A Giant Step: from Milli- to Micro-arcsecond Astrometry
Proceedings IAU Symposium No. 248, 2007
W. J. Jin, I. Platais & M. A. C. Perryman, eds.

doi:10.1017/S174392130801884X

Astrometry with the VLTI: calibration of the Fringe Sensor Unit for the PRIMA astrometric camera

J. Sahlmann[1,2]†, R. Abuter[1], S. Ménardi[1] and G. Vasisht[1,3]

[1]ESO, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany
email: jsahlman@eso.org

[2]Observatoire de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland

[3]JPL-Caltech, 4800 Oak Grove Dr., Pasadena CA 91109, USA

Abstract. The future PRIMA facility at the Very Large Telescope Interferometer (VLTI) in astrometric mode offers the possibility to perform relative narrow-angle astrometry with 10 micro-arcsecond accuracy. This is achieved with a dual-beam interferometer concept, where a reference star and the scientific target, confined in a 60 arcsecond field, are observed simultaneously. The angular separation of the two stellar objects gives rise to an optical delay in the interferometer, which is measured by the Fringe Sensor Unit (FSU) and an internal laser metrology. PRIMA is using two FSU fringe detectors, each observing the interference of stellar beams coming from one of the two objects and measuring the corresponding phase and group delay. The astrometric observable, yielding the angular separation, is deduced from the group delay difference observed between the two objects. In addition, the FSU phase delay estimate is used as error signal for the fringe stabilisation loop of the VLTI. Both functions of the FSU require high precision fringe phase measurements with a goal of 1 nm rms (corresponding to $\lambda/2000$). These can only be achieved by applying a calibration procedure prior to the observing run. We discuss the FSU measurement principle and the applied algorithms. The calibration strategy and the methods used to derive the calibration parameters are presented. Special attention is given to the achieved measurement linearity and repeatability. The quality of the FSU calibration is crucial in order to achieve the ultimate accuracy and to fulfill the primary objective of PRIMA astrometry: the detection and characterisation of extrasolar planetary systems.

Keywords. instrumentation: interferometers, astrometry, techniques: interferometric

1. Introduction and measurement principle

The Fringe Sensor Unit is the central element of the PRIMA (Phase Referenced Imaging and Micro-arcsecond Astrometry) dual-feed facility (Delplancke *et al.* 2006, Mottini *et al.* 2005). Two identical FSU fringe detectors deliver real-time estimates of optical path difference (OPD), group delay (GD) and fringe visibility for the two observed targets. Periodic variations of the relative target position can reveal the presence of an orbiting planet (Launhardt *et al.* 2008). The FSU operates in the infrared K-band and produces four ABCD-signals with a phase spacing of 90° in three spectral bands, respectively. Phase delay (ϕ_i), OPD and GD are computed from the fluxes I_A, I_B, I_C, I_D in the three bands with a modified ABCD algorithm (Eq. 1.1).

$$\tan\phi_2 = \frac{(I_A - I_C)\,\gamma - (I_B - I_D)\,\alpha}{(I_B - I_D)\,\beta - (I_A - I_C)\,\delta},\ \text{OPD} = \frac{\lambda_2}{2\pi}\,\phi_2,\ \text{GD} = \frac{1}{2\pi}\frac{\lambda_3 \cdot \lambda_1}{\lambda_3 - \lambda_1}\cdot(\phi_3 - \phi_1), \quad (1.1)$$

† Present address: ESO, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany.

where λ_i are the effective wavelengths and $\alpha = \sin\phi_C$, $\beta = 1+\cos\phi_C$, $\gamma = \cos\phi_B + \cos\phi_D$ and $\delta = -\sin\phi_B - \sin\phi_D$ take the phase shift errors ϕ_B, ϕ_C and ϕ_D into account. λ, ϕ_B, ϕ_C and ϕ_D in three bands are the parameters to be derived from the calibration.

2. Calibration procedure

We use Fourier Transform Spectroscopy to derive the effective wavelengths. Several OPD scans over the white light fringe packet are performed, while the FSU fluxes and the internal OPD are recorded. For each channel, we combine the consecutive scans and compute the effective wavelength from the Fourier Transform modulus. The relative phase shifts of the ABCD channels are derived by crosscorrelating their fringe packets. Offsets of the crosscorrelation-functions with respect to the autocorrelation of channel A are converted into phase on the basis of the effective wavelengths.

3. Results

Two criteria are used to assess the calibration quality: first the OPD and GD measurement linearity and second the repeatability over consecutive calibrations. We define the linearity parameter as the deviation of the measurement slope from unity. We find that the linearity of the OPD measurement over the central fringe (Figure 1) is within the specifications at ±10 %. In contrast, the GD estimates exhibit large cyclic errors and the linearity is poor with 45 % RMS over the central 12μm range (±20 % is specified). For 14 calibrations within 35 min, we find the central effective wavelength $\lambda_2 = (2.312 \pm 0.003)\mu$m. The central band phase shifts are measured to 74° (nominal 90°), 155° (180°) and 233° (270°) for channel B, C and D, respectively, with a 1° uncertainty. The large deviation from the nominal value is due to imprecisions of the FSU optics.

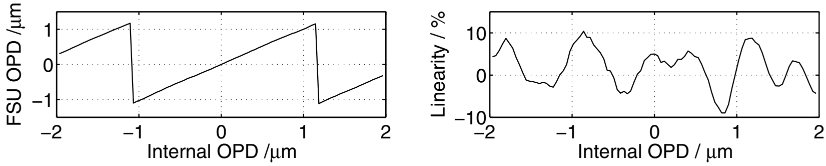

Figure 1. OPD measured by the FSU (left) and the corresponding linearity (right).

4. Conclusions

A calibration procedure for the FSU is established and methods to derive the calibration parameters are presented. The OPD measurement capability of the calibrated FSU is found to be satisfactory. In contrast, the GD linearity is insufficient. Corrective measures on the FSU in terms of hard- and software are currently under implementation. The wavelength determination accuracy has to be improved in order to reach the accuracy goal stated above, whereas the accuracy of the deduced phase shifts is satisfactory.

References

Launhardt, R., Henning, T., Quirrenbach, A., Delplancke, F., Elias II, N. M., Pepe, F., Reffert, S., Ségransan,D., Setiawan, J., Tubbs, R., **and** the ESPRI consortium 2008, *Proceedings of IAUS 248*, in this volume, p.417

Delplancke, F. *et al.* 2006, *SPIE* 6268

Mottini, S., Cesare, S., & Nicolini, G. 2005, *SPIE* 5962, p. 631

https://doi.org/10.1017/S174392130801884X Published online by Cambridge University Press