Calibration and performances of a self-referenced Mach-Zehnder wavefront sensor for extreme adaptive optics

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Abstract

We describe our latest results obtained with the integrated Mach-Zehnder (iMZ), a wavefront sensor based on the Fourier filtering of one of the interferometer arms. This kind of sensor meets extreme adaptive optics requirements, high accuracy ($<$ 10 nm at 5-10 cm spatial scale) and low computational load. As the iMZ performs an absolute measurement of the phase (and amplitude), the aberrations reconstruction is not affected by discontinuities in the pupil : the presence of large or small telescope spiders do not affect the iMZ measurements accuracy. For the same reason, the iMZ performs efficiently while measuring any segmented phase pattern such as the phasing errors on segmented telescopes (such as petal modes) or island effect aberrations. Our contribution will present recent results on the enhanced calibration method we have developed and validated experimentally to extract the phase from the iMZ signal, using several phase patterns introduced by a deformable mirror and the monitoring of the flux variation on the pinhole in the iMZ coronagraphic path.
As the iMZ is based on the spatial filtering of the incoming beam, the quality of the phase retrieval strongly depends on the alignment of the optical beam with the pinhole. Here we present the method and results of the tip/tilt close loop correction using piezo mirror we have developed recently on the XAO testbench at CRAL. The tip/tilt control is based on the centroïd measurement of the coronagraphic point spread function, measured behind of the pinhole and simultaneously with the wavefront sensor with very low non common path

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aberrations. Performances of the iMZ on turbulence residuals will be presented thanks to experimental results of phase measurements on turbulent phase screens introduced on the bench.
We will also report our first laboratory results of real-time phase correction on turbulence residuals using a 12x12 deformable mirror.
We finally present the phase modulation method and the unwrapping algorithm developed to increase the dynamical range of the sensor up to several microns, limited at ± lambda/4 without these strategies. The recent validation of those unwrapping techniques on experimental data will be presented.

Keywords: Wavefront sensing, Extreme Adaptive Optics, Wavefront sensing calibration, phase unwrapping, High Contrast Imaging