CHARA AO
Preliminary Experiments

Version 0.3

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Version	Change / Sections / Remarks
0.1	Creation
0.3	Version at the end of 2017/09 comm run.

1. Executive Summary

This document summarizes the tests performed during the Commissioning of 2017-09-20 to 2017-09-27. The labAO DM and WFS of all telescopes were working during this commissioning. The telescope WFS were all working, although not intensively used, during this commissioning. No ALPAO DM was available.

The main conclusions are:

- The existing systems work well and are robust. Their operation can be made smooth with reasonable effort.
- Most of the improvement in image quality by labAO is from telescope aberrations. The limiting magnitude of labAO is V~4.
- The main open question is whether the pupil shear will be satisfactory and stable during the night.

2. Reference Documents

3. Overall requirements

The CHARA reference beam in the laboratory is defined by two reference-targets: one located in the lab-beacon table and one behind the beam sampler table[1].

The stellar beam shall reach the laboratory un-vignetted, and with a lateral position <1mm from the laboratory reference axis defined by the targets (5% of beam size). Its mean angle shall be <15as-lab-optical from the laboratory reference axis defined by the targets (<0.26as-sky).

To allow efficient injection into single-mode fibers, the static wavefront flatness of the stellar beam in the lab shall be <100nm-rms-optical for near-IR instruments and <30nm-rms-optical for visible instrument.

The requirement for stability for angle over 30min is typically <0.05as-sky for near-IR instruments and <0.02as-sky for visible instruments. As a goal, this stability should be maintained during several hours to allow blind instrument pointing on faint stars.

4. Guiding strategy with Tel-AO and Lab-AO

4.1. On both end of the machine: the Wavefront Sensors

- The star is guided in angle/focus/aberration in the T-wfs (M2+DM).
- The L-wfs is maintained in angle/focus/aberration with the laboratory reference beam (L-wfs reference spots).

4.2. Linking the T-wfs with the L-wfs

- The T-beacon is maintained in focus with the L-wfs (T-beacon parabola).
- The T-beacon is maintained in angle with the pinhole (T-beacon flat).
- The T-wfs is maintained in angle with the T-beacon (T-wfs reference spots).
- The T-wfs is maintained in focus with the T-beacon (acquisition parabola). Actually this is partially

[1] This reference beam is materialized operationally with a green laser aligned in angle and in lateral position with these targets. This reference beam can be feed with a green laser or a white light source.

- The T-beacon is maintained in angle with the L-wfs (DIC).
- The T-beacon is maintained in aberration with the L-wfs (lab-DM).

