Measurement of the VLT pupil motions using a 2×2 lenslet evaluated aberrations

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Abstract

A long baseline interferometer can convert the optical path difference into the astrometric measurements. The optical path difference is equal to the scalar product between the baseline vector of the interferometer and the direction of the star in the sky. The optical path difference can be measured using a metrology system between the interferometric lab and to the VLT pupil plane. During the observations the movements of delay line carriages can alter the effective pupil plane. A misalignment between the sky plane and the effective telescope pupil plane can introduce astrometric errors. For example a 4 cm lateral pupil position error at 8 m beam contributes 8 μas astrometric error. Hence the accurate astrometry measurements require an active pupil plane monitoring during the science observations.

The GRAVITY telescope pupil positions are tracked by the acquisition camera pupil tracking imaging mode [2]. The monitoring is implemented by mounting four pupil guiding laser beacons (1.2 μm) on each telescope secondary mirror spiders and later image them using a 2×2 lenslet inside the acquisition camera. The acquisition camera optics allows the VLT lateral and longitudinal pupil shifts to be converted into the beam tip-tilt and defocus aberrations when it is falling on the 2×2 lenslet. The lenslet allows it to measure the first four primary aberrations successfully. These measurements can be related to the pupil lateral and longitudinal positions with the equations given in Anugu et al. (2014).

We report a simulation of 2×2 lenslet images. Experimentally measured optical aberrations were applied in the numerical simulations. The local slopes can be measured by comparing the distorted spot centers with the reference fiber coupler spot centers. Using the slopes, retrieved the first four aberrations in two fronts: a) Zernike method; and b) Salas-Peimbert et al. (2005) method.

In the Zernike method, the wavefront $W(x, y)$ is represented as the linear combination of Zernike polynomials as given in Eq. 1. In the Salas-Peimbert method, the wavefront is represented as given in Eq. 2 and measured the coefficients using analytical equations derived from the spot shifts. Comparison studies reveal that the Zernike method of evaluation is better than the other. The Zernike method is chosen to estimate the aberrations from the slopes.

$$W(x,y) = \sum_{i=1}^{i<=4} A_{\mathrm{i}} Z_{\mathrm{i}} \tag{1}$$

$$W(x, y) = A_1 + A_2 x + A_3 y + A_4(x^2 + y^2) \tag{2}$$

Where A_1, A_2, A_3 and A_4 are the piston, tip, tilt and defocus beam aberrations. And Z_i is the Zernike polynomial for the i^{th} index.

We measured the pupil shifts by simulating the artificial pupil tracker data at various input shifts. We measured the lateral pupil positions with a precision better than 3 mm at 8 m beam and the longitudinal pupil positions with a precision better than 20 mm at 80 mm compressed UT beam.

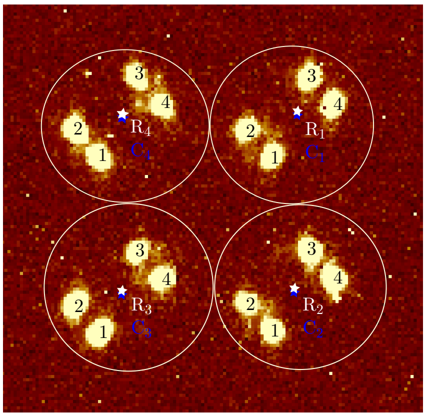

Figure 1: The experimental acquired pupil tracker image.

The GRAVITY calibration unit simulates the artificial telescope and the pupil guiding lasers in the MPE lab. The pupil guiding lasers were implemented by using a multimode fiber laser which illuminates a four hole aluminum mask. The four holes separation corresponds to the actual position of lasers on the VLT secondary mirror spiders. The laser light reflected from the telescope is guided to the four openings of the acquisition camera using the beam splitters and flat mirrors. We acquired the pupil tracker image data with various pupil shifts. The pupil shifts in the instrument are simulated using the pupil motion controllers which are used for the stabilization of the pupil.

As shown in Fig. 1, the spots 1-2-3-4 represents the pupil guiding laser beacons mounted on the telescope. The symbols R_1, R_2, R_3 and R_4 are the reference positions. The C_1 is the barycenter position of 1-2-3-4 laser spots for a single lenslet sub-aperture. The C_2, C_3 and C_4 are the barycenter positions of laser spots for the remaining sub-apertures. In case of lateral pupil shift, the whole barycenters C_i shifts with respect to the reference centers R_i in X or Y directions. A longitudinal shift causes the C_i to diverge/converge with respect to the R_i. In this example one can see the lateral shift along the Y-direction, as the C_i are tilted in Y-direction with respect to the R_i. Using the experimental data, the pupil positions are measured. The pupil position measurement accuracy is within the GRAVITY specifications.

References

[1] Salas-Peimbert, D. et al., *Wave-front retrieval from Hartmann test data*, Applied Optics, Vol. 44, Issue 20, pp. 4228-4238 (2005)

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