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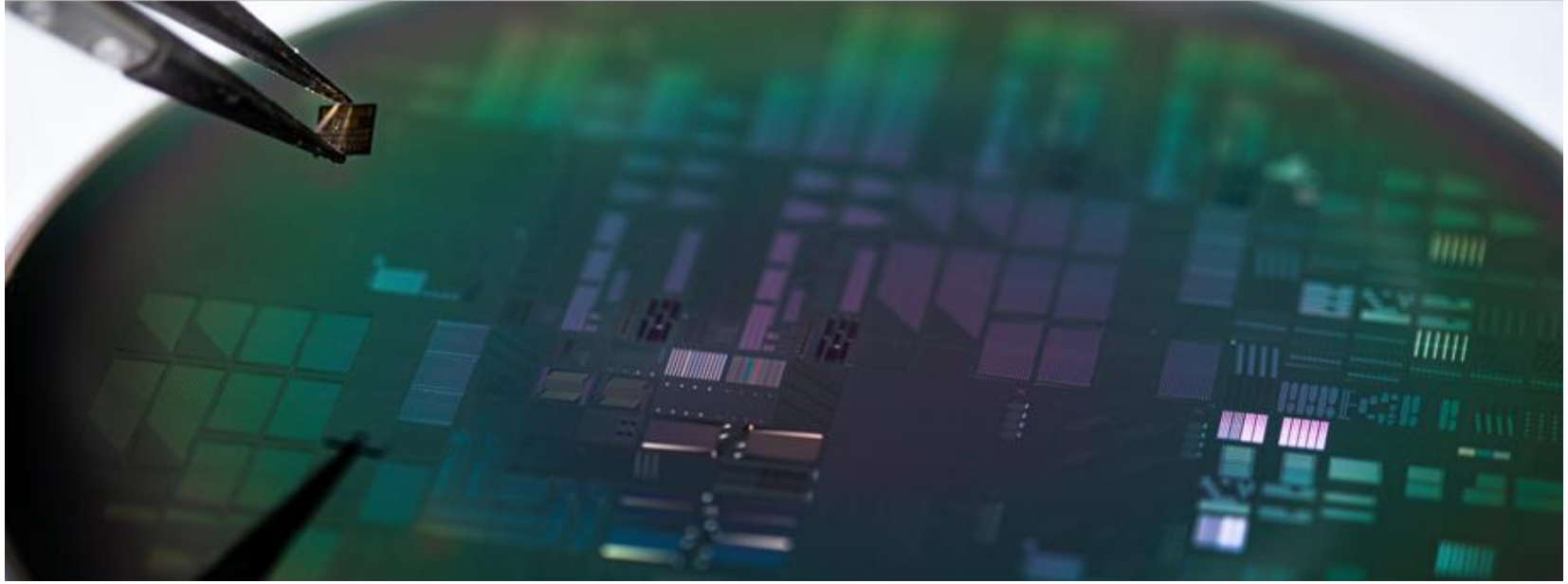
FACING THE CHALLENGES OF OUR TIME

SIMULATION CONFERENCE



ANSYS LUMERICAL: SERVING TO DEVELOP STANDARDIZED PHOTONIC INTEGRATED CIRCUITS COMPONENTS

Alberto Della Torre
R&D Engineer

ELENA
PATTERN
Co-funded by the European Union
Project funded by
Schweizerische Eidgenossenschaft
Confédération suisse
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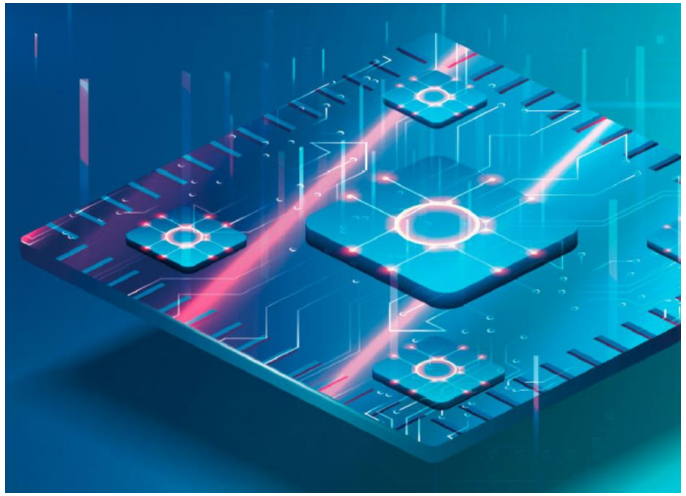
WHAT IS INTEGRATED PHOTONICS

Photonic Integrated Circuit

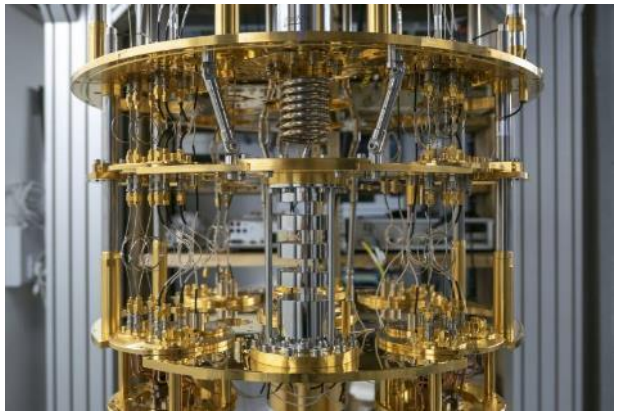
Generation, control, and detection of light (photon)

