Titanium:sapphire-on-insulator for on-chip solid-state laser technology

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Abstract: We present a thin-film titanium-sapphire-on-insulator (Ti:SaOI) nanophotonic Integrated circuits, enabling widely tuneable lasers and picosecond-pulse amplification to a record 1 kW peak power. © 2024 The Author(s)
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1. Main Text

Titanium-doped sapphire (Ti:Sa) laser crystals enable the widest gain bandwidth (650 nm – 1100 nm) of any laser crystal and allow for the generation of ultra-short optical pulses (< 5 fs) [1]. However, this performance comes at a cost as the operation of these table-top lasers require high brightness pump sources in the green or blue wavelength range. This in turn translates into high purchase and operating costs preventing their widespread use. Here we demonstrate, for the first time, a thin-film Ti:Sa nanophotonic platform (Ti:Sa-on-insulator or Ti:SaOI) consisting of a thin (< 1 µm) crystalline Ti:sa laser on top of a SiOx layer (process flow shown in Fig. 1(a)). Moreover, we show that this platform allows for both the realization of high-quality passive photonic waveguides and microring resonators as well as high-performance optical waveguide amplifiers and tuneable laser.

The Ti:SaOI photonic integrated circuits are realized using a grinding-and-polishing fabrication approach that has been previously used for the realization of thin-film silicon carbide photonics [2]. Dies of Ti:Sa are bonded to an undoped sapphire wafer with 3 µm of SiOx deposited on top. Afterwards the film is lapped and polished to create a thin and low roughness Ti:SaOI layer. The final layer thickness is precisely controlled using dry etching. The waveguides are patterned using e-beam lithography and dry etching. This process allows to realize both high-performance nanophotonic waveguide amplifiers (shown in Fig. 1(b)) and widely tuneable lasers. Moreover, the nanophotonic waveguide amplifiers allow for beyond state-of-the-art picosecond pulse amplification up to peak powers of 1 kW (Fig. 1(c,d)).

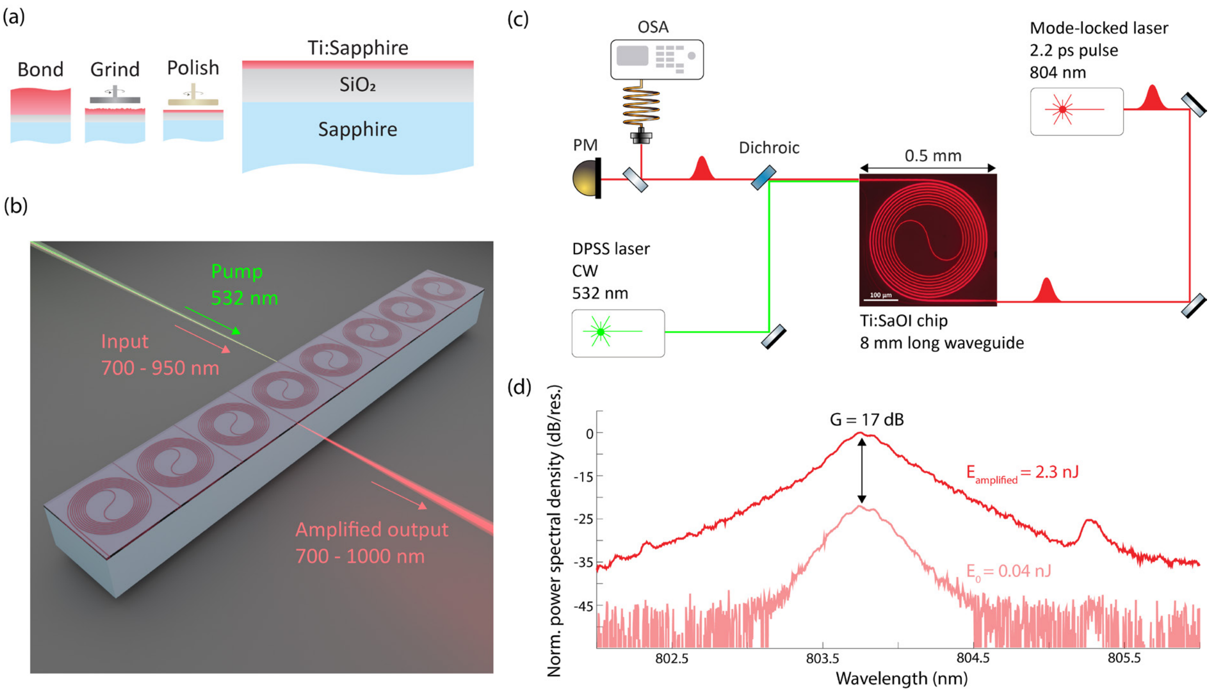

Figure 1: Titanium:sapphire-on-insulator nanophotonic platform. (a) Process flow for the realization of thin-film Titanium:sapphire-on-insulator (Ti:SaOI). (b) Artistic rendering of a Ti:SaOI chip containing 8 nanophotonic waveguide optical amplifiers (chip size: 0.5 mm x 4 mm). (c) Experimental setup for the amplification of picosecond pulses from a commercial mode-locked laser. (d) Resulting optical spectrum obtained using experiment depicted in (c) for output pulse energy of 2.3 nJ. Up to 17 dB signal enhanced is obtained.

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3. References

[1] U. Morgner, F. X. Kartner, S. H. Cho et al. Sub-two-cycle pulses from a Kerr-lens mode-locked Ti:sapphire laser. Opt. Lett. 24, 411-413 (1999).

[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).