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Peak power & average power scaling via fourier domain OPA (FOPA)

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Abstract. FoTaking advantage of pulse shortening upon amplification, we demonstrate 2.5TW pulses (30mJ, 2 cycle, 1.8µm) based on TiSa pumping, while for boosting average power we utilize a 500W Yb platform for pump and seed pulses.

1. Introduction

One important application of Fourier domain nonlinear optics [1] is the optical parametric amplification of few-cycle pulses with FOPA [2]. It enables simultaneous upscaling of pulse energy and bandwidth while this denotes a trade-off for its time domain counterparts like OPCPA. Another grand challenge in contemporary laser science is average power scaling. We will discuss our progress on both FOPA design for high energy operation and the average power boosting based on an Yb Innoslab pump laser. We will present experimental results for high peak power IR pulses in the 2-cycle regime at 1.8µm wavelength carrying 30mJ of pulse energy (>2 TW). Furthermore, we present a 500W average power Yb pump laser with 50mJ pulse energy at 10kHz repetition rate and 1.5ps pulse duration. The system features unparalleled pointing and power stability in the sub-% range.

2. Experimental results

The peak power scaling of few-cycle pulses is facilitated by the separation ansatz of FOPA which allows one to break down a big task into smaller sub-problems. Due to the frequencies's spatial separation in the Fourier plane (FP) of a 4f setup, the amplifier output properties are not restricted by the performance of a single crystal but by the number of different individually optimized crystals. Figure 1 summarizes results obtained from a two-crystal FOPA pumped by a ps TiSa beam carrying 250mJ of energy [3]. Figs 1a) and 1b)

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show that the good input beam quality after the hollow-core fiber compressor is maintained until maximum amplification. Looking at the retrieved SHG-FROG intensity for seed (Fig. 1c) and amplified pulses (Fig. 1d), however, reveals a surprise. The input pulse duration has shortened from 2.5 cycles to 1.9 cycles upon amplification in the FOPA. The reason can be seen when comparing the seed (gray curve In Fig. 1e) and the amplified spectra (colored curves in Fig. 1e). While the wings in the seed spectrum are close to the noise level of the poor IR spectrometer, they get amplified stronger compared to the center of the spectrum. The spectral dip in thee center arises from the joint of the two crystals in the FP. Thus, the experimental gain function (Fig. 1f) of the two cycle spectrum raises in the spectral wings. This tailoring of the spectral gain function is acieved by controling the spatial pump beam profile of the TiSa pump laser in the FP [3].

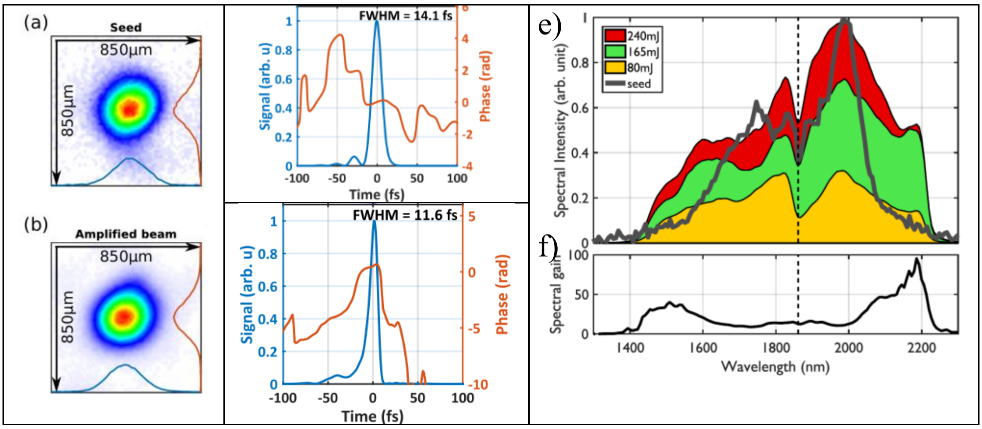

Fig. 1: Input and output specifications for the 1.9cycle, 2.5TW FOPA. Figs a) & b) display focal spot images, c) & d) temporal intensity profiles and e) shows the spectral gain evolution up to 240mJ of TiSa pump energy.