Placing many components next to each other in a compact footprint

Interaction of individual components to deliver a specific functionality

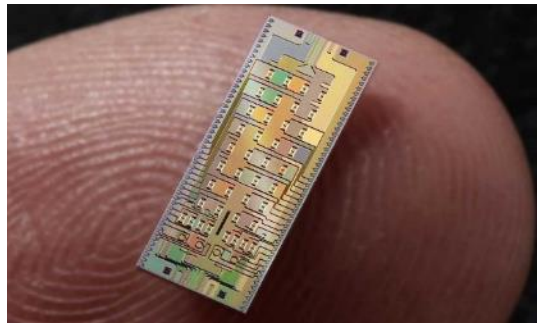


- Miniaturization
- Flexibility in design
- Increased complexity
- Scalability
- Low cost
- Enhanced performance
- Novel functionality



https://www.ucl.ac.uk/

Xanadu's 8x photonic quantum computing chip



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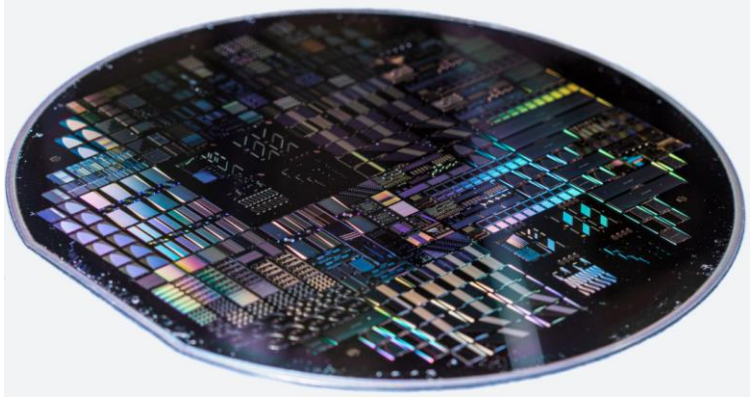
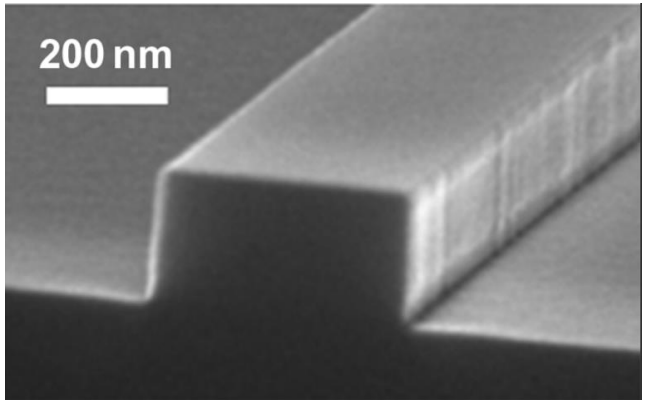
PIC TECHNOLOGY

Integrated photonics as the optical analog to integrated electronics:

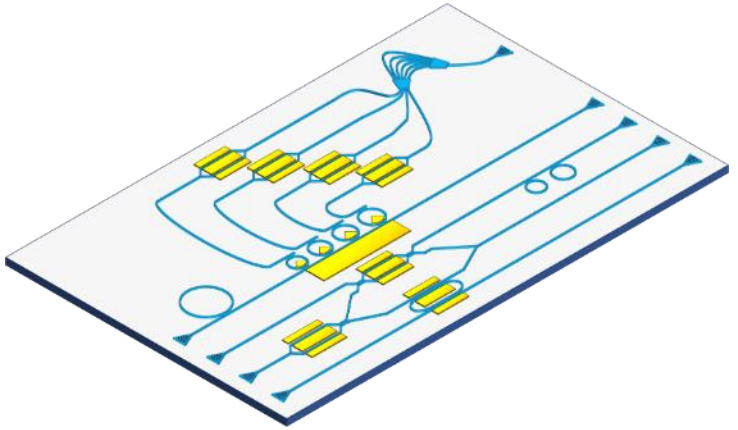
- Use of wafer-scale, thin-film technology
- Waveguides as basic interconnects
- Monolithic integration of passive and active components



Wafer-Scale



Waveguides



Passive + Active Components

Horikawa, T., Shimura, D., & Mogami, T. (2016). Low-loss silicon wire waveguides for optical integrated circuits. *MRS Communications, 6*(1), 9-15.

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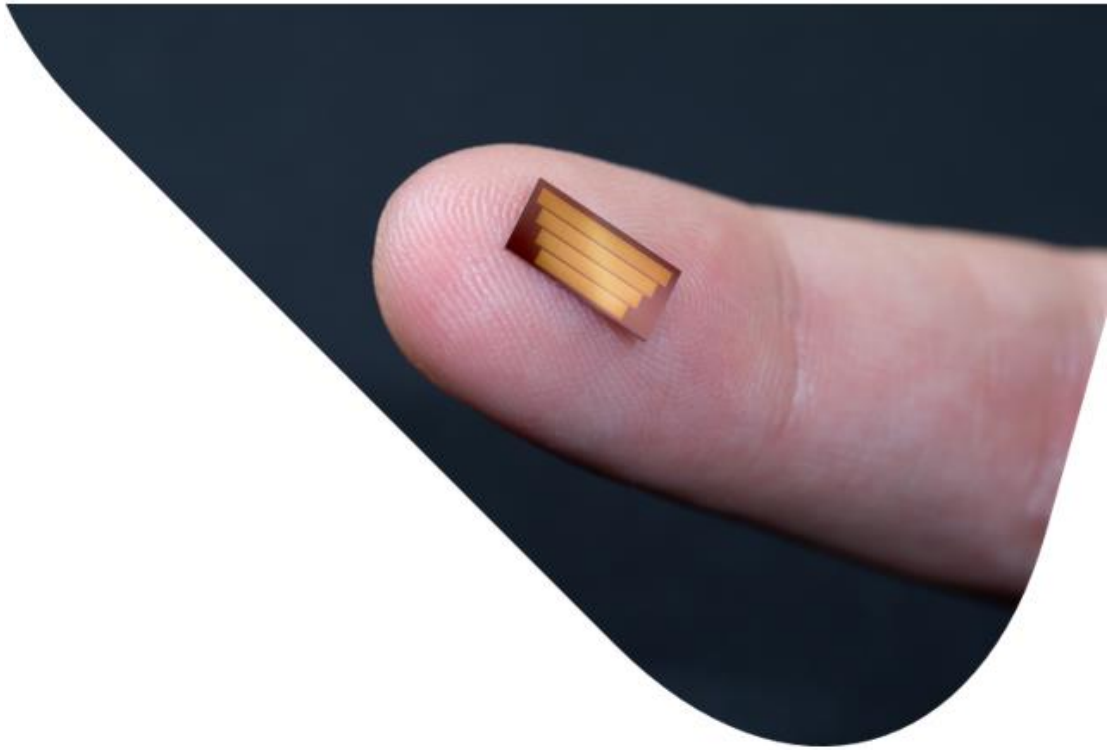
OUTLINE

- Why an LNOI PIC Foundry
- Where Ansys-Lumerical comes into play
- Example of simulation 1: photonic waveguide
- Example of simulation 2: MMI coupler
- Example of simulation 3: PIC
- Final conclusions



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NO IDEAL PHOTONIC PLATFORM

Need for components to generate, transport, process, and detect light
No single material can do everything!

