Status of PRIMA for the VLTI – heading to astrometry

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ABSTRACT

The Phase Referenced Imaging and Micro Arcsecond Astrometry (PRIMA) facility for the Very Large Telescope Interferometer (VLTI), is being installed and tested in the observatory of Paranal. Since January 2011 the integration and individual testing of the different subsystem has come to a necessary minimum. At the same time the astrometric commissioning phase has begun.

In this contribution we give an update on the status of the facility and present some highlights and difficulties on our way from first dual-feed fringe detection to first astrometric measurements. We focus on technical and operational aspects. In particular, within the context of the latter we are going to present a modified mode of operation that scans across the fringes. We will show that this mode, originally only intended for calibration purposes, facilitates the detection of dual-fringes.

Keywords: Astrometric and interferometric instruments, Interferometry

1. INTRODUCTION

PRIMA, currently being installed and tested in the observatory of Paranal, is the dual-field facility of the VLTI. It is designed to enable simultaneous interferometric observations of two celestial objects – each within a field of 2 arcsec diameter – that are separated by up to 2 arcmin, without requiring a large continuous field of view.[1]

With such a design PRIMA shall in principle be able to feature three different modes of operations:

1. an astrometric mode in which it is used to measure the angular separation between two stellar objects,
2. a faint object mode in which it serves to overcome the limiting magnitudes of existing instruments, such as Astronomical Multi-BEam combineR (AMBER) and Mid-Infrared Interferometric Instrument (MIDI),
3. and an imaging mode in which a phase reference technique allows to produce images of the fainter of the two objects.

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In order to achieve all the dual-field capabilities, PRIMA involves the synergetic interaction of several long-established and newly installed subsystems of the VLTI. The installation of these new subsystems has started in summer 2008. Since then, the individual subsystems have been extensively tested during several technical missions in Paranal distributed over a period of almost three years. Since January 2011 the integration and individual testing of the different subsystem has come to a necessary minimum which marked the transition from *sub*system to system testing. As it was decided in April 2010 to give priority to the astrometric mode of PRIMA,[2] early 2011 constitutes also the start of the astrometric system testing phase.

In the following we present the status of the facility as of early 2012 and pick out some highlights as well as difficulties on our way from first dual-feed fringe detection to first astrometric measurements. Further we detail the operational procedures of PRIMA and show that, despite of PRIMA being a rather complex system, its operation is quite streamlined.

2. OVERVIEW ON THE FACILITY

PRIMA is composed of four major sub-systems, which have been added to the VLTI infrastructure: the Star Separators (STSs),[3] the Differential Delay Lines (DDLs),[4] the PRIma METrology (PRIMET),[5] and the Fringe Sensor Units (FSUs)[6] as well as an overall control system including software. A typical configuration of these subsystems used for astrometric tests is depicted in Fig. 1. (A description of the astrometric measurement principle can be found in Ref. 7.)

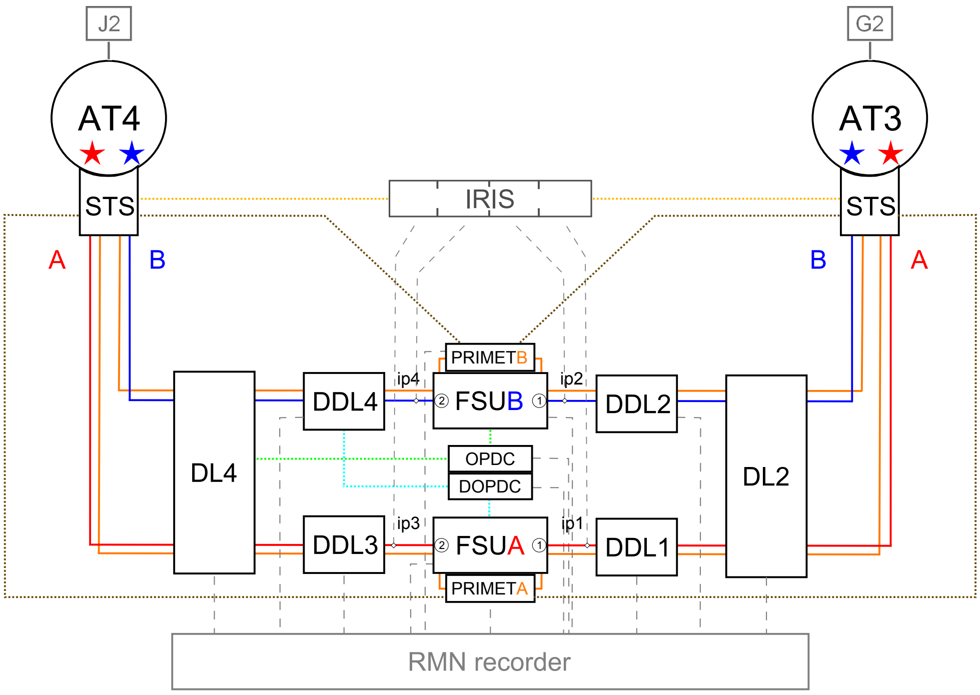

Figure 1. A typical PRIMA configuration for astrometry. The light of the two stars is split by the STSs. (Differential) OPD is compensated by the (D)DLs which are controlled by the (d)OPDC. The control is based on real time estimates of group and phase delay as well as of an SNR which are provided by the two FSUs A and B. The internal difference in OPD is measured by PRIMET A and B. PRIMET provides also the sensors for pupil displacements which are corrected by actuators inside the STSs. Displacements of the image are sensed by IRIS and also actuated by mirrors inside the STSs. All real time data is recorded by the RMN recorder. Solid lines denote light paths, dotted lines denote control loops and dashed lines represent data flow.

