Study of the dynamics of a high-energy normal-dispersion fiber optical parametric chirped-pulse oscillator

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The growing use of nonlinear imaging and spectroscopy - namely multiphoton imaging and coherent Raman spectroscopy - has led to the development of a myriad of ultra-short, tunable, and energetic light sources, mostly based on second-order nonlinear frequency conversion in bulk materials, with outstanding achievements in terms of energy, peak power, and stability [1]. Although these sources fully satisfy the requirements for nonlinear imaging [2], they require high maintenance, limiting their use to a controlled environment. Fiber-based sources then appear as a solution to bring these experiments outside the lab, but are limited to biological tissue imaging because of their limited pulse energy. To expand nonlinear imaging techniques to diluted media (*e.g.* gases), the approach of combining chirped pulse amplification with four-wave mixing in optical fibers to enhance pulse energy has proven effective, as demonstrated by the recent realization of a µJ-level fiber optical parametric oscillator (FOPCPO) pumped with highly chirped pulses [3]. Furthermore, this FOPCPO concept enables improved control of the generated bandwidth by adjusting the relative chirp of the pump and the resonant wave [4]. In this work, we investigated the dynamics of such a FOPCPO to verify its ability to meet the low-noise and high-stability requirements of nonlinear imaging. In addition, we confirmed that parametric oscillators provide a more stable pulse train compared to parametric amplifiers [5].

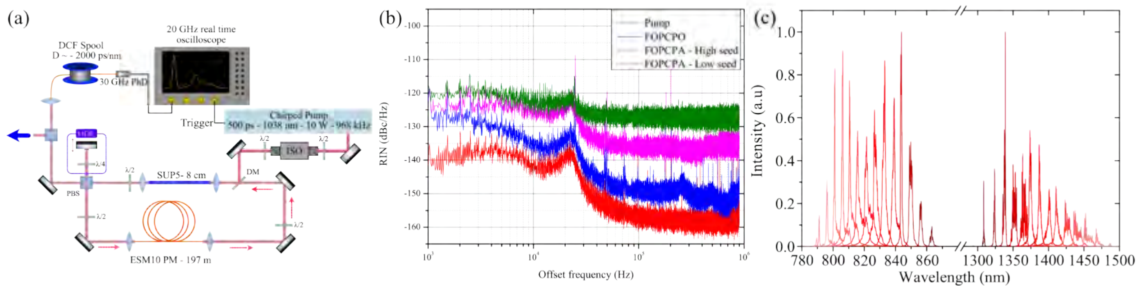

Fig. 1 (a) Experimental setup of the FOPCPO. (b) RIN measurements of the FOPCPO, FOPCPA (with different seed levels), and pump laser. (c) FOPCPO tunability.

The experimental setup of the high-energy FOPCPO developed for this study is depicted in Fig. 1a. The 8 cm long nonlinear fiber (Photonics Bretagne SUP-5-125, ZDW: 1055 nm, MFD: 5 µm) is pumped by a homemade fiber chirped pulse amplifier delivering 500 ps (200 fs transform limited) 1038 nm pulses with energies up to 10 µJ at 1 MHz. The signal-resonant cavity is closed with a 200 m spool of LMA endlessly single-mode fiber (ESM10-PM, Photonics Bretagne, MFD: 10 µm). An optical delay line is used to adjust the length of the cavity to match the pump repetition rate, as well as to tune the output of the FOPCPO through dispersive filtering. The signal pulses can be tuned in a 75 nm band around 820 nm, while the idler pulses can be tuned in a 165 nm band around 1380 nm. The idler pulses are compressed down to 500 fs with a 1200 grooves/mm Treacy compressor. The maximum energies obtained are 500 nJ (resp. 300 nJ) for the 820 nm (1380 nm) band. The FOPCPO exhibits a low relative intensity noise (RIN$<$-125 dBc/Hz), while an equivalent CW-seeded FOPCPA exhibits a higher RIN (up to a 25 dBc/Hz increase), which depends on the seeding power. More details on the noise performances and dynamics of the sources from shot-to-shot measurements through dispersive Fourier transform (DFT) will be discussed during the conference, especially focusing on the impact of the cavity feedback ratio (FOPCPO) or the seeding power (FOPCPA).

References

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