Famous PIC platforms / Property	InP	Si	SiN	LNOI	Polymers
Transparency window	0.9 – 2 µm	1.1 – 8 µm	0.25 – 8 µm	0.3 – 5.5 µm	0.5 – 2 µm
Propagation losses	1.5 to 3 dB/cm	0.1 to 3 dB/cm	0.01 to 0.1 dB/cm	<0.1 dB/cm	<0.5 dB/cm
Two-photon absoprtion	high	high	Very low	Very low	low
Electro-optic coefficient (Modulators)	not intrinsic	not intrinsic	-	High (31pm/v)	Some polymers
Optical gain (lasers, amplifiers)	Yes	-	-	-	-
Detectors	Yes	Yes (<1µm)	-	-	-
Industry Status	Ramping up	High Volume	Low Volume	No Foundry	R&D Qualification

LNOI – A VERSATILE PIC PLATFORM

UNIQUE PROPERTIES

- Electro-optical property
- Wide transparency
- Nonlinear material
- Integration and scalability
- Wide bandgap
- Piezoelectric property

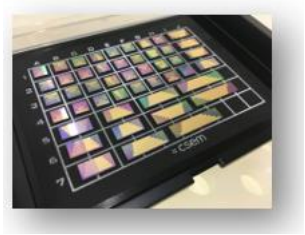
AN ENABLING TECHNOLOGY

OPTICAL COMPUTING

SPACE COMMUNICATION

NONLINEAR OPTICS AND METROLOGY

LIDAR



QUANTUM COMPUTING

TELECOM

SENSING & SPECTROSCOPY

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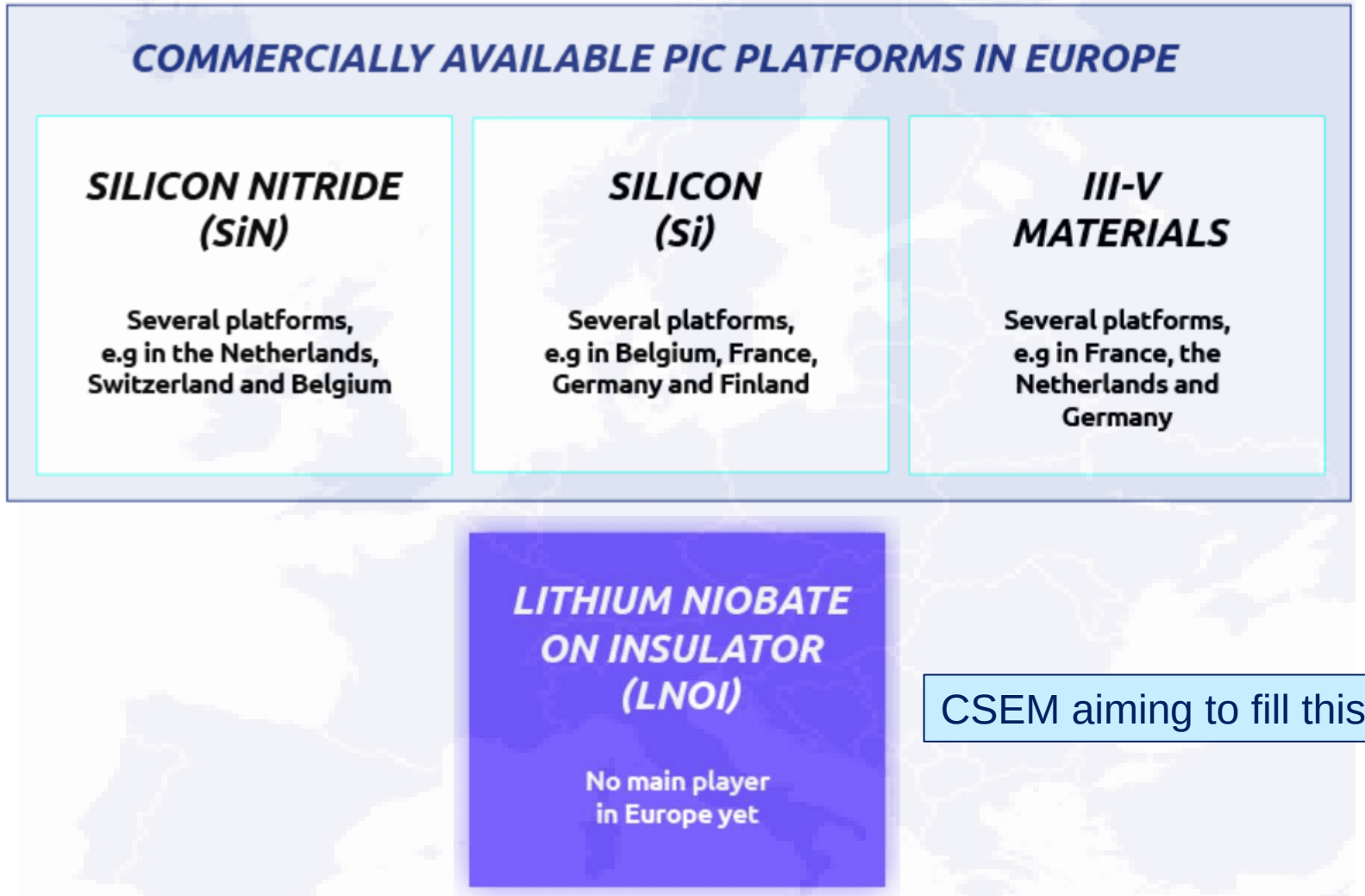
PIC FOUNDRY-LEVEL SERVICES IN EUROPE