The light of the two stars is split at the telescope level by the STSs which deliver four beams, two per telescope (or star respectively), to the VLTI laboratory. While the Delay Lines (DLs) compensate the main Optical Path Difference (OPD) introduced by Earth rotation, the DDLs compensate the additional differential delay, arising from the angular separation between the two stars, such that interference fringes can be obtained simultaneously on both objects with FSUA and FSUB. The FSUs deliver real time estimates of phase- and groupdelay, as well as a Signal to Noise Ratio (SNR) which is used by the Optical Path Difference Controller (OPDC) and differential Optical Path Difference Controller (dOPDC) to control the movement of DLs and DDLs respectively, and to track fringes. The internal difference in OPD between the two feeds of the interferometer is measured by PRIMET. PRIMET delivers also measurements of the pupil displacement which are used by a dedicated control loop to apply proper corrections via the Variable Curvature Mirrors (VCMs) of the STSs. Tip/tilt of the image, arising from turbulences within the VLTI tunnel, are recorded by InfraRed Image Sensor (IRIS), and corrected by actuation of the STSs' Field Selector Mirrors (FSMs).

The resulting real time data required by the different control systems of the VLTI at many different places (FSU, PRIMET, DDL, IRIS, etc. ...) are recorded by a shared memory mechanism, the so-called Reflective Memory Network (RMN) recorder.[8]

From this short sketch it can already be perceived that an astrometric observation with PRIMA involves a elaborate and non-trivial interaction of several different subsystems via several dedicated control mechanisms.

3. SUBSYSTEM STATUS

A more detailed description of the role of each subsystem and its status by the beginning of the year 2010 was given in Ref. 9. In the following we give an update on the status since then, in particular, with regard to astrometry.

3.1 Star Separator

The overall functionality of the STSs has been established and tested. During the commissioning periods, instead of the VCMs, the STSs are equipped with fixed curvature mirrors that relay the pupil longitudinally correctly for the given baseline that is used. The upgrade of the STSs with nominal VCMs, is expected to happen at the end of 2012. Still, the fixed curvature mirrors work fine at the used baseline and do not seem to limit the astrometric performance at the present stage.

We are currently experiencing a problem that has a negative influence on the operation and the astrometry. There is a global and a differential defocus,[10] which at present, cannot be corrected by proper alignment. Global defocus means a defocus that is common to both beams of one telescope, whereas differential defocus means a defocus that is different for the two beams of one telescope.

The defocus is problematic in different aspects. On the one hand, it reduces the coupling of flux into the FSUs' single mode fibers. This has a negative impact on the operation and the sensitivity of the instrument. On the other hand, if the defocus is different between the two arms of the interferometer, it introduces an error on the phase estimation.

The cause of the defocus could not be identified yet, but dedicated analyses are still ongoing.

The delivery of two additional STS-Auxiliary Telescope (AT) is planned for the end of this year. Once the new units will arrive to Paranal, they will be used to replace the 'old' STSs. While the new STSs are installed and tested, the old ones will be sent back to the manufacturer for being retrofit with their VCMs. In addition this provides the opportunity to analyze in detail and hopefully solve the defocus problem.

3.2 Differential Delay Lines

The DDLs have been used routinely during the different testing periods. A critical step towards dual-feed fringe tracking was the commissioning of their blind trajectory which has been accomplished successfully.

One minor problem has been encountered. The actual position of each DDL is measured by an internal laser metrology system. This metrology system is not only used to control the movement of the tracking DDL, but also to servo the reference DDLs to their zero OPD position. It turned out that the application of strong accelerations on the tracking DDL, which typically happens during presets or fast optical path length (OPL) scans, induces mechanical vibrations in the support towers of the laser metrology system of the neighboring reference DDL. As these disturbances are interpreted by the control system as OPL changes they are translated in real parasitic

DDL movements. Although this problem does not directly affect the astrometry, as it does usually not happen during fringe tracking, it will be corrected via a hardware retrofit within the scope of a contract for an additional pair of DDLs that shall be delivered to Paranal by the year 2013.

3.3 The Fringe Sensor Units

Both fringe sensors have been operated on a regular basis in single and dual feed. As has been pointed out in Refs. 9, 11, the performance of the FSUs depends critically on the proper calibration of particular parameters. In the times were only single-feed was available these parameters could be derived solely via measurements in the laboratory with an artificial light source. Meanwhile, the dual-feed setup, enabled the recording of data that allows the determination of these parameters on sky. Preliminary analyses corroborate initial hints that these parameters are different on sky than in the laboratory. This is still subject to an ongoing investigation, and currently different algorithms for the determination of the calibration parameters are compared and tested. We hope that these studies will finally lead to a better tracking performance via an improved parameter estimation.

