Double Ionization in Strong Laser Fields

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Today, optical fields, which are strong enough to yield 100% probability for singly ionizing helium and other atoms, are routinely accessible in the focus of femto-second laser pulses. At such high fields, a surprisingly high probability has been found for ionizing even two electrons from helium and other rare gas atoms. The magnitude and field dependence of the He^{2+} ion yield clearly proves that this process relies almost completely on electron-electron correlation and cannot be explained in an independent electron picture. The mechanisms responsible for this two electron transition, however, are a matter of controversy. All experimental studies and most of the theoretical work on the double ionization of isolated helium atoms in strong laser fields so far considered only the total ion yield as a function of the laser field strength or polarization.

We have performed the first differential measurements for the double ionization process in strong fields. Using the well established technique of Cold Target Recoil-Ion Momentum Spectroscopy (COLTRIMS), we have measured the recoil-ion momentum distributions of the He^{1+} and He^{2+} [1] and Ar^{2+} ions [2]. Similar experiments are reported by Moshammer et al. [3] for Ne target. Such differential ion yields provide more detailed insight into the dynamics of the ionization process and provide a much improved testing ground for the different theoretical models in the discussion.

The linearly polarized light of a titanium sapphire laser at 800 nm, with a pulse width of 220 fsec, and a repetition rate of 1 kHz was focussed by a 5 cm lens onto a precooled (30 K) supersonic He and Ar gas jet target. The ions were projected by an electrostatic field onto a two dimensional position sensitive channel plate detector. The momentum vector and the charge state of the ions was obtained from the position of impact on the detector and the time of flight.

For Helim and Argon the momentum distribution of the doubly charged ions at intermediate laser intensities is much wider than for singly charged ions and does not peak at zero for some intensities. This is a clear proof that the mechanism for double ionisation is different than for single ionisation. Upon further increase of the laser intensity we find for Argon a dramatic narrowing of the momentum distributions which is accompanied by a steep rise of the ratio of doubly to singly charged ions. For the highest intensies the momentum distribution of the doubly charged ions is very well described by an independ particle modell. This indicates a change in ionisation mechanisms. In a subsequent experiment we oberseved the momenta of both emitted electrons in coincidence. These data are analysed at the moment.

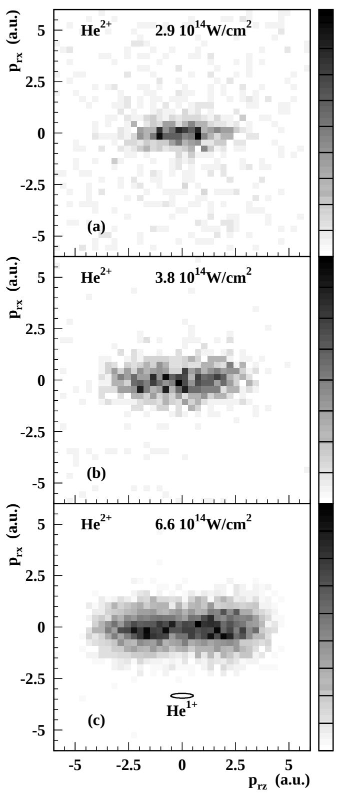

Figure 1: Momentum distribution of He^{2+} ions created in the focus of a 220 fsec, 800nm laser pulse at peak intensities of 2.9 (a), 3.8 (b) and $6.6 \cdot 10^{14}$ W/cm^2 (c) and linear polarization. The horizontal axis shows the momentum component along the electric field vector (p_{zr}), the vertical axis is the momentum component in the direction of the light propagation (p_{xr}). The distribution is integrated over p_{yr}. The grey value indicates the differential ion yield on a linear scale. The small ellipse in (c) labeled He^{1+} shows the distribution of the halfwidth of the He^{1+} for comparison.

This work is supported by DFG, BMBF, GSI and DAAD. Heisenbergprogramm der DFG. The Marburg group thanks the DFG for support through their SFB383 and their Graduiertenkolleg 'Optoelektronik mesoskopischer Halbleiter'.
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