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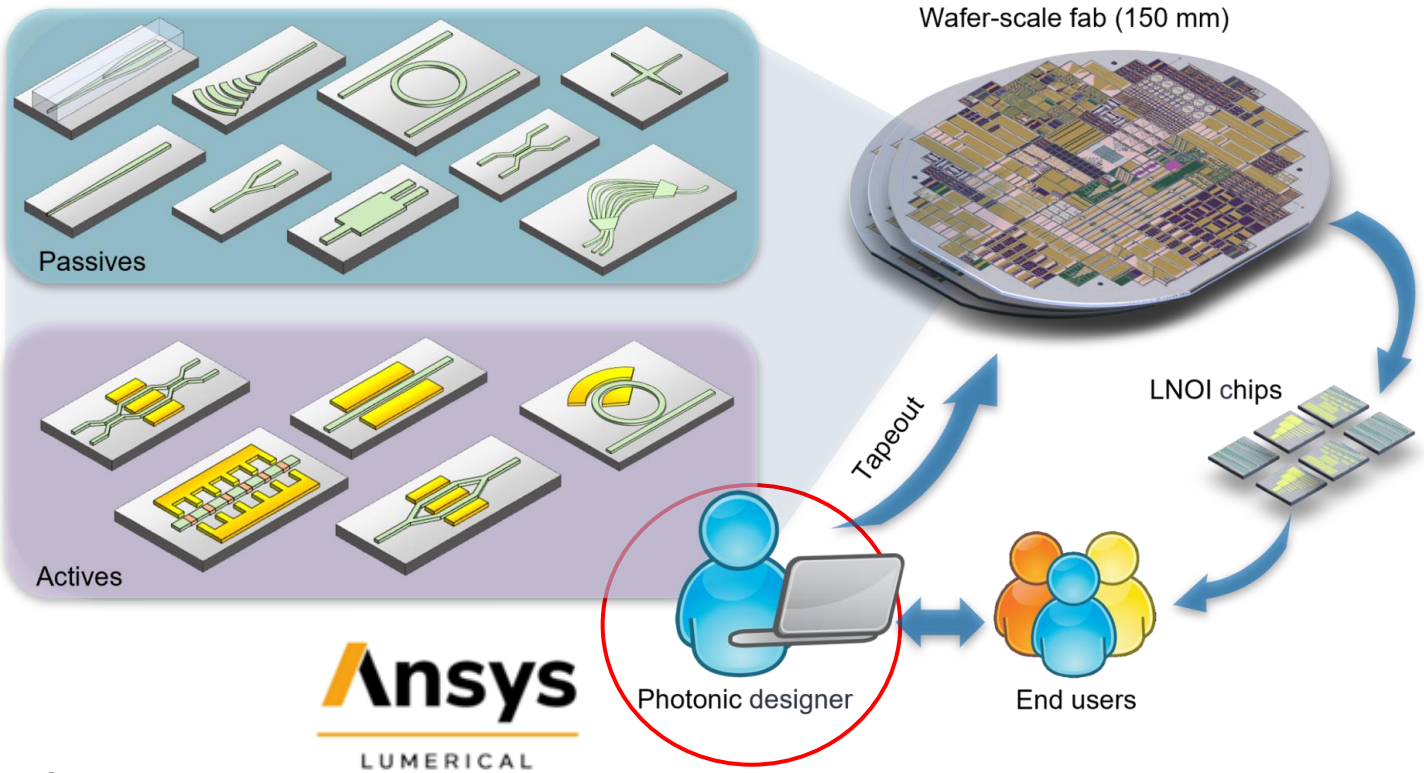
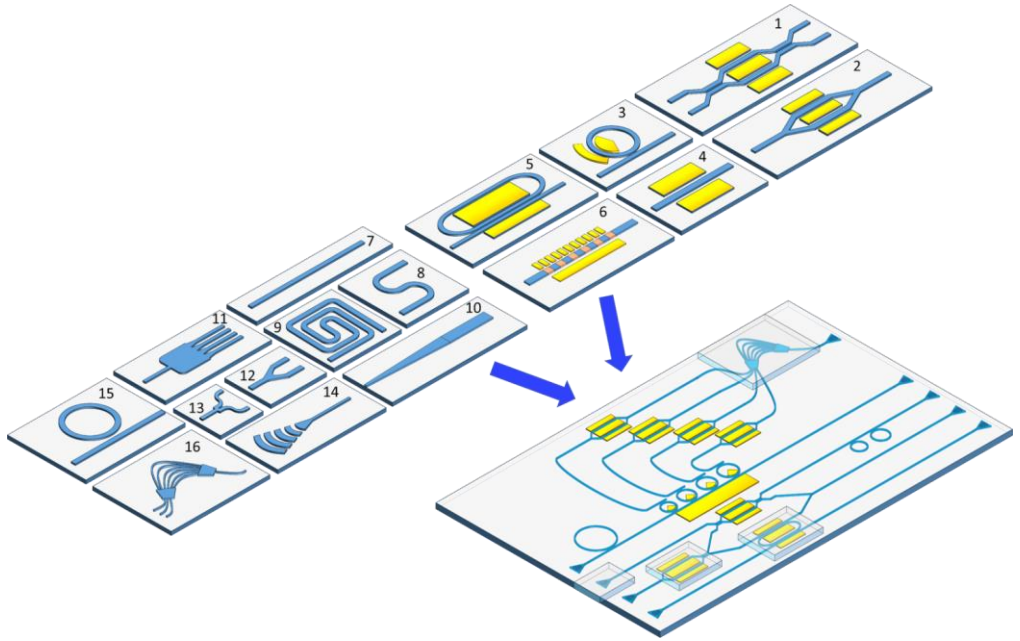
CSEM'S LNOI PIC PLATFORM

