ELENA

Lithium Niobate PICs for Europe

European **electro-optic** and **nonlinear PIC platform** based on **lithium niobate on insulator** (LNOI)

ELENA AIMS TO ESTABLISH

- the first European **LNOI-based open-access PIC foundry** through the creation of a **Process Design Kit** (PDK) library of standard **Building Blocks (BBs)** for the LNOI PIC platform to enable a large variety of PIC designs, accessible through monolithic integration and combination of BBs;
- a **fully European supply chain for the LNOI PIC foundry** from wafer manufacturing, PIC design and simulations to characterisation and packaging.

OBJECTIVE #01

Develop and mature key passive and active BBs for the LNOI PIC platform as well as a **reliable and reproducible BB fabrication process.**

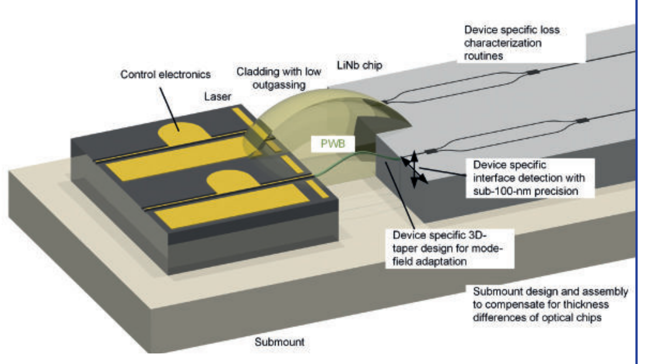
OBJECTIVE #02

Expand the foundry capabilities **by integrating indium phosphide (InP) BBs** (for light emission and detection) with a flexible and automatic assembly process.

OBJECTIVE #03

Develop a **commercialization strategy** including the key aspects of a supply chain:

- establishing the processes to produce **150 mm diameter optical-grade LNOI wafers** on an industrial scale;
- developing a reliable and flexible method for **packaging LNOI chips and interfacing them with other PIC platforms** such as InP using **3D-printed Photonic Wirebonds (PWB)** for low-cost hybrid integration.



OBJECTIVE #04

Produce four PIC prototypes for the end-user partners in the project consortium to **demonstrate the monolithic integration** of the newly developed BBs.

OBJECTIVE #05

Create an **end-user group and a strong network of stakeholders** to promote ELENA's LNOI-integrated photonics.

ELENA: TECHNOLOGY DRIVER FOR NEXT-DECADE PICS

HIGH BANDWIDTH

- Exponential expansion of the internet (beyond 400 Gbit/s)
- Next-generation communication technologies (5G/6G)
- New bandwidth-demanding applications (AR, VR, IoT, etc.)
- Cloud computing

LARGE-SCALE INTEGRATION

- Low-loss and compact footprint
- Heterogeneous integration
- Photonic-electronics co-integration
- Programmable PICs

LOW POWER CONSUMPTION

- Fewer joules per bit
- Cost-effective integrated systems
- Versatile packaging
- Low thermal parasitic effects
- Low-loss waveguide

WIDE WAVELENGTH RANGE OPERATION

- Availability of new bands / expansion of optical data link (L-band, S-band, etc.)
- Demand for PICs in new wavelength ranges such as visible and near infrared:
  - quantum computing
  - biosensing
  - Raman spectroscopy

NEW FUNCTIONALITIES

- On-chip nonlinear wavelength conversion
- Optical isolators and circulators
- Acousto-optical modulators
- Narrow linewidth, fast tunable lasers
- Ultra-fast photodetectors
- Entangled/single-photon sources

LNOI – A VERSATILE PIC PLATFORM FOR THE FUTURE

Intrinsic EO coefficient

- **Fast (> 100 GHz)** and **low Vπ** (< 1 V) modulators
- Addressing the need for a wider bandwidth
- **CMOS-level voltage** operation
- Ultra-**low insertion loss** modulators