Currently, routine fringe tracking is being achieved with the full PRIMA configuration (including STS and DDL) up to magnitude $m_K = 5$ in standard atmospheric conditions. Probing the sensitivity of PRIMA dual feed has not been a priority of the performance testing so far.

A broken fiber on FSUA forced a critical hardware intervention in the beginning of 2011. During a series of warm-up and cool-down cycles of the FSUs' cryostat, the broken fiber was replaced and the new fiber re-aligned. Within the scope of this intervention the alignment of the cold-optics of both FSUs could be substantially improved, in particular with respect to image distortion and spectral dispersion. As a result, differences in the alignment between FSUA and B were reduced and the linearity of the Group Delay (GD) estimation improved.

3.4 PRIMA Metrology

PRIMET has been aligned on both STSs and can be used for FSU calibration as well as for astrometric observation. Both of the two channels, PRIMET-A and PRIMET-B, have been routinely used with pupil tracking and fringe stabilization through the DDL and DL out to AT-mounted STS during nighttime. In order to make this happen, limiters on the speed and the acceleration of DLs and DDLs had to be introduced. These limiters are usually only relevant during the presetting phase or during OPL scans, when the (D)DLs are moved at a high speed over a longer range*. They do not have any influence on the fringe tracking.

As astrometry requires an accurate measurement of the internal OPD variations (accuracy goal 5 nm), the PRIMA Metrology system is based on a Nd:Yag (Innolight, MIR 500NE-FC) laser, whose frequency is stabilized on a transition of Iodine. The frequency stability as well as the absolute frequency on which the laser locks was measured in July 2011 using a frequency comb (FC1500) of Menlo Systems GmbH. Within a period of 33 h, the peak-to-valley excursion of the Nd:YAG laser frequency ν was 4.4 MHz and the standard deviation was $\sigma_\nu = 424$ kHz, leading to a relative stability of $\frac{\sigma_\nu}{\nu} = 1.8 \cdot 10^{-9}$ Root Mean Square (RMS) , which is below the specificationfs limit†.[12]

3.5 Software and Control System

The operation of PRIMA astrometry is fully integrated in the Interferometric Supervisor Software (ISS)‡. All cascaded control loops have been tested and are working routinely.

Special effort was devoted to implement the IRIS-STS-FSM image tip/tilt stabilization loop for four beams. Once four beams of two stars are delivered to the laboratory, they can be simultaneously stabilized for tip/tilt fluctuations happening in the VLTI optical tunnel. The so-called dual Detector Integration Time (DIT) mode, for which the detector is run with different integration times accounting for the different flux levels of the two stars, has been implemented and tested to be working. Current bright-bright on-sky work for the astrometry is

*Typical values for the speed and acceleration limits (mechanical) are 1 mm/s and 8 mm/s^2 for the DDL, and 5 mm/s and 1.8 m/s^2 for the DL.

†The absolute frequency of the Nd:YAG laser was determined to be $\nu = 227\,257\,333\,348\,660$ Hz $\pm$ 529 578 Hz.

‡Even four telescope operation, required by the visitor instrument PIONIER,[13] has been integrated in the Paranal operational version of ISS.

limited to star pairs with a $\Delta m_H \lesssim 2$, but the development team has already demonstrated the ability to go to $\Delta m_H = 5.5$. Still a systematic test of the maximally achievable magnitude difference is outstanding. It will be approached once the full reachable target magnitude space of PRIMA astrometry is going to be investigated.

The OPD control for the main and the differential DLs works well during fringe search and tracking. Additional algorithms have been implemented that allow scanning of the fringes with both, DLs and DDLs, see also Sec. 4. Currently the controllers for the main and differential OPD are two separated entities. In order to increase the tracking performance, in particular with respect to fainter targets, it might be advantageous to join both via a combined state machine. Dedicated studies are going on and some software effort in this direction is envisaged for the future.

On the side of the Auxiliary Telescope Control Software (ATCS) the algorithm of the derotator movement has been improved and an engineering tool was provided which allows the additional recording of information from several different subsystems, such as FSM and VCM piezo positions etc.

4. OPERATION AND HIGHLIGHTS

At present, the time required from a PRIMA preset to dual feed fringe tracking is on average 20 min. This is remarkably short considering how many different subsystems and control loops are involved in order to reach this state. On the way to this present status lays the achievement of several important milestones, some of which are shortly presented in the following together with the way how the system is operated.

4.1 Operation

Fringe tracking with both FSUs involves three elementary steps

1. Fringe detection on FSUA and FSUB
2. Evaluation of the tracking parameters for OPDC and dOPDC[9]
3. Closing the tracking control loop on OPDC and dOPDC.

The critical steps are 1 and 2. Succeeding in those renders step 3 almost straight forward. Therefore considerable effort was devoted to develop a suitable dual fringe detection strategy and a method for the estimation of the tracking parameters.