1. Developing a reliable high-yield wafer scale fabrication process
2. Developing a PDK library





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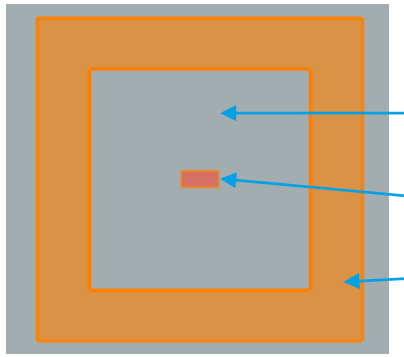
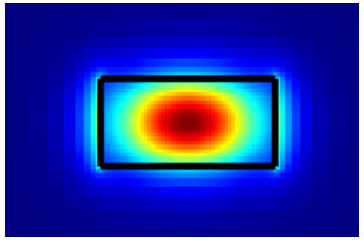
EXAMPLE OF SIMULATION 1: PHOTONIC WAVEGUIDE

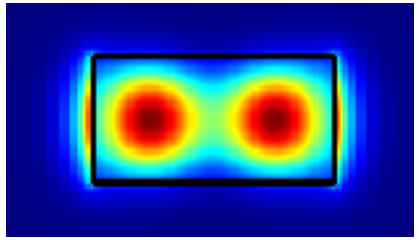
Even a simple waveguide must be properly designed!

Lumerical MODE - Finite Difference Eigenmode (FDE) solver

- The FDE solver calculates the spatial profile and frequency dependence of modes by solving Maxwell's equations on a cross-sectional mesh of the waveguide.
- Calculates mode field profiles, effective index, and loss.
- Used to design single-mode waveguides by adapting the cross-section
- Useful also for engineering waveguides for nonlinear photonics (calculate group velocity, dispersion, etc.)







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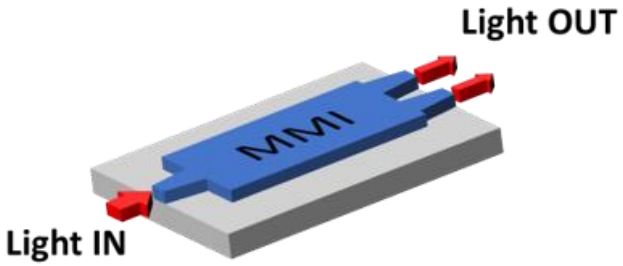
EXAMPLE OF SIMULATION 2: MMI SPLITTER



One of the main components for:
- Mach-Zehnder Interferometer (MZI)
- IQ modulators
- Phase-shifter

Parameters to be optimized

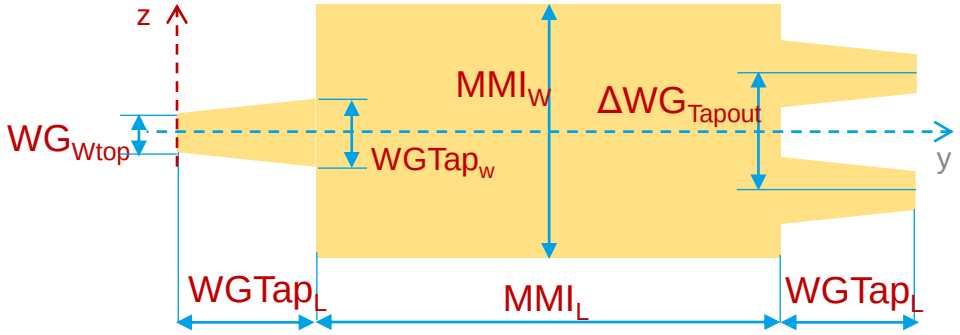


Fig 1. 1x2 MMI (50/50) parameters. $\Delta WG_{Tapout} = MMI_W/2$

Optimization:

- GOAL: maximum transmission $|S31|^2 = |S21|^2 \sim 0.5$
- Process: **1st Select MMI_W (8um), 2nd $WGTap_W$ (0.8-2.4um) sweep:**

Sweep MMI_L	Sweep Input $WGTap_I$	Sweep Output $WGTap_L$	Sweep Wavelength
(I/O $WGTap_L$=10um)	**MMI_L max** Output $WGTap_L$=10um	**MMI_L max** **Input $WGTap_L$ max**	**MMI_L max** **I/O $WGTap_L$ max**

