Metastable argon production via strong-field excitation

R. D. Glover[*] [1], A. J. Palmer[*], M. A. Dakka[†], J. L. Holdsworth[‡], P. S. Light[†], I. V. Litvinyuk[*], A. N. Luiten[†], R. T. Sang[*] [2]

[*] Centre for Quantum Dynamics, Griffith University, Brisbane, QLD 4111, Australia
[†] Institute for Photonics and Advanced Sensing and School of Physical Sciences, The University of Adelaide, Adelaide, SA 5005, Australia
[‡] School of Mathematical and Physical Sciences, University of Newcastle, University Drive, Callaghan 2308 NSW, Australia

Synopsis Strong-field excitation is an exciting prospect for producing noble gas atoms in metastable states with unprecedented efficiency. This process, known as frustrated tunnel ionization, occurs after strong-field tunneling when the returning electron wavepacket recombines leaving the atom in an excited state. We investigate this excitation process using an amplified, few-cycle laser system in conjunction with an argon atomic beam.

Laser cooling experiments with noble gas species are necessarily performed via the closed optical transition from the metastable $^3P_2$ state to excited $^3D_3$ state (2^3S_1 – 2^3P_2 in He). Typically, the metastable state is accessed via electronic excitation in a discharge. This process is inherently inefficient with metastable to ground state ratios on the order of 10^{-4} and is the limiting factor for a number of exciting applications [2, 3].

All optical approaches have been pursued in the past where UV lamps have provided the basis for the excitation scheme [4]. Unfortunately these experiments suffer due to the degradation of the UV lamps and have failed to improve on the efficiencies already attainable using discharge techniques.

We are investigating the production of metastable $^3P_2$ Ar via frustrated tunnel ionization (FTI) in a strong-field laser pulse. FTI is the process of strong-field tunneling proceeded by recombination without ionization. It is similar to strong-field ionization (SFI) and can be explained with the well-known 3-step model, however in FTI after the initial laser interaction the atom is left in an excited Rydberg state (typically $n > 5$). A subsequent cascade decay can populate the $^3P_2$ metastable state in noble gas atoms. Previous experiments with He have reported metastable to ground state ratios similar to what is achieved with discharge techniques [5] and recent results suggest excitation efficiencies with Ar can be at the percent level [6].

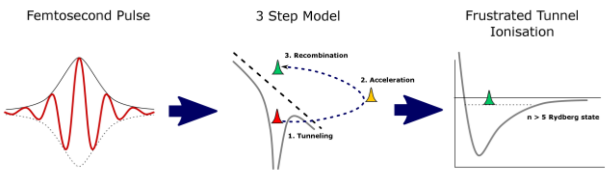

Figure 1. A graphical representation of the FTI process. Initially, a femtosecond pulse results in strong-field tunneling of the electron wavepacket followed by acceleration in the field and eventually the atom being left in a Rydberg state upon recombination.

Our research aims to optimize the population of atoms left in the metastable state after FTI. FTI also produces a rich Rydberg structure that is indicative of the underlying physics. Our laser system is capable of producing amplified and phase stabilized, few cycle pulses at 800 nm. This allows us to precisely control the strong-field interaction and study the FTI process with new levels of precision.

References

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[1] E-mail: rohan.glover@grifith.edu.au
[2] E-mail: r.sang@griffith.edu.au