Finding the fringes is comparably easy if one starts with a good so-called "OPD model" that specifies the baseline vector and the constant internal OPD offset for a given configuration. An OPD model is provided by default at the VLTI, for *single feed* observation. At the beginning of the dual feed operation, no OPD model was available. The single feed model was not accurate enough to apply the standard Zero Path Difference (ZPD) search method. In this method a search trajectory is triggered with the delay line starting from the position where the fringes are supposed to be found according to the used OPD model. The search speed is usually rather slow which restricts in practice the scanning range to a several tens of micrometers. Further, a ZPD search requires a apriori knowledge about suitable SNR thresholds for the controller. In order to overcome these difficulties a new approach was devised.

In this new approach, the main DL is used to apply a large and fast OPL scan. 'Large' in this context means that the stroke is big enough that both fringes are passed, typically a few centimeters. 'Fast' means that the time required to carry out this scan is typically on the order of a few minutes. During the scanning, data is recorded and evaluated in post processing. A dedicated PRIMA Astrometry Camera for Micro Arcsecond astroNomy (PACMAN)[14] observation template was provided that automates the different steps, applying the scan, recording the data and processing it. The operator has to provide input values for the center position of the scan, the length of the scan and the sampling rate (in measurement points per micrometer OPL) at which the data should be taken.

The output of the data evaluation yields the following parameters:

- Fringe center position for FSUA and B

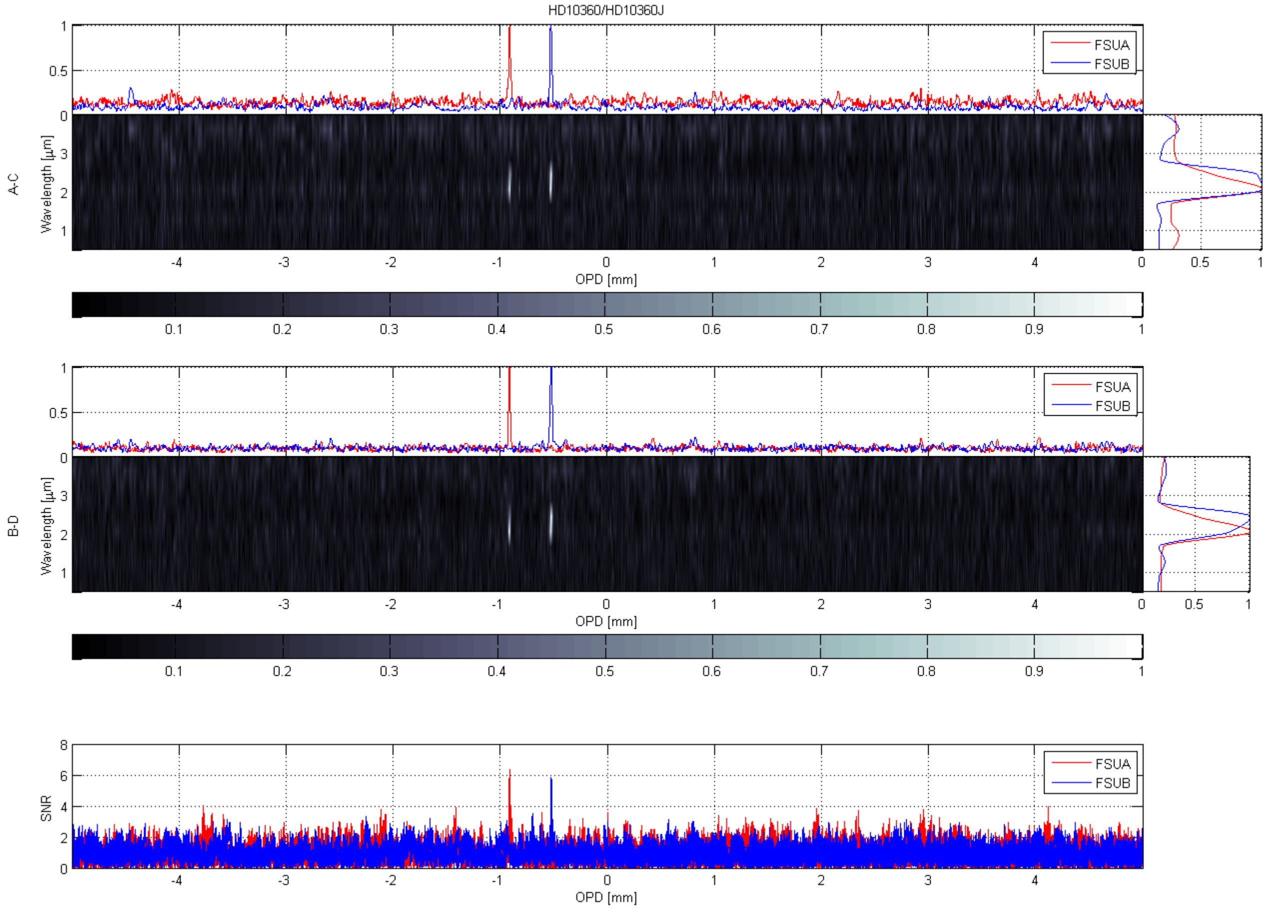

Figure 2. Example output of the data postprocessing of the fringe finding procedure. Bottom: SNR signal of FSUA (–) and FSUB (–) versus OPD offset. Middle and top: moduli of the wavelet transforms of the phasor components of FSUA and FSUB as well as their projections on the OPD and wavelength axes.

