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VERY LARGE TELESCOPE

PRIMA May 2013 technical run report

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1 Scope

This document reports on the PRIMA activities through the technical run of May 2013.

2 List of Abbreviations & Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

AT	Auxiliary Telescopes
DL	Delay Line
DDL	Differential Delay Lines
FSM	Field Steering Mirror
PRIMA	Phase-Referenced Imaging and Microarcsecond Astrometry
PRIMET	PRIMA Metrology
RoC	Radius of Curvature
ROS	Relay Optics Structure
STRAP	System for Tip/tilt Removal with Avalanche Photodiodes
STC	Scientific Technical Committee
STS	Star Separator System
TCCD	Technical CCD
UT	Unit Telescope
VCM	Variable Curvature Mirror
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer

3 List of Applicable and Referenced Documents

3.1 Applicable Documents

None

3.2 Reference Documents

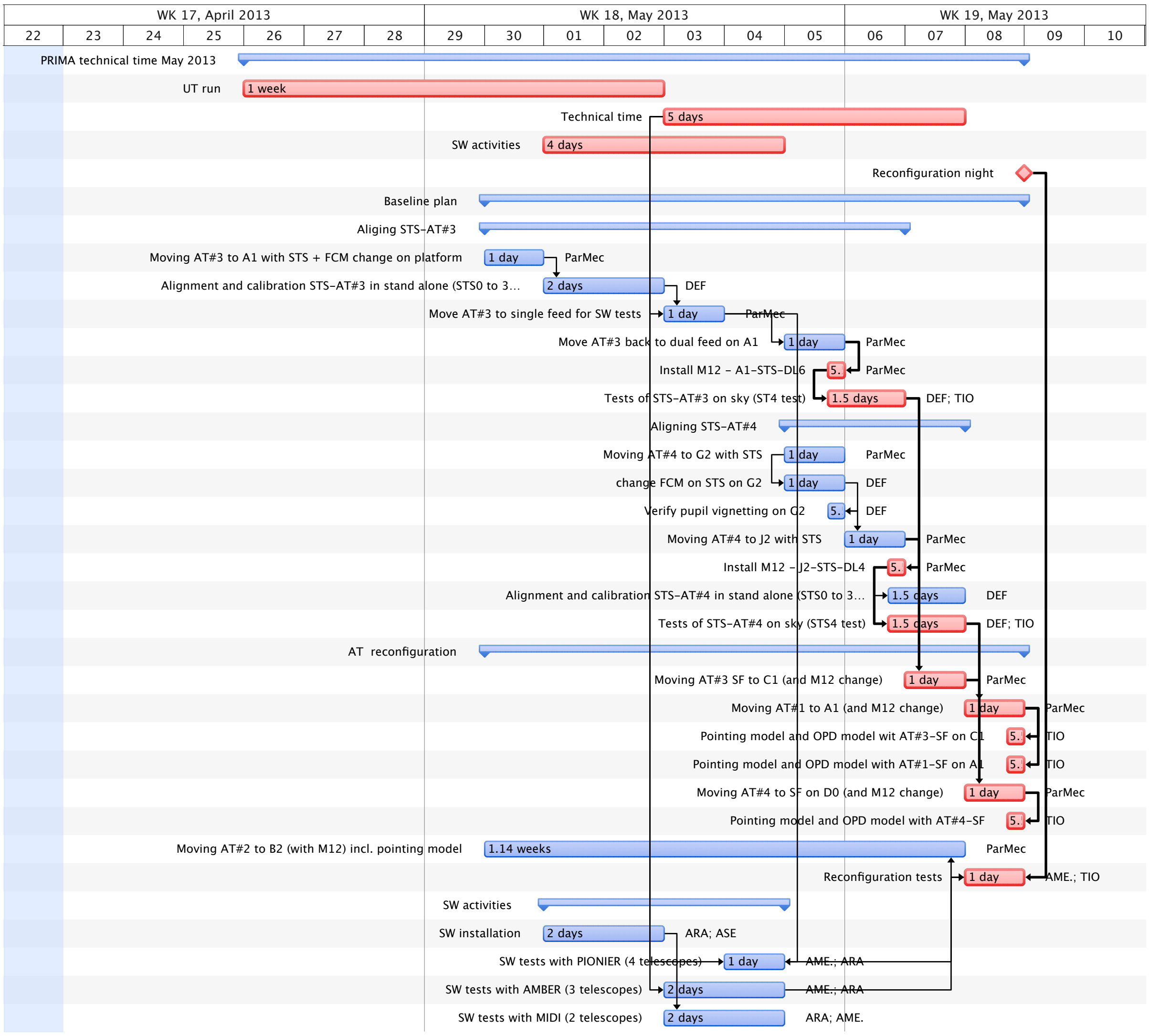
None

4 Initial plan

Illustrated below is the plan for the May technical time, officially May 3 to May 7, as envisioned around mid-April. The constraints imposed by delays in the manufacturing of the fixed curvature STS-VCM mirrors for stations A1 and J2, the limited availability of the ATs, and the level of Paranal support are already factored in:

- There is no PRIMET tuning activities.
- There is no functional test of the larger M2 retro-reflectors.

Both activities are delayed to the June run. The main focus of this slot is the alignment and re-commissioning of the STS of AT3 and AT4 on stations A1 and J2 respectively. The RoCs of the fixed curvature mirrors are close but not exactly equal to the ideal values. The final installation will also be performed at the occasion of the June run.



5 Activities report

5.1 Installation and test of the new retro-reflectors at M2

This activity was an optional activity in case the new retro-reflectors (large aperture) were ready in time for the May run. One retro-reflector was fully ready (with LEDs for materialising the pupil), the other was ready without LED.

