E-O MATERIALS AND DEVICES FOR DATA CENTER AND QUANTUM PHOTONICS APPLICATIONS

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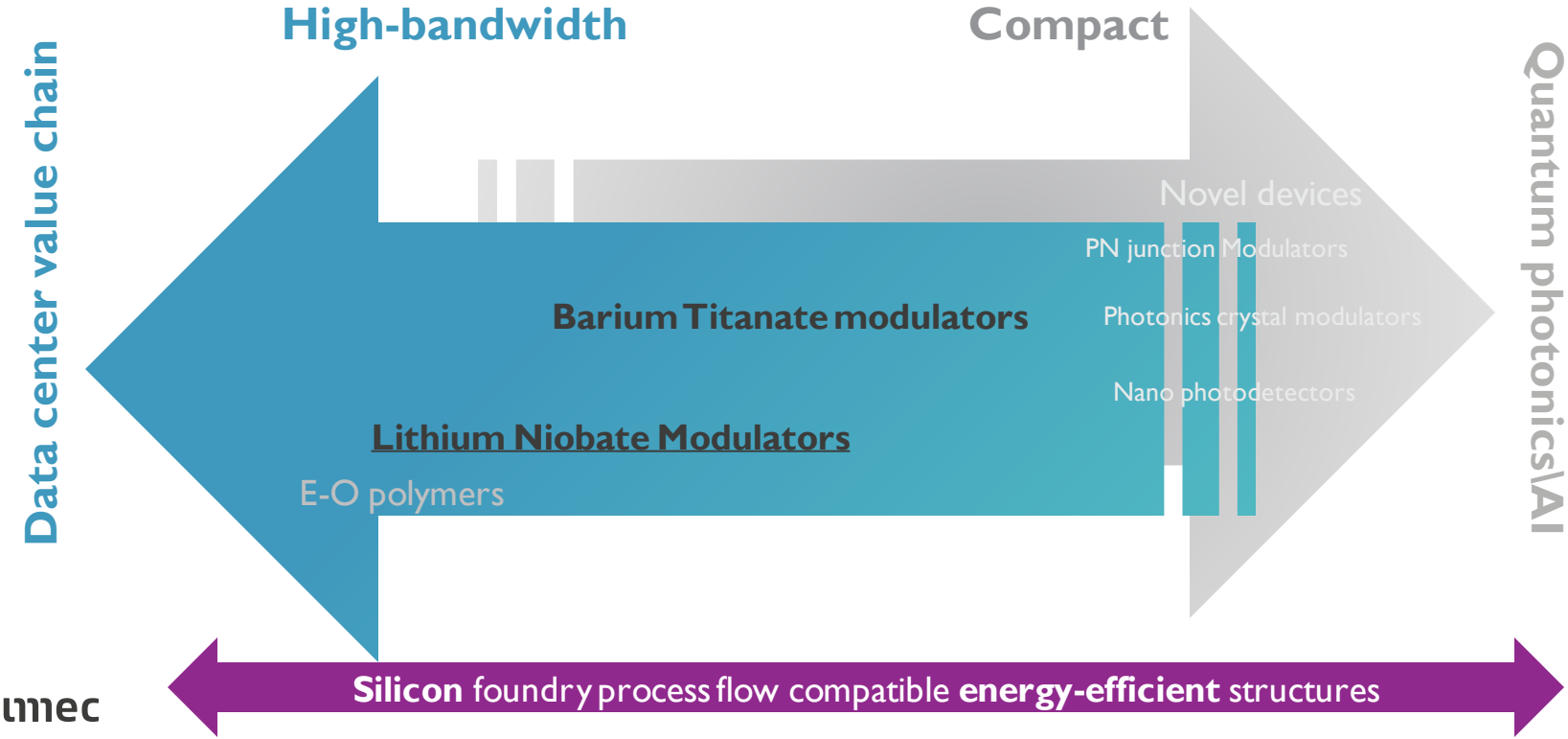
E-O MATERIALS AND DEVICES RESEARCH

