Progress Towards Standardized Thin Film Lithium Niobate (TFLN) Photonic Integrated Circuits (PICs)

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We present advancements in our TFLN PIC open-access foundry, highlighting waveguides, modulators, and edge couplers, alongside platform standardization. Multiple technology nodes support a range of functionalities, promising for robust building blocks for improved performance and scalability.

Background and motivation

Thin-film lithium niobate (TFLN) possesses unique and valuable optical properties [1].

Property	Value
Refractive index	2.21 (o) (@ 1550 nm) 2.13 (e) (@ 1550nm)
Band-gap	3.77 eV
Transparency window	350 nm – 5550 nm
Electro-optic coefficient	r_{33} = 31 pm/V
$\chi^{(2)}$ nonlinearity	-27 pm/V

Table 1. Properties of TFLN.

CSEM established an open PIC foundry based on the TFLN platform, supported by a thoroughly tested process design kit (PDK) library. The aim is to increase the maturity level of the platform for large-scale deployment.

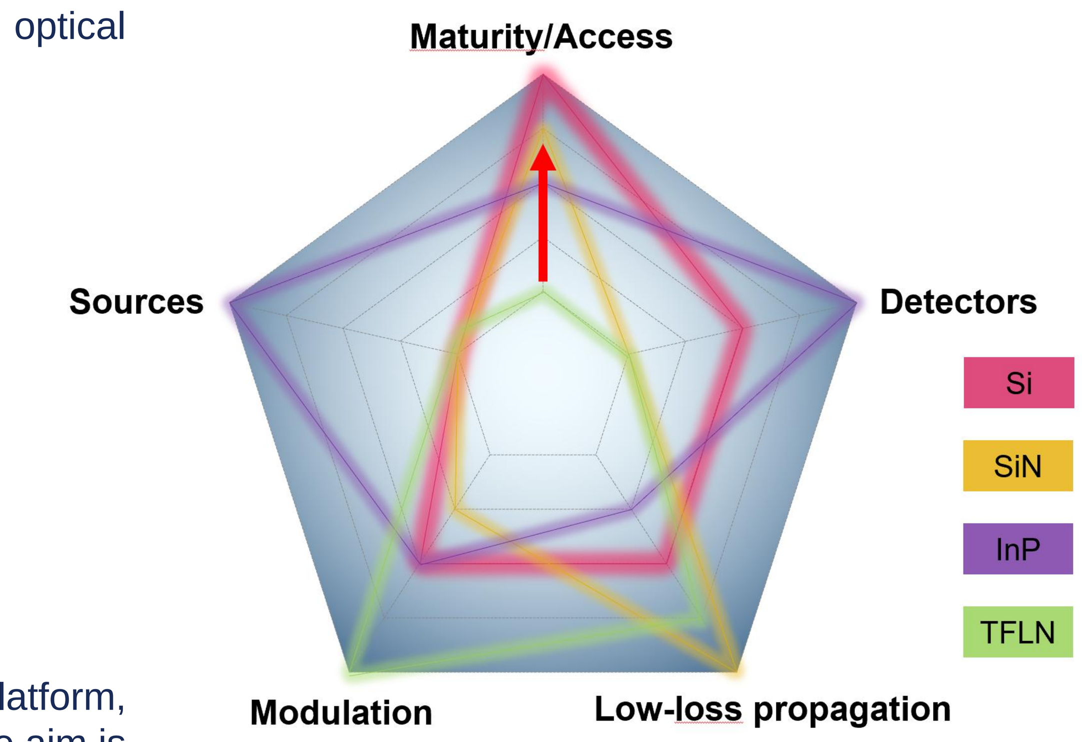

Fig. 1. Properties of various PIC platforms.