Unfortunately, following some maintenance activities, which happened before the PRIMA run, the M2 hexapod was stuck after the relocation of AT#3 to station A1. After 2 days of hard work, Paranal engineering managed to recover the M2 in time for the software tests but then, it was not possible anymore to install the new retro-reflector as Guillaume Blanchard had left Paranal and nobody else was allowed to perform this task.

So this activity was not performed and the interface and usefulness of the LEDs could not be tested. It is postponed to the June run or to any available technical time before then (to be discussed and agreed with Paranal Optics).

5.2 Alignment and performance verification of the STS of AT3 and AT4

5.2.1 Rationale and goals

The main activities were:

- the exchange of the fixed curvature mirrors of both STS by mirrors having a radius of curvature of -250mm (for an ideal value of -200 and -210mm for AT#3 and AT#4 respectively),
- the re-alignment and calibration of the STS parameters on the Nasmyth beacon and on sky for AT#3 on A1 and AT#4 on J2,
- the check of the pupils relayed by both telescopes and STS,
- the measurement of the new Star Separator transmissivity.

5.2.2 Fixed curvature mirror exchange

The fixed curvature mirrors were glued in the provide mounts by Guillaume Blanchard. Françoise Delplancke exchanged them in the Star Separators during the re-location of the telescopes, on the platform, according to the procedure described in the user manual (using the proper trident tool).

After the exchange the mechanisms of the piezo-controller was re-tuned (notch frequencies) and adjusted using the serial-modem-cables and laptop computers dedicated to this activity (in VLTI office, under Jaime Alonso ownership) and the procedure described on:

https://websqa.hq.eso.org/sdd/bin/view/PRICS/CalibDPCAxes

5.2.3 Alignment and calibration of the STS

5.2.3.1 Procedure

The calibration of both STS during daytime used the osf scripts dedicated to this task and created by Luigi Andolfato. The scripts that were used are the following (in the given order):

