前瞻 EUV 光源及新穎光電元件開發

Development of EUV Lasers and Novel Photonic Devices

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Many physical and chemical processes which define our daily life take place on atomic scales in space and time. Capturing the most fundamental dynamics in matters requires short wavelengths for nanometer resolution and short pulse with a duration of femtoseconds (fs $/10^{-15}$ s) or attoseconds (as $/10^{-18}$ s). Challenges arise from the generation of bright coherent short EUV or X-ray. Currently, the temporal resolution of the avaliable Taiwan Light Source (TLS) and the newest Taiwan photon source (TPS) in NSRRC is limited to the pulse duration of 25 picoseconds (ps, 10^{-12} s). Recently, tabletop EUV produced by high harmonic generation (HHG) has received great attention, since it produces coherent EUV with attosecond pulse duration. The key technique behind the field of attosecond science is the availability of CEP-stable few-cycle pulses with sufficient energy for driving isolated attosecond pulses. Thanks to the suppport of Higher Education Sprout Project, some accomplishments are:

A) Self-development of femtosecond laser system: we have designed and built one Yb-based chirped-pulse amplifier, producing 20 W, 1.5 mJ pulses with a pulse duration of 210 fs. One 1030 nm seed is amplified by a regenerative amplifier, producing 7 W at a repetition rate of kHz, 1.4 mJ. Further, pulses are amplified to an average power of > 20W using a 2-passes Yb-YAG power amplifier while keeping a good beam profile and supporting enough bandwidth. We also successfully compressed pulses down to 220 fs. The peak intensity after one focus easily achieved 10^{14} W/cm^2. One chip video presents the plasma generation in copper. [http://mx.nthu.edu.tw/~mingchang/Yblaser20W.MOV].

B) Single-cycle pulse generation: Nonlinear pulse post-compression is one of the most commonly used method in the generation of few-to-single cycle pulses. The mechanism is to enlarge the spectral bandwidth and then compensate the residual spectral phases. It provides a pulse shortening way to long pulses which are naturally limited by the narrow emission bandwidth of the laser gain media. Recently, we propose a new postcompression arrangement to efficiently shorten the pulses into the single-cycle regime [1], advancing strong-field physics and attosecond science.

C) Isolated attosecond pulse generation: In high-order harmonic generation using our single-cycle pulses (3.2 fs), without the need for additional gating techniques we observed a broad and highly carrier-envelope-phase-dependent EUV continuum, providing stable isolated attosecond pulses. The resulted HH EUV supercontinua in He, spanning photon energies from 60 eV to 180 eV, can support 30 attoseconds (transform-limited) isolated pulses [1].

[1] Shian Tsai, An-Yuan Liang, Chia-Lun Tsai, Ming-Wei Lin, Ming-Chang Chen, “Nonlinear compression towards high-energy few-cycle pulses by cascaded focus and compression“, in preparation and under US, EU, TW patent application

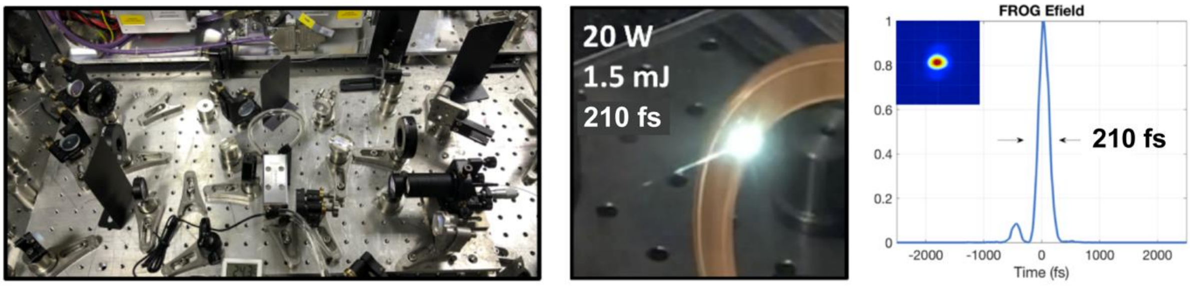

Fig. 1, Schematic of our home-built amplifier (left). The compressed 1.3 mJ pulses with a pulse duration of 210 fs (right), interacting with copper ring and producing bright plasma (middle).

