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Synchronously Pumped Tantalum Pentoxide Waveguide-based Optical Parametric Oscillator

Maximilian Timmerkamp[1], Niklas M. Lüpken[1], Shiqiprim Adrian Abazi[2], Julian Rasmus Bankwitz[2], Carsten Schuck[2], Carsten Fallnich[1]

1. *University of Münster, Institute of Applied Physics, Corrensstraße 2, 48149 Münster, Germany*
2. *University of Münster, Institute of Physics, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany*

Optical parametric oscillators (OPOs) and especially fiber-based OPOs are versatile light sources for a variety of applications in, e.g., nonlinear microscopy [1]. To further miniaturize OPOs, integrated waveguides can be used as the nonlinear gain medium [2]. Tantalum pentoxide waveguides have so far attracted relatively low attention within nonlinear optics, although they offer a ten times higher nonlinearity than the well-established silicon nitride platform, while featuring comparable low loss and high mode-confinement [3]. Here, we present a synchronously pumped waveguide-based OPO (WOPO) employing tantalum pentoxide.

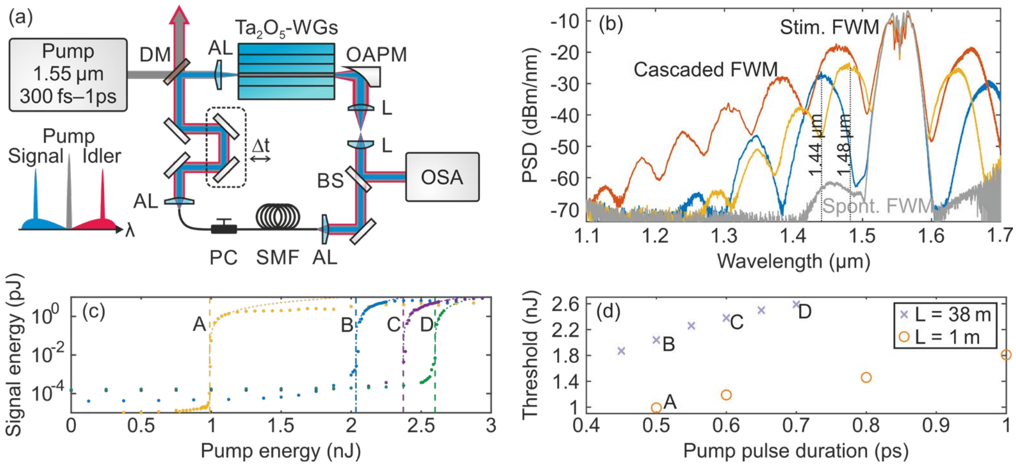

Fig. 1 (a) Schematic experimental setup. (b) Spectra of spontaneous (gray) and stimulated FWM (colored) for three different delays Δt (compare (a)). (c) Energy of the signal sideband (dots) as a function of the pump energy and linear fits (dotted) to determine the oscillation threshold (dashed) for four different parameter sets of pump pulse duration and feedback fiber length, as indicated in (d). (d) Oscillation threshold as a function of pump pulse duration.

We fabricated ridge waveguides and used a 0.6 µm high, 1.7 µm wide and 10 mm long waveguide as the nonlinear gain medium. Fig. 1(a) shows that the waveguide was pumped at 1.55 µm center wavelength with 80 MHz repetition rate. The pump pulse duration was adjusted by means of a Fourier filter. Inside the waveguide, signal and idler sidebands were generated via spontaneous four-wave mixing (FWM). The signal sideband was temporally stretched in a fiber, overlapped with the next pump pulse, and fed back into the waveguide to stimulate the FWM process, as can be seen in Fig. 1(b).

In order to investigate the performance of the WOPO, the length of the feedback fiber was initially chosen to be 1 m, corresponding to one signal pulse oscillating in the resonator. Fig. 1(c) shows an oscillation threshold of 1 nJ for a 500 fs long pump pulse. But the operation range in which the signal energy linearly increased with the pump energy was limited due to the system shifting into a regime of seeded supercontinuum generation (SCG) and, therefore, the maximum reachable signal power was 1 pJ.

To increase the output energy by circumventing SCG that was caused by the insufficient stretching of the signal pulse in the feedback fiber, the fiber length was increased to 38 m (15 pulses in the resonator). In this case, the oscillation threshold increased to 2 nJ at 500 fs pump pulse duration, however, also the signal output energy increased to 6 pJ due to avoiding the entering of the SCG regime by dispersive pulse stretching. Fig. 1(b) shows that the signal sideband's amplification was 40 dB over spontaneous FWM and the signal wavelength was freely tunable in the range between 1.44 µm and 1.48 µm.

In conclusion, we showed a synchronously pumped Ta_2O_5 waveguide-based optical parametric oscillator, that is to our knowledge the first of its kind. The Ta_2O_5-WOPO shows the potential to be fully integrated on a chip for applications in, e.g., optical metrology.

References

[1] M. Brinkmann, A. Fast, T. Hellwig, I. Pence, C. L. Evans, and C. Fallnich, “Portable all-fiber dual-output widely tunable light source for coherent Raman imaging,” Biomed. Opt. Express **10,** 4437 (2019).

[2] N. M. Lüpken, D. Becker, T. Würthwein, K.-J. Boller, and C. Fallnich, “Toward integrated synchronously pumped optical parametric oscillators in silicon nitride,” Opt. Express **29**, 39895 (2021).

[3] L. Splitthoff, M. A. Wolff, T. Grottke, and C. Schuck (2020). “Tantalum pentoxide nanophotonic circuits for integrated quantum technology,” Opt. Express **28**, 11921 (2020).