PHOTONIC INTEGRATED CIRCUITS FOR LIDAR

– Solid-State 2D Beam Steering –

MARCUS DAHLEM, PHILIPPE SOUSSAN, XAVIER ROTTENBERG

EPIC Online Technology Meeting | LiDAR Technology and Applications | April 14, 2020

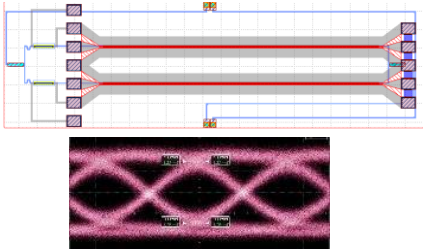
IMEC (founded in 1984)

- World-leading R&D center in **nanoelectronics & digital technologies**
- **International top talent** in a unique **>2B€ leading-edge fab infrastructure**
- **24/7** operation (**200 mm** and **300 mm**) **cleanrooms (12,000 m²)**
- Delivering **industry relevant technology** solutions in ICT, Healthcare and Energy markets, serving **600+** companies
- **>500 M€** R&D budget, **85%** direct from **industry**
- >**4000** people (from **90+** countries)
- **HQ** in Leuven (BE) + sites worldwide

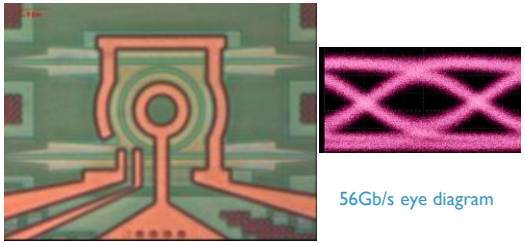