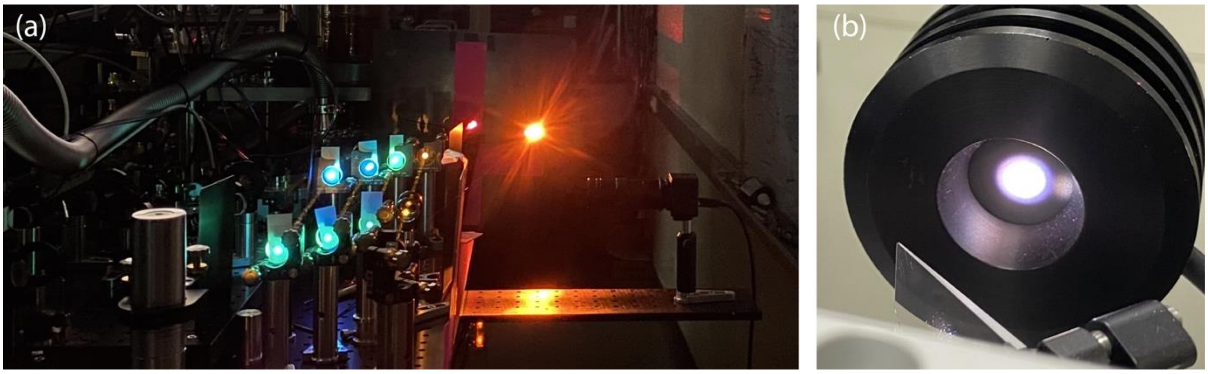

Fig. 2, (a) Generation of intense single-cycle pulse. (b) The beam profile of the single-cycle pulses.

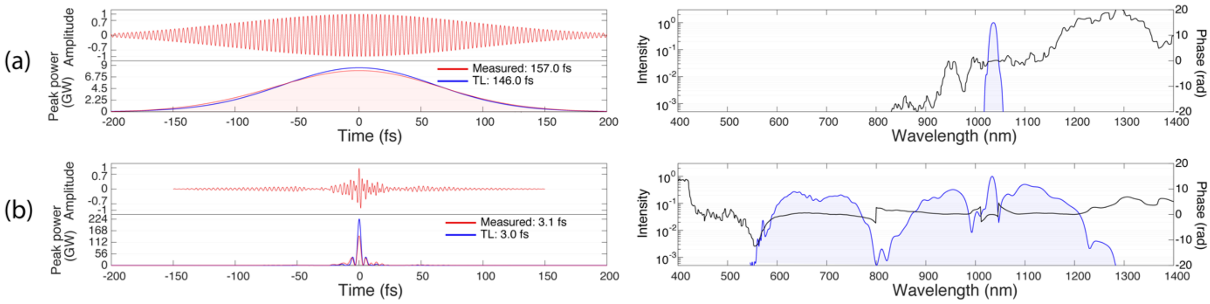

Fig. 3, Temporal characterization of the initial (a) and the postcompressed pulses (b). We demonstrated 50-fold compression of carrier-envelope-phase-stablized, 157 fs and 1.34 mJ pulses at 1030 nm down to 3.1 fs (single-cycle) with pulse energy of 0.98 mJ, corresponding to an overall efficiency of 77%. The waveforms of the pulses were carefully characterized by the subcycle tunneling ionization method. Right columns shows their spectrum and spectral phase. The spectrum of the single-cyle pulse spans from 550 nm to 1280 nm.

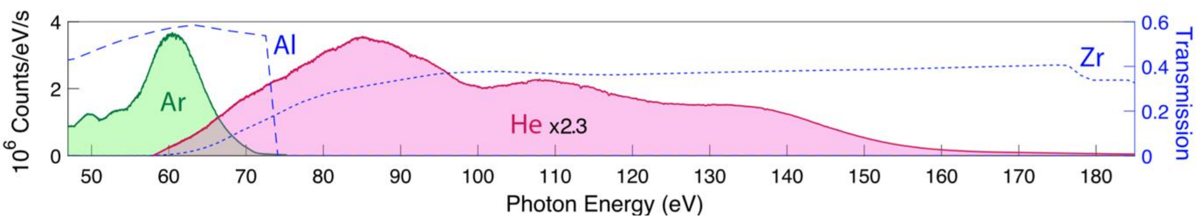

Fig. 4, High-harmonic supercontinuum (isolated attosecond pulses) driven by the single-cycle pulses in Ar and He, together with the transmission of filters.