University of Warwick — Department of Physics

Multidimensional vibrational spectroscopy of defects in diamond

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Atomic-scale defects contained within crystals of diamond provide fascinating opportunities for fundamental and applied physics, including emerging use in quantum technologies and magnetometry. These defects are often a combination of missing carbon atoms, and extra nitrogen and hydrogen atoms. While the unique electronic and vibrational states of defects in diamond can be probed via optical spectroscopy techniques, often only the time-averaged response is accessed.

In this project the PhD candidate will use intense pulses of infared light to promote defects into their vibrationally excited states. The subsequent coherent "shakedown" – the transient vibrational response of the defect – contains information about the vibrational energy levels, cross-coupled vibrational modes and energy relaxation rates. In particular, two-dimensional spectroscopy maps within the coherence lifetime of the vibrations (a few picoseconds) can now allow us to identify which vibrational modes are directly coupled, and hence form part of the same physical defect. Defects may be point-like (e.g. nitrogen-vacancy-hydrogen complexes) or more extended (e.g. dislocations, platelets). This information is crucial in order to better understand the fundamental physics of defects in diamond.

The student will make use of the Warwick Centre for Ultrafast Spectroscopy (go.warwick.ac.uk/WCUS), a joint collaboration between the Physics and Chemistry Departments at Warwick that provides ultrafast spectroscopy experiments covering the ultraviolet, visible, infrared and terahertz ranges. Further, the student will make use of advanced spectroscopy methods such as two-dimensional infrared spectroscopy, available at facilities such as ULTRA (https://www.clf.stfc.ac.uk/Pages/Ultra_Facility.aspx) in Oxfordshire. Additional material characterisation will be undertaken using Warwick's suites of modern spectroscopy (UV-visible, Raman, FTIR, ESR), and microscopy (SEM, TEM) equipment.

This project suits an enthusiastic and motivated student keen to work with advanced experimental methods to further our understanding of the physics of novel materials. Funding is available for excellent candidates for 4 years at standard research council rates (stipend plus fees). The studentship is offered with the support of an industrial partner, the de Beers Group.

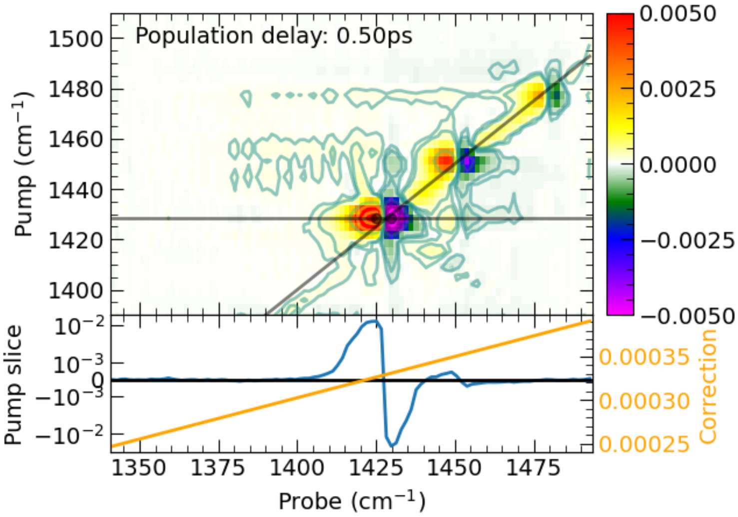

Figure: **Top.** Two-dimensional infrared spectroscopy revealing the possible transition energies (wavenumbers) of different local vibrational modes, in purple and blue, close to the diagonal line (pump=probe frequency), as well as transitions between their excited states (red/orange). **Bottom.** Cross-section at 1428cm^{-1} pump wavenumber shows coupling between different vibrational modes (multiple peaks).

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