HIGH-PERFORMANCE INTEGRATED PHOTONIC ELECTRO-OPTIC DEVICES



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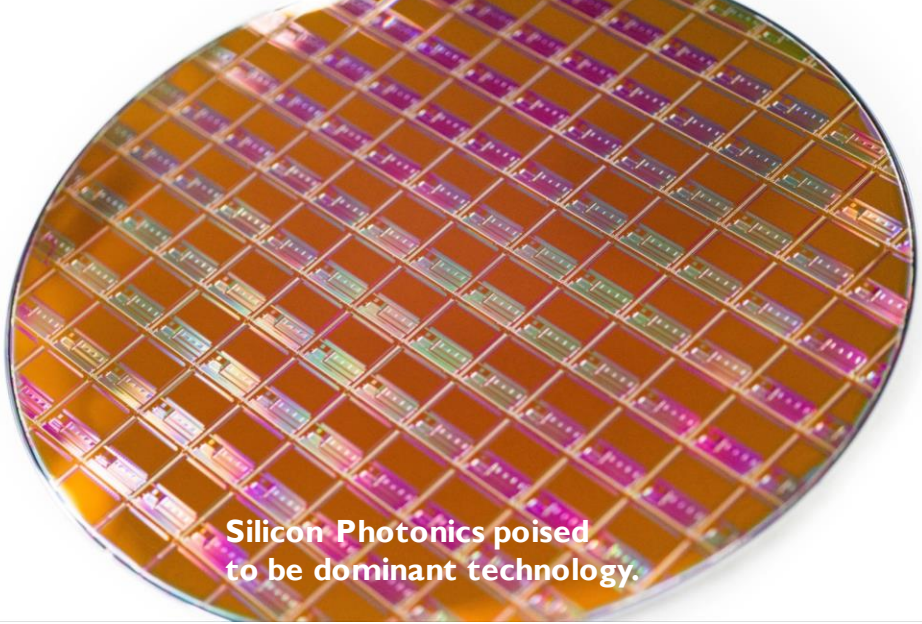
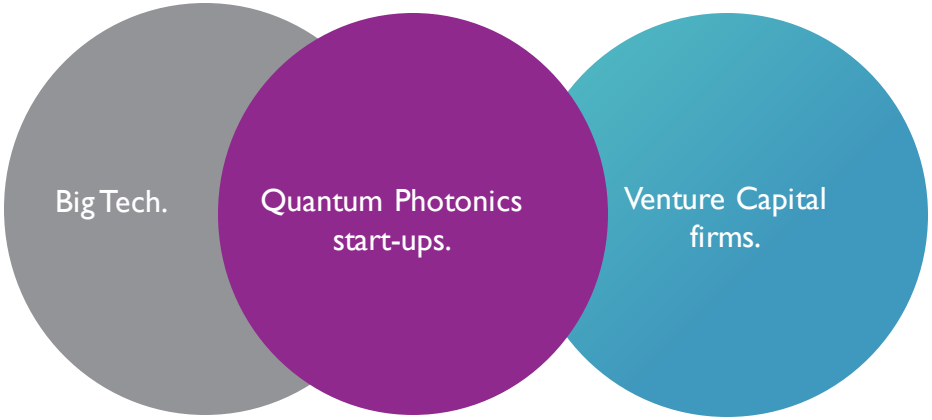
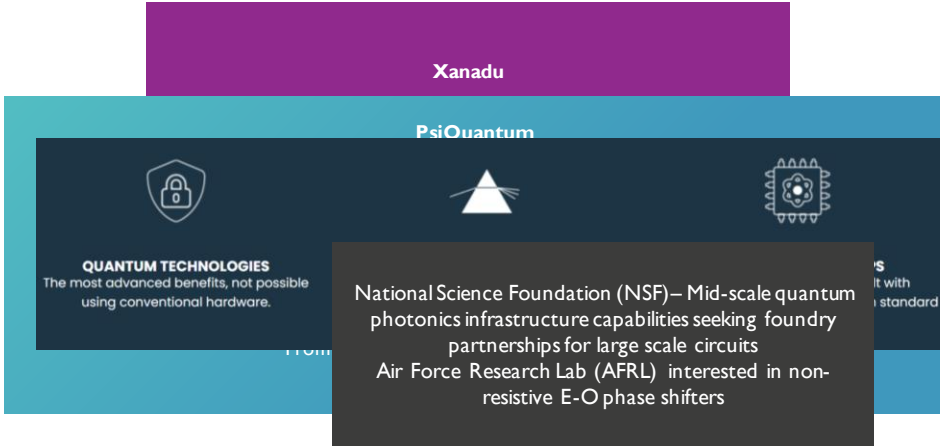


