Spatial tomography of light resolved in time, spectrum and polarisation

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The ability to measure polarisation, spectrum, temporal dynamics, and spatial amplitude and phase of optical beams is essential to study fundamental phenomena in laser dynamics, telecommunications and nonlinear optics. Current characterisation techniques only apply in limited contexts. Non-interferometric methods typically lack access to spatial phase, while phase-sensitive approaches necessitate either an auxiliary reference source or an adequate self-reference, neither of which is universally available. Regardless of the reference, deciphering complex wavefronts of multiple co-propagating incoherent fields remains particularly challenging. Here, we harness the principles of spatial state tomography to circumvent these limitations. A full description of an unknown beam is retrieved by measuring its spatial state density matrices at unique spectral and temporal slices for both polarisations, using a spatial light modulator to display projective holograms and a single-mode fibre to guide the collected signal to a high-speed photodiode and a spectrometer (Fig 1)[1].

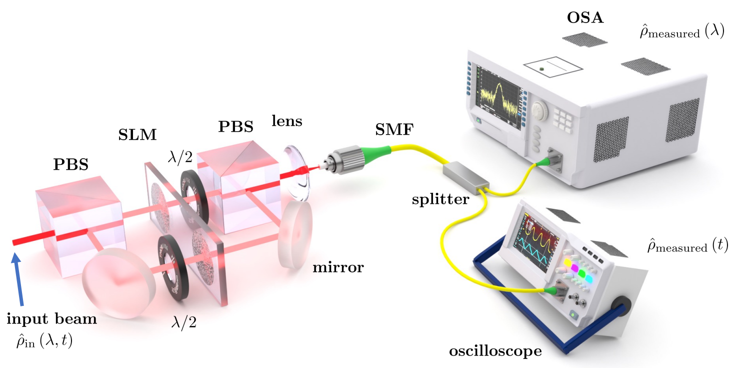

Figure 1: **System for analysing the beam in space, time, spectrum and polarisation**

The advantage of spatial tomography is its ability to resolve multiple arbitrary spatial fields within a single beam, including their phase and amplitude, as well as their spatial coherence. Leveraging the coherence information unlocks unambiguous determination of the spectral and temporal evolution of mutually incoherent fields, even when these spectrally overlap or have an identical time delay. We demonstrate these hallmark features by characterising the rich spatiotemporal and spectral output of a vertical-cavity surface-emitting laser diode that has so far resisted full analysis using existing techniques.

[1] M. Plöschner *et.al.*, *arXiv:2202.01932 [physics.optics]* (2022).