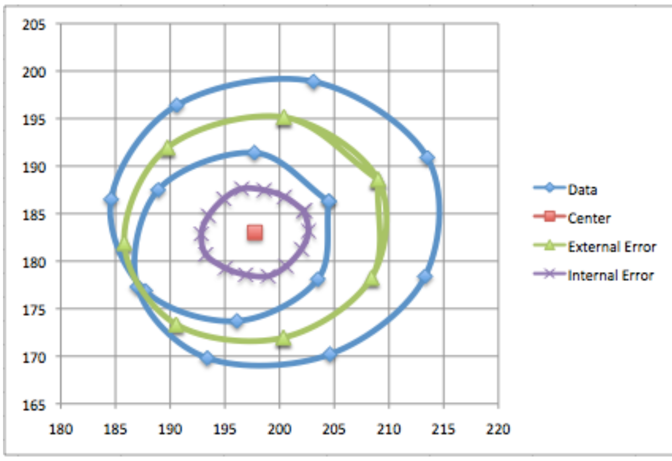
- *atosfDaytimeTests.osf* => to prepare the telescope for daytime calibrations on Nasmyth beacon
- *pscsosfStsAtFindCCDAzRefPos.osf*
- *pscsosfStsAtFindCCDBeamOffset.osf*
- *pscsosfStsAtFindDerCenter.osf*
- *pscsosfStsAtFindFSMOrigin.osf*
- *pscsosfStsAtFindXYTBeamOffset.osf*
- *pscsosfStsAtFindXYTImageScale.osf*
- *pscsosfStsAtFindXYTThetaOffset.osf*
- *pscsosfStsAtFindUVWAngleOffset.osf*
- *pscsosfStsAtFindUVWtoFSM.osf*
- *pscsosfStsAtFindUVWtoXYT.osf*

After the calibration of the Azimuth reference point and derotator center and the visualisation of the M10 edge using the DL metrology ghosts, the Azimuth Reference Position in the database was updated with the x-coordinate of the M10 edge and the y-coordinate of the derotator center. It is the "on-axis" position that minimises the pointing errors when swapping.

Then the TIOs measured pointing models for each telescope in the nights after the re-locations. Then the pointing was tested on sky and the plate scale of the CCD re-measured using a binary star.

5.2.3.2 Problems and issues

In the case of both telescopes, for the derotator center, the value proposed by the script was not used, as it does not represent the real derotator center. But the raw data were noted and J. Woillez computed the position of the center using his Excel script (see figure below). The osf script will be modified in the future to integrate this new computation.



Beacon run-out on the TCCD when rotating the derotator on AT#4. The "external error" corresponds to the offset of the starting position of the beacon w.r.t. the center of the derotator. The "internal error" is intrinsic to the derotator and is the minimum run-out that can be obtained if the beacon were optimally aligned on the "center".

A couple of typos were noted when using the osf scripts. The computation related to the rotation matrices (between FSM piezo X-Y, TCCD, XY-Table and UVW coordinates) will also have to be corrected. This will be done in the next version of the scripts.

On AT#3 due to the strong blooming of the TCCD, the value calculated by the script for the Aximuth reference position and derotator center could not be used as such. Indeed the centroids were totally shifted by the blooming. Fortunately the scripts display the values of the maxima of the beacon spot on the TCCD and it was checked that this value was not affected by the blooming and was a good representation of the beacon position. Thus the values of the maxima were noted manually and the Azimuth reference position and derotator center computed off-line. In the future, the osf scripts will be modified to provide both values: the ones computed based on the centroid position and the ones based on the maxima position. The user will then have to choose which one is the best adapted and update the database accordingly.

For AT#4, originally, it was not possible to bring the DL metrology ghost of FSMA (seen on the TCCD with the Coudé Beam Switching Device in position "MIRROR") on the reference position of the azimuth (on M10 edge): we were reaching the limits of the piezo (38 ; 38) µm before arriving to that point. An AUTOZERO procedure (through the FSM GUI button or with low level instruction) did not solve the problem and was more limiting the range of the piezo. It was then checked that the piezo could move over the full range of voltage (corresponding to 0 to 38µm set points) and it was the case. Therefore the problem was identified as a slight misalignment of FSMA mechanism with respect to the azimuth reference point. It is probably due to the fact that the STS had to be pushed to the limit of its translation to put M10 at the focus of the telescope, therefore lowering the corresponding on-axis position on the M10 edge. It was then decided to correct this misalignment using the manual adjustment screws of the FSM mechanism, which were fortunately easily accessible on station G2. For the FSMA piezos at their nominal position of (28; 28) μm, the manual screws were used to center the DL metrology ghost on the azimuth reference position calibrated before. The fine final adjustment was done with the piezos giving optimal positions of (27.61; 27.8) μm (for station G2, re-measured and slightly different for station J2)

