Recollision-Induced Double Ionization of Ar and Ne Atoms: Wavelength Dependence

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Recent studies on the double-ionization of Ar and Ne gases using 800 nm femtosecond laser pulses have shown that doubly-charged ions are produced by inelastic scattering of the electron removed by the laser field with its parent charged ion. This was revealed by measuring the momentum distribution of the doubly charged ion in the direction parallel to the laser polarization and observing a dip structure around zero momentum in this distribution [1, 2]. Additionally, those studies have also shown a difference in the dip structure between the Ar and Ne targets. The Ne^{2+} ions showed a pronounced dip at zero momentum while Ar^{2+} showed a shallow one. The difference in the dip structure in the ions' recoil momentum was attributed to the difference in the atomic structure and the variation of the electron- impact ionization and excitation cross sections for the two targets [1, 2].

In the present study we used the powerful OPA available at the Canadian Advanced Laser Light Source (ALLS) and tuned the laser wavelength at various values that range between the visible and near-infrared regimes to study the double-ionization of Ne and Ar. Double-ionization of atoms and molecules usually proceeds through rescattering (recollision) process when infrared, low-intensity laser is used, whereas with visible light there is a substantial probability for the electron to reach the continuum directly by absorbing a number of photons with enough energy that enables the electron to overcome the binding barriers. Multiphoton-excitation (ionization) processes are expected to exhibit a strong dependence on the laser wavelength.

We measured the momentum distributions for Ar^{2+} and Ne^{2+} ions at various wavelengths as indicated in Fig.1. We noticed that at 483 nm the dip almost disappears in the Ar^{2+} whereas it becomes very distinct when infrared is used. Similar behavior was also observed for Ne^{2+} ions (not shown in the figure) such that both ions exhibit very similar structure in the far-infrared region.

This new observation can be understood when

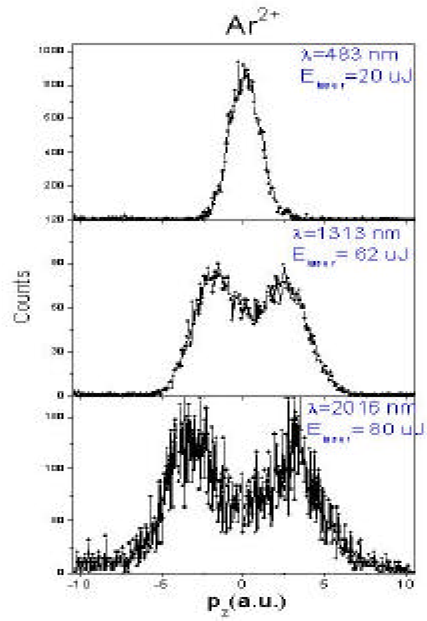

Fig.1. Longitudinal momentum distributions of Ar^{2+} recoil ions at different wavelengths.

the maximum energy that the rescattering electron acquires in the laser field compared to the ionization potential of the singly-charged ion, is considered . At 483 nm, the maximum electron rescattering energy (14 eV) at saturation intensity (0.2 PW/cm^2) is less than the ionization potential of Ar^+ (27.6 eV). Therefore, the rescattering electron is not able to knock out the other electron, which causes the disappearance of the dip in the Ar^{2+} momentum distribution at this wavelength. Similarly, this decrease in the electron's energy will lower the ionization probability of the Ne^+ ion and lead to shallower dip than that observed at 800 nm. On the other hand, for the longer wavelengths the manifestation of the dip structure in both ions indicates that the rescattering electron acquired enough energy in the laser field that enables the removal of the second electron through direct e-2e ionization.

1- K. Zrost *et.al*., *J. Phys. B: At. Mol. Opt. Phys.* **39** S371-S380 (2006).
2- R. Moshammer *et.al*., Phys. Rev. Lett. 91, 113002 (2003), B. Feuerstein *et.al*., Phys. Rev. Lett. 87, 043003 (2001).