# Findings about Alignment in the AO Era

Judit Sturmann

# Introduction

Using new tools, which we have as parts of the AO system, everything is under a magnifying glass, requirements became more strict.

We installed beacons on AO boards at each telescope. These are capable of sending collimated 5”-beams back to the lab.  Besides their main function, the beacon beams can serve also as new diagnostic tools: for example pinpointing vignetting close to the lab in the light pipes.

Some of the artificial sources should provide beams good enough for wave-front sensor calibration. We needed a new a procedure to check the focus of M1-M2 and the beacons; we now have a setup to do that using the rail telescope.

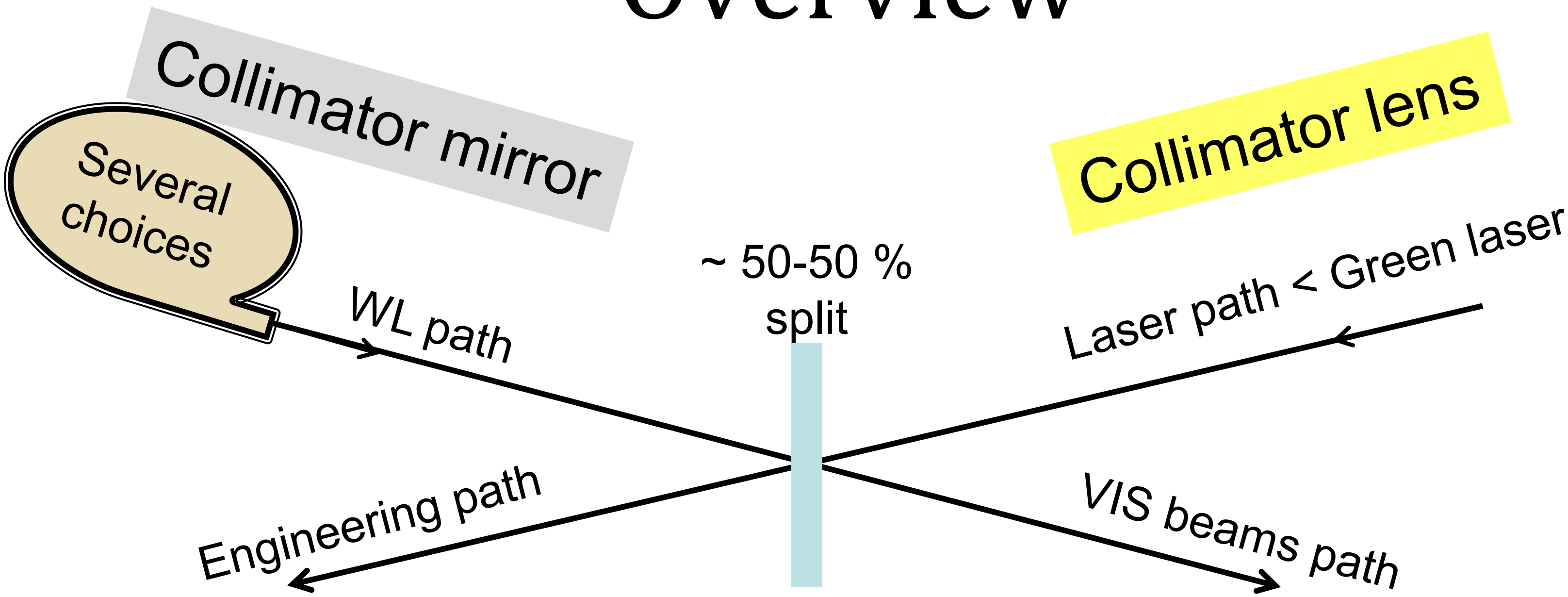
SH wave-front sensors for the LabAO are set up looking at the reduced beams of each telescope before turning to the BC area. The new sensors also provide means to start automating the routine daily alignment. Some known imperfections became, issues as we are trying to implement new automated procedures.

In this presentation I can share only a little bit of the findings associated with the implementation of the CHARA AO system.

# Topics Selected for this Presentation

- Alignment sources
- Using the rail camera: choosing the right time scale
- Lab-WFS auto align - except S1