The scripts related to the XY-table on AT#4 were difficult to run because the optimisation of the flux on the 4 quadrants of STRAP (to center STRAP on the beacon was not converging. This is due to the fact that the STRAP head installed on AT#4 is still off the old type and has a central obstruction. And as the new STS was well installed at the focus of the telescope, the beacon is almost completely absorbed by the central obstruction. The work around was to do the optimisation of the flux by hand: putting a "large" offset in X (>1mm on the XY-Table), we balanced the flux on the 2 Y-halves of the quad-cell by moving the XY-Table step by step in Y; then putting a "large" offset in Y, we balanced the flux on the 2 X-halves[1]. Then the XY-Table was set to the measured Y and X coordinates and the loop could be closed. To solve this problem, it is recommended to install a new STRAP head.

5.2.3.3 Obtained values

The values computed for the various STS parameters were introduced on a temporary basis in the database (with commands like *msgSend latXfsm pspzServer UPDATE ""*) and the pointing tested. At the end of the run, two PPRS were created to update this values on a permanent basis by changing the INSROOT files. This was done by Guillermo Valdes after the end of the run. The updates values are the following:

<u>AT#3-A1 (files *.dbcfg.STS):</u>

```
@wat3tcs:Appl_data:TCS:agws:control:cfdBeam.beamOffsetsSTS
        => line 2 = SPLIT    -1.652   -0.012   2   2

@lat3dcs:probe:control:atp:refPoints:azimuthAxis:ccd.xPos = 218
@lat3dcs:probe:control:atp:refPoints:azimuthAxis:ccd.yPos = 119
@lat3dcs:probe:control:atp:refPoints:azimuthAxis:xyt.xPos = 1.144
@lat3dcs:probe:control:atp:refPoints:azimuthAxis:xyt.yPos = 3.490

@lat3dcs:probe:control:atp:ccd:config.imageScale = 6.55
@lat3dcs:probe:control:atp:ccd:config.thetaOffset = -0.0242
@lat3dcs:probe:control:atp:xyt:config.imageScale = 0.423
@lat3dcs:probe:control:atp:xyt:config.thetaOffset = 3.109

@lat3fsm:pspz:config:PosLoop:mirror1:maxPos.x = 37.99999
@lat3fsm:pspz:config:PosLoop:mirror1:maxPos.y = 37.99999
@lat3fsm:pspz:config:PosLoop:mirror1:minPos.x = 0
@lat3fsm:pspz:config:PosLoop:mirror1:minPos.y = 0
```

---

[1] It seems that the graphical representation of the fluxes on the quad cell on the STRAP usual GUI is inverted in X and Y, which is a little confusing at the beginning.

```
@lat3fsm:pspz:config:PosLoop:mirror1:origin.x = 32.13
@lat3fsm:pspz:config:PosLoop:mirror1:origin.y = 28.63

@lat3fsm:pspz:config:PosLoop:mirror2:maxPos.x = 37.99999
@lat3fsm:pspz:config:PosLoop:mirror2:maxPos.y = 37.99999
@lat3fsm:pspz:config:PosLoop:mirror2:minPos.x = 0
@lat3fsm:pspz:config:PosLoop:mirror2:minPos.y = 0
@lat3fsm:pspz:config:PosLoop:mirror2:origin.x = 13.23
@lat3fsm:pspz:config:PosLoop:mirror2:origin.y = 8.35

@lat3vcm:pspz:config:PosLoop:mirror1:maxPos.x = 37.9999
@lat3vcm:pspz:config:PosLoop:mirror1:maxPos.y = 37.9999
@lat3vcm:pspz:config:PosLoop:mirror1:minPos.x = 0
@lat3vcm:pspz:config:PosLoop:mirror1:minPos.y = 0
@lat3vcm:pspz:config:PosLoop:mirror1:origin.x = 18.9
@lat3vcm:pspz:config:PosLoop:mirror1:origin.y = 21

@lat3vcm:pspz:config:PosLoop:mirror2:maxPos.x = 37.9999
@lat3vcm:pspz:config:PosLoop:mirror2:maxPos.y = 37.9999
@lat3vcm:pspz:config:PosLoop:mirror2:minPos.x = 0
@lat3vcm:pspz:config:PosLoop:mirror2:minPos.y = 0
@lat3vcm:pspz:config:PosLoop:mirror2:origin.x = 17
@lat3vcm:pspz:config:PosLoop:mirror2:origin.y = 19
```

