Ground layer correction on an 8m telescope: a NIRVANA from the lab to the sky

Luca Marafatto

Department of Physics and Astronomy, Padova University, vicolo dell’ Osservatorio, 3, 35122 Padova, Italy

Abstract. LINC-NIRVANA will be the Fizeau beam combiner for the LBT, with the aim to retrieve the sensitivity of a 11.8 m telescope and the spatial resolution of a 22.8 m one. The adaptive optics correction is made possible by 4 wavefront sensors, two per each arm of the telescope, arranged in a layer-oriented Multi Conjugated Adaptive Optics (MCAO) mode. The Ground layer Wavefront Sensor (GWS) retrieves the deformation introduced by the lower atmosphere, known to be the main aberration source, while the MHWS senses the aberrations introduced by a layer at 7.1 km. The instrument takes advantage of the Multiple Field of View approach, which foresees to use different FoVs for different conjugation layers. While the GWS uses 12 small devices, called Star-Enlargers, to select up to the same number of Natural Guide Stars in a wide annular 2'-6' arcmin Field of View (FoV), the Mid-High Waverfront Sensor (MHWS) looks for up to 8 reference stars in the central 2 arcmin FoV. Having been completed the alignment, integration and verification phase of the single wavefront sensors by last year, the goal for this year was to fully integrate and align at least one of the two arms of the instrument and verify the performance closing the adaptive optics loop in lab. I actively participated to this phase in Heidelberg, where the instrument currently is located, aligning the Calibration Unit of LINC-NIRVANA and the MHWS to the rest of the instrument. With the integration of the GWS on the bench the integration of the arm is almost complete and ready to be tested. Meanwhile the other GWS was at the telescope for a pathfinder experiment, and following the success of the last year, when we were able to close the loop on sky on a third magnitude star, we aimed this year to close the loop on multiple stars.

Key words.

1. Introduction

The Ground layer Wavefront Sensor (GWS) and the Mid-High Waverfront Sensor (MHWS), installed on the NIRVANA (Herbst et al. 2003) instrument at LBT (Hill et al. 2010) are adaptive optics wavefront sensors working in a MCAO Multiple Field-of-View layer-oriented mode (Ragazzoni et al. 2002) (Farinato et al. 2006). This technique foresees to use, for the wavefront sensing phase at the level of the ground layer, the light collected in an annular field of view, letting the central part of the Field of View go to the MHWS for the analysis of the turbulence introduced by a layer at 7.1 km (Farinato et al. 2008). As suggested by its name, the GWS is optically conjugated to the ground layer, in a way to sense the deformations introduced on the incoming wave-
front by the atmospheric lower layer, specifically about the first 100 m. The information retrieved by each GWS about the shape of the wavefront are converted into a correction signal and sent to the corresponding Adaptive Secondary Mirror (ASM) of the LBT with a max 1 KHz frequency. Each ASM is equipped with 672 actuators, which modify the mirror shape to reproduce the opposite of the perturbations introduced by the lower atmosphere, in order to correct them. The light from the 2'-6' FoV is folded by an annular mirror into the GWS. Here 12 optical devices, the Star Enlargers (SEs), can be positioned along the FoV using XY stages in a way to be able to pick up the light of a maximum of 12 Natural Guide Stars (NGSs) (Marafatto et al. 2012). The central 2 arcmin beam passes through the hole in the annular mirror and is split in 2 by a dichroic: the infrared light is folded toward the scientific camera in a cryostat below the NIRVANA bench, while the visible light is re-focused by F/20 optics at the entrance of the MHWS. Here up to 8 SEs can pick up the light of the reference stars. The corrector for the high layer perturbations is a piezostack DM located on the NIRVANA bench, conjugated at the same height as the MHWS and shaped by 372 actuators to counteract the action of the higher part of the atmosphere. As widely known, one of the main challenges of using the optical layer oriented approach is the optical co-addition of the light from the reference stars on the same detector, increasing the SNR of the system and allowing the use of fainter stars. This requires that the pupil superposition at the level of the detector must be as similar as possible to that occurring at the conjugations altitude. In the GWS case the conjugation quote is 100 m, where there is a complete pupils overlap, while at 7.1 km the overlap is partial and depending by the asterism. The achievement of a reasonably similar pupils super-imposition on the detector requires a great number of optomechanical constraints and tolerances, making the Alignment, Integration and Verification (AIV) of the system very challenging.