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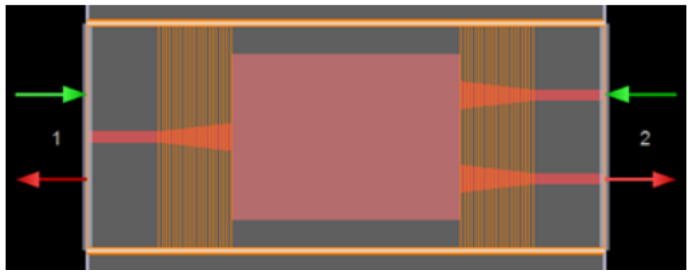
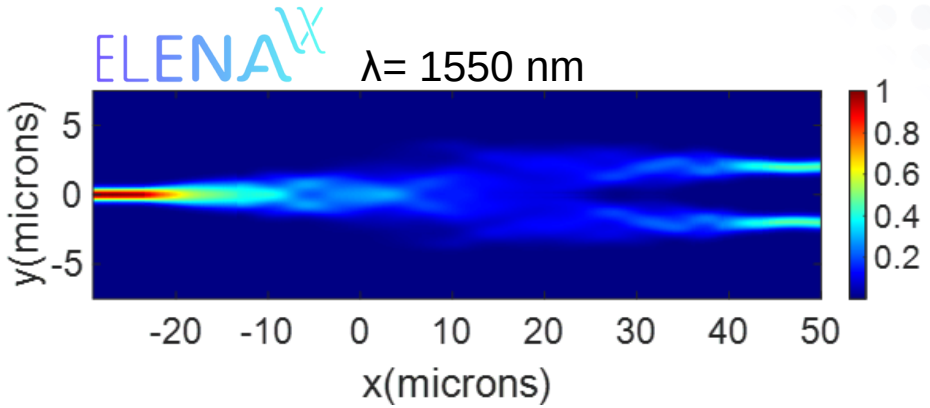
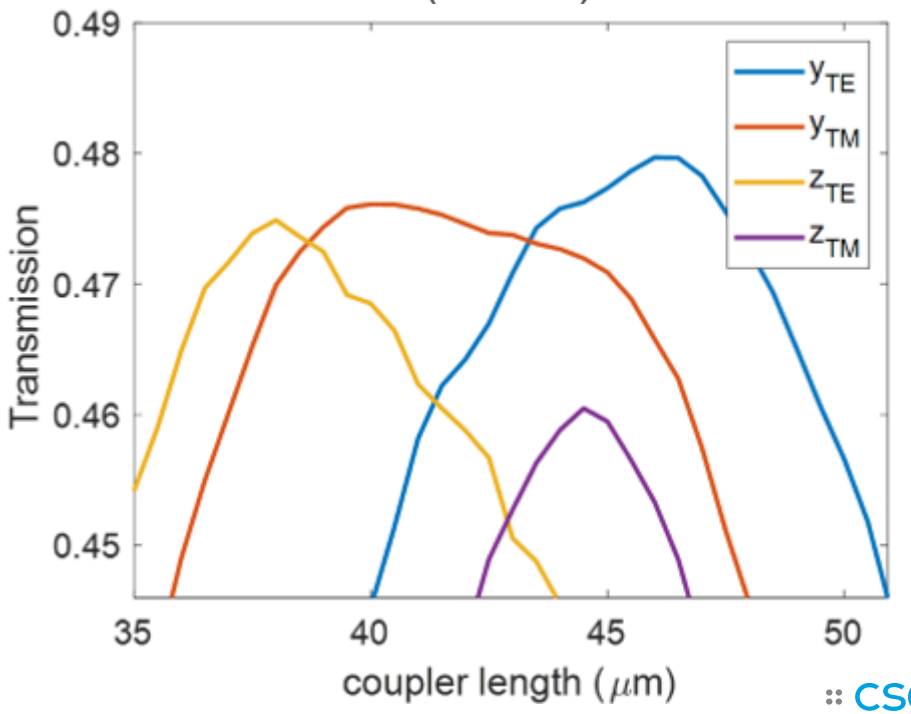
FIRST DESIGN BY PARAMETERS SWEEP

Lumerical MODE - EigenMode Expansion (EME) solver

- The EME method is a frequency domain method for solving Maxwell's equations
- Ideal for simulating light propagation over long distances → Higher accuracy than beam propagation methods (BPM), faster than FDTD methods
- Modal decomposition of electromagnetic fields into a basis set of eigenmodes and then solving for the modes at the interface between adjacent cells



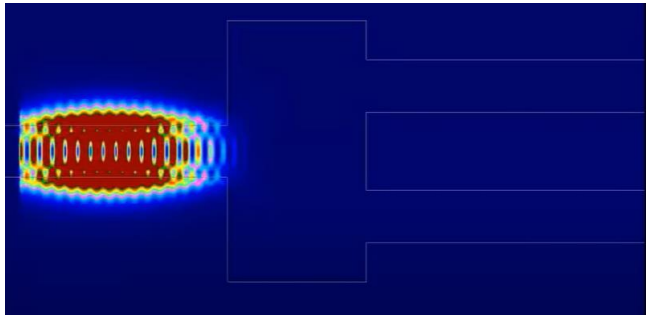


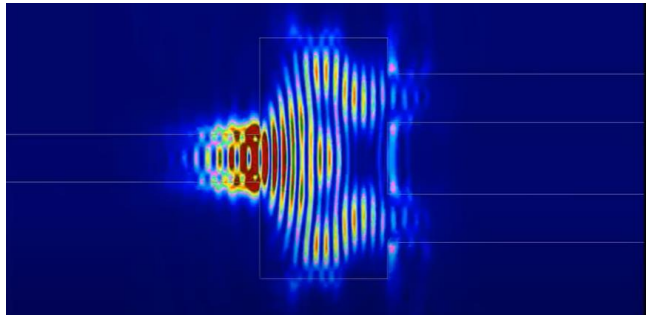


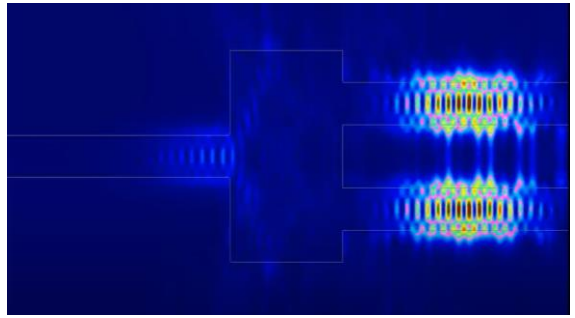
FINAL OPTIMIZATION

Lumerical FDTD - Finite Difference Time Domain

- Gold-standard for modeling nanophotonic devices
- Best accuracy → used to validate the design







Screenshots from Ansys Photonics YouTube

Lumerical MODE – 2.5D varFDTD solver

- Complementary tool for optimizing the MMI device
- Based on collapsing a 3D geometry into a 2D set of effective indices
- Better suited to providing broadband results

EXAMPLE OF SIMULATION 3: PHOTONIC CIRCUIT

Lumerical INTERCONNECT

- Used to calculate the overall frequency and time domain response of a circuit
- Mainly used by foundry service users