SI PHOTONICS PLATFORM @ IMEC

State-of-the-art mature and versatile platform

56G Silicon Mach-Zehnder Modulator

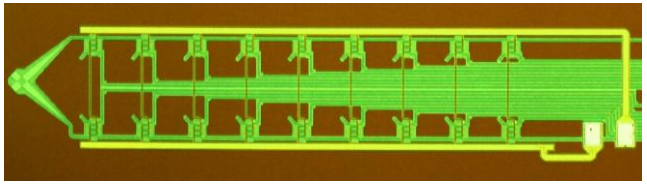


56G Silicon Ring Modulator

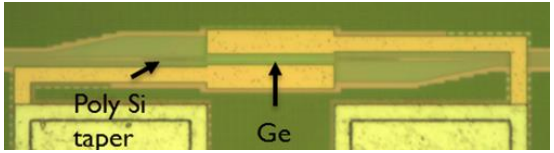


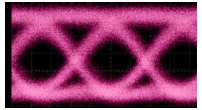
56Gb/s eye diagram

8+1-channel DWDM (De-)Multiplexing Filter



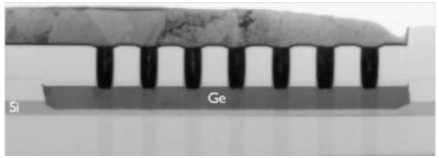
56G GeSi Electro-Absorption Modulator



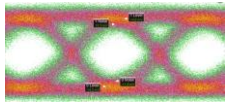


56Gb/s eye diagram

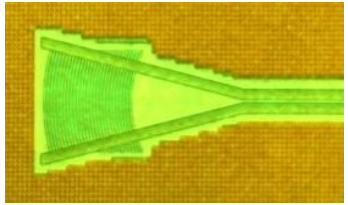
50G Ge Photodetector



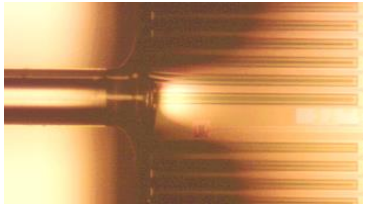
50Gb/s eye diagram



Grating Coupler



Edge Coupler

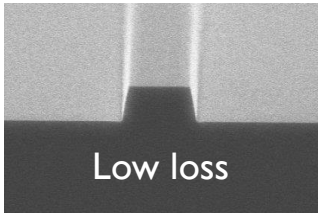


Philippe Absil et al., *Optics Express* 23(7), pp. 9369–78, 2015

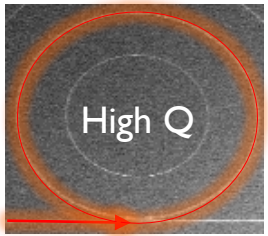
SIN PHOTONICS PLATFORM @ IMEC

