A CEP stable, sub-two-cycle, over 100 mJ IR DC-OPA: Towards a sub-microjoule water window isolated attosecond pulse

[1]Ultrafast Coherent Soft X-ray Photonics Research Team, RAP, RIKEN, 2-1 Hirosawa, Wako, 3510198, Japan
[2]Attosecond Science Research Team, RAP, RIKEN, 2-1 Hirosawa, Wako, 3510198, Japan
[3]Extreme Laser Science Laboratory, CPR, RIKEN, 2-1 Hirosawa, Wako, 3510198, Japan

Lu Xu[1,2], Bing Xue[1,2], Katsumi Midorikawa[2], and Eiji J. Takahashi[1,3]

E-mail: lu.xu@riken.jp; ejtak@riken.jp

Currently, as an efficient way of generating ultrashort coherent extreme ultraviolet (XUV)/soft-X-ray sources, high harmonic generation (HHG) has been one of the most attractive research areas in the past decades. To generate both high photon flux and photon energy isolated attosecond pulses (IAP) based on HHG, high energy, a few-cycle, CEP stable infrared (IR) laser pulse is strongly desirable. By employing the dual-chirped optical parametric amplification (DC-OPA) method [1] and type-I BiBO crystals, we demonstrate a 10 Hz, CEP stable, IR laser source with the output energy of over 100 mJ and pulse duration down to 10.4 fs (1.8-cycle at 1.7 μm). In addition, the half-cycle cutoff (HCO) [2] originated from a few-cycle pulse-driven HHG process has also been recorded.

In our IR laser system (Fig. 1a), the 4 mJ, 25 fs laser pulses from the 1kHz Ti:sapphire front end are injected into a 1.6 bar krypton gas cell for spectral broadening via optical filamentation, followed by difference frequency generation (DFG) based on a 1 mm thick BiBO crystal, to produce passive CEP stable, broadband IR laser pulses (1.2 μm – 2.2 μm) as seed for the subsequent three DC-OPA stages, where type-I BiBO crystals with cutting angle (θ) of 11 deg. are employed and the thickness of crystals in each stage is 6 mm, 5 mm, and 4 mm, respectively. Based on the noncollinear geometry used in each stage with the pump energy of 1.5 mJ, 30 mJ, and 740 mJ, respectively, the final output reaches 102 mJ after compression in the 130 mm long water-free fused silica bulk compressor with a pulse duration down to 10.4 fs. Meanwhile, a home-built single-shot f-to-2f interferometer is implemented to characterize the CEP stability, which is 207 mrad (RMS) within 20 seconds. Moreover, in the Ar HHG process, the recorded HHG spectrum (with the highest cut-off reaching 210 eV) via CEP shift has demonstrated the characteristics of the HCO that happens in the HHG process driven by sub-two-cycle laser pulses (Fig. 1b).

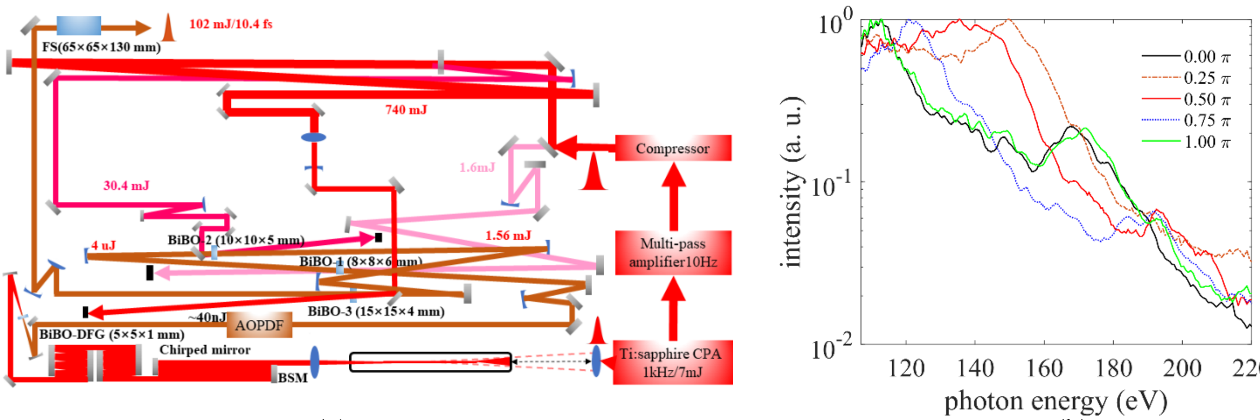

Fig. 1. (a) the schematic of the IR source based on DC-OPA; (b) CEP-dependent HCO in a sub-two-cycle pulse.

Reference

1. Q. Zhang, E. J. Takahashi, O. D. Mücke, P. Lu, and K. Midorikawa, Opt. Express 19, 7190 (2011).
2. C. A. Haworth, L. E. Chipperfield, J. S. Robinson, P. L. Knight, J. P. Marangos, and J. W. G. Tisch, Nat. Phys. 3, 52 (2007).