Modelling of a novel point diffraction interferometer wavefront sensor design for laser guide star wavefront phase retrieval

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Abstract

Wavefront sensing is crucial for adaptive optics as it measures the phase of an incoming wavefront, allowing the effects of atmospheric turbulence to be removed. Most current adaptive optics systems use a Shack-Hartmann Wavefront Sensor (WFS) which indirectly estimates the phase by measuring the wavefront's local gradients (slopes). However, in strong turbulence, particularly when breakpoints occur in the intensity measurement, the achieved Strehl ratio decreases dramatically, meaning poor wavefront reconstruction. The point diffraction interferometer (PDI) WFS offers an alternative by directly measuring the phase. In this work, we present a novel design of this wavefront sensor with a central pinhole which aims to optimise the light throughput and dynamic range while keeping its high sensitivity. We will present the modelling of this sensor using numerical propagation with Fourier optics; we have established a framework to retrieve the phase reversing the interferometric process which differs from the traditional retrieval methods either using an off-axis pinhole or phase stepping. These results look promising showing accurate phase retrieval in a variety of conditions. The final goal is to compare conventional numerical methods with a machine learning approach to skip the unwrapping of the phase and directly relate the incoming wavefront with the deformable mirror command matrix. The combination of PDI WFSs and machine learning has the potential to operate in a diverse range of conditions, adapting to the more and more demanding wavefront sensing requirements of the extremely large telescopes. We will present preliminary results and the pathway forward to the laboratory implementation.

Keywords: Point Diffraction Interferometer, Interferometry

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