A large library of experimentally verified components is available

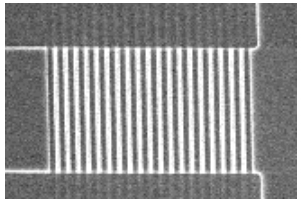
Waveguides



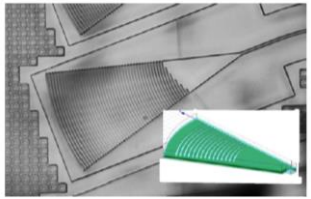
Ring Resonators



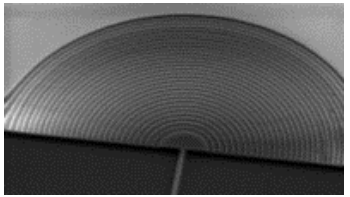
Fiber-to-WG



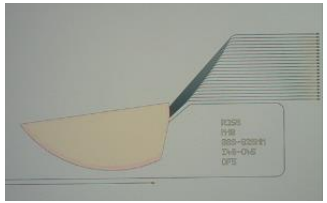
Low reflection

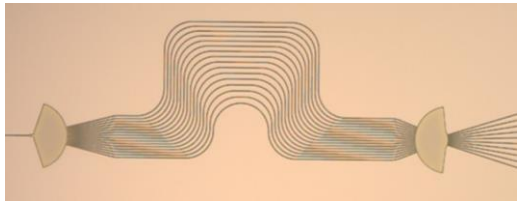


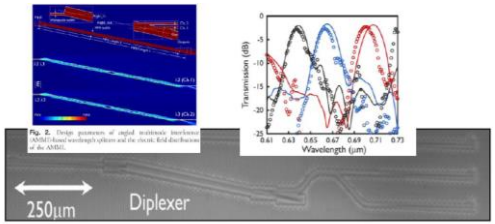
Focusing



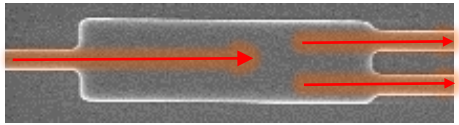
Basic spectrometers



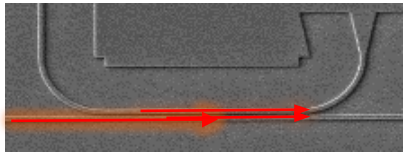




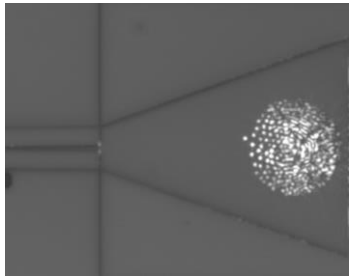
Multi-mode interferometer



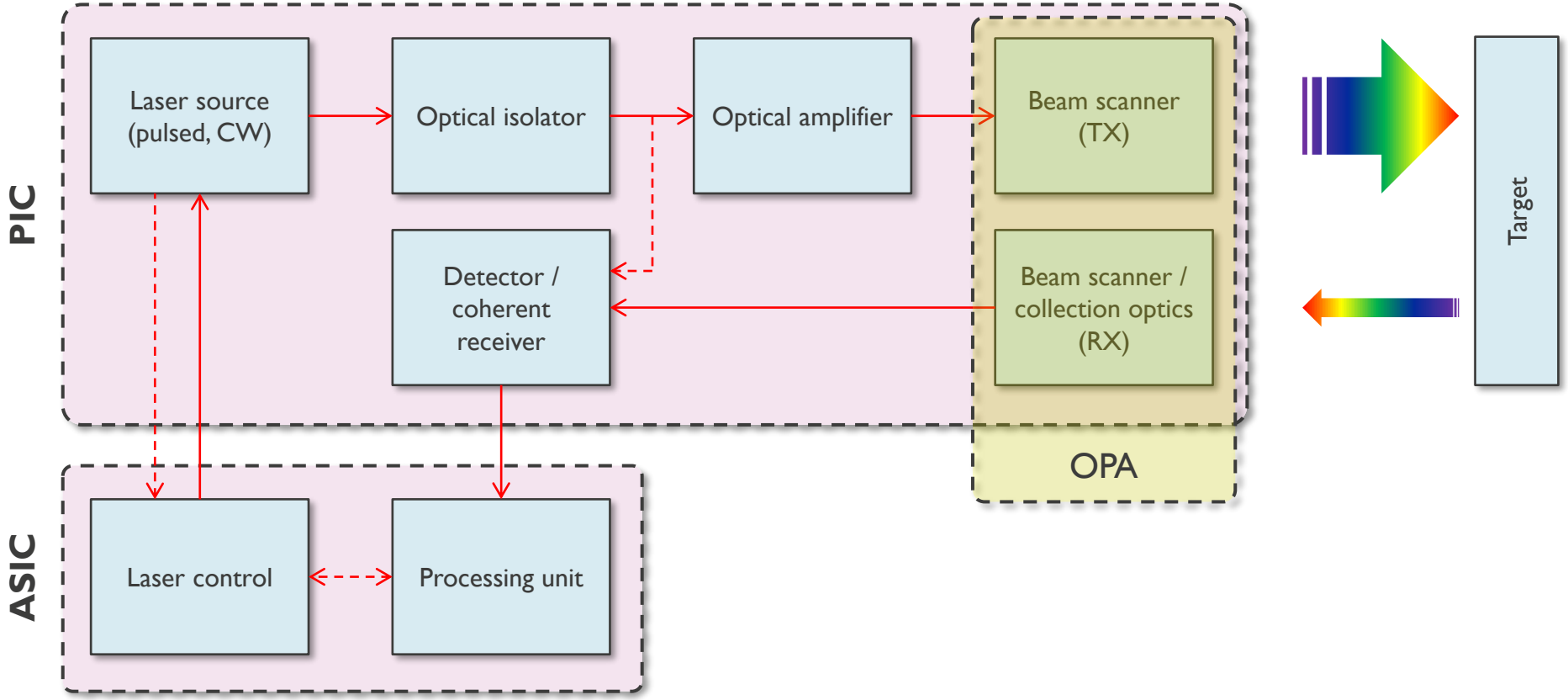
Evanescent coupler



Pseudo-random

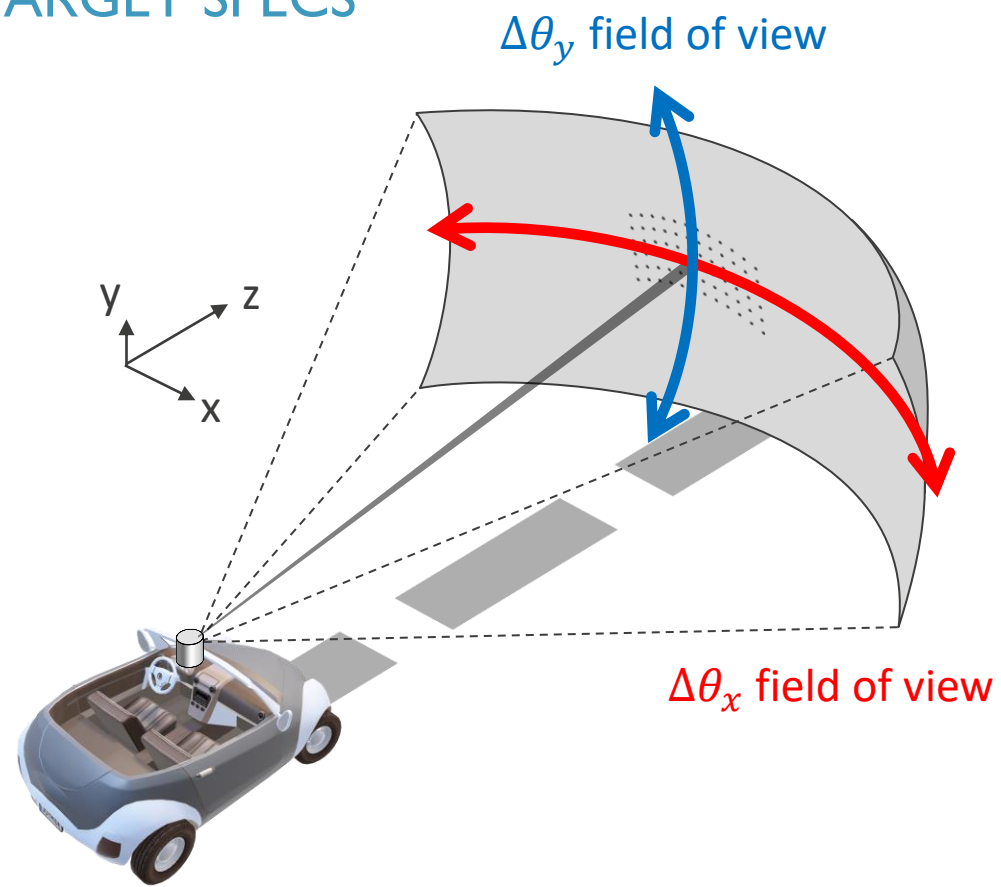


LIDAR GENERAL BUILDING BLOCKS



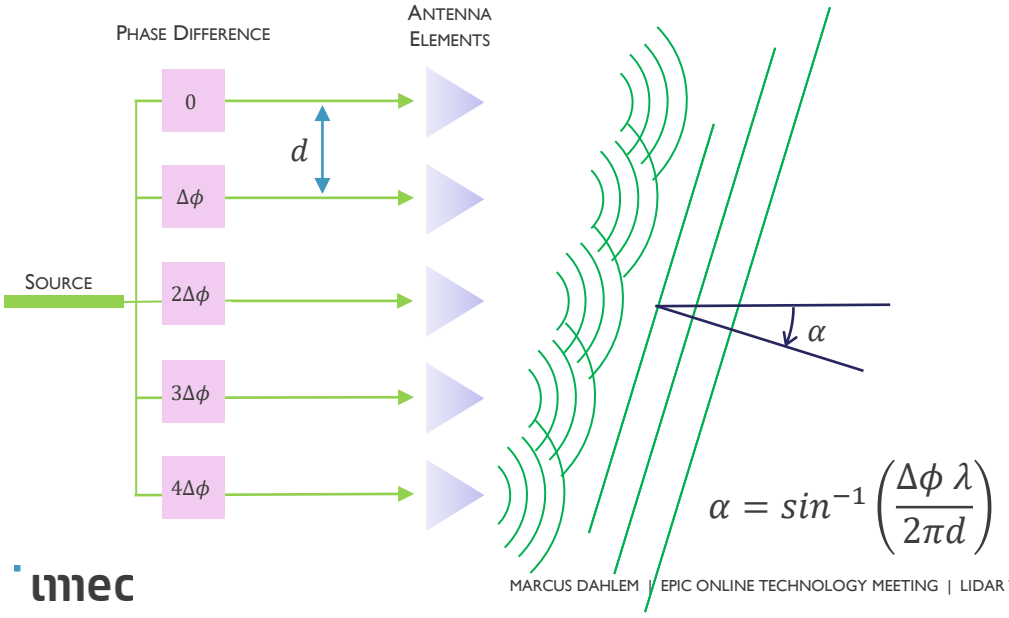
AUTOMOTIVE LIDAR GENERAL TARGET SPECS

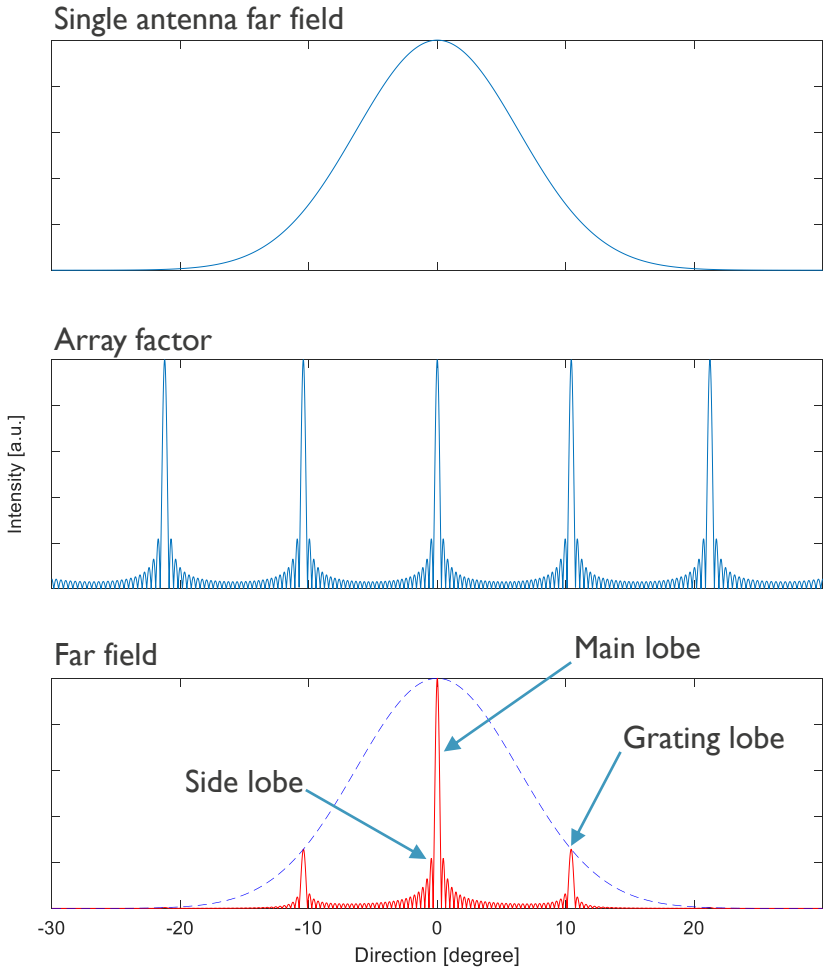