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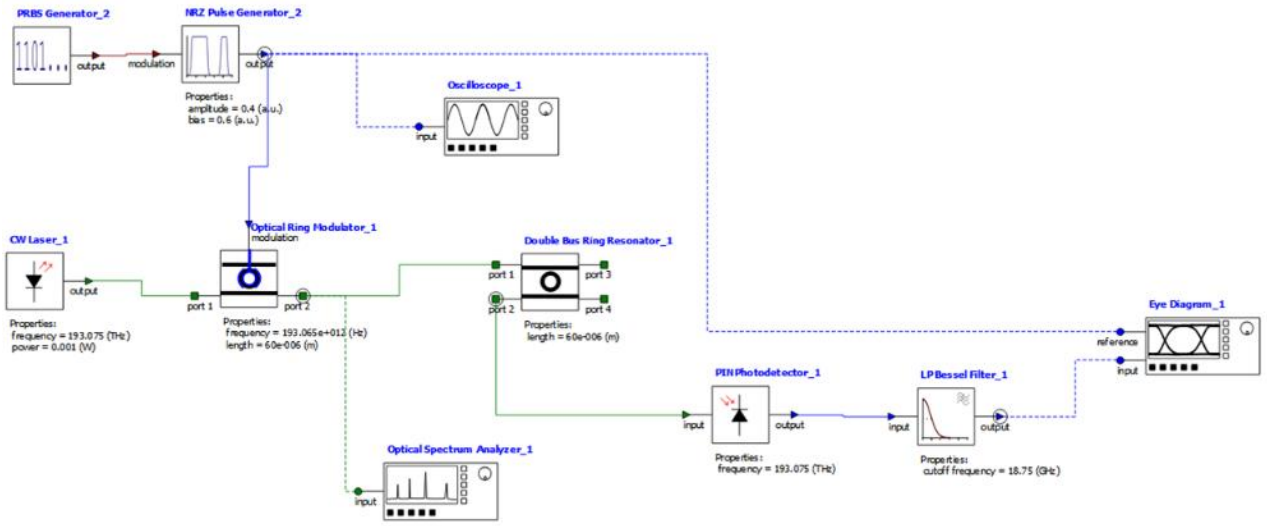
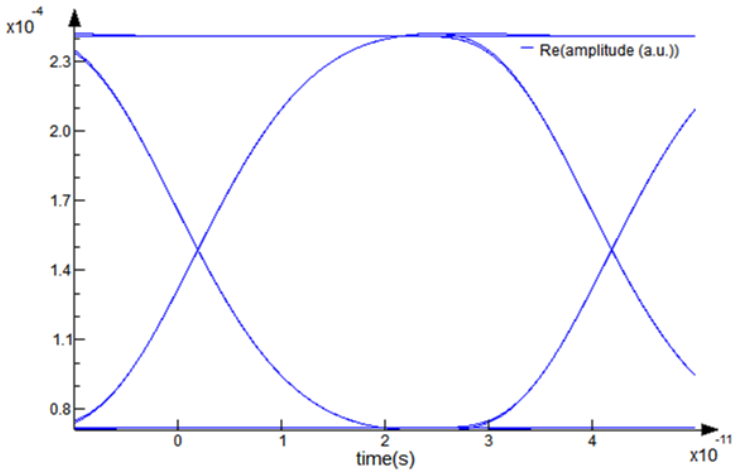
Wavelength Division Multiplexer





https://www.lumerical.com

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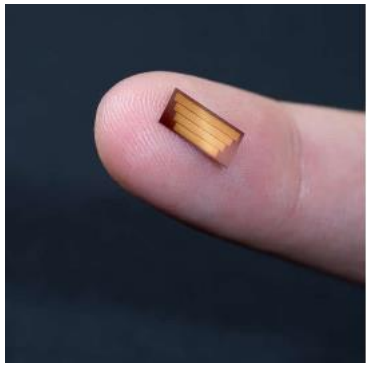
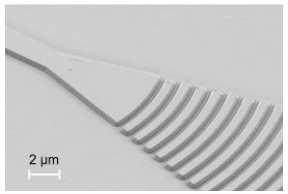
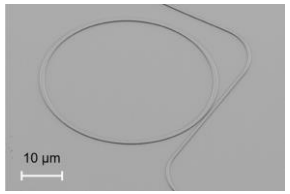
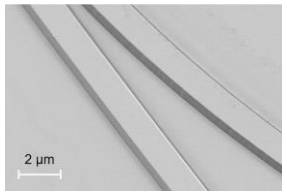
CHIP FABRICATION AND TESTING

