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Terahertz time-domain spectroscopy of quantum materials under high pressure in a diamond anvil cell

We present a new method for performing equilibrium and time-resolved terahertz spectroscopy of quantum materials while continuously tuning temperature and pressure conditions [1]. These tuneable parameters allow precise control of the sample ground state and investigation of excited states reached with an optical pump. The technique combines a broadband THz time-domain spectroscopy system (0.1-8 THz), an 800 nm pulsed optical pump, a diamond anvil cell (DAC) generating pressures up to 10 Gpa, and a cryostat reaching temperatures as low as 10 K in a tabletop setup.

The DAC sample chamber is hundreds of micrometres wide and $< 100 \mu\text{m}$ thick, limiting measurements to small samples. Crucially, these small dimensions lead to clipping of the THz beam ($\sim 450 \mu\text{m}$ FWHM), which creates reflections and diffraction. We analyse how the DAC geometry affects THz-TDS spectra and develop new extraction methods for pressure-dependent material parameters of bulk samples in pressure media, as standard analysis procedures are no longer applicable. Different pressure media are tested and evaluated using these new methods, and we present the obtained material parameters compared to literature values.

We also characterize the pressure and temperature dependence of the THz response of these pressure media, as well as their hydrostaticity in different external conditions.

Time-resolved measurements under pressure are demonstrated using optical pump-THz probe spectroscopy, validated on bulk silicon by comparison with literature values. This new step enables the investigation of ultrafast dynamics under tuneable ground state conditions.

[1] Suter, Tim; Macdermid, Zia et al. "Terahertz Time-Domain Spectroscopy of Materials under High Pressure in a Diamond Anvil Cell." *Review of Scientific Instruments*, vol. 97, no. 1, 2026

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