- Sensing depth: 3D mapping
- Range: 100-300 m
- Cost for high volume production: $100-$200
- Field of view: 30°-100° (H) × 10°-30° (V)
- Angular resolution: <0.05°
- Power consumption: <50 W
- Weight: <0.5 kg
- Size: < 10 cm × 10 cm × 10 cm
- Samples per second: >>300k (frame rate: 10-30 Hz)
- Wavelengths: 905-940 nm / 1310 nm / 1550 nm
- LiDAR engine: FMCW or ToF
- Beam delivery: Optical Phased Array (OPA)



PHASED ARRAY

- A uniform phase difference $\Delta\phi$ between neighboring antennas results in beam steering
- Far-field radiation pattern is the product of the *antenna radiation pattern* and the *array factor*, assuming identical antennas





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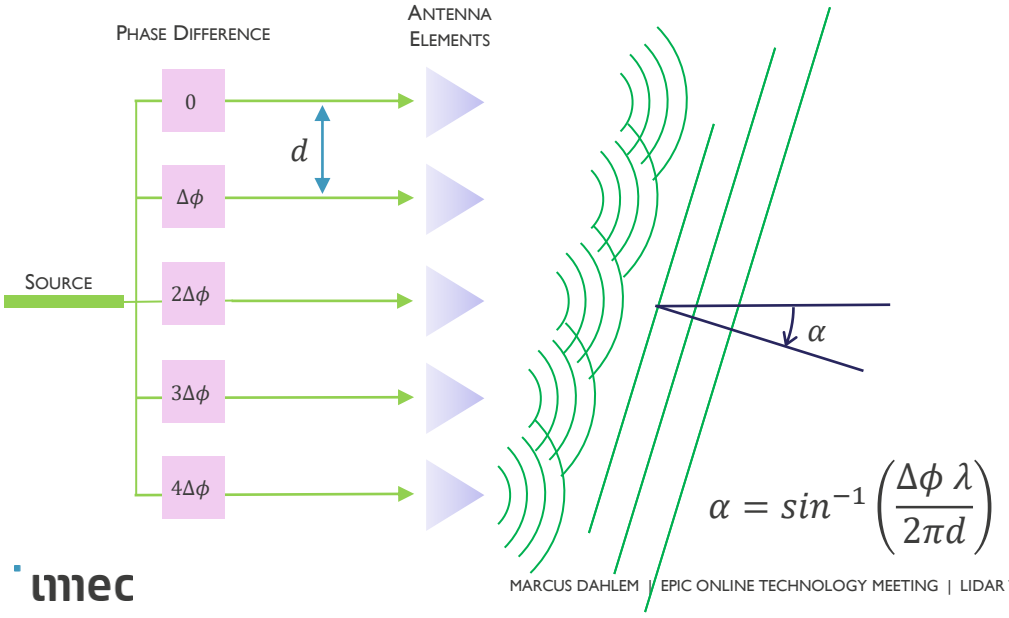
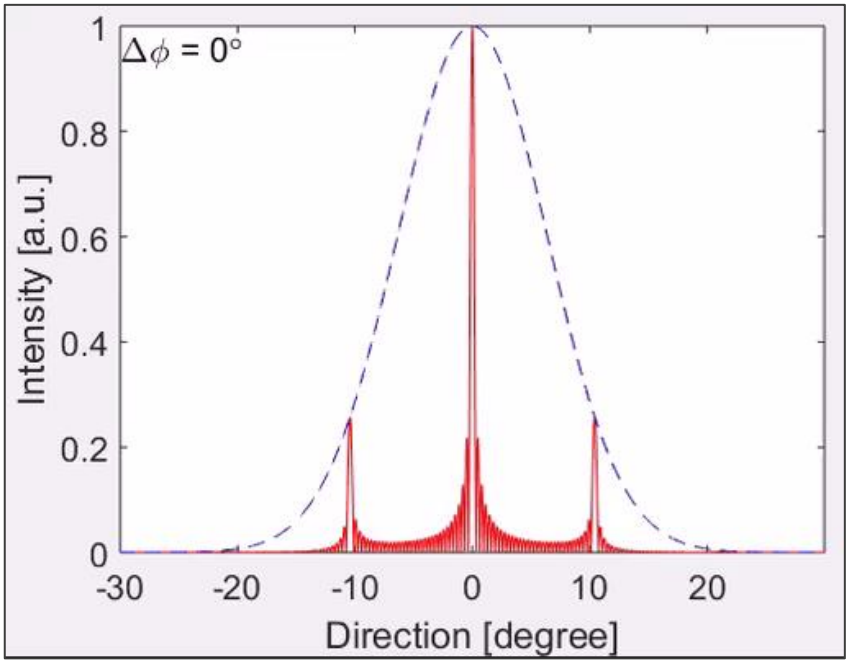
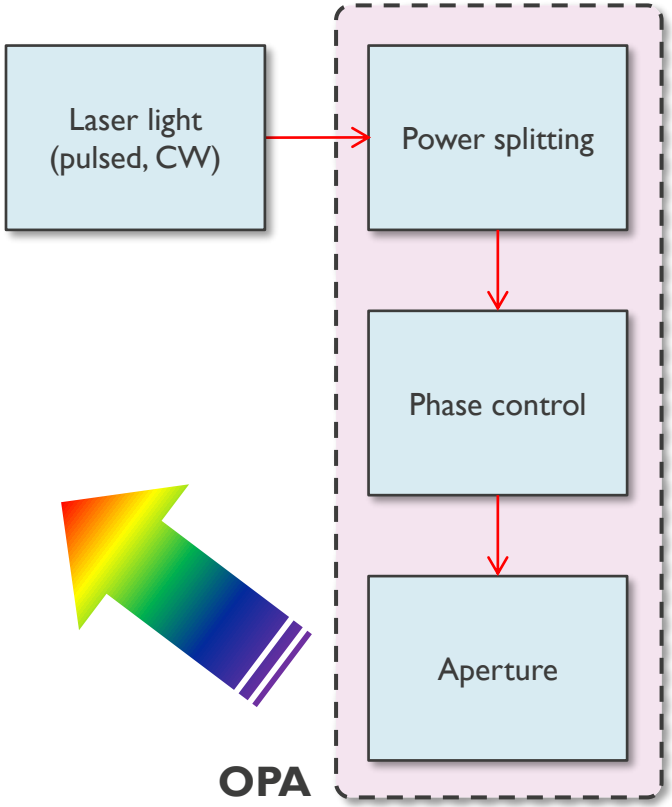