Integration and scalability

- **Low-loss waveguides (< 0.1dB/cm)**
- **Small bending radii (~30μm)**
- Compact circuit footprint
- Low-power building blocks
- Programmable photonics
- High-port-count switches

Wide bandgap

- **$LiNbO_3$ bandgap = 4.9 eV**
- High optical power handling
- Low optical loss
- No parasitic two-photon absorption

Large 2nd and 3rd order optical nonlinearities

- Non-linear photonics and metrology
- **Wavelength conversion**, 2nd harmonic generation, DFG, and SFG
- **Optical frequency** combs and **supercontinuum** generation
- Entangled photon pair generation

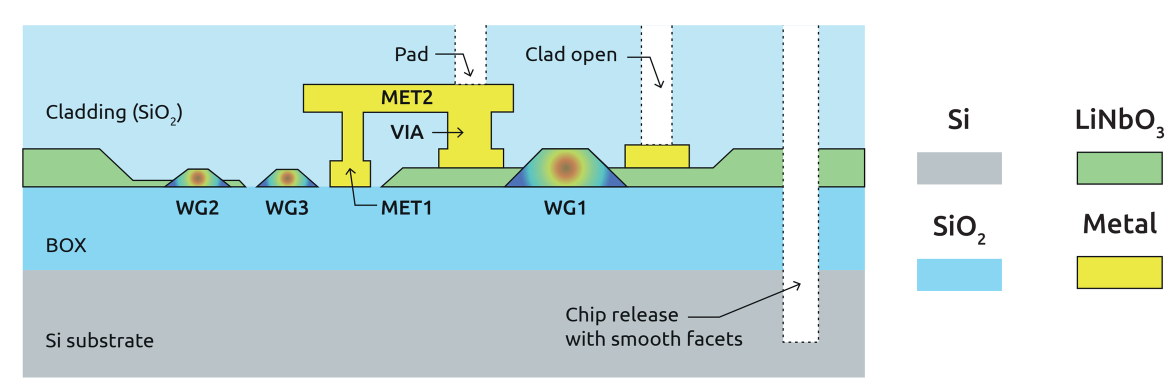
Piezoelectric effect

- **Acousto-optical modulators (AOM)**
- Optical MEMS integration
- Gyros and pressure sensors

Wide transparency window

- $LiNbO_3$ is transparent for **350 nm to 5.5 μm** wavelength span
- Availability of new bands / expansion of optical data link
- Electro-optical light control below μm wavelength (the range in which Si or InP are not transparent)

