

Co-phasing closed loop laboratory experiment with the pyramid WFS.

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Abstract.

All the ELT projects present a segmented primary mirror. The quality of the PSF produced by these instruments is strongly dependent from the segment phasing accuracy [1]. In order to obtain a diffraction limit lower than the single segment one, the segments need an active alignment system. To obtain a resolution commensurable with a monolithic telescope of the same diameter, the system must be driven by an optical phasing sensor. In this work we will present the first laboratory experiment that shows the performances of the pyramid wavefront sensor (PWFS) operating in closed loop as phasing sensor.

The PWFS has been introduced by R. Ragazzoni in 1996 [2] as a wavefront sensor for adaptive optics systems. In 2001 Esposito [3] proposed the PWFS as phasing sensor for segmented mirrors, demonstrating, with numerical simulations, that the sensor can sense and control at the same time differential piston, tip and tilt of each segment.

The first characterization of the signal produced in the PWFS by a phase discontinuity was reported in [4]. This and further analysis show the existence of this signal and its sinusoidal dependence from the step phase. The comparison between the phase measurement of the PWFS and the external metrology demonstrates an accuracy lower than $3nm$, operating in double pass with a wavelength of $633nm$.

The next experimental step is aimed to demonstrate that this sensor can control the phasing of several segments operating in closed loop. Our laboratory closed loop system is mainly composed by: the PWFS

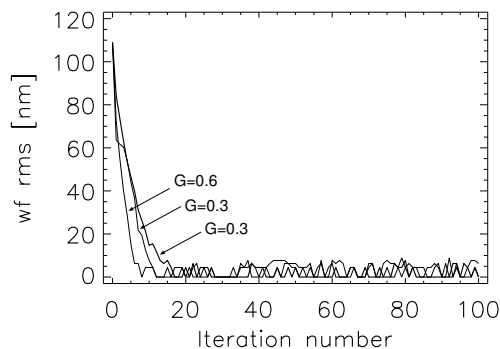


Figure 1: The RMS of the differential piston commands for all the actuator in the system pupil. In the case of the higher gain G , after 8 iteration the reference position is reached; than the residual RMS is due at the sporadic fluctuation of ± 1 step for one or two segment at time.

unit for the LBT first light AO [5], a PC as wavefront computer (WFC) and a segmented mirror purchased by Boston Micromachines. This mirror is a MEMS composed by a 12X12 array of square plane mirrors with a single side of $300\mu m$; each segment has only the differential piston as degree of freedom and is adjustable by physical steps of round $10nm$. The pupil of the optical system is arranged on this mirror covering a diameter of 5 segments and the reflected beam is analyzed by the PWFS; the signals so generated are sent to the WFC that calculates the differential piston commands to co-phase the MEMS segments, starting from a scrambled actuator position. The measurement-correction loop is iterated until the reference pattern is reached; this position is identified by a set of known signals.

The system demonstrates the ability to correct individually all the mirror actuators in the pupil at each loop step, reaching the reference position after few iterations. Completed the transitory period, in closed loop all the piston commands are bounded between ± 1 step from the reference positions. This shows that the performances of this experimental system are limited by the MEMS step size (20nm wavefront) before the PWFS accuracy, in agreement with the results obtained in the sensor calibration shown.

At the end of 2004 a new experiment has been performed at the William Herschel Telescope in participation with the University of Durham. A new co-phasing loop has been arranged with the PWFS and the segmented mirror of NAOMI [6] (the AO system located at the telescope nasmyth platform). The segments of this mirror have 3 degree of freedom, in this case the loop controls at the same time tip, tilt and piston for each segment. The results are currently under study.

A detailed analysis and comparison of PWFS with other phasing sensors is the target of the ESO project called Active Phasing Experiment (APE)[7].

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