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Editorial: Strong field physics and attosecond science

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Editorial on the Research Topic
Strong field physics and attosecond science

Light-matter interaction is an essential process in nature. The development of light pulses in the few-femtosecond to attosecond duration allows scientists to tackle ultrafast processes in atoms, molecules, and more complex systems. Many new strong field phenomena have attracted wide attention, such as multiphoton ionization, above-threshold ionization, non-sequential double ionization, high-order harmonic generation, attosecond pulse generation, coherent EUV emission, etc. These phenomena have been of interest from the perspectives of both fundamental physics and potential applications. In this Research Topic, authors address several recent developments and applications of ultrafast technology in strong field physics and contribute eight quality articles as explained below.

The studies of high-order harmonic generation promoted the development of non-linear optics from IR to XUV. Recently, Yang et al. experimentally investigated enhanced coherent EUV emission from Rydberg atoms. Substantial neutral atoms can be excited after tunneling in a strong laser field, in the process known as frustrated tunneling ionization. The generation of coherent emission from the excited-state atoms produced by the frustrated tunneling ionization is demonstrated to be dependent on the chirp of the laser pulse. This chirp dependence also provides a new way to investigate the dynamics of Rydberg states. Kong et al. explored the influence of mechanical strains on the high-order harmonic generation in the monolayer hexagonal boron nitride crystal by using time-dependent density functional theory. They found that the band structure is sensitive to the structural deformation modulated by strains. This result may be useful in probing lattice deformations in crystals and heuristic to enhance the optoelectronic efficiency of solid-state nano-devices.

Novel non-linear effects triggered by the femtosecond laser filamentation have attracted widespread attention, such as laser power density clamping in the filamentation, super-continuous white light, and self-steepening effects. In this Research Topic, Li et al. investigated the fluorescence emission of the multiple combustion intermediates from the femtosecond filamentation with an ultrashort laser pulse at the wavelength of 1,030 nm, from which they proposed an optimizing rule to improve the signal-to-noise ratio of the fluorescence emission intensity in the ethanol/air flame using femtosecond laser filament excitation. This research promotes a further application of the femtosecond laser pulses to simultaneously monitor the multiple combustion intermediates.

Plenty of ultrafast processes are directly triggered by photoionization, which is the foundation of many ultrafast phenomena and is very useful in revealing microscopic physical mechanisms. For example, valence electron excitation plays a critical role in strong-field processes, and a recent experiment shows that, in addition to the direct ionization of low-lying molecular orbital, the bond-softening mechanism with laser coupling between the ground state and an electronically excited state in a polyatomic molecule can significantly contribute to electron excitation Hu et al. Amplitude and phase describe the quantum attributes of electron wavepackets, Neoričić et al. studied resonant two-photon ionization of helium atoms via the 1s3p, 1s4p, and 1s5p states, and the phase of the photoelectron wavepackets was measured by an attosecond interferometric technique. With the ability to combine good angular resolution, high energy resolution, and attosecond-time-resolution in the experiments, the fast phase variations across emission angles and energies were measured. Decoding the amplitude and phase information angularly and spectrally for an electron wavepacket from a photoemission provides the ability to record 3D movies of photoelectrons at the attosecond time scales. In addition, over-barrier ionization is an interesting Research Topic in strong-field physics. Wang et al. investigated this process of hydrogen atoms in intense circularly and elliptically polarized laser fields, which demonstrates that the photoelectron momentum distributions show a spiral distribution. They further explored the relationship between the instantaneous ionization rate and initial transverse momentum in over-barrier ionization and pointed out that the non-adiabatic effect and long range Coulomb interaction play important roles. Wang et al. examined the photoelectron momentum distribution of hydrogen atoms in the super-intense ultra-short high-frequency pulses by numerically solving the time-dependent Schrödinger equation. They observed dynamic interference effects even in a tightly bounded system when there are circularly polarized pulses present in addition to the linearly polarized laser field. The Coulomb re-scattering effect is responsible for the observed substantial variations in photoelectron momentum distributions by linearly and circularly polarized extreme ultraviolet pulses. On the other hand, non-sequential double ionization has drawn much attention because it contains extensive information about collision dynamics and electron-electron correlation. Ben et al. investigated this from Ar atoms in the combined fields of linearly polarized laser and circularly polarized laser through 3D semiclassical simulations. By tuning the delay time between the two laser pulses, the double ionization yields and recollision trajectories with different return times can be controlled. This research shows that the electron dynamics in one or few optical cycles can be controlled in multicycle laser fields, which do not have to be limited to few-cycle laser pulses.

In conclusion, this Research Topic presents the latest advances and trends concerning strong-field physics and attosecond science. Our special thanks to the Frontiers in Physics team for the technical assistance with publishing. Many more efforts are still ongoing in this fascinating area. We expect that this field will attract increasing attention and benefit potential applications in the near future.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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