Multi-TW single-cycle laser based on the advanced DC-OPA

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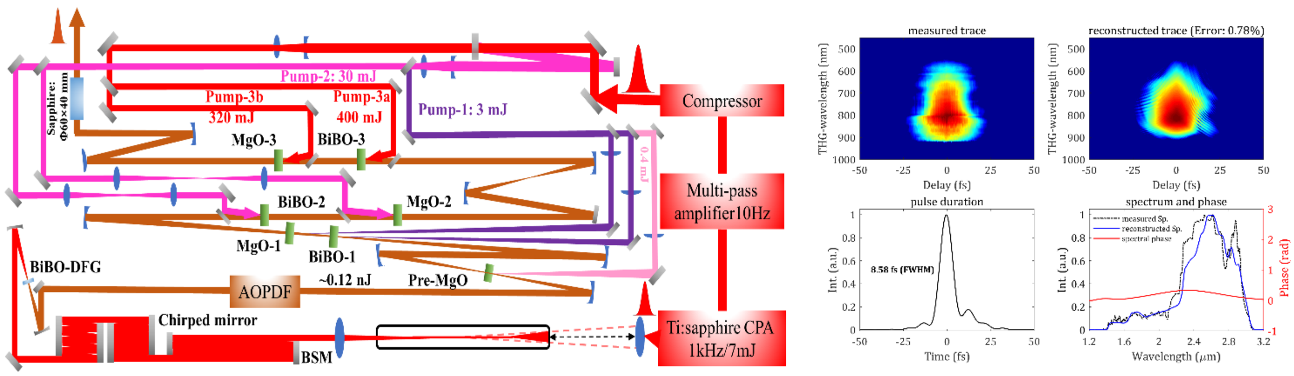
According to the "cut-off" law of high-order harmonic generation (HHG), it was evident that a driving laser with a longer wavelength was the essential requirement for extending the cut-off photon energy through the ponderomotive scaling. Moreover, the driving laser with a less-cycle can generate a broader HHG continuous spectrum, which gives the potential of creating an isolated attosecond pulse with a shorter pulse duration. Previously, a 100 mJ-class, sub-two-cycle, carrier-envelope phase (CEP)-stable 1.7 μm laser was demonstrated [1]. In this paper, we further extended the center wavelength to 2.4 μm and energy scaled the output of the single-cycle laser source, where two kinds of nonlinear crystals ($MgO:LiNbO_3$ + BiB_3O_6) were combined in the dual chirped optical parametric amplification (DC-OPA) scheme.

As illustrated in Fig.1 (a), the 4 mJ, 25 fs pulses from a 1kHz Ti:sapphire front-end laser are focused 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 with the cut angle at 65° for type-II phase matching in the X-Z plane. Thanks to the DFG, the CEP of the seed pulse (1.4 – 3.1 μm) is passively stabilized, and then, the seed pulse propagates in AOPDF to be given the suitable dispersion corresponding to the manner of DC-OPA (Fig. 1 (a)). To achieve more than one-octave bandwidth amplification in the DC-OPA, both type-I BiB_3O_6 with a cutting angle of 11° and type-I $MgO:LiNbO_3$ with a cutting angle of 42° were employed simultaneously, where the BiB_3O_6 crystal mainly amplifies the wavelength range from 1.4 μm to 2.3 μm and the $MgO:LiNbO_3$ crystal amplifies the wavelength range from 2.3 μm to 3.1 μm. It should be noted that the amplification based on $MgO:LiNbO_3$ crystal is one step more than that based on BiB_3O_6 crystal, to compensate for the difference in quantum conversion efficiency during the amplification of different wavelength ranges. By taking full advantage of the pump energy (750 mJ) and compression in the sapphire bulk (ϕ62 mm × 40 mm), the final output laser pulses with spectrum centered at 2.44 μm, pulse energy of 53 mJ and pulse duration of 8.58 fs were achieved (see Fig.1 (b)), which resulted in a 6 TW, 1.05 cycle, 10 Hz, CEP-stable laser source.



(a) (b)

Fig. 1. (a) Multi-TW single-cycle laser system; (b) Compression results with a center wavelength of 2.44 μm

Reference

1. L. Xu, B. Xue, N. Ishii, J. Itatani, K. Midorikawa, and E. J. Takahashi, "100-mJ class, sub-two-cycle, carrier-envelope phase-stable dual-chirped optical parametric amplification," Opt. Lett. **47**, (2022).