GRAVITY near infrared multiple beams analysing system: software and characterization results

Narsireddy Anugu[1], Paulo Garcia[2], Antonio Amorim[3], Paulo Gordo[4] and GRAVITY consortium
[1]Faculty of Engineering University of Porto, Porto, Portugal (narsireddy.anugu@fe.up.pt); [2]Faculty of Engineering University of Porto, Porto, Portugal (pgarcia@fe.up.pt); [3]Faculdade de Ciências da Universidade de Lisboa (antonio.amorim@sim.fc.ul.pt); [4]Faculdade de Ciências da Universidade de Lisboa (prgordo@fc.ul.pt)

1. Introduction

GRAVITY is an instrument for the European Southern Observatory Very Large Telescope Interferometer (VLTI). It combines four VLT beams and delivers astrometry with an accuracy of 10 micro arc seconds (Eisenhauer et al. 2011). It is aimed to monitor positions of stars near the Galactic Centre super-massive black-hole and subsequently to probe physics of strong gravity in detail. In order to achieve the astrometric accuracy, the four telescope's beams entering GRAVITY are required to be stabilized. This is achieved by correcting the beam offsets induced by atmospheric turbulence and telescope systematic errors during whole observational process (Lacour et al. 2014).

Part of this beam stabilisation system, beam monitoring and guiding into the fibre-fed GRAVITY beam combiner is implemented with the acquisition camera subsystem (Gordo et al. 2014). The acquisition camera subsystem operates in near infrared wavelengths (1.2 and 1.65 micrometres). It has four optical functions as presented in Figure 1: a) field tracker; b) pupil imager; c) pupil tracker; and d) beam aberrations tracker. The field tracker images four input sky beams fields. The pupil imager images four telescope pupils. The pupil tracker images four guiding lasers mounted on the secondary mirror of telescope using 2x2 lenslets. Whereas the aberration tracker images Shack-Hartmann lenslet array images of the object.

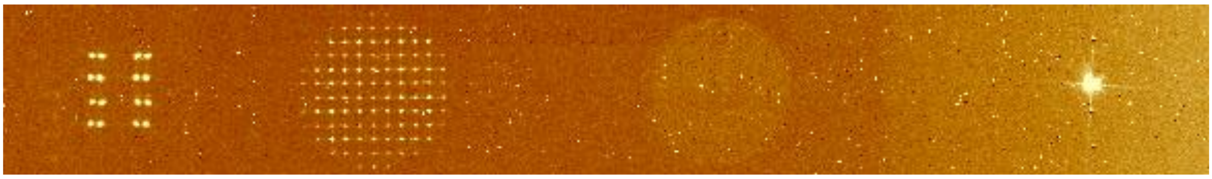

Figure 1. The acquisition camera detector image for one input beam. From left to right: a) pupil tracker; b) aberration tracker; c) pupil imager and e) field tracker windows.

2. Materials and Methods

The acquisition camera software accepts detector image as the input and delivers beam stabilisation parameters to the instrument database at a 1 Hz rate. It is developed in the VLT2014 OS using the ESO Common Library for Image Processing (Ballester et al. 2008).

The field tracker software evaluates brightest star's position in the 4″x4″ field of view. It is implemented in two steps. As a first step, stars in the field are scanned using a predetermined star sigma as a threshold. Secondly, the detected stars are sorted out on the flux order. A Gaussian fit is applied to the brightest star to obtain its accurate position. The determined position is used in stabilizing the star light injection into the fibre.

The pupil imager images the four telescope pupils for monitoring and alignment purposes.

The pupil tracker evaluates lateral and longitudinal pupil positions for each telescope. As a first step in software, positions of the pupil tracker spots (2x2 lenslet images) are computed using a predetermined spot sigma as a threshold. Secondly, these spots positions are compared with the reference grid and spots shifts are computed. Shifts in x and y directions allow one to measure the lateral pupil positions. The amount of divergence or convergence of spots shifts allows one to evaluate the longitudinal pupil positions.

The aberration sensor measures beam quasi-static aberrations in Zernike polynomials. As a first step in software, the aberration sensor Shack-Hartmann spots positions are computed using a standard weighted centroid algorithm. Secondly, by comparing the spots positions with the reference grid, wavefront slopes are computed. Finally, using the wavefront slopes, wavefront representing Zernike polynomials coefficients are evaluated.

The field and the pupil tracker software extracted parameters are used as the inputs for the tip-tilt and pupil controllers, and the corrections are applied in a closed loop. The aberration sensor detected wavefront aberrations are used for the beam quality characterization and to correct non-common path errors.

3. Discussion

The acquisition camera subsystem is now successfully operational within GRAVITY instrument. Using GRAVITY calibration unit's experimentally simulated stars in the MPE lab, the acquisition camera software performance was characterised. Experimentally tip-tilts, pupil shifts were applied to the experimental data using actuated controllers. The characterisation performance results show that the acquisition camera beam sensing accuracies are within GRAVITY specifications.

References

Ballester, P., P. Biereichel, A. Kaufer, M. Kiekebusch, and H. Lorch. 2008. "CLIP: Bridging Pipelines to Instrument Control Software." *Astronomical Data Analysis Software and Systems ASP Conference Series* 394. http://adsabs.harvard.edu/abs/2008ASPC..394..577B.

Eisenhauer, F., G. Perrin, W. Brandner, C. Straubmeier, K. Perraut, A. Amorim, M. Schöller, et al. 2011. "GRAVITY: Observing the Universe in Motion." *The Messenger* 143: 16–24. http://adsabs.harvard.edu/abs/2011Msngr.143...16E.

Gordo, Paulo, Antonio Amorim, Jorge Abreu, Frank Eisenhauer, Narsireddy Anugu, Paulo Garcia, Oliver Pfuhl, et al. 2014. "Integration and Testing of the GRAVITY Infrared Camera for Multiple Telescope Optical Beam Analysis." In *SPIE Astronomical Telescopes + Instrumentation*, edited by Jayadev K. Rajagopal, Michelle J. Creech-Eakman, and Fabien Malbet, 91461V. International Society for Optics and Photonics. doi:10.1117/12.2056572.

Lacour, S., F. Eisenhauer, S. Gillessen, O. Pfuhl, J. Woillez, H. Bonnet, G. Perrin, et al. 2014. "Reaching Micro-Arcsecond Astrometry with Long Baseline Optical Interferometry." *Astronomy & Astrophysics* 567 (July). EDP Sciences: A75. doi:10.1051/0004-6361/201423940.