2. LINC-NIRVANA

During this year I have co-aligned in tip-tilt and focus the Star Enlargers of the MHWS also establishing the mapping of the SEs, in order to know their position in the focal plane at any moment, allowing blind acquisition of the guide stars and avoiding collisions between SEs.

I have also aligned one of the two Calibration Units (CU) needed for multiple purposes, from the standard alignment of the F/20 optics to the calibration of the MHWS. The CU is composed of a reference fiber, simulating an on-axis star, a fiber plate with 23 fibers for the interferometric calibration and for the MHWS adjustment and tuning, and an integrating sphere for the flat-fielding of the science and fringe-tracking detectors. An auxiliary rotating flat mirror reflects the light coming from different reference/calibration sources into the main beam of the telescope. The fiber plate has demonstrated to have a curvature slightly different from the nominal one, leading to a field-dependent defocus signal measured by the SEs. Moreover, the outer ring of fiber spots exceeds the 2 arcmin FoV investigated by the SEs. Nevertheless, the fiber plate was aligned and used for the fine alignment of the MHWS SEs, but a new one will be manufactured in the next months to match the requirements.

3. Pathfinder Experiment

Meanwhile GWS DX was at LBT for a Pathfinder Experiment, whose aim is to realize a fully-working Ground Layer Adaptive Optics (GLAO) system to prove that the seeing disk can be significantly reduced by correcting only the aberrant effects of turbulence in the ground layer. Another important issue of the Pathfinder Experiment is the verification of the instrument to telescope interface, both mechanical and optical, and to check the ability of the system to control the LBT adaptive secondary mirror. During last year we were able to close the loop on a third magnitude star (Epsilon Aurigae) so the goal for this year was to acquire and close the loop on multi-
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Fig. 1. In the left panel the 4 spots produced by a SE for the tip-tilt alignment. A SE is considered aligned when the mean center of the 4 spots is $[20.00 - 20.00] \pm 0.1$ with a pyramid angle within $[-0.15 - 0.15]$. In the right panel the 4 pupils produced by a SE for focus alignment. A SE is considered aligned in focus when the defocus coefficient, $J_4$ in the figure, is 0 and the discrepancy between all the SEs is less than 0.15.

Fig. 2. Current status of LINC-NIRVANA bench. With the installation of the GWS the left arm of the instrument is almost completely integrated, while the integration and alignment of the right arm is ongoing.

Multiple stars, a mode that is central to the operations of LINC-NIRVANA's multi-conjugate adaptive optics. As of this writing we were able to close the loop on a fainter star (9.6th magnitude) and to simultaneously acquire multiple (2) stars, also improving the star acquisition procedure implementing a spiral search and a centering script for the SEs, but due to very bad weather and luck we could not close a full GLAO loop, which will be the main goal for the next Pathfinder runs.

4. Ongoing work

After all the subsystems of NIRVANA are integrated on the bench and tested the instrument will be disassembled in its sub-units and shipped to the telescope. This is currently planned for mid 2015, and once there a long sequence of tests will start to verify possible misalignments of the optical components and, in case, fix them. Finally NIRVANA will be mounted at the telescope and co-aligned to the LBTs optical axis. Other Pathfinder runs are in schedule for the next year, to achieve the last important goal to close the loop on multiple stars.

References

Fig. 3. The fiber plate of the LINC-NIRVANA’s calibration unit. The on-axis fiber can be reached by all the SEs and was used for the SEs focus alignment. Six fibers are connected to the outer ring here, but some of them are not reachable by any SE, suggesting that this ring is reproducing a FoV slightly bigger than the theoretical 2 arcmin observed by the MHWS