The PRIMA Fringe Sensor Unit: Operating Principle and Calibration Procedure

Johannes Sahlmann[a,b], Roberto Abuter[a], Serge Ménardi[a], Gautam Vasisht[a,c]
[a]European Southern Observatory, Karl-Schwarzschildstr. 2, 85748 Garching, Germany;
[b]Observatoire de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland;
[c]JPL-Caltech, 4800 Oak Grove Dr., Pasadena CA 91109, USA

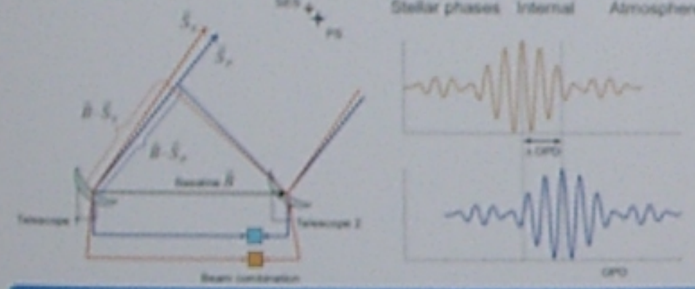
Introduction

The ESO **V**ery **L**arge **T**elescope **I**nterferometer[1] (VLTI), future host of PRIMA, the **P**hase **R**eferenced **I**maging and **M**icro-arcsecond **A**strometry facility[2].

The Fringe Sensor Unit[3,4] (FSU) is the central element of the PRIMA dual-feed facility. The stellar beams are combined in the FSU, which both produces the scientific data and provides the fringe tracking signal. The FSU delivers estimates of optical path difference (OPD), group delay (GD) and fringe visibility for the two observed targets. The astrometric or imaging signal is deduced from the differential OPD between the two stars:

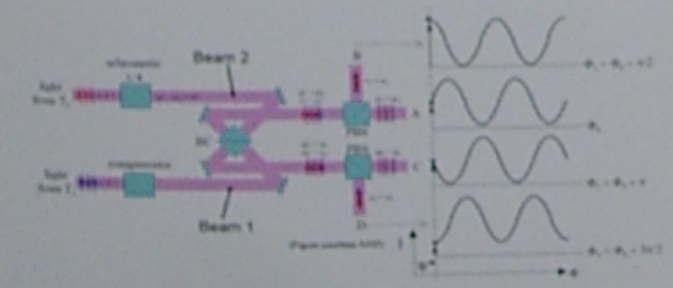
$$\Delta OPD = (\vec{S}_P - \vec{S}_R)\cdot\vec{B} + \frac{\phi_P}{k_P} + \frac{\phi_T}{k_T} + \Delta L + \Delta A$$

Stellar phases | Internal | Atmosphere



Layout and principle

- The FSU operates in the infrared K-band and beams are combined in bulk optics
- Spatial phase modulation of input beams to create ABCD channels separated by 90°
- Spatial filtering with single-mode fibres that route the light to the cold camera
- Cryogenic infrared camera with dispersive element to obtain 3 spectral channels



The PRIMA Fringe Sensor Unit

The two fringe detectors FSU A and FSU B are identical and share the cryostat for their cold optics and detectors. Each unit combines two stellar beams originating either from the primary star or the secondary star.

OPD and GD algorithms

- The phase delay is computed from the central spectral channel with a modified ABCD algorithm, that takes the phase shift errors into account:

$$\tan\phi = \frac{(I_A - I_C)\gamma - (I_B - I_D)\alpha}{(I_B - I_D)\beta - (I_A - I_C)\delta} \qquad \mathrm{OPD} = \frac{\lambda}{2\pi}\phi$$

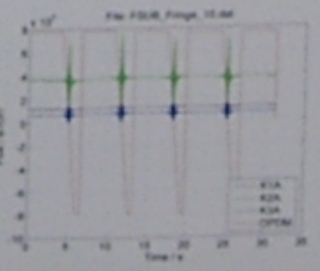
- The Group Delay is derived from the phase delays in the two exterior spectral bands:

$$\mathrm{GD} = \frac{1}{2\pi}\frac{\lambda_3\cdot\lambda_1}{\lambda_3 - \lambda_1}\cdot(\phi_3 - \phi_1).$$

- The parameters that need to be derived from the calibration are the effective wavelengths λ_i and the phase error coefficients $\alpha, \beta, \gamma, \delta$, in the 3 spectral channels.

Calibration Procedure

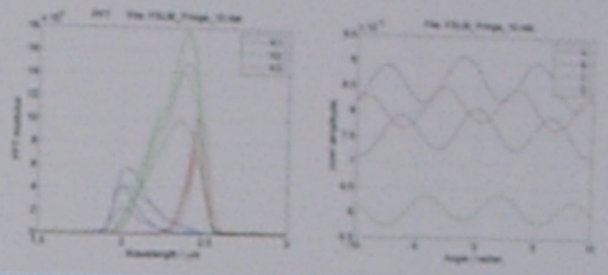
- Fourier Transform Spectroscopy is used to derive the effective wavelengths
- Several OPD scans over the fringe packet are performed with a linear motor while the FSU fluxes and the internal OPD (measured with the internal metrology) are recorded simultaneously



- The obtained fringes are collapsed, resampled and smoothed

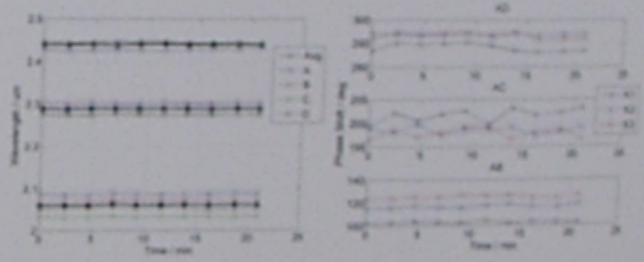
Parameter Computation

- Each fringe packet is Fourier transformed and the effective wavelengths are computed from the barycentre of the FFT modulus
- The phase shifts are derived from the crosscorrelation of the fringe packets with respect to the channel A fringes

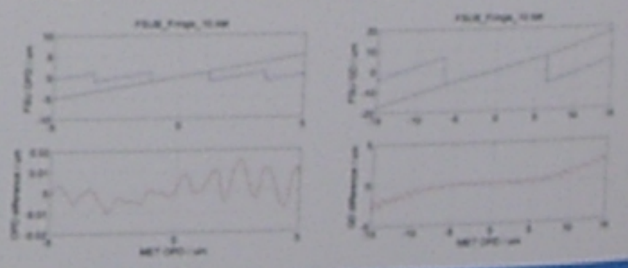


Results

- Parameter stability over 10 consecutive calibrations:
  - Effective wavelength PTV variation is below 4 nm
  - Phase shift variation PTV variation is below 4°



- OPD measurements show low deviation from expected values, the derived linearity is good (<10%)
- GD measurements exhibit large cyclic errors, linearity is not satisfactory



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 estimations exhibit large errors. Both the GD algorithm and the calibration procedure need to be improved.

References

1. M. Schöller et al., "Recent progress at the Very Large Telescope Interferometer", Proc of SPIE, vol 6268, 2006
2. F. Delplancke et al., "PRIMA for the VLTI: a status report", Proc of SPIE, vol 6268, 2006
3. M. Gai et al., "The VLTI Fringe Sensors: FINITO and PRIMA FSU", Proc of SPIE, vol 5491, 2004

* The FSU has been built by Alcatel Alenia Space Italy (AASI)