Towards joint wavefront sensing and scene reconstruction with photonic lanterns: automated characterisation with digital off-axis holography

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Abstract

Photonic lanterns are devices that encode both the amplitude and phase of the electric field in the image plane into a series of single mode fibres. They can recover non-common-path aberrations, accurately sense low-wind-effect and petal modes, and provide wavelength resolution, enabling reconstruction of the wavefront (by neural network or other algorithm). Previous results have demonstrated the capability as a focal plane wavefront sensor, including with on-sky testing on large, single aperture telescopes. Photonic lanterns also offer potential as an imager to resolve structure at and beyond the telescope diffraction limit, complimenting a coronagraph's inner working angle. In this work, we present the latest developments in this technology, including image reconstruction, closed loop operation and direct measurements of the modal mapping of photonic lanterns. Our characterisation setup probes devices in reverse, exciting one single mode output and capturing the resulting electric field using digital off-axis holography. By varying the injected light, we understand how the mapping of a photonic lantern varies with both wavelength and polarisation. Our results can be used to validate simulations, manufactured devices and previous learning based approaches, as well as inform future reconstruction methods. Finally, we discuss avenues of future work including the problem of co-phasing many apertures on the next generation of extremely large telescopes.

Keywords: Photonic lanterns, photonics, image reconstruction, digital off, axis holography

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