Deep Learning Wavefront Reconstruction With Collimated Lasers Using Experimental Data from the PPPP Bench

Nazim Bharmal*[1], Carlos González-Gutiérrez[2], Jorge Rodríguez Muro[2], Timothy Morris[1], and Francisco De Cos Juez[2]

[1]Centre for Advanced Instrumentation, Physics, Durham University – United Kingdom
[2]Instituto Universitario de Ciencias y Tecnologías Espaciales de Asturias – Spain

Abstract

Conventional LGS are downwards illuminating beacons, which render them impractical for several wavefront sensing applications. The converse idea of upwards illuminating lasers for wavefront sensing is explored by Durham & Oviedo using the PPPP concept. The key concept is that a non-focused beam can illuminate any relevant volume of turbulence (and it might also be the signal beam for FSOC, for example). By diffracting as it passes through turbulence, the intensity changes in the beam cross-section encode the wavefront it has encountered. The measured back-scatter samples that cross-section. Linear reconstruction for PPPP uses the transport of intensity equation from two different planes but this causes an implementation difficulty in the free atmosphere: the need to sample backscattered light with short intervals. A solution is to sample the intensity variations in just one plane and results from this approach are reported in this presentation by using non-linear reconstruction. An existing PPPP testbench, originally created to confirm that simulations of PPPP could be replicated, by comparing measurements between a Shack Hartmann WFS and a PPPP WFS with a DM conjugated to the pupil, has been used. It was extended to investigate machine learning reconstruction as this was more tolerant to noise in simulations: an approximately 10x reduction in laser power for an equivalent SR (> 0.10). The testbench was configured to record cross-sections from beams propagated to distances equivalent to 30 and 44km from a 4m pupil, together with a pupil-conjugate DM which was set to 220k wavefronts. That leads to the same number of image pairs and wavefronts, from the SH WFS. Of these, 200k pairs were used for training and the remaining 20k pairs, randomly chosen, for testing against the SH's wavefront. The curious result is that using one of the back-scattered images with back-propagation of the WFE results in better performance than using either alone or the two together or the pre-calculated difference of the two images.

*Speaker