Electronically and rapidly tunable fiber-based optical parametric oscillator for nonlinear microspectroscopy

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Nonlinear microscopy techniques such as coherent anti-Stokes Raman scattering (CARS) or multiphoton microscopy have become an important tool in biomedical research. In order to enable a widespread routine application of these techniques outside specialized laboratories, fiber-based light sources constitute a promising approach, as they offer an alignment-free and robust operation combined with a compact footprint. We present a fiber-based optical parametric oscillator (FOPO) synchronously pumped by a fiber-integrated, amplified laser diode. The pump pulses, emitted with a tunable repetition frequency around 1 MHz, had a wavelength of 1030 nm, a pulse duration of 10 ps and a pulse energy of 120 nJ. The FOPO consisted of 10 cm of highly nonlinear photonic crystal fiber to frequency-convert the pump pulses via four-wave mixing and about 200 m of single-mode fiber to form the resonator. Due to dispersion in the fiber resonator, the fed back signal pulse was temporarily stretched to about 1.8 ns, such that only a narrow spectral part of it overlapped with the next pump pulse and was thus amplified. Via this dispersion filtering, output idler pulses with a bandwidth of about 3 nm, i.e. 24 cm\textsuperscript{-1}, a temporal duration of about 5 ps and a pulse energy of up to 20 nJ could be produced. By changing the repetition frequency of the pump laser diode by about ±1 kHz, the wavelength of the output pulses could be tuned between 1130 and 1310 nm, i.e. between 860 and 2075 cm\textsuperscript{-1} relative to the pump. As this tuning mechanism was solely based on electronic means, we were able to tune the FOPO with a speed of 8 \mu s per wavelength step, independent of the width of the step. We believe, that this tuning speed, which has not been reached with similar systems, such as FOPOs relaying on a mechanical delay line [1] or with temperature-controlled OPOs [2], offers high potential for nonlinear microspectroscopy, e.g. for hyperspectral CARS imaging: it allows to tune the wavelength in a frame-by-frame manner in a time which is negligible compared to the acquisition time for one image, when imaging with video rate (40 frames/s). As furthermore, all optical components are or can be fiber-integrated, the presented FOPO is representing a promising approach for an all-fiber light source.

REFERENCES: