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Optical parametric oscillator based on silicon nitride waveguides

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Optical parametric oscillators (OPOs) are ubiquitous sources for efficient frequency conversion and have evolved into robust fiber technology [1]. However, integrated waveguides offer in contrast to photonic crystal fibers a higher nonlinearity resulting in lower necessary pump energies and shorter interaction lengths [2]. Therefore, OPOs would require smaller footprints on a chip with additionally improved stability [3]. Here, we present a waveguide-based OPO (WOPO) exploiting four-wave mixing (FWM) in silicon nitride (Si_3N_4) waveguides, with the potential to be fully integrated.

The experimental setup consisted of a Si_3N_4 waveguide (950 nm high, 1350 nm wide, and 7 mm long) pumped by an ultrafast fiber laser emitting 900 fs pulses with 4 nJ pulse energy centered at 1033 nm wavelength in order to generate signal and idler sidebands by degenerate FWM (see Fig. 1(a)). The signal sideband was fed back with dichroic mirrors and a single-mode fiber (SMF) to stimulate the FWM process. A temporal delay (Δt) was used to select the wavelength by adjusting the overlap between the pump pulse and the temporally stretched signal sideband. The comparison of the output spectrum of the WOPO (red curve) with the spontaneous FWM sideband (blue curve), shown in Fig. 1(b), reveals a 35 dB enhancement of the power spectral density (PSD). The presented Si_3N_4 WOPO showed a higher threshold energy of 3.5 nJ due to the lower nonlinearity compared to a silicon-based WOPO with a picojoule-level threshold [3]. However, lower losses allow should for a complete integration of the resonator on the chip in silicon nitride [4].

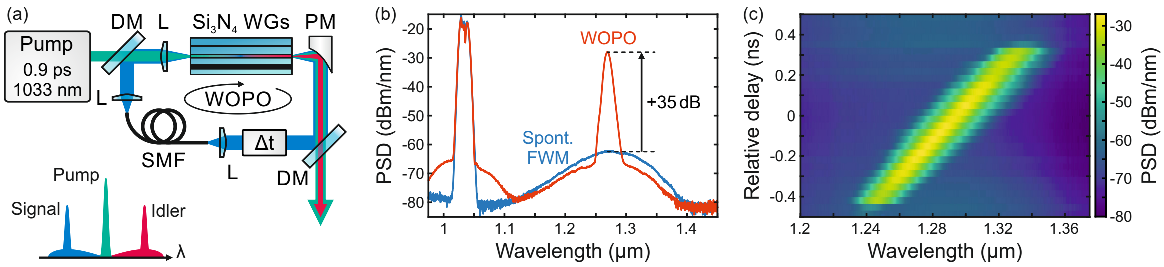

Fig. 1 (a) Schematic of the experimental setup. (b) Spectra of spontaneous FWM (blue) and the WOPO output (red). (c) Color-coded spectra as a function of the relative delay show the tuning capability.

The output idler wavelength could be tuned from 1250 nm to 1330 nm by changing with the delay line the temporal overlap of the fed back signal sideband with the subsequent pump pulse (Fig. 1(c)). The accessible wavelength region depends on the wavelength span of the parametric gain. This wavelength range can be engineered by changing the waveguide dispersion via the cross-sectional geometry. Numerical calculations showed that WOPOs with output wavelengths suitable for CARS measurements from the fingerprint region to the CH-stretch region [2] or, when pumping in the telecom wavelength region, for mid-infrared absorption spectroscopy are possible.

In the future, the WOPO light source has the potential to be set up as an all-integrated device due to the low-loss silicon nitride technology paving the path to small-footprint OPOs for spectroscopic and imaging applications.

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