IEEE 2020 bandwidth assessment indicates need for 1.6Tbps.

Reaching limitations for bandwidths silicon-based modulators.

High bandwidth modulators based on silicon photonics with post-processed electro-optic materials





Investments have quadrupled in the past 5 years.

Silicon based quantum technologies are getting bulk of the investment.

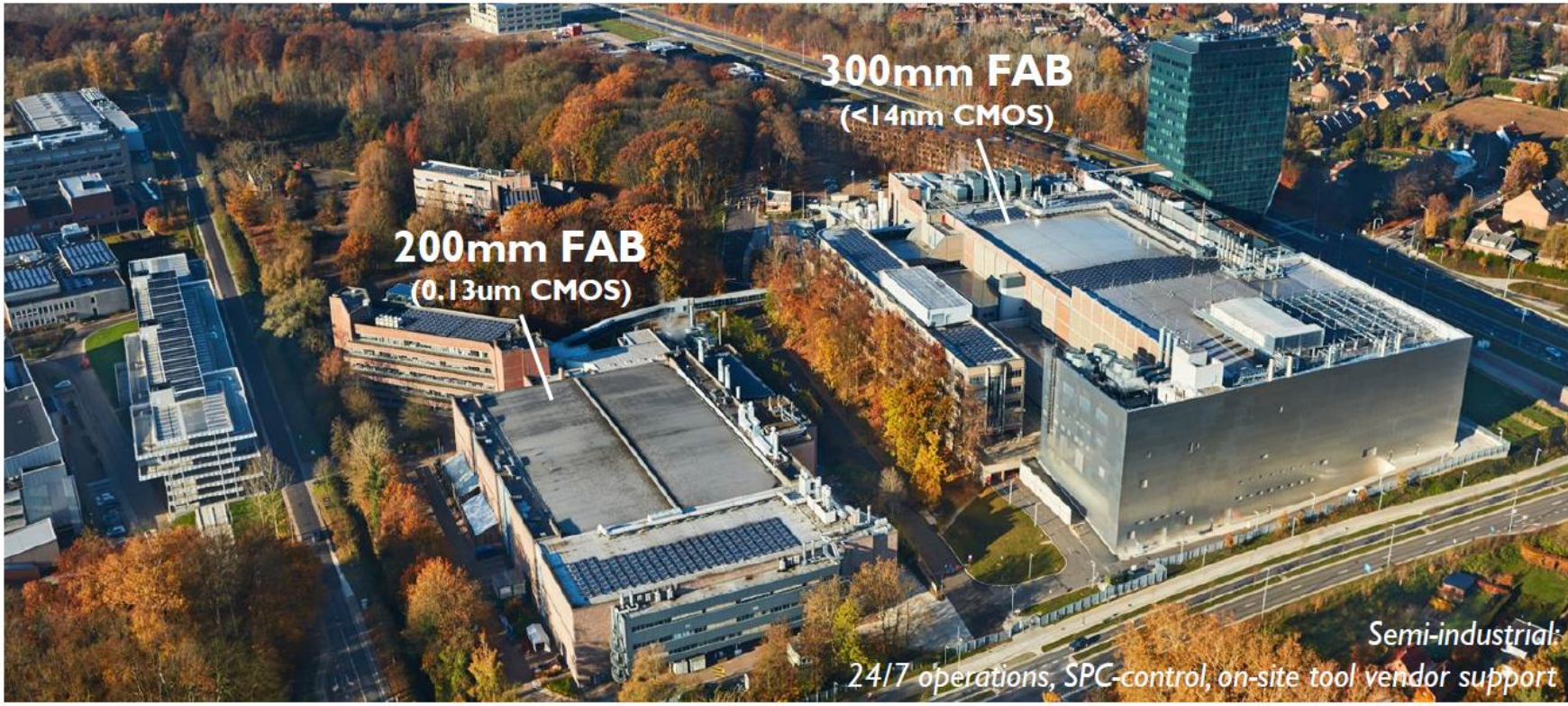
Next 10 years will focus on viability at scale and path to commercialization.

