Phasing the GMT in the Natural Guide star Adaptive Optics mode: from simulations to testbeds

Fernando Quiros-Pacheco*[1], Antonin H. Bouchez[1], Rodolphe Conan[1], Richard Demers[1], Marcos Van Dam[2], Jan Kansky[3], Brian A. Mcleod[3], Laird Close[4], Sebastiaan Y. Haffert[4], Jared Males[4], Guillermo Gonzalez[5], and Bijan Nemati[5]

[1]GMTO – United States
[2]Flat Wavefronts – New Zealand
[3]Smithsonian Astrophysical Observatory – United States
[4]University of Arizona – United States
[5]Tellus1 – United States

Abstract

One of the major challenges facing the Giant Magellan Telescope (GMT), which has a doubly-segmented primary mirror with a diameter of 25.4 meters, is achieving accurate and stable control of segment piston in the diffraction-limited adaptive optics (AO) observing modes, such as Natural Guide Star AO (NGAO) and Laser Tomography AO (LTAO).
In the first part of this paper, we present NGAO bootstrapping simulations that start from a realistic initial state of GMT M1 and M2 segment misalignments and M1 figure errors, which have a wavefront RMS of approximately 100 microns. We demonstrate how multiple wavefront control loops, including Active Optics, Coarse Phasing, Adaptive Optics, and Fine Phasing, work together to reduce the wavefront error to the phased condition with an RMS of approximately 100 nm.

To validate our wavefront sensing and control strategies, GMTO is collaborating with partner institutions to develop two laboratory optical testbeds. The Wide Field Phasing Testbed (WFPT), developed in collaboration with the Smithsonian Astrophysical Observatory, is currently being used to validate the Active Optics and Coarse Phasing aspects of wavefront sensing and control using a full-scale prototype of the GMT's Acquisition Guiding and Wavefront Sensor (AGWS) unit. Secondly, the High Contrast AO testbed (HCAT), developed in collaboration with the University of Arizona and INAF-Arcetri, will validate the Adaptive Optics and Fine Phasing aspects of NGAO control using a full-scale prototype of the pyramid wavefront sensor and the Holographic Dispersed Fringe Sensor (HDFS).
In the second part of this paper, we describe the testbed models that we have developed to support the experiments, design tests and procedures, and predict testbed performances. We also discuss efforts to improve the models of the wavefront sensors to better match the characteristics of the prototypes, such as wavelength-dependent responses and optical fabrication errors.

Keywords: GMT, pyramid wavefront sensor, dispersed fringe sensor, testbeds, prototypes, simulations

*Speaker