- A set of SNR thresholds for FSUA and B.

Upon approval by the operator, these parameters are sent automatically to the OPDC and dOPDC respectively. If the procedure was successful the tracking loop can be closed afterwards on both fringe sensors.

The methods involved in the data processing are described in more detail in the following section.

4.2 Post processing of the data

The detection of the fringes relies on two different evaluation methods, first on a evaluation of the SNR signal, second on a wavelet transform of the phasor components. As the meaning and definition of the PRIMA FSUs' SNR is described in detail in Ref. 6 and 9, we focus here on the wavelet transform.

When passing through the fringes, we expect not only a signal peak in the SNR, but ideally also a fringe pattern in the flux signals of the FSUs at a wavelength of ~ 2.2 µm. A wavelet transform is a suitable tool to analyze this signature in the flux signals, as – in contrast to a fourier transform – it provides us not only with spectral but also with spatial resolution[§].

[§]Naturally the spatial resolution comes at the cost of the spectral one. However, for the fringe detection we are primarily interested to know where in OPL space the fringes appear. The spectral information serves as an additional tool to separate the signal from the noise.

As wavelet, ψ, we chose the theoretically expected fringe signal, i.e., a complex phasor ϕ with a sinc-shaped envelope a:

$$\psi(x\,;x_0,\lambda) \;=\; c(\lambda)\,a(x\,;x_0,\lambda)\,\phi(x,\lambda), \quad \text{with} \tag{1a}$$

$$a(x\,;x_0,\lambda) \;=\; \mathrm{sinc}^2\left(\frac{2\pi}{w(\lambda)}\,(x-x_0)\right) \quad \text{and} \tag{1b}$$

$$\phi(x\,;\lambda) \;=\; \cos\left(\frac{2\pi}{\lambda}x\right) + \imath\cdot\sin\left(\frac{2\pi}{\lambda}x\right). \tag{1c}$$

Thereby, λ denotes the wavelength, x_0 is the center position and $w(\lambda) = n\,\lambda$ the relative width of the wavelet with a typical value of $n = 50$. $c(\lambda)$ is a normalization constant chosen such that

$$\|\psi\| = \sqrt{\langle\psi|\psi\rangle} \equiv \int \sqrt{\psi(x\,;x_0,\lambda)^*\psi(x\,;x_0,\lambda)}\,\mathrm{d}x = \int |\psi(x\,;x_0,\lambda)|\,\mathrm{d}x \overset{!}{=} 1$$

During the post processing of the data, we numerically evaluate estimators for the integrals

$$\widetilde{X}(x_0,\lambda) \;=\; \int X(\xi)\,\psi(\xi\,;x_0,\lambda)\,\mathrm{d}\xi \quad \text{and}$$

$$\widetilde{Y}(x_0,\lambda) \;=\; \int Y(\xi)\,\psi(\xi\,;x_0,\lambda)\,\mathrm{d}\xi$$

in the wavelength range $\lambda \in [0.5\ \mu\mathrm{m},\ 4\ \mu\mathrm{m}]$, where $X(\xi) = I_{1,A}(\xi) - I_{1,C}(\xi)$ and $Y(\xi) = I_{1,B}(\xi) - I_{1,D}(\xi)$ are the phasor components measured by the FSUs depending on the OPD offset ξ sent by the OPDC to the DL. $I_{i,\Gamma}$ are the real time fluxes in the notation as defined in Ref. 6. In order to flatten the fluxes for photometric variations we normalize them by a running average.

An example of the output from the postprocessing is shown in Fig. 2. The figure displays the moduli of the wavelet transforms, $|\widetilde{X}|$ and $|\widetilde{Y}|$, for FSUA and B and their projection onto the OPD and wavelength axis. On the very bottom the SNR signals of both FSUs is shown.

In the chosen example the fringe signal is clearly visible in all signals. However, we observed instances in which the fringe signature was only visible in one of the signals (either SNR or the wavelet transform modulus). Hence, the advantage of looking at both signals at the same time is clearly that the fringe detection probability is increased.

The wavelet transforms serves mainly to detect the fringe and locate its position. The SNR signal is used to derive the SNR threshold values required by OPDC and dOPDC, see Ref. 9. To this end the peak in the signal is fit by a Gaussian. Afterwards the (d)OPDC detection level is defined as the value of the Gaussian function one standard deviation away from the maximum, and the close level as the value two standard deviations away from the maximum. The open level is defined as the value of the average noise floor. This method does not provide as good thresholds as the histogram based method described in Ref. 9. Still, for a starting set of thresholds the derived values are good enough. As soon as one tracking file is recorded, and in case the lock ratio is not good enough yet, the thresholds can be refined according to the histogram method.

4.3 Highlights

All the procedures involved in an astrometric measurement, from the preset of the telescopes to the dual feed fringe acquisition, are meanwhile streamlined and executed routinely (at least on bright target pairs). This was not like this from the beginning, and several important achievements were necessary to reach this point.