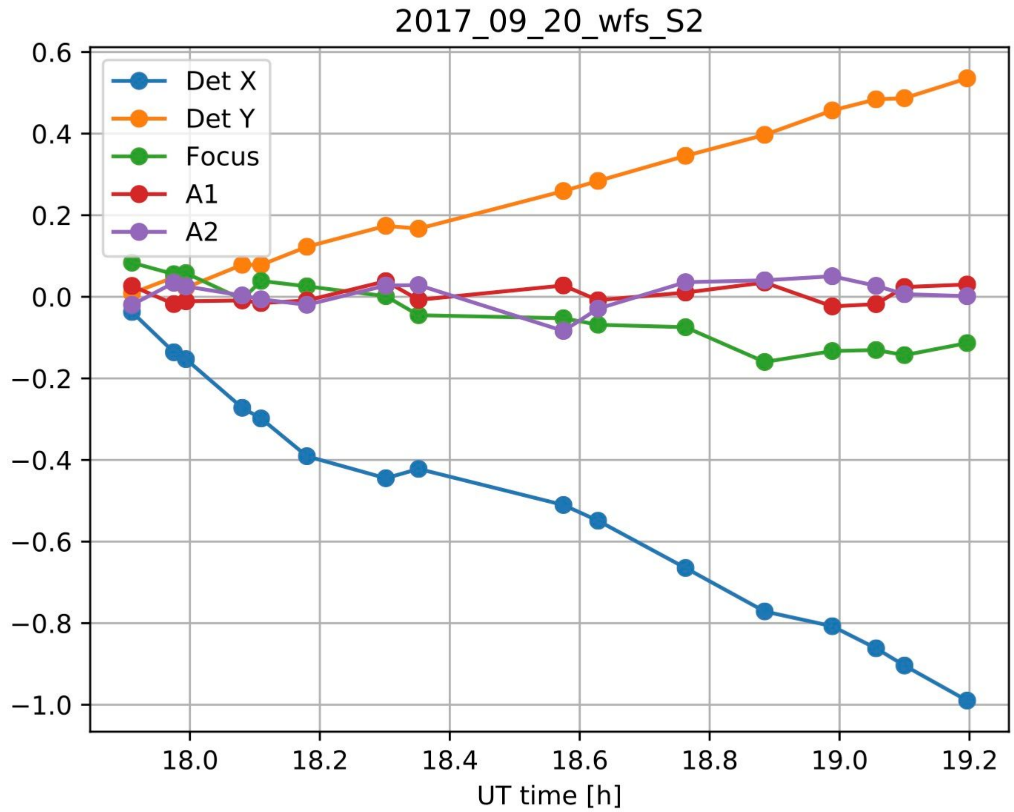
5. Stability of T-Beacon with T-WFS

We want to assess the short-term stability of the telescope beacon with respect to the telescope WFS.

5.1. Daytime measurement

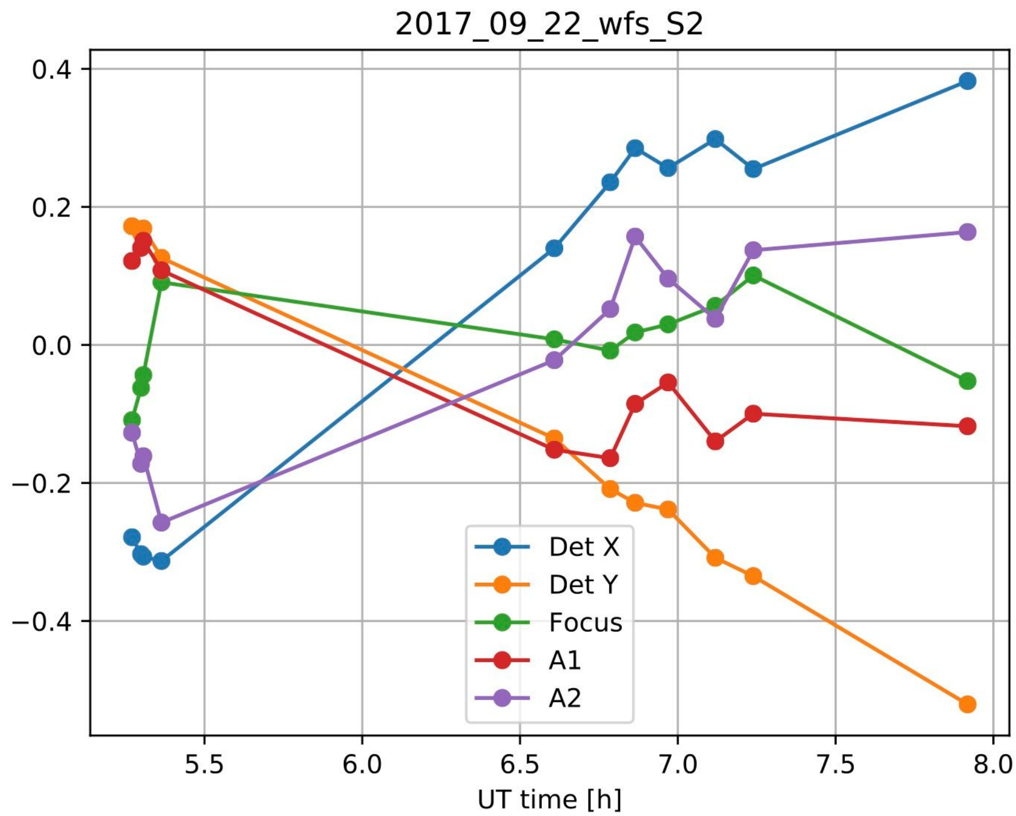
We align the telescope beacon with the telescope WFS. We record the Zernikes by files of ~1s over several hours during the day, starting at 11am. The results are shown in figure below. The tip-tilt increases linearly over time. After 1.2h, the spots reach the outer boundary of the sub-aperture.