AT#4-J2 (files *.dbcfg.STS):

```
@wat4tcs:Appl_data:TCS:agws:control:cfdBeam.beamOffsetsSTS
        => line 2 = SPLIT    -1.692   0.061   -1.47   2.83

@lat4dcs:probe:control:atp:refPoints:azimuthAxis:ccd.xPos = 198.9
@lat4dcs:probe:control:atp:refPoints:azimuthAxis:ccd.yPos = 183.0
@lat4dcs:probe:control:atp:refPoints:azimuthAxis:xyt.xPos = -0.52
@lat4dcs:probe:control:atp:refPoints:azimuthAxis:xyt.yPos = 1.805

@lat4dcs:probe:control:atp:ccd:config.imageScale = 7.074
@lat4dcs:probe:control:atp:ccd:config.thetaOffset = -0.03178
@lat4dcs:probe:control:atp:xyt:config.imageScale = 0.454
@lat4dcs:probe:control:atp:xyt:config.thetaOffset = 3.1392

@lat4fsm:pspz:config:PosLoop:mirror1:maxPos.x = 37.99999
@lat4fsm:pspz:config:PosLoop:mirror1:maxPos.y = 37.99999
@lat4fsm:pspz:config:PosLoop:mirror1:minPos.x = 0
@lat4fsm:pspz:config:PosLoop:mirror1:minPos.y = 0
@lat4fsm:pspz:config:PosLoop:mirror1:origin.x = 27.95
@lat4fsm:pspz:config:PosLoop:mirror1:origin.y = 26.77

@lat4fsm:pspz:config:PosLoop:mirror2:maxPos.x = 37.99999
@lat4fsm:pspz:config:PosLoop:mirror2:maxPos.y = 37.99999
@lat4fsm:pspz:config:PosLoop:mirror2:minPos.x = 0
@lat4fsm:pspz:config:PosLoop:mirror2:minPos.y = 0
@lat4fsm:pspz:config:PosLoop:mirror2:origin.x = 12.07
@lat4fsm:pspz:config:PosLoop:mirror2:origin.y = 7.73

@lat4vcm:pspz:config:PosLoop:mirror1:maxPos.x = 37.9999
@lat4vcm:pspz:config:PosLoop:mirror1:maxPos.y = 37.9999
@lat4vcm:pspz:config:PosLoop:mirror1:minPos.x = 0
@lat4vcm:pspz:config:PosLoop:mirror1:minPos.y = 0
@lat4vcm:pspz:config:PosLoop:mirror1:origin.x = 19.42
@lat4vcm:pspz:config:PosLoop:mirror1:origin.y = 23.5
```

```
@lat4vcm:pspz:config:PosLoop:mirror2:maxPos.x = 37.9999
@lat4vcm:pspz:config:PosLoop:mirror2:maxPos.y = 37.9999
@lat4vcm:pspz:config:PosLoop:mirror2:minPos.x = 0
@lat4vcm:pspz:config:PosLoop:mirror2:minPos.y = 0
@lat4vcm:pspz:config:PosLoop:mirror2:origin.x = 18.7
@lat4vcm:pspz:config:PosLoop:mirror2:origin.y = 21.7
```

Note: The rotation matrices (UVW to FSM or XYTable or TCCD) were not updated.