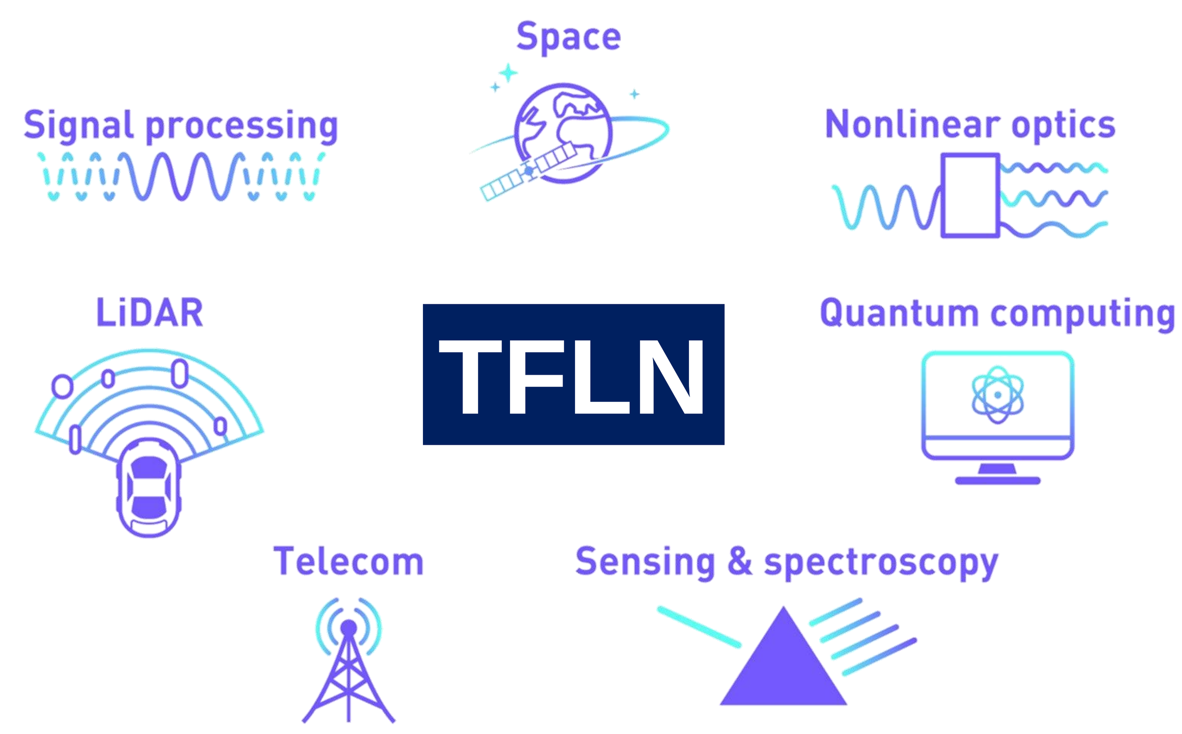

Fig. 2. Application domains of TFLN PICs.

Our platform

- 150 mm wafer scale standard foundry process [2]
- Three waveguide layers
- Two metallization layers connected by a VIA.

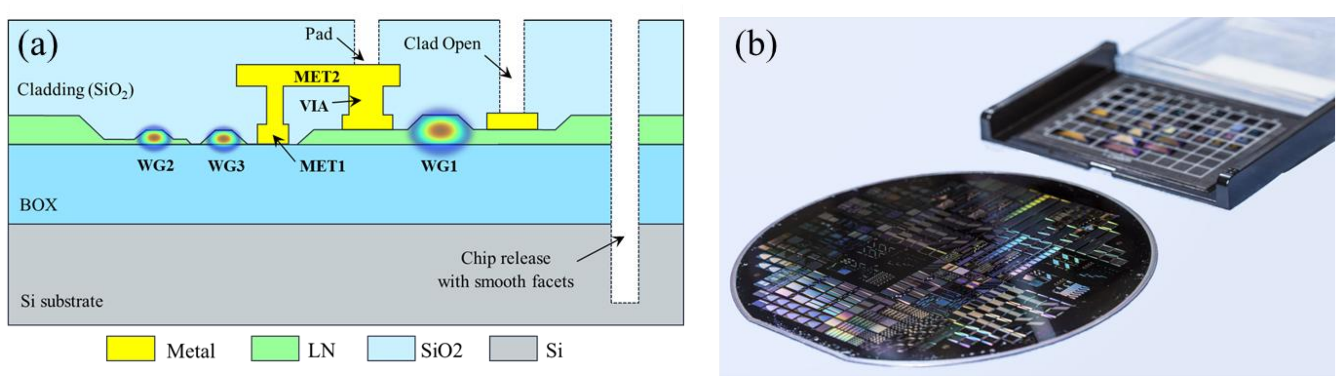

Fig. 3. (a) Schematic of the TFLN PIC platform's technology cross section, (b) 150 mm TFLN wafer with fabricated PICs.

