Characterising THz vortex beams using atom-based THz imaging

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Hot atomic vapours excited to Rydberg states have been used for the detection and imaging of THz and RF-frequency electric fields [1, 2, 3]. Recently we demonstrated high-speed 2D imaging of THz fields using a hot vapour of Cs atoms to perform THz-to-optical conversion [4]. Here we discuss the principles behind this THz imaging scheme and show that it achieves near-diffraction-limited spatial resolution and can image at speeds of over 1000 frames per second. These capabilities represent a step-change in the state of the art for THz imaging technologies. We then demonstrate using this scheme to image THz vortex beams with both radial and azimuthal phase, and describe how this could have a disruptive impact on THz-based free-space communications.

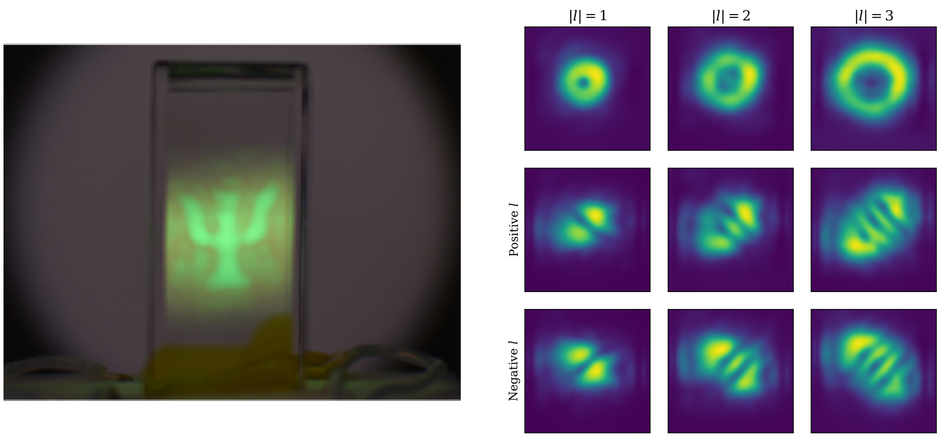

Figure 1. *Left:* True-colour THz image of a 'Ψ'-shaped aperture revealed as green fluorescence in a Cs vapour cell. *Right:* False-colour images of intensity (top row) and auto-interference patterns of THz vortex beams with differing azimuthal phase l.

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[2] C. L. Holloway *et al.*, Sub-wavelength imaging and field mapping via electromagnetically induced transparency and Autler-Townes splitting in Rydberg atoms, APL **104**, 24 (2014).
[3] C. G. Wade *et al.*, Real-time, near-field terahertz imaging with atomic optical fluorescence, Nat. Photon. **11**, 40 (2017).
[4] L. A. Downes *et al.*, Full-field terahertz imaging at kilohertz frame rates using atomic vapor, PRX **10**, 011027 (2020).