Two and three-photon double ionization of lithium

M. Schuricke*, C. Dornes[1], G. Armstrong[2], J. Colgan[2], A. Kheifets[3], J. Ullrich[4], and A. Dorn[1]

[1] *Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany*
[2] *Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[3] *Research School of Physics and Engineering, Australian National University, Canberra, Australia*
[4] *Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Germany*
m.schuricke@mpi-hd.mpg.de

The advent of free electron lasers, as a source of intense and short VUV laser pulses, paved the way to investigate new regimes in light-matter interaction. In these, the most fundamental reactions are constituted by the interaction of few-photons with few-electrons, resulting in multiple ionization of the parent atom or molecule

Pioneering differential experiments performed at the free electron laser in Hamburg (FLASH) on two-photon double ionization (TPDI) of the closed shell atoms helium and neon [1, 2], could already identify the direct (non-sequential), sequential and virtual sequential removal of the electrons. The results presented here aim to explore how two or three photons interact with electrons in different shells.

Therefore, a cold and dense lithium target, confined in a magneto-optical trap (MOT) combined with a many-particle momentum spectrometer (reaction microscope), i.e. a MOTREMI, was set up at FLASH. Recoil-ion momentum distributions, giving insight into the electrons' sum momentum and mutual emission angle, have been recorded.

Two and three-photon double ionization (DI) of atomic lithium has been studied for photon energies of 50 eV and 59 eV at an intensity of $I \approx 5 \times 10^{13}\ \mathrm{W/cm^2}$. For a photon energy of (E_γ = 50 eV) no intermediate real state is reached and thus DI is energetically only allowed for the simultaneous absorption of two photons. The reaction equation for this process reads:

$$\mathrm{Li}(1\mathrm{s}^2 2\mathrm{s}) + 2\cdot\gamma \rightarrow \mathrm{Li}^{2+}(1\mathrm{s}) + 2\mathrm{e}^- . \quad (1)$$

The resultant Li^{2+} momentum distribution, is diamond shaped and centered at zero momentum. The shape and intensity of the recoil-ion cross section indicates a strongly correlated motion of the two outgoing electrons.

If the photon energy is tuned to the (1s $\rightarrow$ 2p) transition in lithium, significant changes in the cross-section pattern are observed. Now DI proceeds via an intermediate state following the equation:

$$\mathrm{Li}(1\mathrm{s}^2 2\mathrm{s}) + \gamma \rightarrow \mathrm{Li}^{*}(1\mathrm{s}2\mathrm{s}2\mathrm{p}) + \gamma \rightarrow \mathrm{Li}^{2+}(1\mathrm{s}) + 2\mathrm{e}^- . \quad (2)$$

Here, the second step resembles photo double ionization (PDI) of the doubly excited state. It is found that the cross section exhibits a dumbbell like structure with the two main peaks oriented along the laser polarization axis and a plateau region between them. For both experiments a competing three-photon reaction, where the emission of the electrons is independent, yields recoil ions with larger momenta.

The results are discussed and compared to two state-of-the-art calculations. These apply the convergent close coupling (CCC) [3] and time-dependent close coupling (TDCC) [4] approach.

References

[1] M. Kurka *at al*, New J. of Phys. **12**, 073035 (2010)
[2] A. Rudenko *at al*, Phys. Rev. Lett. **101**, 073003 (2012)
[3] A. Kheifets *at al*, Phys. Rev. A **80**, 063413 (2009)
[4] G. Armstrong *at al*, Phys. Rev. A **86**, 023407 (2012)