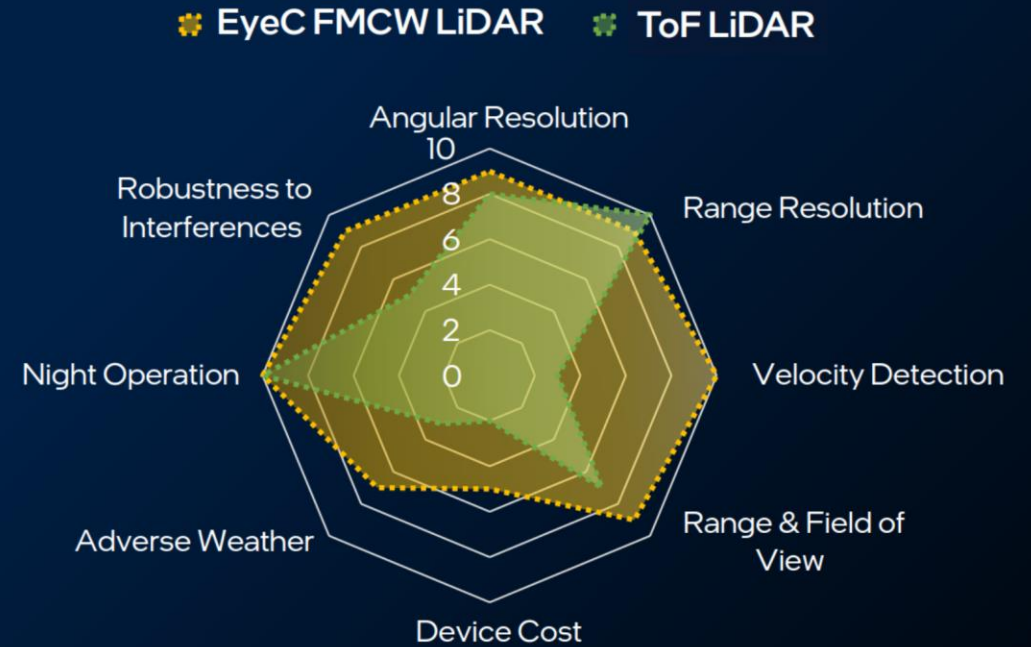
PHOTOGRAPH: MOBILEYE

<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>

FMCW LiDAR

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>

LiDAR Required Capabilities

Moving from ToF LiDARs

To FMCW

To achieve:

- 3D sampling (range, azimuth, elevation)



- 4D (+Doppler for relative velocity measurement)

- Instant heading measurement
- Point-levels TTC
- Reliable clustering and tracking

- 200m max. range
- $1/R^2$ decay



- 300m max. Range
- $1/R$ decay

- Enhanced ODD
- Higher effective dynamic range

- Sensitivity to interferences



- High immunity to interference through coherent detection

- Avoid impairments from sun, other LiDARs, retroreflectors



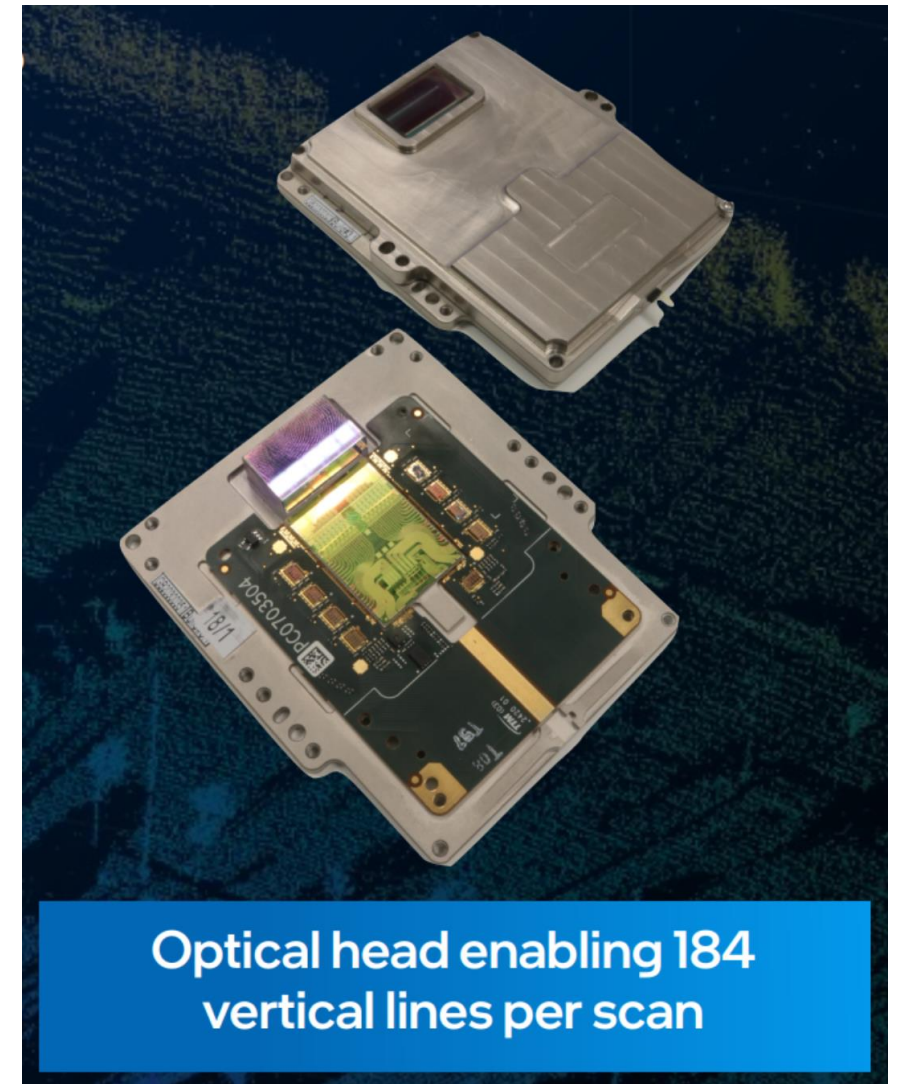
- Maintaining high res. sampling
- 2M PPS
- 600 pts per degree²

- Achieve accurate environmental perception

<https://newsroom.intel.com/wp-content/uploads/sites/11/2021/01/Under-the-hood-deck.pdf>

Summary – Silicon Photonics for FMCW LiDAR

- **Intel Silicon Photonics has ramped to high volume production**
 - Industry's highest SiPh volume with industry-leading quality and reliability
 - Wafer-level test and burn-in
 - Fast development cycles due to wafer-level test data
- **On-chip gain for lasers and SOAs**
 - Unique and mature capability with proven laser reliability
 - SOAs with up to 100mW output power
- **Developing FMCW LiDAR for 2025 high volume deployments**
 - Significantly better performance than ToF; 2M points per second
 - Ideal application for Silicon Photonics



<https://newsroom.intel.com/wp-content/uploads/sites/11/2021/01/Under-the-hood-deck.pdf>

Thank You!

www.intel.com/siliconphotonics

More questions?
robert.blum@intel.com