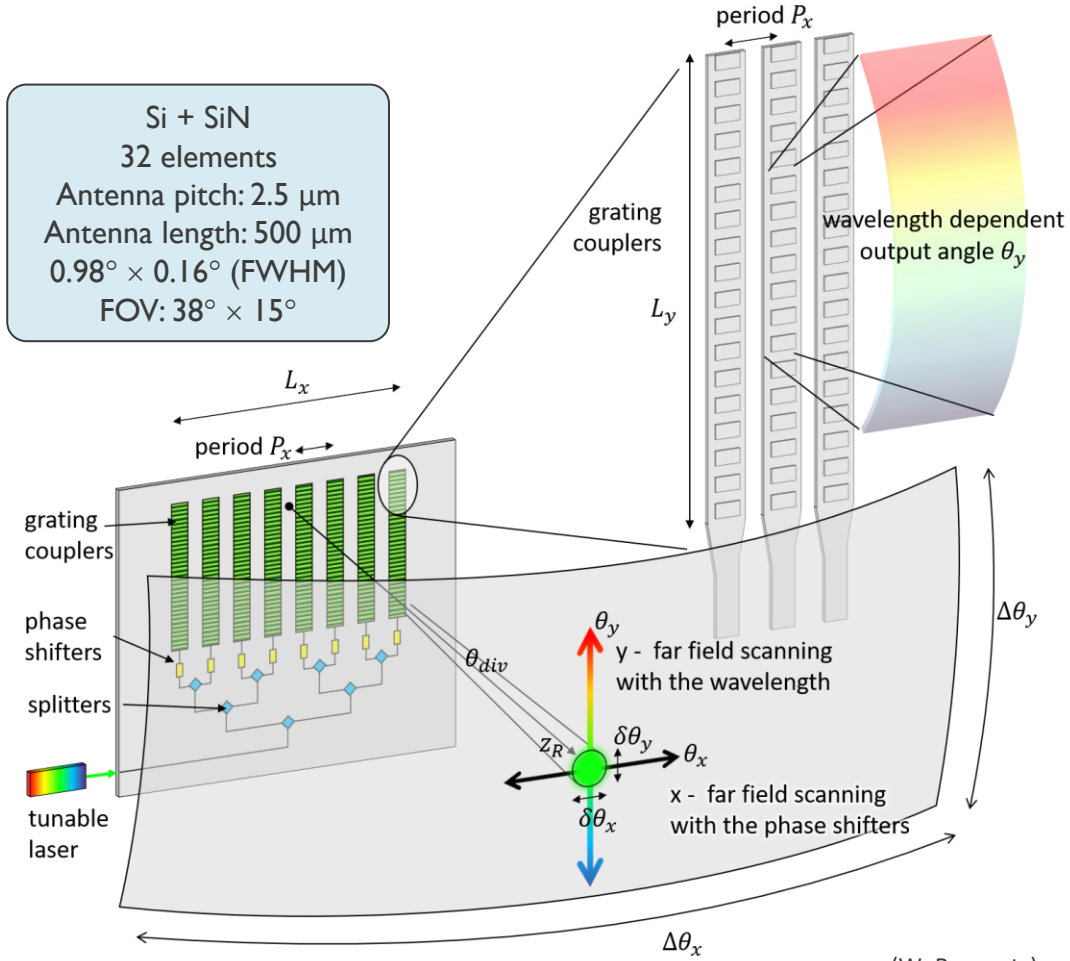
$$\alpha = sin^{-1}\left(\frac{\Delta\phi\,\lambda}{2\pi d}\right)$$