# Alignment Sources in the Lab Overview




- Light in 1 beam at a time
- At least 4 time more light than normal path

- Light in 2 beams at a time
- Used also for phase referencing

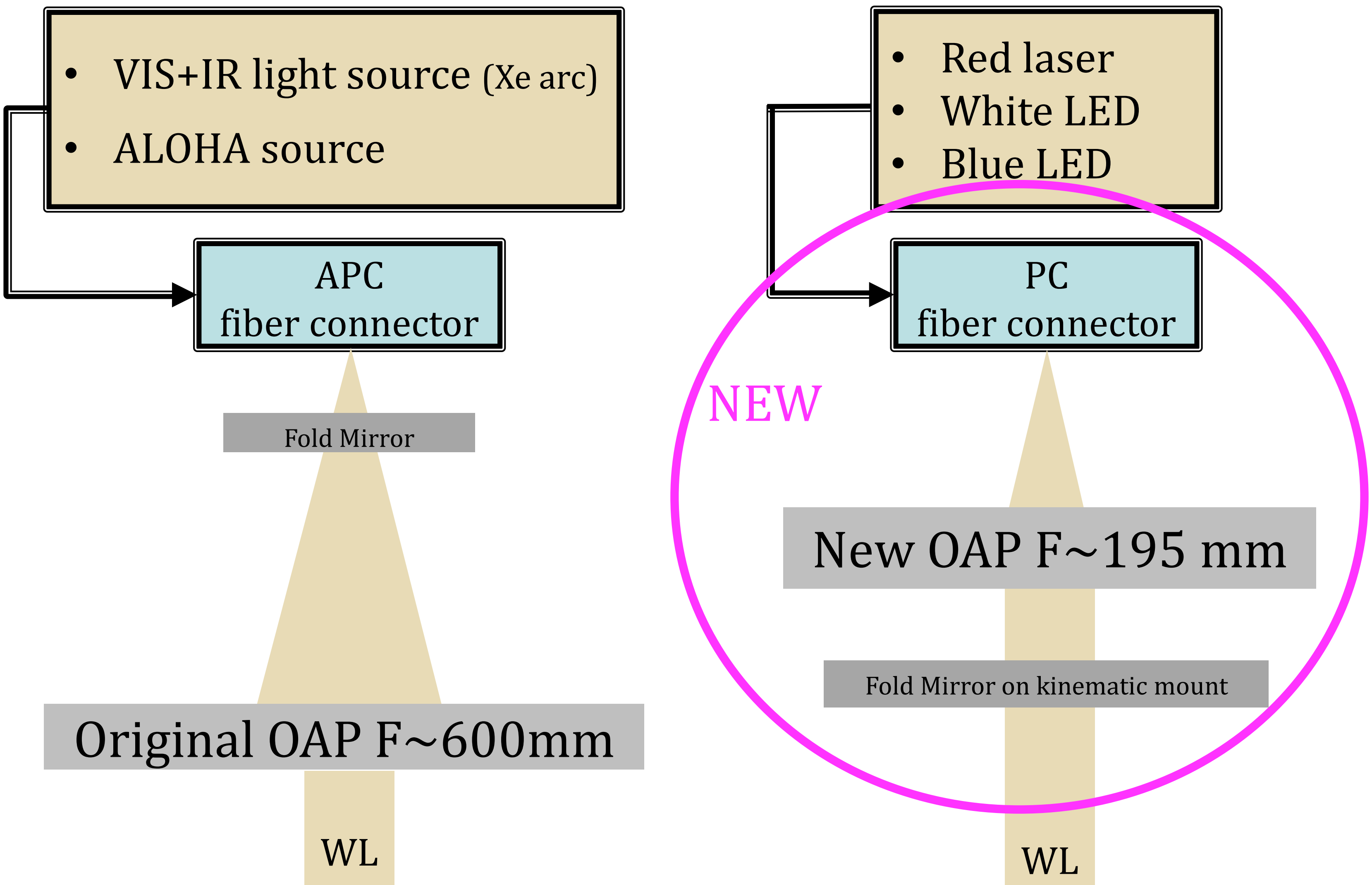
# Light Source Requirements for AO

1) new wavelength: BLUE

2) good quality wave-front for WFS calibration

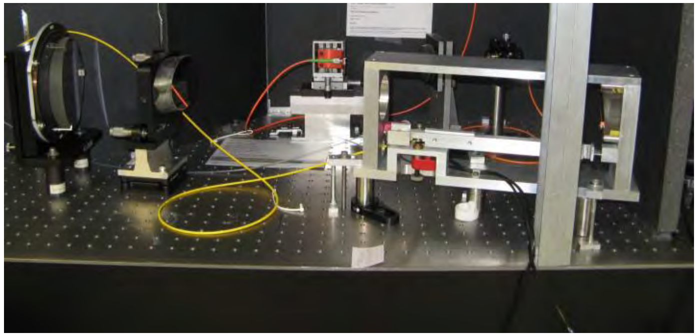
3) bright enough

# Available Through WL Path

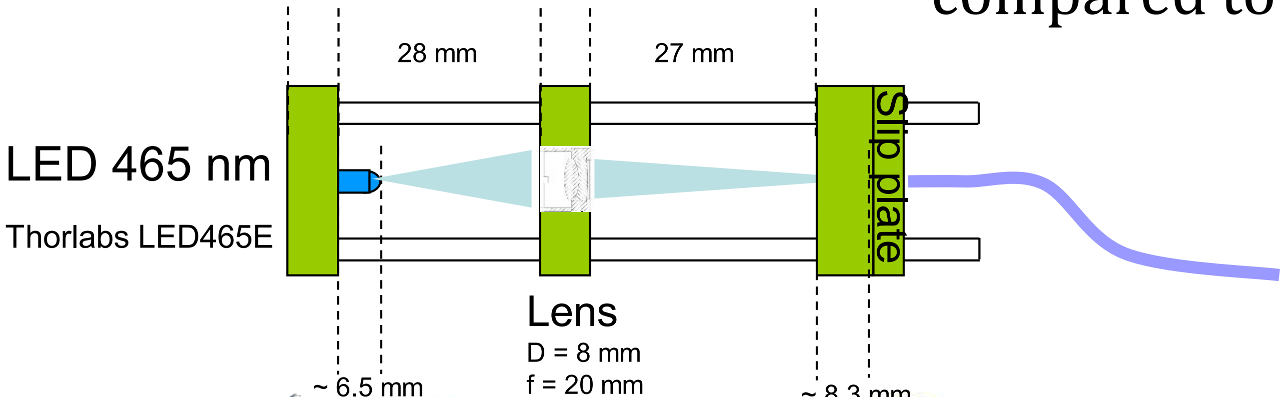


