

Project title: Skewed-Polarisation Absorption Spectroscopy

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Helpful existing knowledge: Quantum Mechanics (such as MTH4031, MTH3032, PHY3001)

Funding status: To be confirmed

Project Description:

With recent improvements in laser technology, experimentalists are routinely able to measure electron dynamics in atoms and molecules on the attosecond scale ($1 \text{ as} = 10^{-18} \text{ s}$) [1]. When electrons are removed from an atom during ionisation, the electrons left behind respond to the new vacancy in ways that require a proper, time-dependent, quantum mechanical description.

We are now at a point where the sensitivity and resolution of modern experimental techniques have rendered simplified theoretical models redundant. At Queen's we are uniquely well-placed to inform and support ongoing experimental efforts because of our development and maintenance of the sophisticated R-matrix with Time Dependence (RMT) method [2]. The theory and associated computer codes can describe the multielectron dynamics of atoms and molecules driven by short, intense, arbitrarily polarised pulses of light.

Our recent work has focused on the rich dynamics driven by two-colour pulses with 'skewed polarisation' - i.e. the relative polarisation plane of the two, ultrashort pulses is a controllable parameter in the experiment [3]. Whereas linearly polarised light drives dynamics along relatively predictable pathways, breaking the symmetry populates many more of the available quantum states, whose interference determines the resulting experimental observable. This project will combine that research with another technique we have helped to drive: Attosecond Transient Absorption Spectroscopy [4]. While so-called 'multidimensional spectroscopy' was an idea proposed some years ago [5], the lack of a suitably advanced theoretical method halted progress. RMT is perhaps the only method capable of tackling the complexity of the scheme, and in this project, you will drive that effort, identifying experimentally realisable schemes for observing dynamics in the residual ion during ionisation.

Useful references

- [1] [Advanced information. NobelPrize.org. Nobel Prize Outreach 2025. Tue. 4 Nov 2025.](#)
- [2] [A. C. Brown *et al*, Computer Physics Communications **250**, 107062 \(2020\)](#)
- [3] [W. Jiang *et al*, Nature Communications **13**, 5072 \(2022\)](#)
- [4] [L. R. Hutcheson *et al*, Physical Review Research **7**, L022074 \(2025\)](#)
- [5] [H. J. B. Marroux *et al*, Science Advances **4**, eaau3783 \(2018\)](#)