Kasper Van Gasse*
J. Yang*, D. M. Lukina*, M. A. Guidry, G. H. Ahn, A. D. White, J. Vučković
Photonics Research Group, Ghent University - imec, Ghent, Belgium
E. L. Ginzton Laboratory, Stanford University, Stanford, CA, USA

Titanium-sapphire-on-insulator photonics

Titanium-doped sapphire (Ti:sapphire) laser crystals are renowned for their exceptionally broad gain bandwidth (650 nm to 1100 nm), making them ideal for generating ultra-short optical pulses (<5 fs) [1]. However, their operation requires high-brightness pump sources in the green or blue spectral regions, resulting in high costs that hinder broader adoption. In this work, we introduce a thin-film titanium-sapphire nanophotonic platform, termed titanium-sapphire-on-insulator (Ti:SaOI), which consists of a thin crystalline film of Ti:sapphire bonded to an oxide-coated sapphire wafer, analogous to silicon-on-insulator technology, as illustrated in Fig. 1(a). This platform enables scalable, ultra-compact photonic integrated circuits incorporating both passive components, such as waveguides and microring resonators, and active devices, including optical amplifiers and tunable lasers. The Ti:SaOI circuits are fabricated using a grinding and polishing approach previously demonstrated for thin-film silicon carbide photonics [2]. As shown in Fig. 1(b), titanium-sapphire dies are bonded to a sapphire wafer coated with a 3 µm thick SiOx layer, followed by lapping and polishing to produce a smooth, thin Ti:SaOI layer. Subsequent dry etching provides precise thickness control, while waveguides are defined through electron-beam lithography and additional dry etching. This process yields high-performance waveguide amplifiers and tunable lasers. Notably, the waveguide amplifiers enable on-chip pulse amplification with peak powers reaching up to 1 kW for the first time, as demonstrated in Fig. 1(c).

References

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[2] D. Lukin, C. Dory, M. Guidry et al. 4H-silicon-carbide-on-insulator for integrated quantum and nonlinear photonics. Nat. Phot. 14, 330–334 (2020).

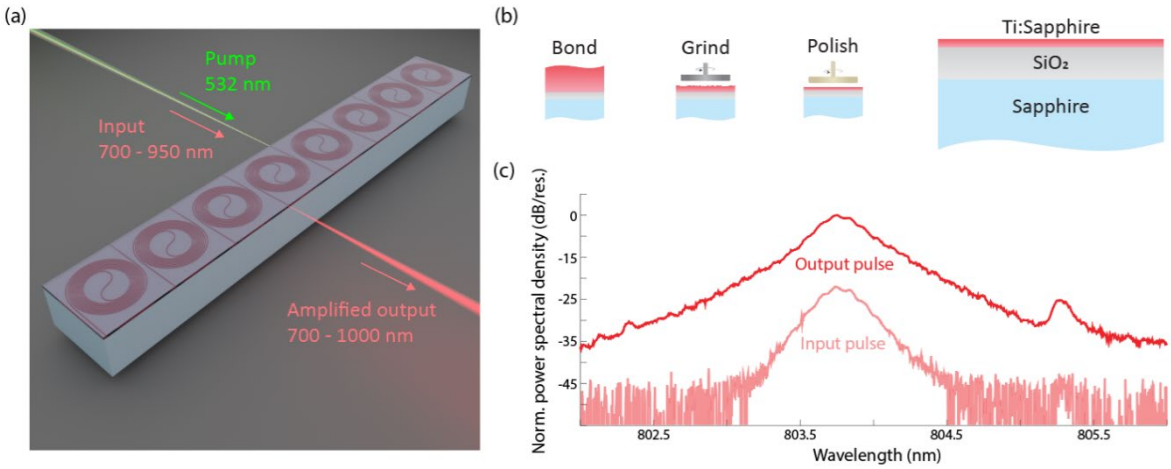

Figure 1: Overview of the titanium-sapphire-on-insulator platform. (a) Artistic rendering of the waveguide amplifier chip. (b) Fabrication process of the Ti:SaOI platform. (c) Optical spectra showing pulse amplification.