Probing Xenon Double Ionization on the Attosecond Time Scale

E. P. Månsson[1], D. Guénot[1], C. L. Arnold[1], D. Kroon[1], S. Kasper[1], J. M. Dahlström[2], E. Lindroth[2], A. Kheifets[3], A. L'Huillier[1], S. L. Sorensen[1] and M. Gisselbrecht[1]

[1]Department of Physics, Lund University, Box 118, 221 00 Lund, Sweden

[2]Department of Physics, Stockholm University, Sweden

[3]Research School of Physical Sciences, The Australian National University, Canberra ACT 0200, Australia

mathieu.gisselbrecht@sljus.lu.se

Advances in the production of short light pulses in the attosecond time scale (1s=10^{-18}s) renewed the interest in understanding the temporal aspects of electron emission in atoms[1,2], molecules[3] and solid state[4]. Despite these pioneering works, which often highlight the importance of electronic correlations, little is known about electron-electron interaction time. We present here the first investigation of double ionization atto-second dynamics following the absorption of a single photon, which is one of the most fundamental processes involving the interactions between electrons.

We study the photoemission of two electrons from the $5p^6$ shell in xenon with coincident detection of the electron pair. Our method based upon interferometry uses a frequency comb of high order harmonics with photon energies ranging from 32 to 42 eV for the photoionization and a weak infrared laser field for probing the outgoing electrons. Coincidence technique allows us to disentangle events arising from single ionization and double ionization and to compare their relative emission time. Hence we can explore the photoemission dynamics in the vicinity of the double ionization threshold region [5].

We examine the influence of the weak infrared field, which introduces new processes for the two-electron ejections. We demonstrate that xenon atoms can be doubly ionized both through sequential and non-sequential processes. The non-sequential process arising primary from the simultaneous interaction with two photons (harmonic and IR photons) is essential in determining the emission time.

Based on theoretical analysis, we interpret our measurement on the difference of emission time between single and double ionization and estimate that electron-electron interaction time in the continuum has an upper limit of about 200 as. The measurement of such a quantity represents one of the most challenging tests for theory, especially in the vicinity of a threshold, but raises the possibility to study the coherence properties in multi-electron processes.

References:
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