OPTICAL PHASED ARRAY

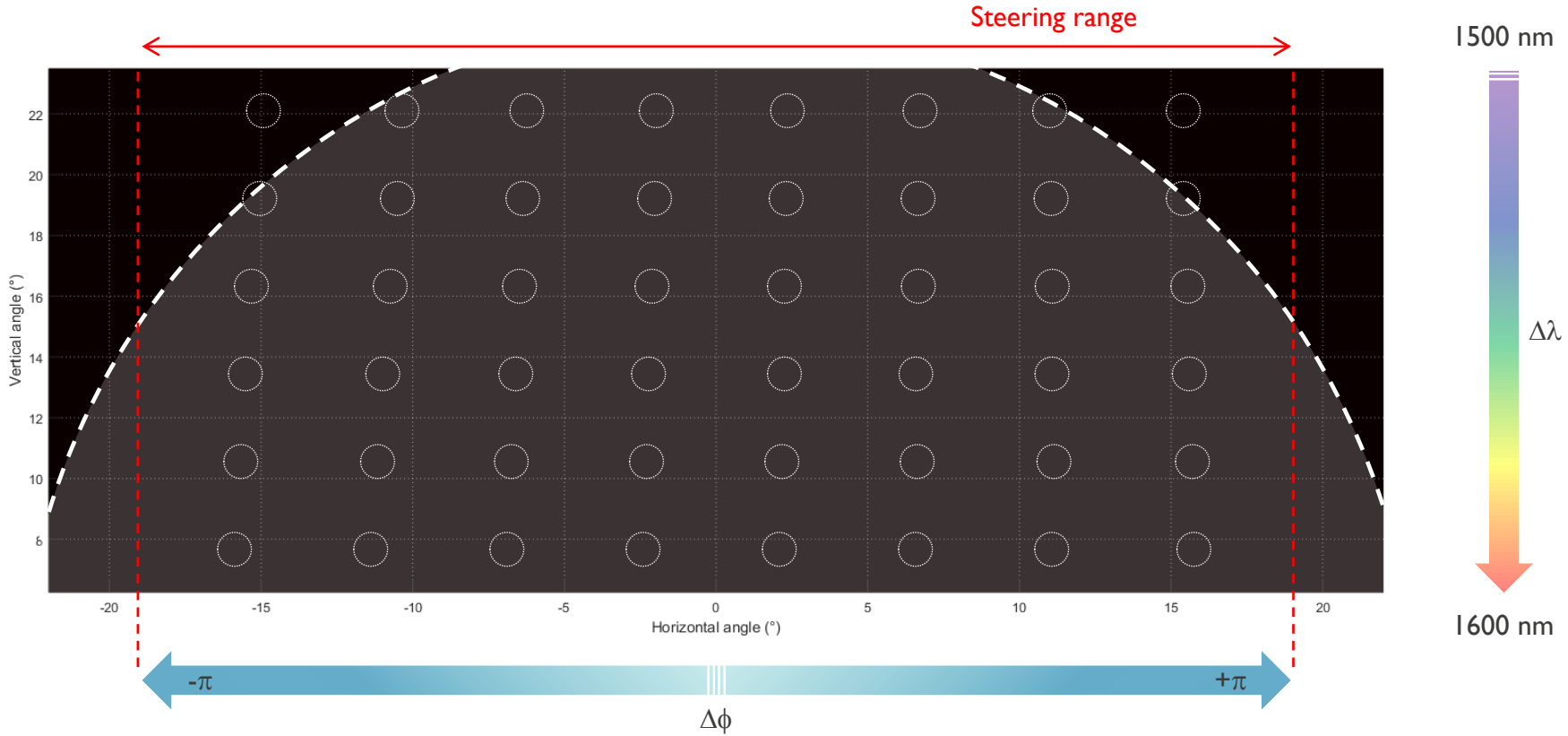


Si + SiN
32 elements
Antenna pitch: 2.5 µm
Antenna length: 500 µm
0.98° × 0.16° (FWHM)
FOV: 38° × 15°