5.2.3.4 Verification of the pointing

With the above parameters both telescopes could be pointed efficiently using the usual procedure:

- CORRECT FROM GS

- OPTIMISE STRAP

- CLOSE LOOP - Field Stabilisation

The 2 stars were then immediately in IRIS field of view. The ISS alignment GUI for the FSM could be used to center by hand and the laboratory guiding loop IRIS-FSM could be closed. The field stabilisation was kept running during a long period without lab guiding and the beams remained centered in IRIS field of view.

The alignment offsets to be sent to the FSM to center the stars on IRIS were small (<60" physical => < 0.6" on sky) and did not have to be changed after swapping.

Visually no differential defocus and no strong aberration (e.g. coma) were observed. However specific quantitative measurements of these aspects were not performed.

5.2.4 Pupil alignment and verification

The pupil alignment was verified and adjusted on sky, with a very bright star. The pupil was imaged on IRIS pupil viewer bypassing the Differential Delay Lines and offsetting the set point of the VCM of the Delay Lines to have a sharp pupil image. The pupil were aligned to be at the center points of the fields limiting the pupil (identified by scanning the pupil with the handset). This is close to the pupil circles automatically defined on IRIS. I did not use these circles because it is not certain that they were calibrated for the configuration of the laboratory that was used. Anyway, the fine alignment will have to be done by closing the loop of the PRIMA Metrology on the retro-reflector (either the one at the Coudé or the one at the center of M2). This will be done during the June run.

For AT#3 on A1, the handset was used to center the stellar pupil as well as possible with piezo values of 19µm (middle of range). Then a fine alignment was performed with the piezos of the VCM leading to values of (18.9 ; 21) and (17 ; 19) µm for FSMA and FSMB respectively.

On AT#4, the pupils were first checked and aligned on station G2 where the access to the ROS was easy. The handset control for the motorised slow alignment of the STS-VCM was used to center the pupil on IRIS. When moving the telescope to J2, the pupil had moved so little that it was fully within the range of the VCM piezos and no additional alignment with the handset was done. The fine alignment values of the VCM piezos are in this case (19.42 ; 23.5) and (18.7 ; 21.7) µm for FSMA and FSMB.

The Delay Line VCM pupil offsets that were imaging the pupils on IRIS pupil viewer were respectively 20m and 25m for AT#3-A1 and AT#4-J2. This seems to be quite compatible with the expected pupil position due to the non-optimum radii of curvature (to be verified quantitatively).

Screen shots of the pupils on IRIS have been taken but are still on Paranal computers (not directly transferrable to Garching). One can see a very slight vignetting of the pupil to the side on AT#4 - FSMA mainly by a circle of slightly larger diameter. This vignetting occurs "upstream" from the STS VCM and is probably at the level of the alignment of the telescope pupil with the FSM of the STS. The run-out of the pupil was not measured because it is not supposed to be different as the derotator has not been exchanged nor re-aligned.

5.2.5 New STS transmissivity

With the help of the TIOs, Philippe Gitton's procedure to measure the transmissivity of the telescopes till IRIS in J, H and K bands has been adapted and used for both AT#3 and AT#4. This will allow the comparison of the transmissivity with and without the STS (without => using measurement done routinely in April). During the measurements, the Beam Compressors were used but not the Differential Delay Lines.

It was not possible to adapt the script to measure simultaneously single-feed and dual-feed telescopes. Indeed, during the procedure IRIS has to take a background and sends OFFSGUVs to the Coudé for that. The ways to forward these commands (to the XY-Table in single feed and to the FSM with dual-feed) are not compatible together.

Data on only dual-feed telescopes were taken during 2 nights. The data have not been reduced yet. This report will be updated when the results of the transmissivity tests become available.