The scaling of the result is unknow. A displacement of ~0.2 corresponds to the size of the sub-aperture spot on the WFS. The spot size is lbd/D/6 = 0.6as-sky. Therefore the scaling is around 3as-sky/unit. The result shows a motion of ~0.6unit/30min, hence **1.7as-sky/30min**.



5.2. Night time measurement

We repeated these measurements during the night. The results are shown in figure below. The tip-tilt increases linearly over time. After some time, the spots reach the outer boundary of the sub-aperture. Assuming the scaling of 3as-sky/unit, the result shows a **motion of 0.6as-sky/30min**.



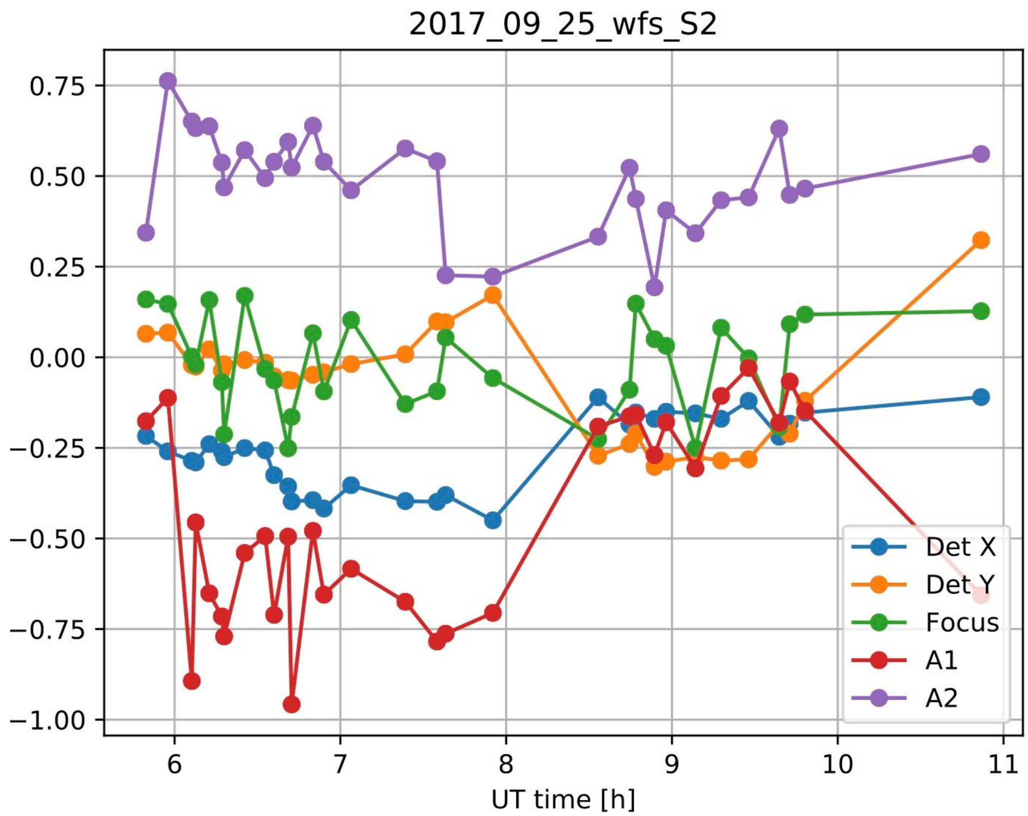
5.3. Discussion

The result point toward a temperature sensitivity of the relative alignment (constant drift, less during the night). During the night, the stability is compatible with ~5min of operation with MIRCx.