A prerequisite to fringe tracking is that the light coming from the two stars is delivered to the lab in form of four beams which are injected in a stable manner into the fibers of the FSUs. This is ensured by the IRIS image tip/tilt stabilization which was for the first time achieved for all four beams in December 2009, see Fig. 3.

In February 2010, there were loose hints for fringes in both FSUs at the same time. The first unambiguous proof for dual feed fringe detection could, however, be reached only during the subsequent mission in July 2010.

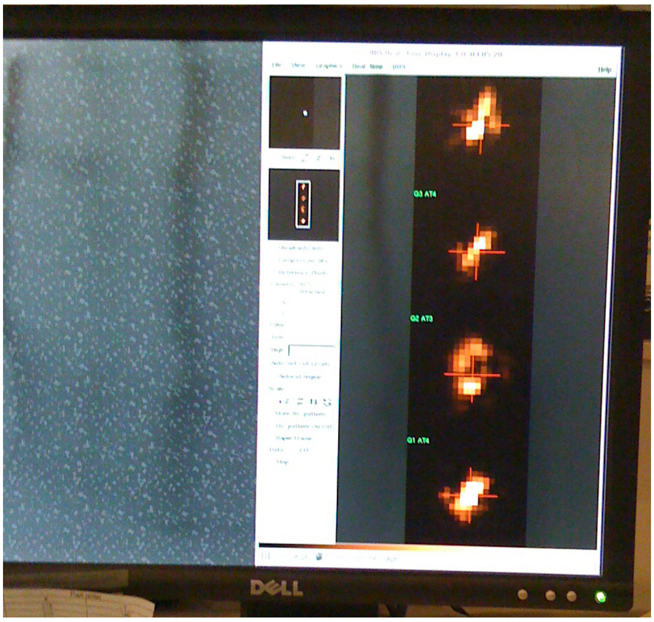

Figure 3. First IRIS lab guiding on four beams. The picture shows a terminal screen with the GUI of IRIS with the four quadrants of the detector. The bright spots are the four beams of the two stars coming from the two feeds of the interferometer.

Fig. 4 shows a fringe scan with the DDL on FSUA on the secondary star while tracking on the primary with FSUB. The bottom plot displays the groupdelay of FSUB as well as its tracking state (green equals tracking, red equals not tracking). Although the tracking on the primary was lost during the scan, the fringes on the secondary could be found. The three plots on the top show the SNR signal of FSUA and the moduli of the wavelet transforms on the phasor components, cf. Sec. 4.2. The red arrows in the figure indicate the fringes. They appear at a slightly different wavelength as they were supposed to be because the OPD was not stabilized while passing through them.

During the same mission we could close the tracking loop with both fringe trackers. This is shown in Fig. 5 where one can see the group delay of each FSU and its tracking status. The tracking performance on FSUA was still not very good due to inappropriate control parameters, but it denotes the beginning of the dual feed fringe tracking at the VLTI. A bit later, in the same night for the same target, we even achieved lock ratios of almost 100 and 70 percent on FSUB and A, respectively.

Despite this success, it is clear that dual feed fringe tracking alone is not sufficient to do astrometry. Hence the next milestone to reach was to combine the tracking with the synchronous measurement of the internal OPD difference by PRIMET. This comprises in particular a glitch-free PRIMET recording during the two different types of presets, 'normal' and 'swap'. It turned out that this was not something trivial to achieve. The behavior of the DLs during the preset procedure had to be modified and the speed and acceleration at which they move to be limited. All the different measures led finally to the recording of the first astrometric sequence in January 2011. Fig. 6 displays the differential OPD, ΔOPD, as measured by PRIMET in normal an swapped configuration. The measurement points are corrected by the internal OPD offset and the sign difference between normal and swap in order to display them as one trajectory. Also shown is a least-squares fit of the differential delay. Parameters of the fit are the internal OPD offset and the secondary star coordinates.

As the dual DIT mode of IRIS had been successfully implemented and tested two missions before (see Sec. 3) in October 2010, we were able to try observing a target pair with a bigger difference in brightness in February 2011. Stabilizing the atmosphere by tracking the fringes on HD87640 ($m_K = 4.8$) with FSUB, we systematically increased the integration time of FSUA up to one second scanning through the fringes on SAO221759 ($m_K = 7.1$, 6.6" distant). Availing ourselves of the excellent weather conditions (0.87" seeing, 10 ms coherence time) we achieved a coherent integration of the fringes on FSUA over a time span of more than 3 min. The result can

