Journal of Physics: Conference Series **635** (2015) 092005 doi:10.1088/1742-6596/635/9/092005

# Electron rescattering in strong-field photodetachment of $F^-$

**O. Hassouneh***, **S. Law***, **S.F.C. Shearer***, **A.C. Brown*** and **H.W. van der Hart*** [1]

* Centre for Theoretical Atomic, Molecular and Optical Physics, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom

**Synopsis** The description of processes in mid-IR laser fields presents new challenges to theoretical atomic physics. We apply time-dependent R-matrix theory to study multiphoton detachment of $F^-$. Through comparison with the strong-field approximation, we observe signatures of rescattering in the analysis of the final wavefunction, demonstrating the accuracy of the time-dependent R-matrix approach.

The development and application of new laser technology continues to be at the forefront of science and technology. This ongoing development needs to be matched by the development of theoretical approaches capable of explaining the new phenomena seen in experiment. To this end, at Queen's University Belfast we have developed time-dependent R-matrix theory [2, 3]. This theory explicitly accounts for all the electrons in an atom, and is capable of studying their response to an external laser field.

When an atom is placed in an intense laser field, an escaping electron is driven back and forth by the oscillating field. If the escaping electron returns to the residual atom, a wide variety of highly non-linear processes can occur [1]. The maximum distance an electron can escape from the residual atom prior to return increases rapidly with increasing wavelength. At an intensity of $2\times10^{14}$ W/cm$^2$, this maximum distance is 11 $a_0$ at 390 nm, 44 $a_0$ at 780 nm, and 234 $a_0$ at 1800 nm. Hence, an accurate theoretical description of atomic processes in the near-IR regime needs an accurate description of the moving electronic wavepacket at large distances.

Previously, we have demonstrated that time-dependent R-matrix theory can accurately describe the harmonic response of Kr and Xe atoms to strong light fields in the mid-IR regime, including harmonics up to order 275 [4]. However, the harmonic response is given by the Fourier transform of the time-dependent dipole moment, and, as such, it does not provide direct insight into the quality of the final-state wavefunction.

This quality can be assessed more accurately through its direct analysis. We have therefore carried out an investigation into multiphoton detachment of F−, and the influence of rescattering on this detachment. This process was previously investigated in [5, 6]. Through comparison with a strong-field approximation for multiphoton detachment of $F^-$, using the same pulse characteristics [7], we can clearly identify the signatures originating from the rescattering process.

We obtain an ejected-electron momentum distribution through analysis of the final wavefunction. The rescattered electrons can be clearly distinguished from the directly emitted electrons through the rings centered around a displaced origin on the $z$-axis. This displacement can be associated with the vector field at the moment of recollision. The overall characteristics of the momentum distribution are in agreement with the distributions obtained in [5, 6].

One of the advantages of time-dependent R-matrix theory is the capability to include the electron-repulsion interaction in detail. We have therefore carried out calculations using a Hartree-Fock representation of the residual F atom [8], and using a larger description, including double excitations out of the $2p^5$ shell [9]. When the basis set is increased, the momentum distributions have the same qualitative structure, but the overall magnitude of photodetachment is notably reduced.

## References

[1] P. Corkum 1993, *Phys. Rev. Lett.* **71** 1994

[2] L.A.A. Nikolopoulos 2008, *Phys. Rev. A* **78** 063420

[3] L.R. Moore *et al* 2011, *J. Mod. Opt.* **58**, 1132

[4] O. Hassouneh *et al* 2014, *Phys. Rev. A* **90** 043418

[5] X.X. Zhou *et al* 2008, *Phys. Rev. A* **77** 053410

[6] B. Fetić *et al* 2011, *J. Mod. Opt.* **58**, 1149

[7] S.F.C. Shearer *et al* 2013, *Phys. Rev. A* **88** 033415

[8] E. Clementi *et al* 1974, At. Data Nucl. Data Tables **14** 177

[9] C. Niang and M. le Dourneuf, unpublished

[1] E-mail: h.vanderhart@qub.ac.uk