During the test, the telescope hit the limits and probably stopped quickly. The telescope beacon get completely off.

6. Stability of the T-WFS with lab

In order to disentangle the beacon part and the WFS part of the optical bench, we investigated the stability of the the stellar spot on the T-WFS. Actually, this was done while the star was guided from the laboratory guiding (quad-cell). Therefore this stability contain all the term up to the laboratory.



Note that we change star around 8h. We also changed star at 9h30, but staying on a nearby position on sky. And again a 10h. It seems the astigmatism depends on the position on the sky but is rather stable in time.

We measure a motion of **0.2as-sky/30min for tip/tilt**. This is significantly smaller than the motion of the T-beacon to the T-WFS. Hence the main culprit for the instability reported in the previous section is a motion of the beacon itself.

7. Stability of MIRC with L-WFS

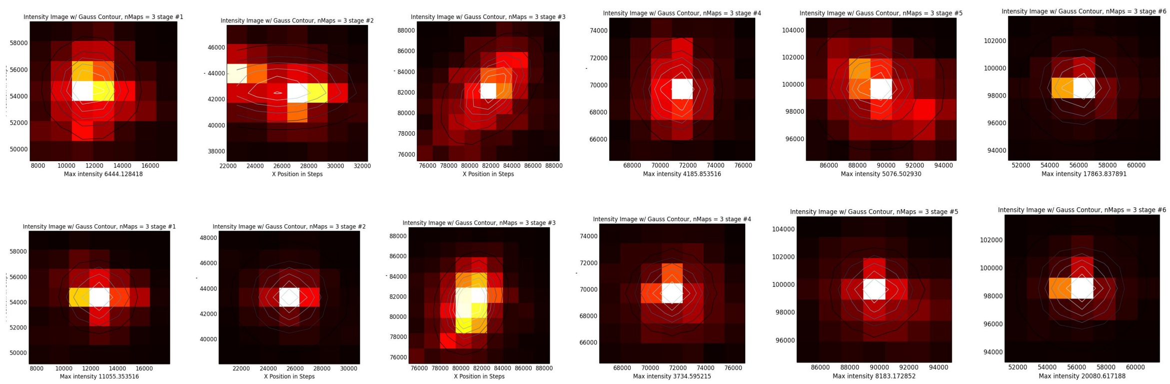
Visually, the MIRC axis and the laboratory reference-axis are stable at <0.2as-sky over hours. However, at night, what really matter is the stability between MIRC and the L-WFS. This hasn't been established yet but the we believe the risk is low. A possible procedure to quantity this stability could be:

- Set the white-light source in the lab, with the flat reference mirror on the DL.
- Close the lab-AO loop (L-WFS and T-WFS), including tip-tilt.
- Perform regular fiber-explorer on MIRC.

8. Running labAO with the star light

8.1. Improvement in image quality

The following images are the MIRC fiber explorers for telescope W1-S2-S1-E1-E2-W2, without (top) and with (bottom) labAO running at 40Hz on a bright star in V-band. The tip-tilt was guided from the lab, by the quad-cell sensor. Each pixel is 0.4”.



The corrected aberrations are mainly focus, astigmatism and coma. In all cases, the labAO DM reached saturation or almost (command = 1 on some actuator).

8.2. Limiting magnitude

With the blanc DIC and tip-tilt guided from the lab with the quad-cell, the labAO works well for V<2.5. It till corrects significant static correction for V<4.5, but not much help below that.