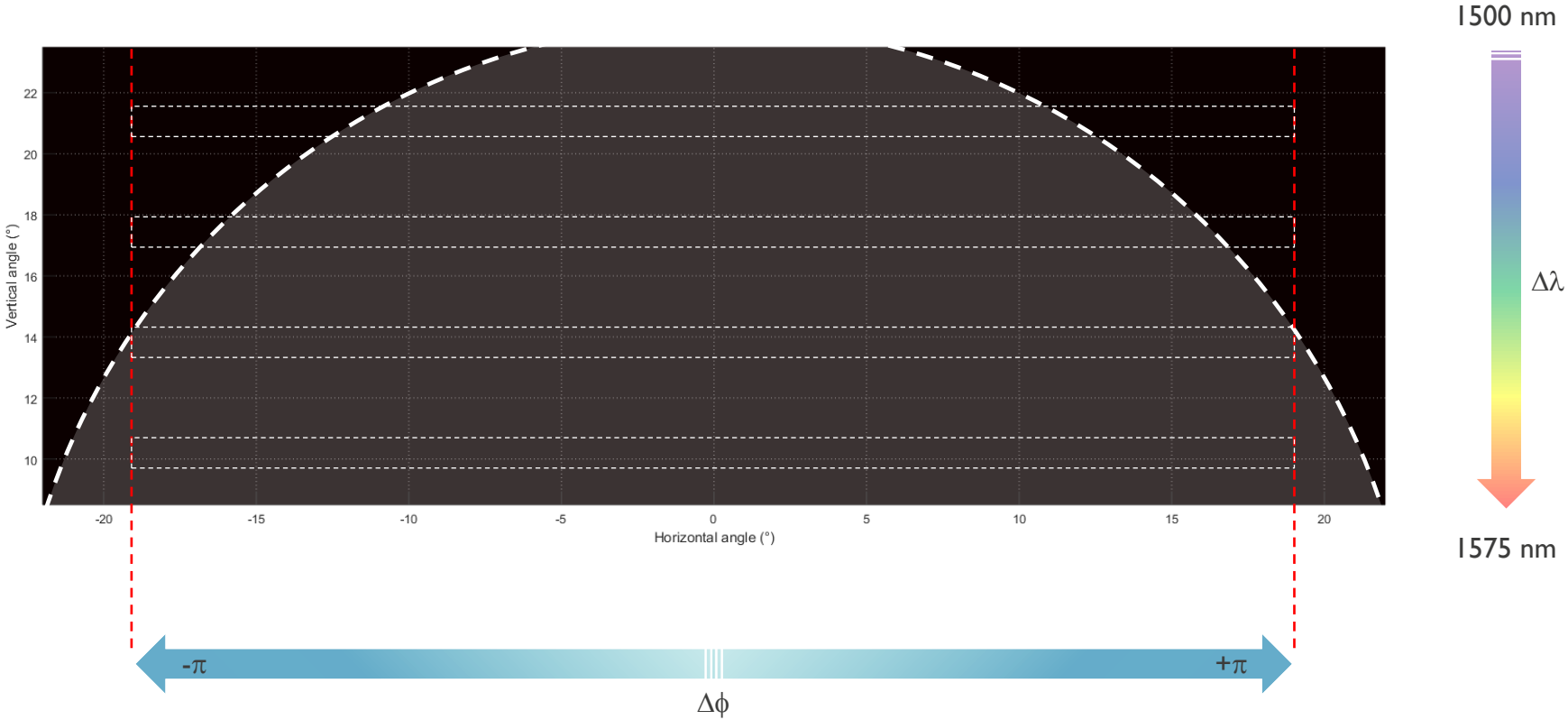


(W. Bogaerts)

2D STEERING DEMONSTRATION



2D STEERING DEMONSTRATION



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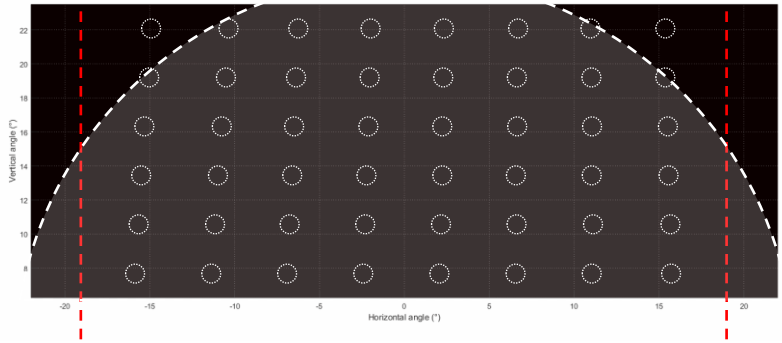
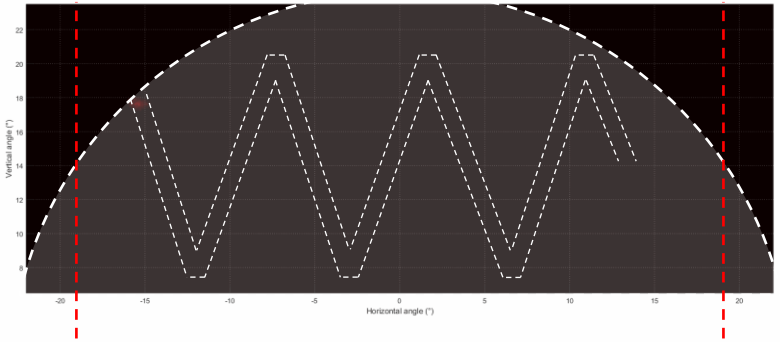
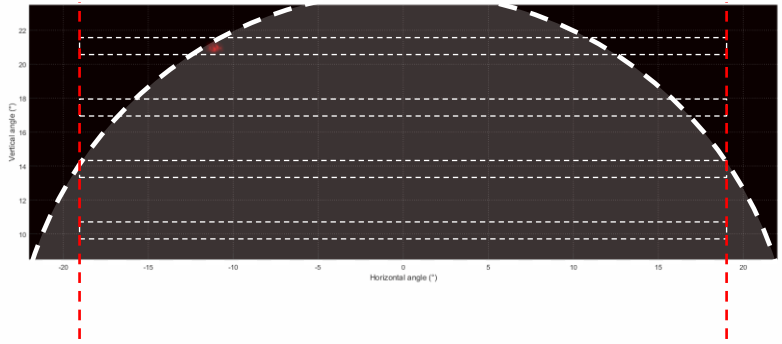
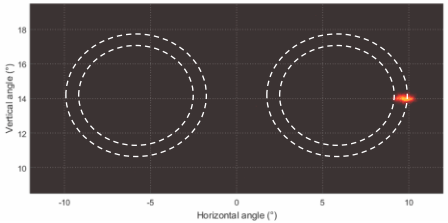
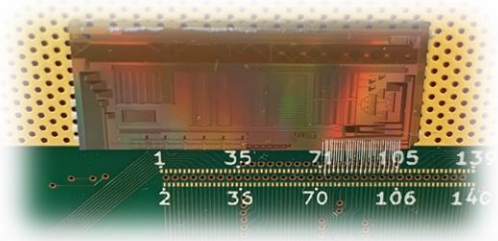