5.3 **PRIMET return from primary space retro-reflector**

5.3.1 Rationale

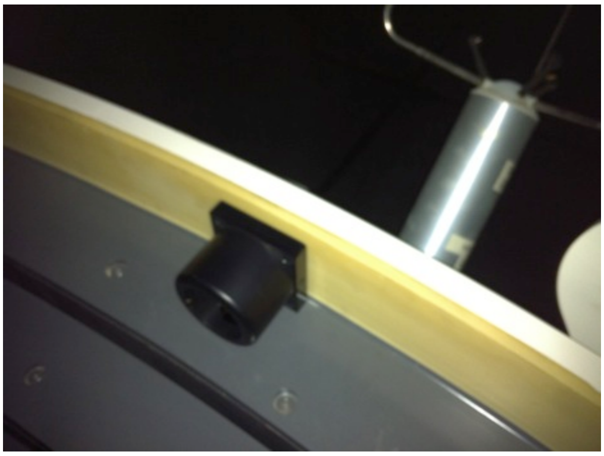
As the STS3 and STS4 alignment and performance verification was ahead of schedule an opportunistic PRIMET test was carried out on AT4, involving a corner cube retro-reflector placed in front of M1 in primary space. The goal of the test was twofold.

- Check the returned flux from a corner-cube place in a collimated beam as a way to investigate the contribution of the lens in the smallest M2 retro-reflector assembly to the amplitude loss which, combined to the polarization losses, are responsible for the initial M2 retro-reflector failure.

- Perform a first assessment of the functional viability of extending PRIMET beyond M2, into primary space, for a potentially more stable narrow angle baseline implementation.

5.3.2 Procedure

Borrowed from the PRIMA auto-collimation setup with the delay lines, a 63 mm diameter protected gold hollow corner cube retro-reflector was installed on the edge of the northern dome shutter of AT4, as shown in the picture below. The telescope was then pointed to its minimum elevation angle (Elevation ~20 deg) and in the direction of the corner cube (Azimuth ~200 deg), as a way to “install” the corner cube inside the telescope aperture. The PRIMET metrology was turned on to its maximum intensity (300 mW, 100% AOM transmission, no neutral density). Using the search



feature of the pupil tracker, a return flux was finally detected for a VCM pointing at an offset of the telescope chief ray. The returned flux was then optimized on the quad-cell by 1) adjusting the longitudinal position of the pupil with the DL VCM, and 2) orienting the derotator to an angle providing the best polarization transmission for the telescope attitude in use. For a total quad-cell gain of 1 (PGA gain of 1, TRA gain of 1), the returned flux was measured at SUM = 1.5 V.

5.3.3 Implications on M2 retro-reflector amplitude transmission

This measurement confirms that the major contributor to the failure of the small M2 retro-reflector is the amplitude effect, probably caused by the wrong focal length for the lens in the retro-reflector assembly. Indeed, in the polarization optimized orientation of the derotator, the returned flux at maximum PRIMET flux was on the order of a few volts but only with a quad-cell gain of x100. In addition, the 63 mm retro-reflector in primary space corresponds to a 6.3 mm retro-reflector at M2, whereas the small M2 retro-reflector is on the order of 10 mm, contributing to a returned flux difference of x2.5. Removing the x4 double-pass contribution of the beam splitter in the small M2 retro-reflector assembly, the double-pass contribution of the lens should be on the order of x60. This number is somewhat in agreement with the amplitude error budget, constructed for the AT4 retro-reflector measurements given in Nicolas Schuhler’s report (http://vlti.pl.eso.org/tec_doc/VLTISE-NSC-2012-011.pdf), and predicting a x32 contribution of the lens.