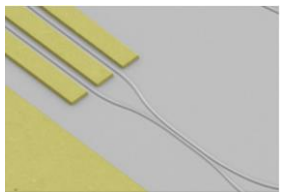
CLEANROOM FACILITY AT CSEM



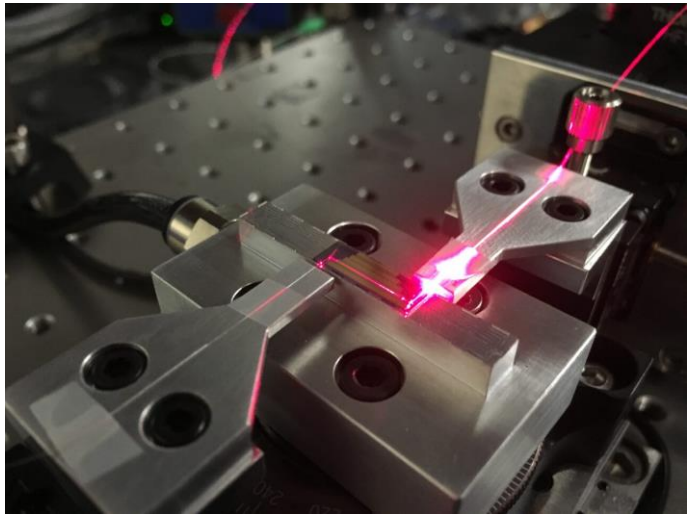


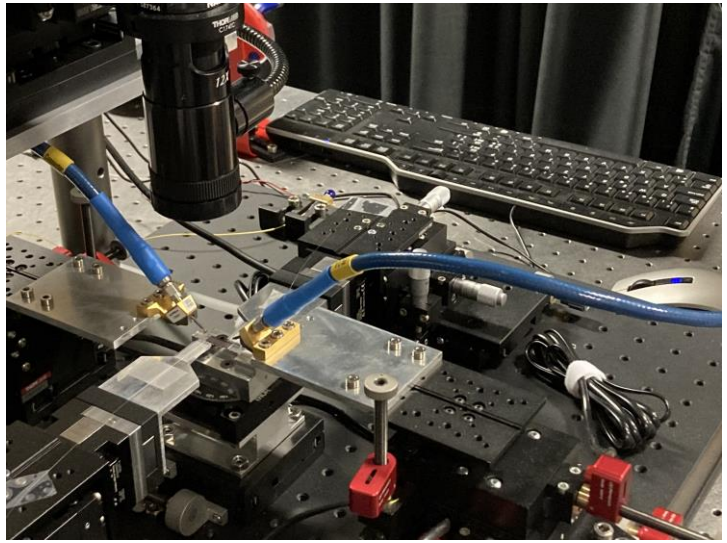






QUALITY VALIDATION





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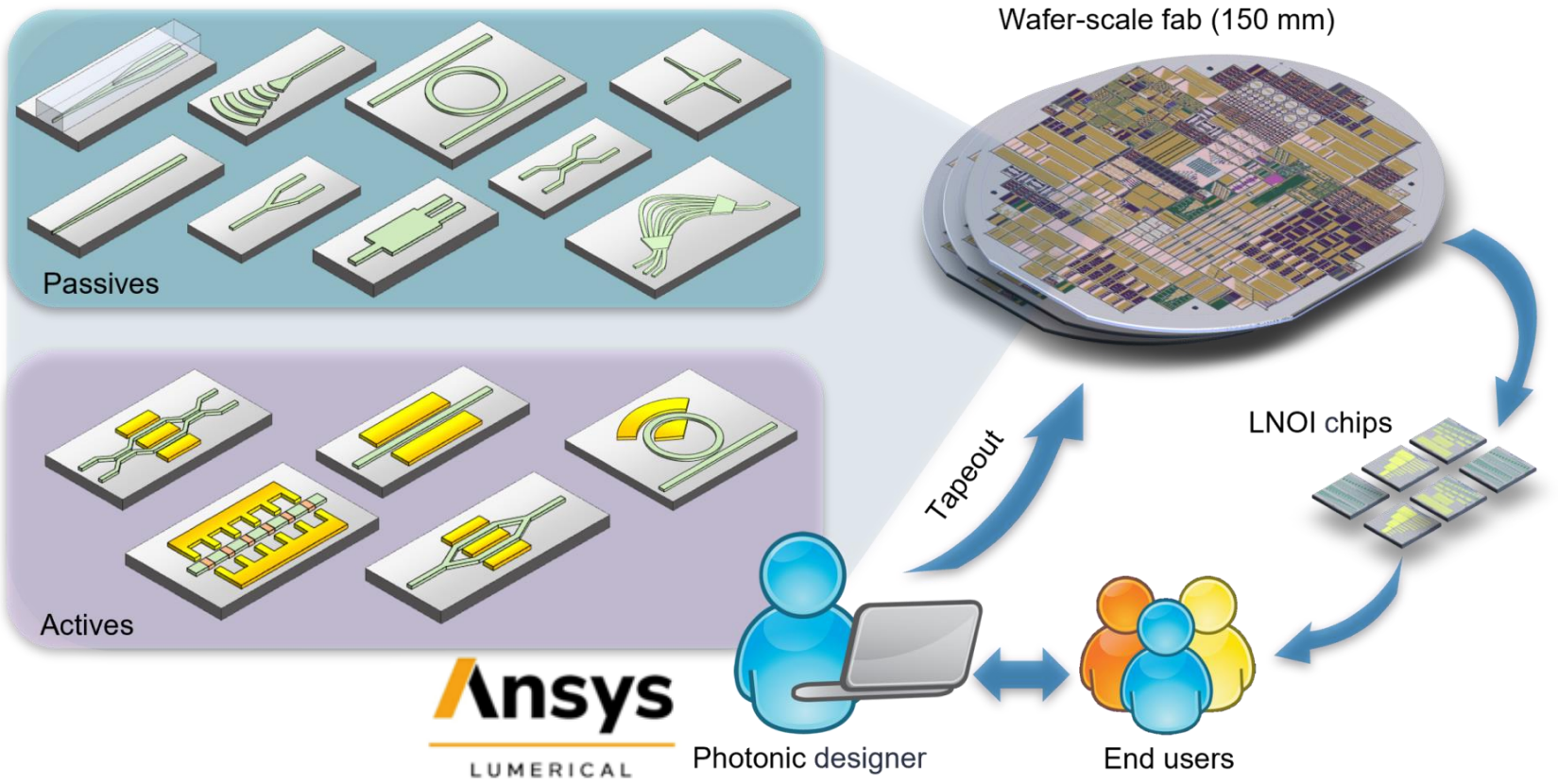
AN ITERATIVE PROCESS FOR AN OPTIMIZED PDK



Simulations are essential to sustain the optimization flow

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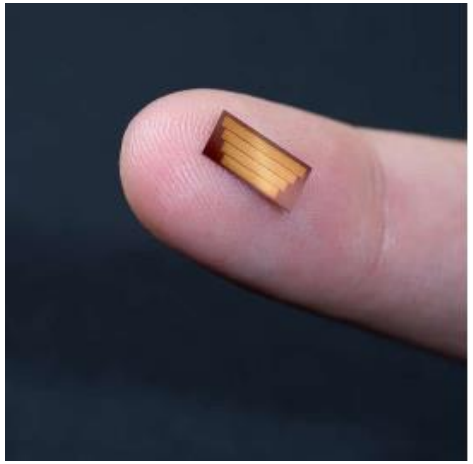
CONCLUSION

- Integrated photonics: a strategic technology
- LNOI platform for next generation PICs
- CSEM is establishing the first European open-access LNOI PIC Foundry
- Ansys-Lumerical as essential design and simulation tool



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THANKS FOR YOUR ATTENTION

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