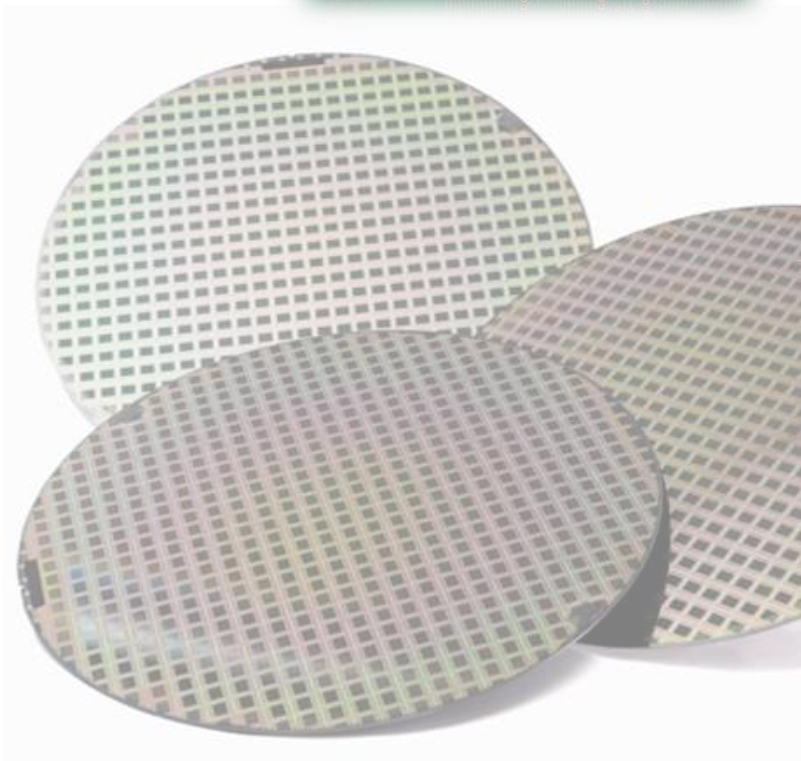




SUMMARY AND OUTLOOK



- 2D beam steering (thermal phase shifting + wavelength tuning) demonstrated in a Si-SiN platform
- Phase calibration essential for high quality beam forming
- Integrated photo detectors for on-chip monitor read-out
- Larger arrays (128 elements and beyond) and 2D lenses
- Main challenges:
  - Insertion loss
  - Power consumption (for phase shifting)
  - Number of antennas (for large aperture size)
  - Electronics control for phase shifters
  - Tight specs on tunable laser (linewidth, power, wavelength precision)
  - CMOS integration desired for complex electronics



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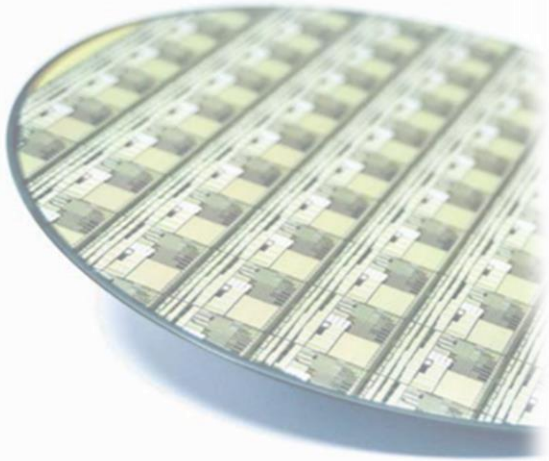
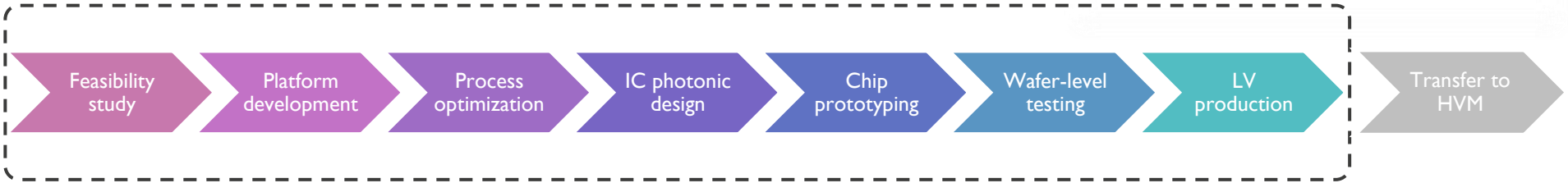


- Related research activities @ imec:
  - Si and SiN hybrid platforms (thick SiN, integrated mirrors, a-Si, etc.)
  - Laser development and gain medium integration on Si/SiN
  - Chip packaging solutions (mode conversion and edge coupling)
  - Low-power phase shifters (LC, electro-optic, MEMS-based)
  - Integrated PDs (e.g. for FMCW LiDAR engine, on-chip calibration schemes)

- Development on Demand:



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