100W, 1 mJ, few-cycle pulses at 2 µm wavelength

Ziyao Wang[1*], Tobias Heuermann[1,2,3], Martin Gebhardt[1,2,3], Mathias Lenski[1], Philipp Gierschke[1,4], Robert Klas[1,2,3], Cesar Jauregui[1] and Jens Limpert[1,2,3,4]

1. Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-University Jena, Albert-Einstein-Str. 15, 07745 Jena, Germany

2. Helmholtz-Institute Jena, Fröbelstieg 3, 07743 Jena, Germany

3. GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

4. Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Str. 7, 07745 Jena, Germany

**Corresponding author: ziyao.wang@uni-jena.de*

In recent years, few-cycle laser sources with high pulse energy and high repetition rate in the short-wavelength infrared (SWIR) region (from 1.4 µm to 3 µm) have become increasingly impactful for scientific and industrial applications [1, 2]. Compared to the well-developed 1 µm technologies, the longer wavelength possesses fundamental advantages for nonlinear frequency conversion processes, such as mid-infrared [3], THz [4], and soft X-ray [5] generation. One common method to address the SWIR region is optical parametric chirped pulse amplification (OPCPA), which already demonstrated direct generation of sub 20 fs pulses [5] or more than 100 W average power [6] with mJ-level pulse energies. An alternative method is to post-compress the output of thulium(Tm)-doped fiber laser systems, which have been proven to be a viable approach for power scaling in the SWIR region, reporting 1 kW of average output power [7] or 15 GW of pulse peak power [8] in ultrafast operation. In this contribution, we present our first results of nonlinear post compression of a high-power Tm-doped fiber laser in a gas-filled capillary. The laser source is based on the coherent combination of four ultrafast Tm-doped fiber amplifiers, delivering a combined pulse energy of 1.67 mJ, with 85 fs pulse duration at a repetition rate of 101 kHz [8]. The post compression stage consists of a 63 cm long rod-type hollow-core fiber with an inner diameter of 350 µm, which is placed on a V-groove inside a high pressure gas vessel filled with ~2 bar of argon. The output pulses are recompressed using ~3 mm of fused silica. In this experiment, we launched an average power of 145 W to the hollow core fiber. Fig. 1 shows the compression results. The output spectrum is measured with a multi-mode fiber. The compressed pulses are analyzed by a commercial TIPTOE device (company: SourceLab) [9]. We achieved 102.8 W of average output power and a compressed pulse duration of 17.6 fs (2.75 cycles), corresponding to an output pulse energy of 1.01 mJ and an estimated pulse peak power of 35.8 GW.

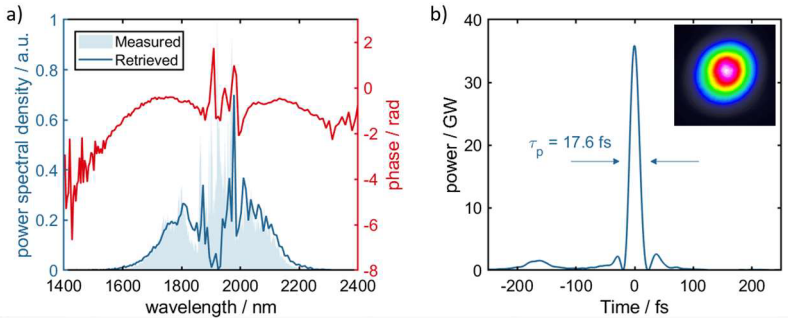

Fig. 1 Results of the nonlinear compression. a) measured spectrum (light blue), retrieved spectrum (dark blue) and retrieved phase (red). b) retrieved pulse profile. The inset in b) corresponds to the near-field image of the beam at the output of the hollow-core fiber.

To the best of our knowledge, this system represents the highest average output power mJ-class few-cycle source in the SWIR to date. Given its unique parameter set, this source can serve as the ideal platform for nonlinear frequency conversion into the soft X-ray, mid infrared and THz regions. Furthermore, we believe that the scalability of coherent beam combination of Tm-doped fiber lasers combined with hollow-core fiber compression will enable multi-mJ, multi 100 W, few-cycle output at 2 µm wavelength in the near future.

References

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