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Collective autoionization dynamics of He clusters resonantly induced by intense XUV pulses

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The ionization dynamics of He nanodroplets irradiated by intense femtosecond extreme ultraviolet pulses in the range of $10^{10} - 10^{11} W/cm^2$ power density and photon energy of $21.4eV$ has been investigated by photoelectron spectroscopy. The experimental results are interpreted with the help of numerical simulations based on a system of rate equations of various processes such as multi-step ionization, Interatomic Coulombic Decay (ICD) [1,2], secondary inelastic collisions and desorption of electronically excited atoms from He clusters, as well as electronic relaxation processes. In the case of small He clusters (below 1,000 atoms), resonantly excited He-droplet states decay efficiently and fast to low lying $1s2s^3S$, $1s2s^1S$ and $1s2p^1P$ atomic excited states by droplet-induced intra-band and/or inter-band transitions, and then ICD takes place between pairs of electronically excited states, which is then followed by multi-step photoionization. In the case of a few thousand atoms within the He nanodroplet, a pronounced broadening of the photoelectron spectra is observed and the different lines start to interfere due to an increase of the total number of created ICD electrons.
In large He nanodroplets (> 50,000 atoms), inelastic electron scattering starts to play the main role and a cold, dense plasma is formed [2]. Furthermore, when more than two electronically excited atoms are involved the ionization dynamics develops from simple ICD type processes to collective autoionization (CAI) and higher order CAI and/or thermal electron evaporation processes take place. Our results provide an understanding of how the autoionization develops from low power density, characterized by single sharp photolines, to complex ionisation involving many different processes resulting in a cold dense plasma which emits electrons with broad structured distributions.

[1] A. I. Kuleff et al., Phys. Rev. Lett., vol. 105, p. 043004, 2010.
[2] Y. Ovcharenko et al., Phys. Rev. Lett., vol. 112, p. 073401, 2014.

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