Enhanced Polarisation Control in Terahertz Time-Domain Spectroscopy,

and Extreme Terahertz Electric Fields

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Terahertz time-domain spectroscopy (THz-TDS) is a powerful tool for characterizing the optical properties of materials in the terahertz region of the electromagnetic spectrum (0.1 – 10 THz, corresponding to photon energies of 0.4 – 40 meV). A wide variety of quasiparticles and collective excitations occur at these energies, including magnons, plasmons, and phonons. Many materials also demonstrate anisotropic behaviour at THz frequencies, such as birefringence created by anisotropy in the vibrational or electronic response, and electro- and magneto-optical effects. The light-matter interaction in these materials can introduce both absorption and polarisation changes to the THz beam, which may be difficult to distinguish between using standard THz-TDS methods; the accurate generation and precise detection of THz beams with well-defined polarisation states is therefore increasingly important for the spectroscopy of anisotropic materials.

In the first part of my talk, I will describe the development of new techniques and components that enhance the experimentalist's control over the terahertz polarisation state, and their applications in the spectroscopy of anisotropic materials [1,2].

Traditionally many tabletop sources of THz radiation have remained weaker than other regions of the electromagnetic spectrum. However, new THz generation techniques coupled with amplified femtosecond lasers have begun to bridge the gap, with high-power sources now capable of producing single-cycle pulses of THz radiation with electric field strengths exceeding 1 MV/cm [3].

For the remainder of my talk I will discuss two applications of this extreme THz radiation: THz spectroscopy in the nonlinear regime, and THz particle acceleration.

[1] C. D. W. Mosley *et al.*, *Scientific Reports* **7**, 12337 (2017).

[2] C. D. W. Mosley *et al.*, *AIP Advances* **9**, 045323 (2019).

[3] H. Hirori *et al.*, *Applied Physics Letters* **98**, 091106 (2011).