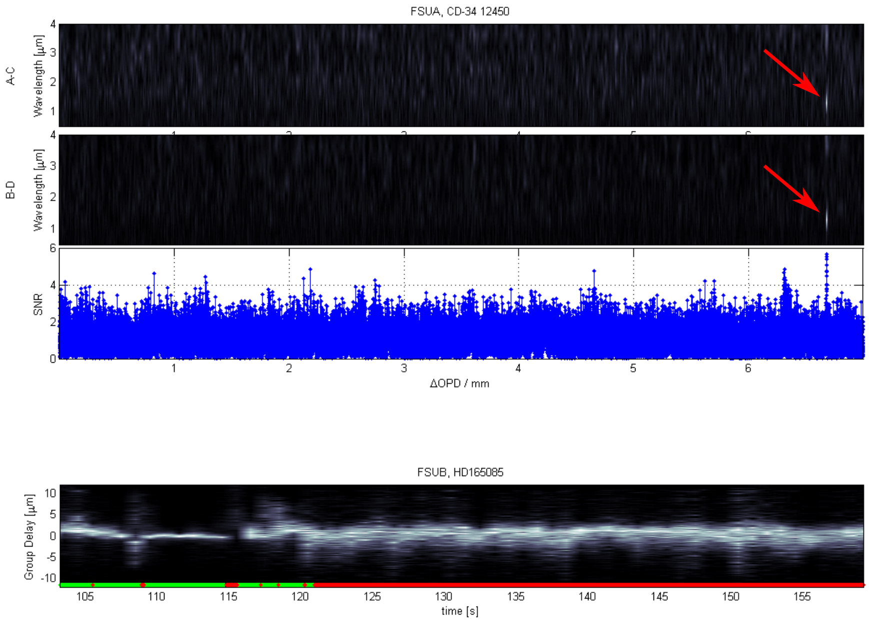

Figure 4. First dual feed fringe detection. Bottom: GD and tracking state ((●) tracking, (●) not tracking) of FSUB versus time. Top: Fringe scan with the DDL on FSUA, with fringe signal in the SNR (–) and in the moduli of the wavelet transform of the phasor components.

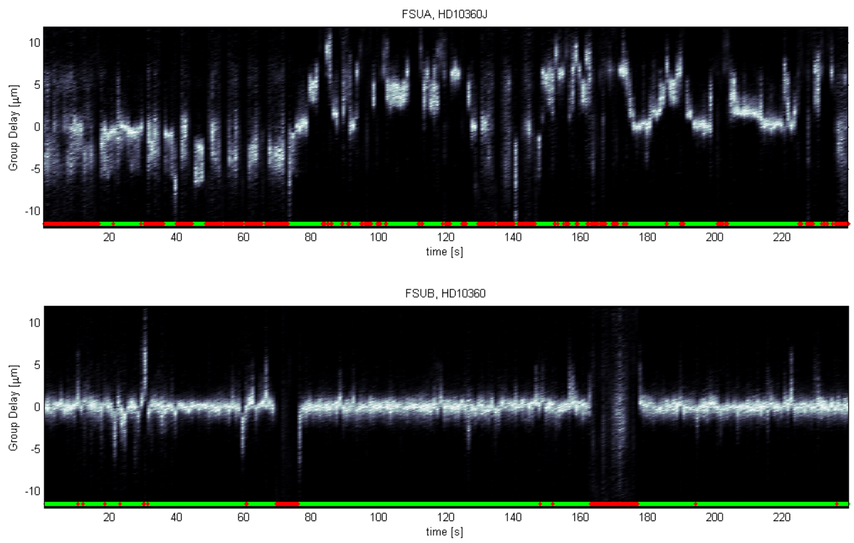

Figure 5. First dual feed fringe tracking. GD and tracking state ((●) tracking, (●) not tracking) of FSUB (bottom) and FSUA (top) versus time.

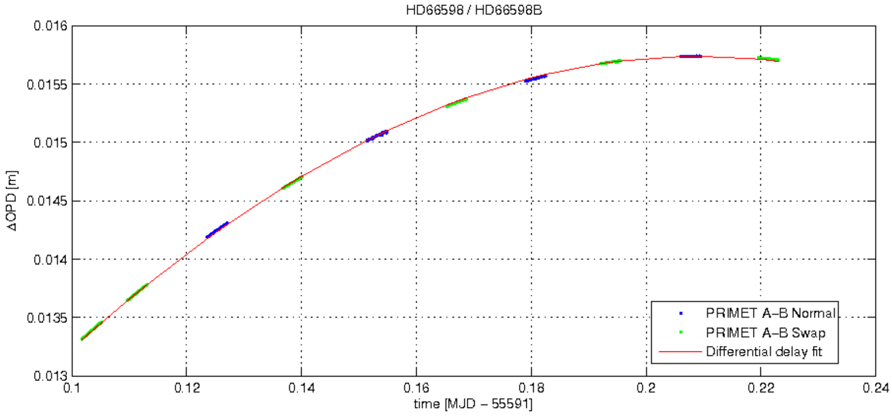

Figure 6. First astrometric sequence. Measurement of the internal differential OPD, ΔOPD, as recorded by PRIMET in normal (•) and swapped (•) configuration. Least squares fit (−) of ΔOPD with three parameters: constant internal OPD offset, secondary star coordinates.

