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# 33 W OPCPA at 10 kHz repetition rate with four cycle pulse duration at 2.1 µm based on a single pump laser

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Powerful Mid-IR sources are key tools for advanced spectroscopic applications, high field science and conversion to high frequency radiation. In particular, the so-called water window spectral region between 2.3 nm and 4.4 nm attracts a lot of attention, as it covers the K-shell absorption edges of carbon, nitrogen and oxygen and is therefore ideally suited for spectroscopic studies of biomolecules in their natural aqueous environment [1].

On a laboratory scale, pulses with a central wavelength of a few nm can be obtained by generating high harmonics, where the physics of this highly nonlinear process favors the use of driver lasers in the 2 µm wavelength region. However, due to the extremely low conversion efficiency, meaningful soft X-ray photon flux can only be provided by employing high average-power high pulse energy mid-infrared driver lasers [2].

Here we present a 2.1 µm OPCPA delivering 3.3 mJ pulses at a repetition rate of 10 kHz, thus improving our previous results [3] and setting a new record in terms of average power in the 2 µm wavelength region.

Our setup starts with a commercially available 500 W Yb:YAG thin disk laser (DIRA 500, Trumpf Scientific Lasers) operating at 10 kHz, serving both as pump and signal generation source. The latter is performed in a front-end developed by Fastlite, and makes use of supercontinuum generation, followed by difference frequency generation. The resulting pulses are centered around 2.1 µm and pre-amplified to an average power of 280 mW.

Owing to the system design, the 2 µm pulses should feature passive carrier-envelope phase (CEP) stability. Indeed, first measurements of the single shot CEP noise in our setup yielded results around 200 mrad. However, further improvements are expected since in comparable systems values below 100 mrad have been reported [4].

For power amplification, the pulses are stretched to 1 ps duration with a pair of silicon wedges, so that they fit the pump pulse duration of 2 ps in the two power OPA stages. The first one consists of a 2 mm thick BiBO crystal pumped with 130 W of the DIRA output power. This allows to amplify the 2 µm beam to an average power of 10 W. The second OPA stage is a 5 mm thick YCOB crystal pumped with 320 W, and delivers an output power of 33 W. The amplified pulses are compressed with a 4 cm thick suprasil glass block.

We obtain a slightly elliptic beam profile, as shown in Fig. 3(a). The measured spectrum (Fig.3(b)) extends from 1.8 µm to 2.4 µm, with a FWHM of 430 nm. The modulations result from our front-end configuration, which is optimized for the shortest pulses after power amplification. The spectrum would allow for a Fourier transform limited pulse duration of only 22 fs, which is close to the experimental value of 25 fs inferred from an autocorrelation measurement (Fig. 3(c)).

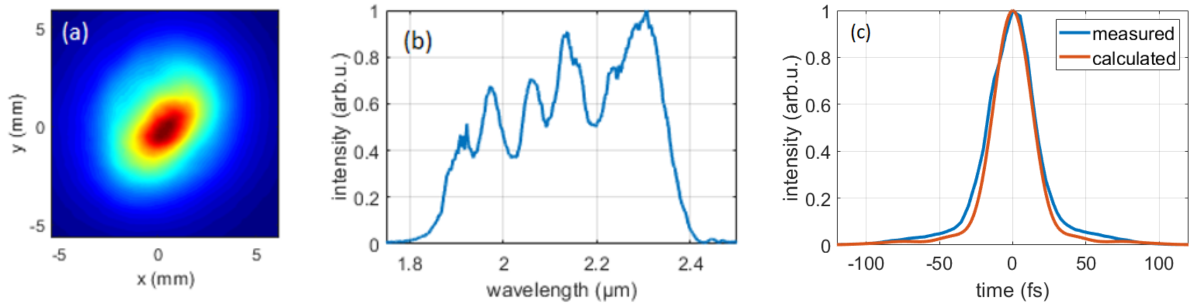

**Fig. 1** Characterization of our power OPCPA system: (a) Near field spatial beam profile, (b) measured spectrum (FWHM = 430 nm) and (c) autocorrelation function, where the measured curve is shown in blue (FWHM = 34 fs) and the one calculated from the measured spectrum is shown in orange. The inferred pulse duration is 25 fs.

With these unique parameters our setup is well suited for future experiments in strong field and attosecond physics including the generation of high harmonics in the water window. Since the system will serve as an application laboratory, further development will be dedicated to improve the stability and reliability of its output.

## References

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