

16 mJ 1.8-cycle pulses at 1 kHz repetition rate from single thin plate compression

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Abstract

First results of the post-compression experiments with the SYLOS 2 laser system are presented, where a single thin plate spectral broadening stage is utilized. Spectrally broadened pulses with 16 mJ output energy are obtained, where dispersion compensation with custom chirped mirrors and fused silica results in 4.75 fs temporal duration.

Introduction

Novel laser sources based on parametric processes are able to generate pulses with multiple tens of mJ energy already at 1 kHz repetition rate [1]. Pulse duration for such systems can be as low as a few optical cycles in the near infrared spectral range. However, single-cycle duration is still an area, which is practically impossible to reach directly from amplifier systems. Energetic isolated attosecond pulse generation [2] and next generation particle acceleration [3] require single-cycle pulses with peak intensities in the range of 10^{19} - 10^{21} W/cm². Post-compression of sub-mJ to mJ energy laser pulses has been already demonstrated down to the single-cycle duration in multiple dielectric thin plates (MPC) with high efficiency [4,5]. Recently, energy scaling of this technique was also presented down to 10 fs duration with 100 TW-class input pulses [6]. Reaching the single-cycle regime with multiple TW driver pulses has never been demonstrated so far, while there is a huge demand from the scientific applications on them.

Experimental results

We realized an experimental setup in vacuum environment, where a single 500 μ m thick fused silica (FS) plate is used to spectrally broaden the 7.5 fs long pulses of the SYLOS 2 laser system with 20 mJ input energy. The thin plate was installed in the intermediate field after the focus of a 4 m focal length concave mirror, where the intensity was tuned by moving the plate along the propagation direction.

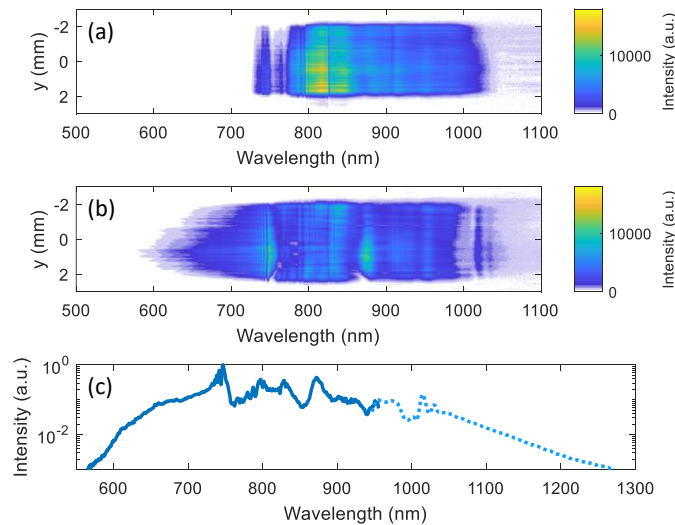


Fig. 1. Spatially resolved spectrum in the vertical direction for the input (a) and spectrally broadened pulses (b). Linear spectrum obtained from the combined spectrometers is shown in (c), where the solid and dashed lines are measured by the visible and infrared spectrometers, respectively.

The spectrally broadened pulses were sampled by taking the reflections from FS wedges, after which they were characterized and compressed in air with an energy of only 17 μ J. 2D spectrum of the full energy pulses without and with spectral broadening are shown in Fig. 1 (a) and (b), respectively. The red side of the broadened spectrum was possible to capture only with combined linear spectrometers, from which the results are shown in Fig. 1 (c).

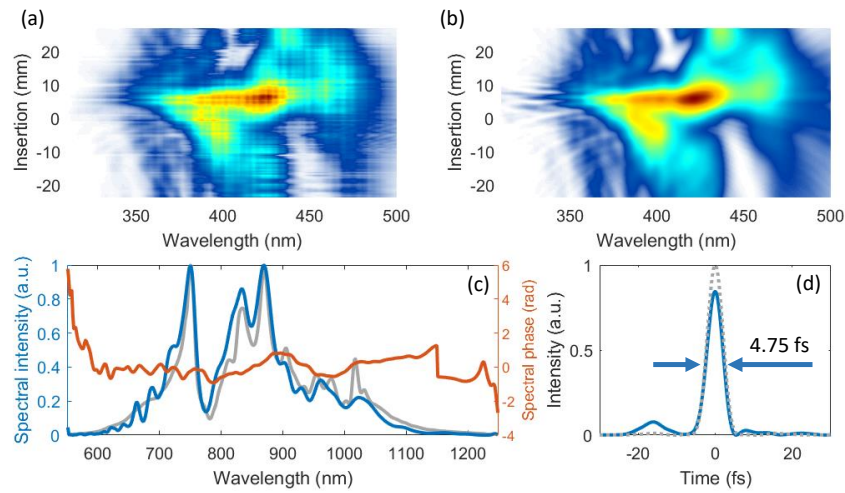


Fig. 2. Measured (a) and retrieved (b) d-scan traces, measured (blue) and retrieved (grey) fundamental spectra with the retrieved spectral phase (c), and finally the FTL (dashed grey) and retrieved (solid blue) pulse temporal profiles (d).

Compression was achieved by using two bounces on a complementary pair of chirped mirrors (PC2007, Ultrafast Innovations) and propagation through FS. Compressed pulses were characterized by using a custom D-scan device (D-cycle NIR 500-1250, Sphere Ultrafast Photonics). We obtained 4.75 fs pulse duration, where further optimization was not possible due to lack of time in the experimental campaign. Output energy after the vacuum compressor was calculated to be 16 mJ in average, with an 0.6% RMS short term stability.

Discussion

The obtained >3 TW pulses can be further decreased in pulse duration by improving the spectral broadening in the next experimental campaigns. Pulses as short as 3.5 fs are achievable with the current chirped mirrors, which are limited to the spectral range of 550 – 1200 nm. Carrier-envelope phase stability is also under investigation for the post-compressed pulses, where the driver pulses exhibit a phase noise of only 250 mrad on the long term.

References

- [1] Sz. Toth et al, J. Phys. Photonics **2** (2020) 045003.
- [2] S. Kühn et al, J. Phys. B: At. Mol. Opt. Phys. **50** 132002 (2017).
- [3] D. Guenot et al, Nat. Photon **11**, 293-296 (2017).
- [4] C.-H. Lu et al, Optica **1**, 400-406 (2014).
- [5] M. Stanfield et al, Opt. Express **29**, 9123-9136 (2021).
- [6] J. I. Kim et al, Opt. Express **30**, 8734-8741 (2022).