Silicon Photonics could be that path.

Energy efficient, compact phase shifters based on silicon photonics with post-processed electro-optic materials

IMEC's State-of-the-Art Fabrication Facilities

@Leuven Headquarters (25km east of Brussels, Belgium)



- Silicon Photonics Prototyping in 200mm FAB
- Advanced Silicon Photonics R&D (mostly) in 300mm FAB

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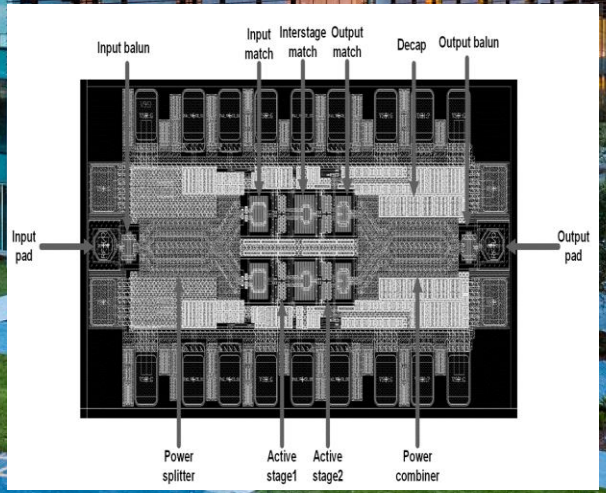
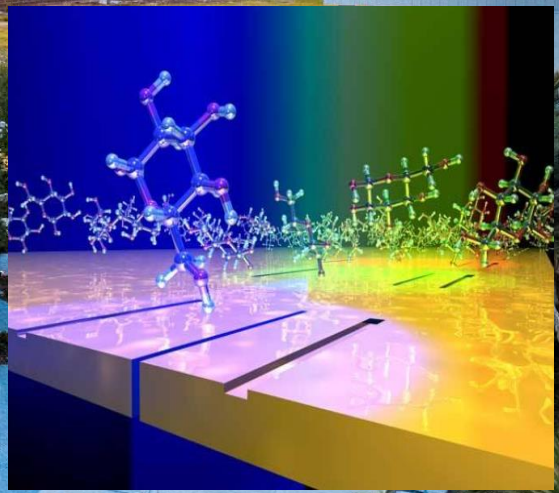
Imec-USA Nanoelectronics Design Center.

Photonics Design.



Electronics Design.



Electro-optic materials and process flows.