To achieve average power scaling, we moved from the TiSa pumping to an Yb Innoslab laser (Amphos GmbH) because of the superior thermal properties of the crystal host material. The main advantages of this type of pump laser are the high gain obtained with a compact multi-pass design and the excellent properties even at 500W output (see Fig. 2) [4]. Remarkably, an energy stability of about 0.25% RMS fluctuations is measured over a period of 8h. Furthermore, the beam is of very good spatial quality. The M^2 of the compressed 500W output is 1.1 in both directions. A high stability is essential since we split off a small fraction of the Yb beam at an early stage prior to the main InnoSlab amplifier and booster. A total of only 16m beam path through amplifier & compressor will enable to use the same oscillator pulse for self-seeding and final pumping. To get broadband IR seed pulses, we first generate white light in a YAG plate and simultaneously compress & selected spectral components with a 4f setup. The 4f setup also allows to control the timing and polarization between different white light components prior to their difference frequency generation (DFG) [5].
Since we aim to derive 2-cycle IR pulses directly from the ps pump laser, we compressed the VIS pulses (10fs @ 700nm, 14fs@ 600nm) to a duration that supports 2 cycle IR pulses. Consequently, when we perform DFG of the 14fs, 620nm pulses with a narrowband part at 900nm we achieve an IR spectrum centered at 2µm wavelength that spans from 1.4-2.4µm, see Fig. 2d).
This spectrum will be further amplifeid in a chain of FOPA stage, ultimately pumped by 500W of avergae power

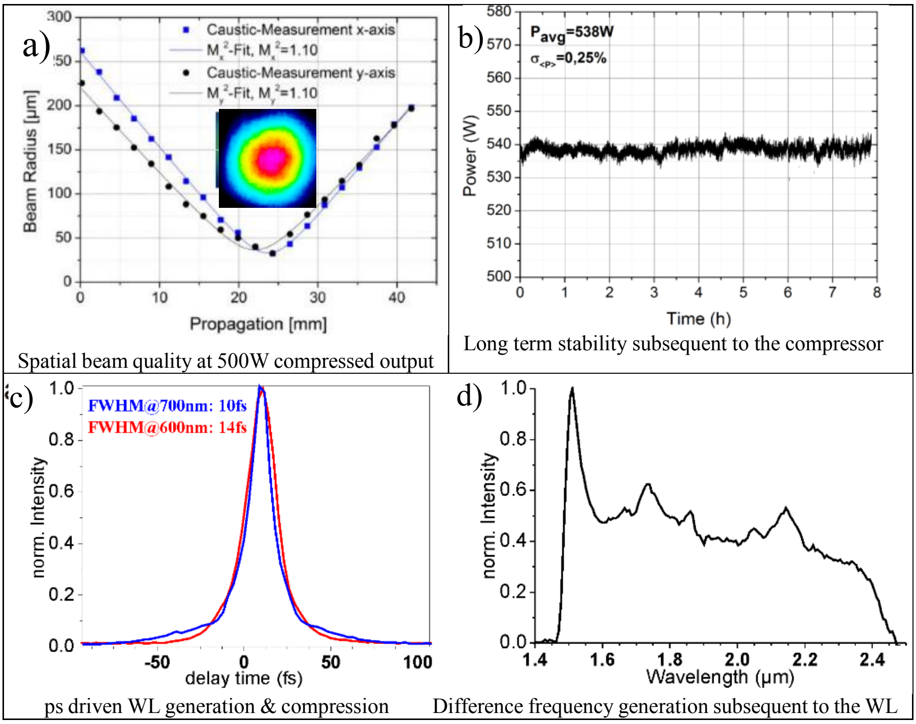

Fig. 2: Characterization of the 500W output (a &b) and of the white light driven with 3µJ, ps pulses in c). IR seed pulses are derived through DFG, generated by selecting different spectral components of the white light (d).

3. Conclusion

We explain and demonstrate how frequency domain nonlinear optics enables the linear transfer of arbitrary phase functions as well as the decoupling of amplitudes and phases and why this is not possible in time domain interaction. A powerful application is deep UV shaping at 207nm.

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