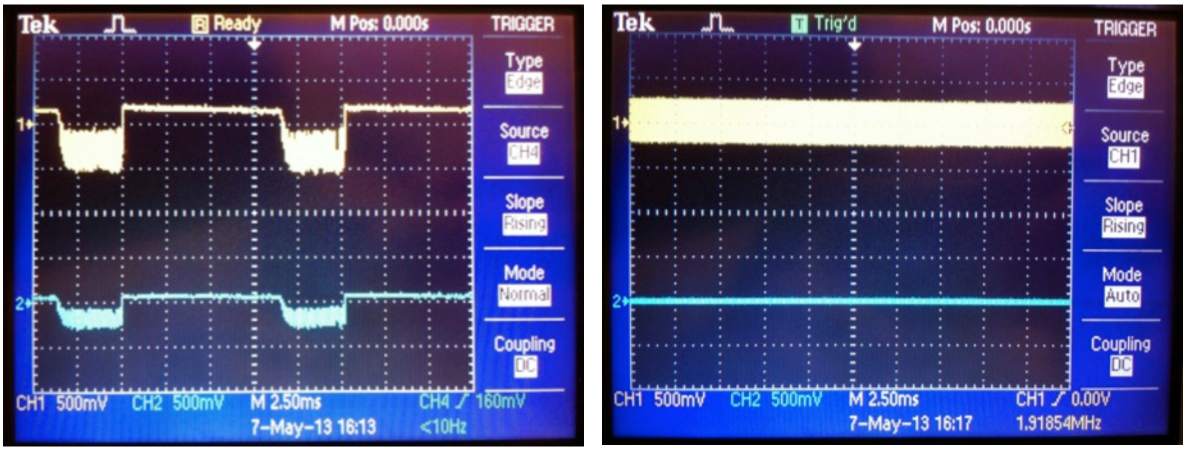
To put this test into a broader context, the small (12.5 mm) M2 retro-reflector is currently being replaced by a larger (25.4 mm) retro-reflector also located at M2, that does not contain any 50:50 beamsplitter, and has a lens with an (hopefully) improved focal length.

5.3.4 Implications on extending PRIMET to primary space

The returned flux measured on the PRIMET pupil tracker (SUM = 1.5V) is compatible with the operation of the phase meter, based on past M9 retroreflector working configurations. Therefore, the installation of a 63 mm retroreflector on the telescope spiders looks promising as a potential way forward for the extension of PRIMET beyond M2, but will still require further investigations. There is also enough VCM range to make PRIMET work with an offset from the telescope chief ray.

5.4 **DDL 1 & 3 metrology failure**

While checking out the health of the PRIMA subsystems, it was noticed that the DDL would come online. The problem was traced down to an issue with the metrology of DDL 1 and 3. The initial suspicion was that the metrology was misaligned. Further investigations, while attempting to recover the alignment, showed that the metrology laser head for these two DDL was failing. The two pictures below show the metrology signals detected for all four DDL (Left: 1=DDL1, 2=DDL3, Right: 1=DDL2, 2=DDL4). DDL2 shows a nice heterodyne modulation of 500 mV amplitude. DDL4 has no signal, but this DDL is known to have an alignment issue that does not impact basic astrometric performance and awaits an intervention on the metrology towers inside the vacuum vessels. DDL1 and DDL3 display intermittent modulations and are the symptoms of a failing laser head.



Measurement of the DDL metrology signals. Left: DDL1 and DDL3 in channels 1 and 2 respectively. Right: DDL2 and DDL4 in channels 1 and 2 respectively.

A spare laser head is currently being shipped to Paranal from Geneva, through Garching, for a replacement scheduled for the June technical run.

6 Perspectives

The STS for AT3 and AT4 are both ready for the June integration run, with the only exception that the final exact RoCs for the VCM need to be installed. If the new VCMs are not ready, the system can however be operated with the current ones by applying an offset of the pupil of the Delay Lines of 20m and 25m respectively (AT3-DL6 and AT4-DL4). A minor alignment check is expected in June, especially if the VCMs are exchanged. The failure of the DDL metrology is however adding an additional activity to the June run. The new large retro-reflectors at the center of M2 could not be tested due to the failure of the M2 hexapod and will have to be tested (interface and return flux) before or during the June run.

Overall, the project stays on the schedule established at the beginning of 2013. June will be the integration run with the validation that we can go back on sky with PRIMET at M2. August and September will be the astrometric performance assessment runs, in time for the PRIMA Gate Review ahead of the fall 2013 STC.

Remarks:

- At some point, one should install the new STRAP heads in the dual-feed ROS. The ones without the central dead zone.
- There could soon be a problem with the TCCDs. According to Frédéric Gonté, the old TCCDs in Paranal are failing and starting to be a rare item. No old TCCD can be obtained from decommissioning on the UTs for the remaining 2 STS and there is no spare in case one fails in one STS. The TCCD currently installed in the STS could even be cannibalised in case one is missing on an operating system. This would therefore jeopardize the autumn gate review milestone. We should be looking into the issue.