HI-PED PROGRAM OBJECTIVES

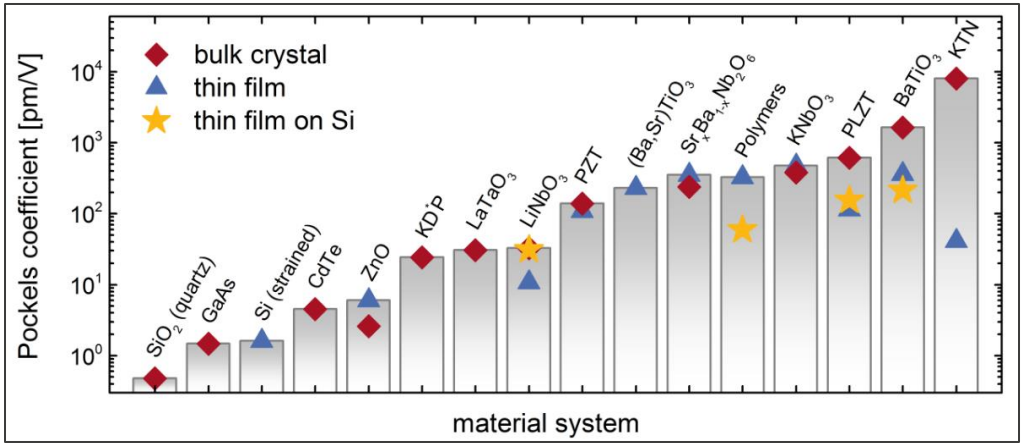
Integrated Modulator Performance Targets	Year 1 (2020-2021)	Year 2 (2021-2022)	Year 3 (2022-2023)
RF Bandwidth	50GHz	70GHz	100GHz
Operating Wavelengths	C,L,O	C, L,O	C, L, O
Target Vpi-L	3V-cm (2V-cm)	2V-cm (1V-cm)	<1V-cm (<0.5 V-cm)
Insertion Loss (fiber-to-fiber)	<6dB	<4dB	<2dB

Explore silicon photonics foundry compatible electro-optical material integration processes and structures for the development of compact, energy-efficient, ultra-high-performance modulators for communication, and compute applications targeting 100GHz bandwidth and CMOS compatible drive voltages

TECHNOLOGY OVERVIEW.

CURRENT STATE OF THE ART.

ELECTRO-OPTIC MATERIALS



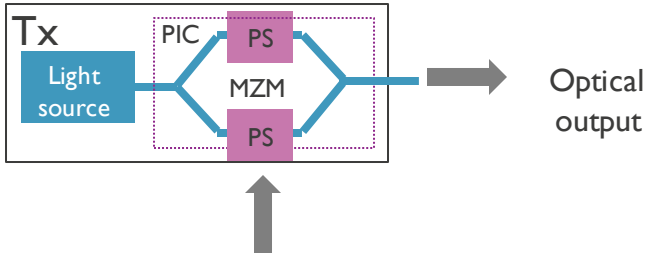
URL: https://www.zurich.ibm.com/st/photonics/materials.html

Abel et al., "A strong electro-optically active lead-free ferroelectric integrated on silicon", Nature Comm. 4, 1671 (2013)

Abel et al., "A Hybrid Barium Titanate–Silicon Photonics Platform for Ultraefficient Electro-Optic Tuning", J. Lightwave Tech. 34(8), 1688 (2016)

THIN FILM LITHIUM NIOBATE RESEARCH TRACK.

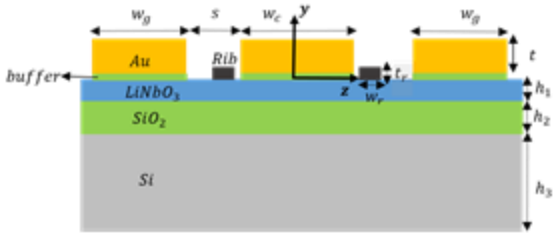
WHY TFLN - COMPACT HYBRID SILICON EO-MATERIAL MZM



	Silicon modulators	Conventional LN	LN on Silicon
Length (mm)	< 6	> 60	8
$V_\pi L$ (V.cm)	2 to 3	> 10	2 to 3
Optical loss (dB/cm)	~ 1	0.3	<0.4
Extinction ratio (dB)	~ 10	> 20	>20
RF bandwidth (GHz)	> 40	> 100	> 100
Power Handling	10mW	>200mW	>1W
Integrability with silicon photonics	Yes	No	Yes
Linearity	No	Yes	Yes