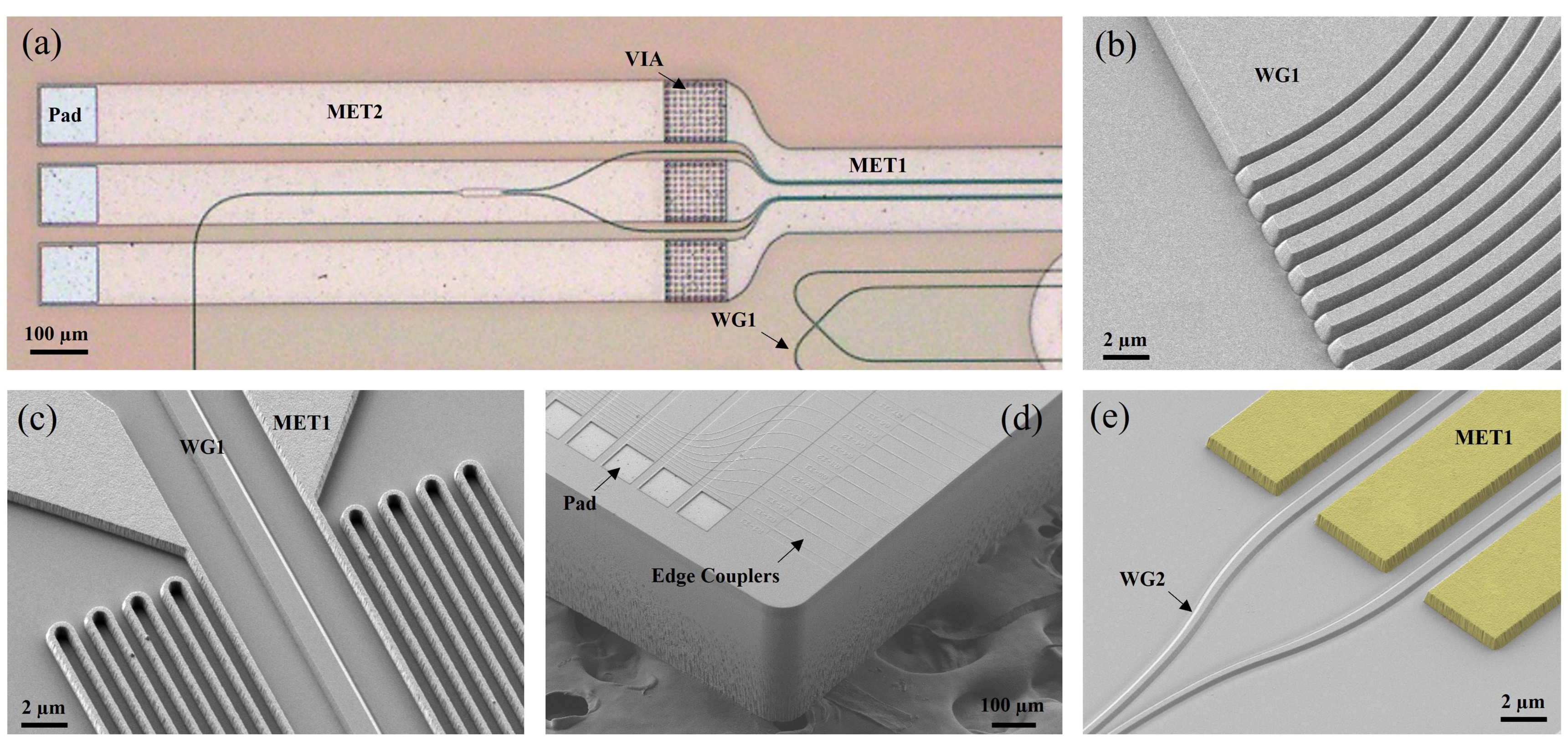

Fig.4. (a) Optical microscope image of the TFLN PIC after the fabrication, (b) SEM image of a grating coupler patterned in WG1 layer, (c) SEM image of a thermo-optical phase shifter composed of a heater in MET1 layer and WG1 waveguide layer, (d) SEM image of a TFLN PIC encompassing a series of Pads for electrical probing and double-layer edge couplers for coupling to fibers, and (e) SEM image of an electro optical modulator in WG2 and MET1 layers (MET1 layer false-colored).

Performances

- Smooth facets (< 3 dB/facet coupling loss using 6-µm MFD fibers)
- Propagation loss < 1 dB/cm in single mode waveguides, < 0.2 dB/cm in multimode [3]
- V_π.L ~ 2 V.cm
- EO bandwidth to beyond 50 GHz
- V_π to below 1 V in folded modulators [4]

