Multiple plate continuum driven by high power OPCPA at 1.55 μm

Chia-Lun Tsai[1], Yi-Hsun Tseng[1], Ming-Wei Lin[2], Shang-Da Yang[1], Ming-Chang Chen[1]

[1]*Institute of Photonics Technologies, National Tsing Hua University, Hsinchu, Taiwan*

[2]*Institute of Nuclear Engineering and Science, National Tsing Hua University, Hsinchu, Taiwan*

tsaichalun@gmail.com

Abstract: We demonstrate 3.3 mJ, 81 fs, 1.55 µm pulses produced by optical parametric chirp pulse amplifier (OPCPA) at 1-kHz repetition rate. The spectrum broadened in 11 thin-plate, supporting 18 fs (3.5-cycle) transform-limited pulse width.

High-order harmonic generation (HHG) has been extensively studied for coherent, attosecond, extreme ultraviolet light source generation. Using a longer wavelength laser of 1 μm to 4 μm, bright coherent X-ray light source has been demonstrated due to a favor of a larger pondermotive energy (*1*). To develop efficient HHG in water window, 1.6 μm lasers will be very ideal because it has high pondermotive energy and also keeps a high recombination probability of HHG. One of the approaches is BIBO-based optical parametric chirp pulse amplifier (OPCPA) pumped by Ti:Sapphire laser (*2*). Sub-two-cycle 1.6 μm lasers have been demonstrated. An alternative way is KTA- or KTP-based OPCPA, Mitrofanov et. al. have demonstrated >100 mJ OPCPA at 1.5 μm pumped by matured 1.064 μm lasers with intense energy up to 1 J (*3*). However, due to phase-matching bandwidth limit of KTP, the pulse duration is limited to 80 *fs*.

In this work, we have built a similar 1.55 µm carrier envelop phase (CEP)-stabilized KTP OPCPA (3.3 mJ, 81 fs) but running at a repetition rate of 1-kHz as shown in Fig. 1(a-b) (*4*). To shorten the pulse width further, we employed multi-plate continuum (MPC) (*5*) and demonstrate spectral broadening in 11 pieces, 50 μm-thick quartz plates. For the lack of space, in the first try we only focused 0.83 mJ pulses by a lens of 1-m focal length. The intensity on the first plate is 8 TW/cm^2. Fig. 1(c) shows the broadened spectra after every plate. In the beginning, self-phase modulation effect dominates the spectral broadening process that bandwidth in blue and red part are equally increasing. After the 4th or 5th plates, self-steepening effects dominates and more blue part has been generated. The final transform-limited pulse duration is 18 fs. Fig. 1(c) inset shows the output beam profile after 11 quartz plates. The beam profile in the central lobe contains over 60.2 % overall conversion efficiency after 11 plates. We will use the 3 mJ in MPC, expecting to produce ~2 mJ, < 20 fs CEP-stabilized pulses in the near future for bright water window HHG.

In summary, we have demonstrated MPC system driven by milli-joule OPCPA at 1.55 µm running at a repetition rate of 1 kHz that expands the bandwidth of KTP-based OPCPA laser by > 4 times, while keeping a good output beam quality. After phase compensation, the peak power of these pulses could reach several gigawatts. Such intense, stable diode-pumped few-cycle 1.55 µm OPCPA will enable bright water window HHG for bio-imaging applications.

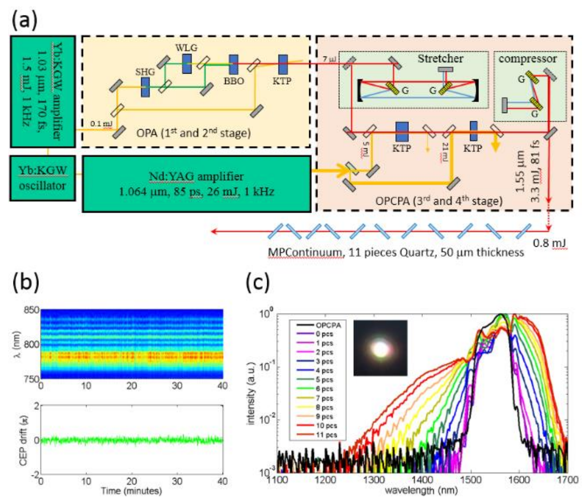

Fig. 1 (a) OPCPA setup. (b) CEP measurement of the front-end 1.55 μm pulses in a f-to-2f interferometry. CEP shifts with a fluctuation of 257 mrad acquired for 40 minutes. (c) Spectra of the pulses from OPCPA directly, passing through air only, and through different numbers of quartz plates. All the spectra are set to normalize its maximum value. Inset figure: Photographic image of MPC taken by a visible camera right after the 11th quartz plate.

REFERENCES

1. T. Popmintchev *et al.*, *Science*. **336**, 1287–1291 (2012).
2. N. Ishii, *et al. Optics Letters*. **37**, 4128 (2012).
3. A. V. Mitrofanov *et al.*, *Sci. Rep.* **5**, 8368 (2015).
4. O. D. Mücke *et al.*, *Opt. Spectrosc.* **108**, 456–462 (2010).
5. C.-H. Lu *et al.*, *Optica*. **1**, 400 (2014).