

**Multidimensional ultrafast spectroscopy of vibrational
coupling in perovskite semiconductors**

Project supervisor: Prof. James Lloyd-Hughes

The terahertz and infrared vibrational modes of metal halide perovskites (MHPs) strongly interact with electrons, limiting the mobility of these solution-processable materials with otherwise outstanding light emission and absorption performance. In this PhD project the student will use multi-dimensional coherent spectroscopy to unpick the coupling between the vibrational modes, mobile electrons and excitons. Understanding how the nonlinear vibrational dynamics impacts the electronic properties of materials will help enable the next generation of advanced optoelectronic materials and devices [1-4].

In this project the PhD candidate will use intense pulses of terahertz and mid-infrared light to probe the coupling of vibrational modes and electron motion. The subsequent coherent “shakedown” – the transient vibrational response – contains information about the vibrational energy levels, cross-coupling to different states and energy relaxation rates. In particular, two-dimensional spectroscopy maps within the coherence lifetime of the vibrations (a few picoseconds) will allow the student to identify which vibrational modes are directly coupled and how they impact upon lattice dynamics and electron motion. This information is crucial in order to better understand the fundamental optoelectronic properties of MHPs. In addition, and more broadly, nonlinear interactions in materials drive advanced functionalities, such as the ability to convert light from one wavelength to another.

The student will make use of the Warwick Centre for Ultrafast Spectroscopy (go.warwick.ac.uk/WCUS), a facility that provides ultrafast spectroscopy experiments covering the ultraviolet, visible, infrared and terahertz ranges. They will have the opportunity to contribute to the development of new ultrafast spectroscopy methods, including ultrafast optical microscopy, gaining valuable experience with ultrafast lasers and advanced optical components. Additional material characterisation will be undertaken using Warwick's suites of modern spectroscopy (UV-visible, Raman, FTIR), and microscopy (SEM, TEM) equipment.

This project suits an enthusiastic and motivated student keen to deploy advanced experimental methods to further our fundamental understanding of the physics of novel materials. Funding is available for excellent candidates for 3.5 years at standard research council rates (stipend plus fees).

* Please feel free to contact me on j.lloyd-hughes@warwick.ac.uk if you have any questions regarding this project.

Some of our relevant recent papers include:

- [1] Nature Photonics **17**, 798–805 (July 2023)
- [2] Phys. Rev. Applied **22** 024103 (Aug 2024)
- [3] Phys. Rev. Lett. **135** 216902 (Nov 2025)
- [4] J. Phys. Chem. Lett. **17** 5249 (Apr 2026)

For a full list of our recent work see go.warwick.ac.uk/ultrafast/publications/?tag=Lloyd-Hughes