Electron release dynamics in double ionization of Ar and Ne by elliptically polarized laser pulses

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Synopsis: Elliptically polarized laser pulses are suitable to investigate double ionization isolated from electron recollision effects. For Ar and Ne we observe a characteristic transition in the momentum spectra of the doubly charged ions when the laser peak intensity is varied across the over-barrier intensity of the second ionization level. We find a qualitative agreement of our data with a simulation based on sequential double ionization and interpret our observation as a sensitive fingerprint of depletion.

Double ionization of atoms exposed to strong laser fields can occur via sequential mechanisms, where the electrons interact independently with the laser field, and non-sequential mechanisms, where the electrons cannot be treated separately. For linear polarization, the dominating non-sequential mechanisms involve recollision of the first ionized electron with the remaining ion. Elliptical polarization excludes rescollision, and therefore allows focusing on non-recollision mechanisms.

Laser pulses with a duration of 5.5 fs and a center wavelength of 720 nm were focused onto cold Ar and Ne atoms inside a COLTRIMS setup. The ellipticity was adjusted to about 0.8 with an achromatic quarter-waveplate and the peak intensity was varied from about 5 to 60 x 10^{14} W/cm^2. Whereas the momentum distribution of the doubly charged ions parallel to the major axis of the polarization ellipse (x-axis) is always close to gaussian, the projection onto the y-axis shows a characteristic dependence on intensity (Fig 1): For low intensities the distribution exhibits 3 peaks, whereas high intensities result in a 4-peak structure. An explanation for the 4-peak distribution was given by [1].

We found our observation to be consistent with a simulation based on ADK rates and sequential electron release. Due to depletion the release time of the electrons is shifted from the pulse center towards the beginning of the pulse with increasing peak intensity. Because the depletion is different for the two ionization levels, the average time between the successive ionization steps grows, which causes the center peak in the momentum distribution to split. The characteristic intensity for this transition is the over-barrier intensity for the second ionization level, which is 11.7 x 10^{14} W/cm^2 for Ar.

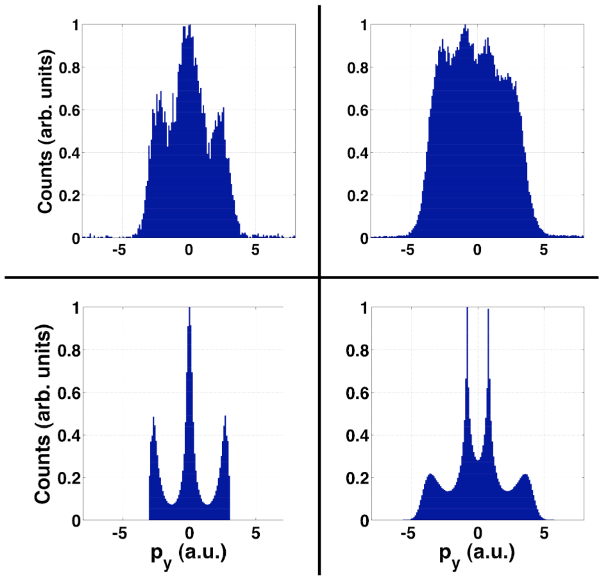

Fig. 1. Momentum spectra of doubly charged Ar ions. Upper panel: Data for low (left) and high (right) intensity. Lower panel: Simulation for 8 x 10^{14} W/cm^2 (left) and 40 x 10^{14} W/cm^2 (right).

The positions of the peaks are reasonably well reproduced by the simulation, and the discrepancies might stem from simplifications in the simulation. Further investigation of potential electron correlation will clarify the validity of the sequential electron release in different intensity regimes.

References

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