New perspectives in photo ionization - from VUV to X-ray

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The general process of photo ionization by a single photon seems to be quite simple and well understood: in general the photon carries energy, longitudinal and angular momentum. At lower photon energies - usually below 1 kV - the photon-electron interaction is treated in the so-called dipole approximation, where also the photon's longitudinal momentum is absorbed. Here the absorbed quantities, angular momentum and energy, are directly shown in the photoelectron's kinetic energy and angular distribution of a singly ionized atom. In this regime, double ionization takes place via initial state correlation (shake-off) or final state interaction (two-step-one), where an electron is knocked-out.

At higher photon energies (≈1 kV and above) a new double-ionization mechanism comes into play. The so-called quasi-free-mechanism (QFM) probes the spatial wave function, where two electrons are initially placed closed to each other [1,2]. On top higher order terms of the photon-electron-interaction become more and more important: the photon's momentum is still small, but not negligible any more. Non-dipole effects, originating as the interference term of dipole and quadrupole term shift the electron-angular distribution forward/backward as a function of the photon energy. At even higher photon energies (a few keV), the photon momentum, plays now an important role. The electron can be directly knocked-out by the photon in a two-body-collision (Compton scattering). Here a typical scattering characteristics, similar to those known from (e,2e) or ion-impact ionization [3], was observed. All afore mentioned effects will be discussed on the atomic and molecular show-case systems with two electrons: Helium and H_2. [4,5]. The experiments were carried out mainly at the Petra III synchrotron (beamline P04). A gas jet of helium or H_2 was ionized. The produced ionic fragments and electrons were 3d momentum imaged using the COLTRIMS Reaction microscope technique [4].

References

[1] M. S. Schöffler et al., Phys. Rev. Lett. **111**, 013003 (2013)
[2] S. Grundmann et al., Phys. Rev. Lett. **121**, 173003 (2018)
[3] H. Gassert et al., Phys. Rev. Lett. **116**, 073201(2016)
[4] M. Waitz et al., Nat. Comm. **8**, 2266 (2017)
[5] M. Waitz et al., Phys. Rev. Lett. **117**, 083002 (2016)
[6] R. Dörner et al, Phys. Rep. **330**, 95 (2000)