

Double Ionization of Helium Atom in Combined Near-infrared and XUV Pulses

Shaohao Chen¹, Andreas Becker²

JILA and Department of Physics, University of Colorado, Boulder 80309-0440, USA

Synopsis We investigate the double ionization process in He atom by applying an XUV attosecond pulse in the presence of an intense near-infrared femtosecond few-cycle laser pulse. To this end, we solve the time-dependent Schrödinger equation based on a three-dimensional model. We compare the double ionization signals obtained with and without the application of the attosecond pulse.

The advent of sub-femtosecond laser technology with the generation of attosecond pulses in recent years has opened new perspectives towards observation and analysis of multi-electron dynamics in atoms and molecules[1]. For example, the correlated electron dynamics in double ionization (DI) processes of atoms induced by intense infrared femtosecond laser fields has been one of the interesting topics[2, 3].

It is well known that such dynamics can be interpreted by the rescattering mechanism [4]. According to this picture, first one electron is ionized to the continuum at a maximum of the field, then it is accelerated and driven back by the strong oscillating field, and recollides with the parent ion at about 3/4 cycle after the ionization. A few interesting topics have been established according to different pathways, that is, elastic scattering contributing to above-threshold ionization, direct non-sequential double ionization, recollision-induced excitation of the parent ion plus subsequent ionization by the field (RESI)[5], recombination to the parent ion plus high harmonic generation.

We theoretically investigate the RESI process in He atom by applying an XUV attosecond pulse in the presence of an intense near-infrared femtosecond few-cycle laser pulse. The population in excited states of He⁺ ion is first pumped by the infrared laser field at the time of rescattering, then it is subsequently ionized most probably at the next maximum of the field. Therefore, there is a population and decay of ionic excited states within about a quarter of a field cycle (i.e. a few hundred attoseconds). We apply an XUV attosecond pulse during this period of time to

ionize and probe the excited populations.

To this end, we solve the time-dependent Schrödinger equation by the Crank-Nicholson method, based on a three-dimensional model for He atom in linearly polarized laser fields [2], in which the center-of-mass motion of the two electrons is restricted to the field direction, while the electron correlation is fully retained via the relative coordinate of the electrons. An 800 nm near-infrared femtosecond laser pulse (5×10^{14} W/cm²) and a 70 nm XUV attosecond pulse (1×10^{14} W/cm²) both polarized along the same direction with various time delays are used in our calculations. Comparing the DI probabilities induced by the femtosecond pulse only and by the femtosecond pulse plus the attosecond pulse, we observe some new interesting DI signals arising from the excited states of He⁺ ion due to the attosecond pulse. We also obtain the correlated momentum and energy spectra of the two ionized electrons at the end of the attosecond pulse, and analyze the relationship between these spectra and the excited structures of He⁺ ion.

References

- [1] F. Krausz and M. Ivanov, *Rev. Mod. Phys.* **81**(1), 163 (2009).
- [2] C. Ruiz et al., *Phys. Rev. Lett.* **96**, 053001 (2006).
- [3] A. Staudte et al., *Phys. Rev. Lett.* **99**, 263002 (2007).
- [4] P.B. Corkum, *Phys. Rev. Lett.* **71**, 1994 (1993).
- [5] B. Feuerstein et al., *Phys. Rev. Lett.* **87**, 043003 (2001).

¹E-mail: shaohao@jilau1.colorado.edu

²E-mail: andreas.becker@colorado.edu