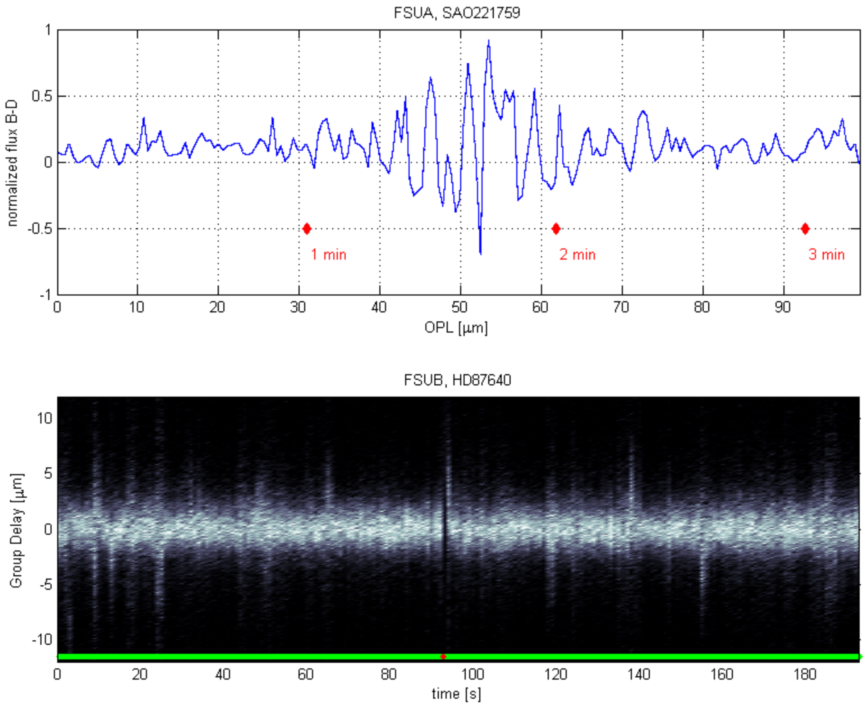

Figure 7. Three minutes coherent integration. Star SAO221759 ($m_K = 7.1$) on FSUA stabilized by HD87640 ($m_K = 4.8$, 6.6" distant) on FSUB (weather: 0.87" seeing, 10 ms coherence time). Bottom: GD and tracking state ((•) tracking, (•) not tracking) of FSUB versus time. Top: Fringe signal as seen in the normalized flux difference of quadrants B and D of FSUA versus OPL.

be seen in Fig. 7. The bottom plot shows the GD of FSUB as well as its tracking state (green tracking, red not tracking). The plot on the top displays the fringe signal as recorded in the flux of FSUA.

After the principal functionality of astrometry had been established at the beginning of 2011, the next three technical missions have been devoted to the assessment of the astrometric performance. A summary of the astrometric data analysis and the obtained results can be found in Ref. 7. Unfortunately, a detailed study of the astrometric data taken so far showed that the performance of PRIMA is not sufficient for astrometric science, at least within the scope of the Extrasolar Planet Search with PRIMA (ESPRI) project.[7] We are currently facing a couple of problems and difficulties some of which shall be shortly listed in the next section.

5. PROBLEMS AND DIFFICULTIES

The analyses of the astrometric commissioning results revealed that the astrometric residuals show large biases which limit PRIMA's accuracy to the milliarcsecond regime. These errors seem to be systematic and there are evidences that their source lies in the part of the optical train that is currently not monitored by PRIMET, i.e, from mirror M9 inside the STS up to mirror M2 of the AT. On top of the fact that this part of the beam path is not monitored, come alignment problems on the same optics. Apart from the afore mentioned problems on the STS side, it was observed that the ATs show a pupil run-out with regard to the azimuth axis that seems to degrade significantly in time after re-alignment.[15] On the one hand, this run-out impacts the astrometric baseline, on the other hand it can become so big that it introduces a pupil vignetting, even for a perfectly aligned STS.

Pupil vignetting together with a defocus problem (see Sec. 3) limit the PRIMA performance also in terms of limiting magnitude. With dual feed fringe tracking being demonstrated so far on targets around $m_K \approx 5$ and magnitude differences between primary and secondary star of $\Delta m_K \approx 1 - 2$, sensitivity is the other issue in which PRIMA currently underachieves its expectations for science applications. In order to render PRIMA a valuable tool for planet detection a surplus of 2 to 3 would have to be achieved in both, absolute fringe tracking magnitude and magnitude difference.[7]

For some of the current problems there are already concrete plans on how to address them. For instance, PRIMET shall be extended to the M2 mirrors of the ATs. First prototypes of the necessary retroreflectors have been designed, procured, and are supposed to be installed in an upcoming technical run in July 2012. Still, it remains to be seen how strong the improvement will actually be and what other layer of error sources will appear underneath once the currently predominant terms are eliminated.

6. CONCLUSION

In this contribution we have given a short update on the present status of PRIMA. We showed that a lot of effort has been devoted to bring all the different subsystems to a state in which they can be operated and tested together on a system level as one single astrometric instrument. Although the operation is already rather streamlined and first results on dual feed fringe tracking are very promising, there is still plenty of room and especially need for improvement. In its current state, PRIMA is capable of performing narrow-angle astrometry, but yet only at a very limited performance. In order to turn it into a high precision astrometric measurement apparatus there is still hard work to do and a lot of effort to make. The necessary measures to make this happen cannot be restricted to PRIMA alone but have to affect the VLTI as a whole.

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