Investigating The Feasibility of a Thin Diffuser Based Wavefront Sensor

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Abstract

In a collaborative effort between the University of Galway and TU Dublin, the Space-PHORM (Space based applications using PHOtosensitive Recording Materials) project was created with the aim of developing novel wavefront sensing approaches for space applications. In this context, the relatively novel Thin Diffuser Based Wavefront Sensor (TDWFS) offers a simpler and cost effective alternative to conventional wavefront sensors, encoding wavefront information through speckle patterns produced by a thin diffuser. Some studies have demonstrated the use TDWFS in ocular aberrometry and in 3D nanoparticle localisation. However, an investigation into the effect of various aberrations, their corresponding amplitudes and wavelength used to generate the speckle images on wavefront reconstruction accuracy remains unexplored. We aim to investigate the precision of a TDWFS system in measuring single and multi multiple low-order Zernike mode containing wavefronts. We show that the accuracy of wavefront reconstruction depends on the specific Zernike mode within a wavefront, its corresponding amplitude, the distance between the diffuser and detector and the wavelength of the incident beam used for generating speckle images. We demonstrate that the amplitude and type of aberrations within a wavefront determines the optimal detector-diffuser distance for reconstruction. Our results highlight the wavelength-dependent performance of TDWFS, with shorter wavelengths proving advantageous at larger detector-diffuser distances due to reduced speckle interference. Moreover, the distribution of individual amplitudes within a multi-mode containing wavefront significantly influences TDWFS accuracy, with higher residual RMS values observed when the magnitude of spherical aberration is greatest, followed by coma, defocus, and astigmatism, respectively.

Keywords: Wavefront Sensing, Zernike Modes, Thin Diffuser Based Wavefront Sensor, Aberrations, Speckle Images

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