University of Warwick Department of Physics

Ultrafast terahertz spectroscopy of novel perovskite photovoltaics

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Understanding the physics of the light-matter interaction in materials with the perovskite crystal structure is an extremely active and exciting topic at present. Inorganic-organic hybrid perovskites have provided an entirely new class of optoelectronic materials with excellent photovoltaic performance (over 22% solar power conversion efficiency), and have further potential for use in light emitters [1]. However, the physics of what happens after light is absorbed in these compounds is poorly understood: some studies have concluded that free, mobile charges are created directly, while other work has reported the formation of excitons – bound electron-hole pairs. How free charges and excitons are created and subsequently move can be investigated with ultrafast terahertz spectroscopy [2]. This is an advanced experimental method that probes the conductivity of materials as they respond to pulses of light with <1ps duration (1ps = 10^{-12}s).

The project will make use of the new Warwick Centre for Ultrafast Spectroscopy [2], a joint collaboration between the Physics and Chemistry Departments at Warwick that provides ultrafast spectroscopy experiments covering the ultraviolet, visible, infrared and terahertz ranges. This massive spectral coverage lets us examine electron transfer between different electronic states, free electron transport, and the influence of vibrational modes. This information is crucial in order to better understand the fundamental physics of charge transport in novel perovskite nanomaterials such as lead-free systems developed in the Department of Chemistry at Warwick [3].

During this project the student will employ advanced ultrafast spectroscopy techniques such as optical-pump terahertz-probe spectroscopy (OPTPS) to study perovskite nanomaterials. This approach utilises ultrashort pulses of laser light to generate and detect single-cycle pulses of terahertz radiation [4]. These THz probe pulses are then used to measure transient changes in the photoconductivity of a nanomaterial, over picosecond to nanosecond times after light is absorbed. Additional material characterisation will be undertaken using Warwick's suites of modern optical spectroscopy (UV-visible, Raman, FTIR), and microscopy (AFM, SEM) equipment. This project therefore 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 exceptional UK and EU candidates for 3.5 years at standard research council rates (stipend plus fees). The student will be part of the Materials Physics Doctorate scheme (go.warwick.ac.uk/MPDOC). This gives access to a tailored research degree to help you exploit our own outstanding materials growth, fabrication, characterisation and computational capabilities, and those at central facilities. A broad education in Materials Physics is provided through dedicated modules under the Midlands Physics Alliance Graduate School, and external courses.

References

[1] Snaith, J. Phys. Chem. Lett. **4** 3623 (2013), dx.doi.org/10.1021/jz4020162.
[2] go.warwick.ac.uk/WCUS
[3] Marshall *et al.*, Nature Energy **1** 16178 (2016), nature.com/articles/nenergy2016178.
[4] Lloyd-Hughes & Jeon, J. Infrared MM THz Waves **33** 871 (2012).

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