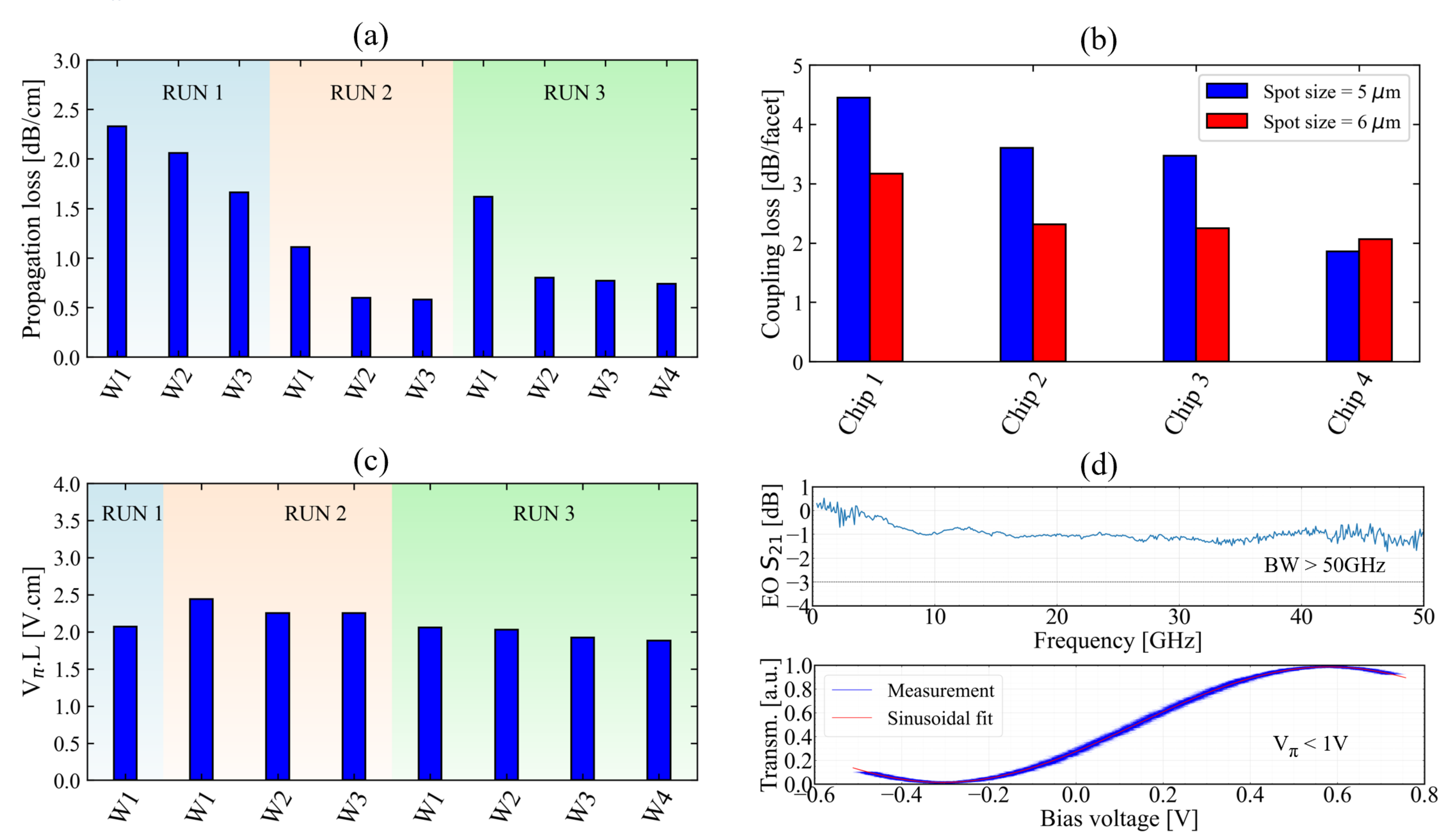

Fig.5. (a) Statistical measurement results of waveguide propagation loss through last three fabrication RUNs, (b) Edge couplers' measured coupling efficiency for two different spot sizes, (c) Statistical measurement of standard PDK EO modulator through last three RUNs, and (d) top: EO bandwidth measurement for the standard PDK EO modulator optimized for high-speed operation and bottom: Transmission spectrum of an EO modulator optimized to operate at CMOS-level voltages. RUN3 is the most recent RUN.

Conclusion and outlook

- TFLN capabilities—fast electro-optical modulation, wavelength conversion, low-loss waveguides, and compatibility with hybrid integration—distinguish it from other PIC platforms
- Our open-access foundry and PDK development process, from design to testing, provide photonic designers worldwide with a dependable set of building blocks
- Future reports will present further statistical analysis of PDK components, supported by ongoing characterization and design optimization

References

[1] D. Zhu *et al.*, Adv. Opt. Photon. 13(2), 242-352 (2021).

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[3] J. Leo *et al.*, in European Conference on Optical Communication (2022), paper Mo3F.4.

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Our foundry