PRIOR ART TFLN

- Optimized modulator structure for low power design
  - Asymmetrical optical waveguides
    - Electrode spacing optimized to **reduce RF loss**
      - Addition of SiO_2 buffer layer between LN and gold
    - Buffer layer between electrodes to **lower optical loss**
- Targeting bandwidth larger than 100GHz



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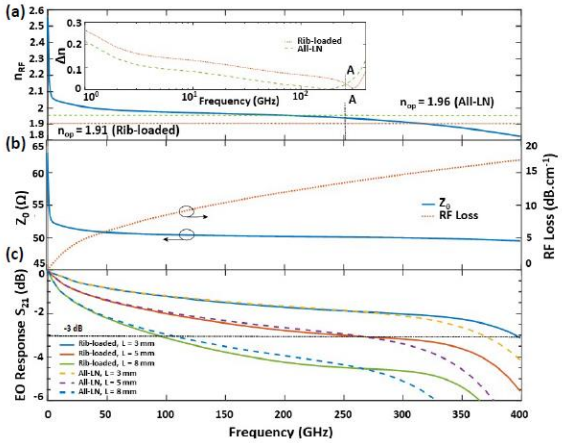
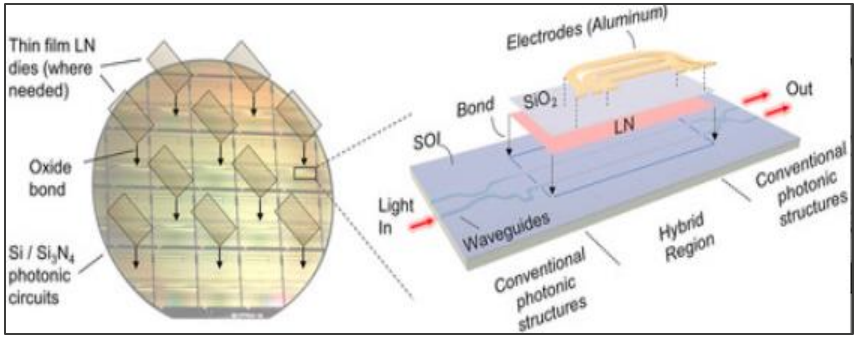
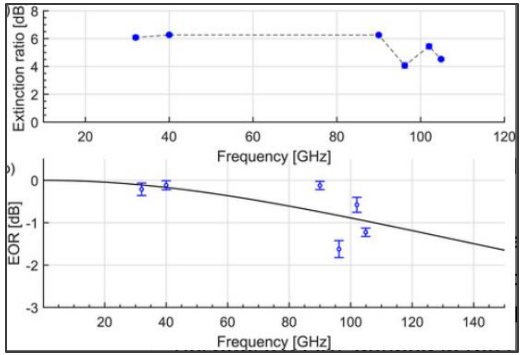


FOUNDRY COMPATIBLE FABRICATION LACKING at present DUE TO LITHIUM RELATED ISSUES





Mookherjea, et.al., "Achieving beyond-100-GHz large-signal modulation bandwidth in hybrid silicon photonics Mach Zehnder modulators using thin film lithium niobate", APL Photonics 4, 096101 (2019) (Sandia, UCSD)

CALL TO ACTION

IN CONCLUSION

- What makes the research program interesting?
  - Pre-competitive research track enabling longer term roadmaps for industry partners
  - Pure phase shift modulators
  - Ultra-high bandwidth (100GHz+) devices
  - Integration with 200mm and 300mm Silicon foundry platforms

- Imec proposes research roadmap & invites the industry
  - Inviting industry partners in the data center space and quantum photonics space
  - Partners subscribe to the full program or parts thereof and can request additional specific work next to the program

at imec, we shape the future