8.3. Beam shear

Many beam trains showed ‘pupil shear’ or vignetting of order 1 sub-aperture on the WFS that was not possible to recover. We are not sure why. It would be interesting to check if this shear rotate with azimuth.

9. Brainstorming about alignment procedure

9.1. Prerequisite

Here is a list of prerequisite for the static optics on the telescope.

A beam aligned in angle with Azimuth axis and centered in M5-cover, shall be:

- centered laterally on the Azimuth axis (M6-M5)
- centered laterally on the Elevation axis (M4)
- centered laterally on M1 (M3-M2)

The focus of the pinhole shall be compatible with the focus of the reference beam in the lab, so that the T-beacon can pass the pinhole un-vignetted.

9.2. Regular alignment

- Define the reference spots on the L-WFS with the L-GREEN. How to ensure the L-DM is truly flat during this procedure ?
- Align M7 so that the angle of reference-axis is aligned with the Azimuth mechanical axis (so called Coude alignment). This is done by minimizing the run-out of L-GREEN on acquisition camera (corner-cube on M2).
- Aligne M10/Periscope/Pop to have a non vignetted L-GREEN beam centered on M5 (assuming Coude alignment is OK).

Warning: The two last points are iteratives!! Because the actuators (M7/M10/Periscope/Pop) move both the angle with respect to Azimuth mechanical axis and the shear on M5 cover.

9.3. Daily startup/alignment of beacon-link

- T-RED and G-GREEN (corner cube on M2) shall overlap to better than 1arc-sky, and fall within the hole in the acquisition camera. A possibility to do so is to:
  - Center L-GREEN on the hole with the DIC.
  - Overlap the reflections of L-GREEN and T-RED on the acquisition camera, with the beacon-flat.
  - This shall be automatized.
- After previous step, T-BLUE shall fall within a sub-aperture of the L-WFS. It is aligned onto the L-WFS:
  - Angle is aligned with beacon-flat.
  - Focus in aligned with beacon-parabola [BEACON FOCUS].
  - This shall be automatized.

- The spot of T-RED in the T-WFS are marked to be the reference position. The focus of the acquisition shall be changed only if the spots are really arranged in a non-regular way.

9.4. During the night / at slewing

- Regularly, T-RED is turned on and aligned onto the T-WFS with the beacon flat-mirror. (Hypothesis: Most of the drift of beacon versus L-WFS are tip/tilt from the beacon itself, not from the T-WFS). This procedure can be fully automatized because the star re-acquisition in T-WFS is robust.
- T-BLUE is kept guided on the L-WFS with DIC. The guiding can be kept during slewing and during beacon alignment.

10. Open questions

The safest operational scenario for night-time lab-guiding is to use the DIC only. Indeed, this optics is not seen in Coude alignment, nor in the alignment of the LASER-LAB toward M5.

Do we have an operational reference for possible lateral guiding? Could the L-wfs be maintained in lateral with the laboratory reference beam (beam steering = moving x-y the sub-apertures)?

Is the daily alignment toward M5 compatible with the previous Coude alignment ? Is the Coude alignment temperature dependent ? Shall we have daily Coude alignment ? Or at least during some night to have better temperature ?

11. Operational needs

LabAO start-up

- LabAO server shall be started at twilight. We often had the issue of dead processes, or processes stuck with sockman.
- Smaller the size of L-WFS (x0.4, this is just a change of ‘pixmult’)

T-WFS startup

- T-WFS camera and server shall be properly started at twilight. The main problem is that one has to first start the camera before the server (seems this ‘camera on’ is a kind of power cycle). Hence we should think on how to make this operationally stable. Or we should find a way to keep the T-WFS server running and reconnect to the camera when the latter is turned on.

- Once camera is on and T-WFS server started. One should: start the camera cooling, open shutter, start USB connection.
- Smaller the RTD display of T-WFS (x0.65)