CSEM'S LNOI PIC PLATFORM



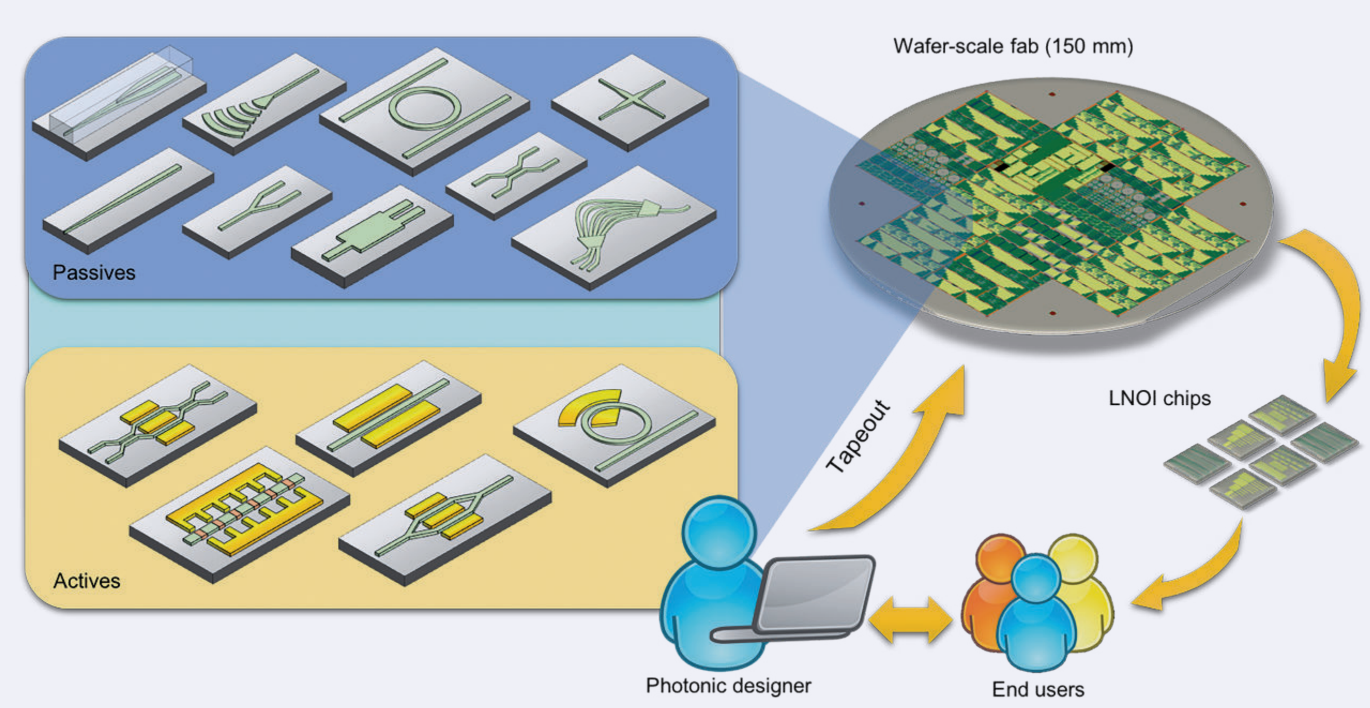
Property	Value
Wafer cut	x
Refractive index (ordinary)	2.21 (@ 1550 nm)
Refractive index (ex-ordinary)	2.13 (@ 1550 nm)
Bandgap	4.9eV
Transparency window	350nm - 5.5 μm
EO coefficient	r_{33} = 31 pm /V
$X^{(2)}$ nonlinearity	$3x10^{-11}$ m/V
$X^{(2)}$ nonlinearity	$1.6x10^{-21}$ m^2 V^{-2}
Piezoelectric coefficient	d_{33} = 6.0 x 10^{-12} C/N

APPLICATIONS

Thanks to the unique properties of lithium niobate, an LNOI PIC platform could serve many applications ranging from **telecom** (e.g. supporting ultra-high-speed transceivers beyond 100 GHz), LIDAR (e.g. ideal for FMCW **LIDAR** engines and OPAs) and **space applications** (compatibilities with harsh environments and wide transparency range), to **nonlinear photonics** (e.g. new functionalities such as on-chip wavelength conversation), **optical signal processing** and **optical computing** (e.g. neuromorphic computing), **sensing & spectroscopy** (e.g. on-chip bio sensing at visible and NIR and mid-IR gas sensing), as well as **quantum computing** (e.g. continuous variables, photonics drivers of atomic systems and QKD).

Signal processing · **LiDAR** · **Telecom** · **Sensing & spectroscopy** · **Space** · **Nonlinear optics** · **Quantum computing**

ELENA'S ENVISIONED LIBRARY OF STANDARDISED BUILDING BLOCKS: TOWARDS THE FIRST LNOI PHOTONICS PROCESS DESIGN KIT (PDK)



CONSORTIUM

csem · soitec · VPIphotonics · ETH zürich · vanguard automation / MYCRONIC · THALES · III-V lab · Rosenberger · UP · cea

IN A NUTSHELL
42 months, starting date: 1/1/2022,
10 partners, EC grant: 5 M€

COORDINATOR
Dr Hamed Sattari, CSEM

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www.project-elena.eu
ZENODO / ELENA community

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