# Alignment Sources
## Recent Improvements

- New fiber collimator → more light due to better NA matching, more colors, more fiber connector type for lab alignment beam

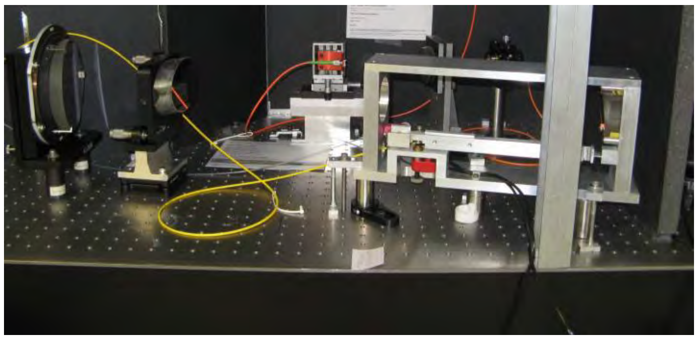


- Improved LED injection → over 3x more* blue light compared to first version injection



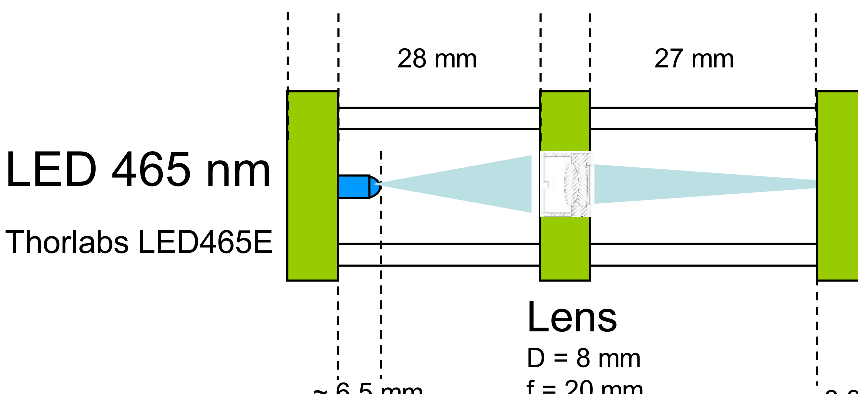
# Alignment Sources
## Recent Improvements

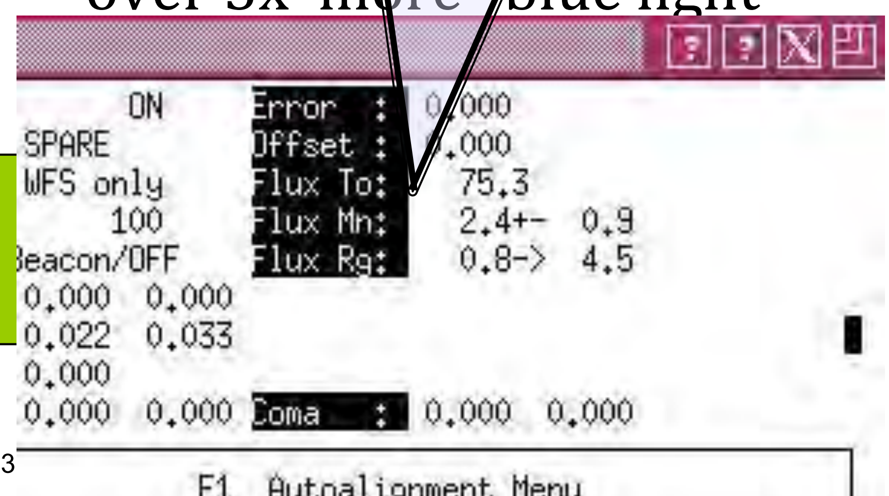
- New fiber collimator → more light, more colors, more fiber connector type for lab alignment beam



* S2 Labwfs total
old ~750 → new ~2750

- Improved LED injection → over 3x more* blue light



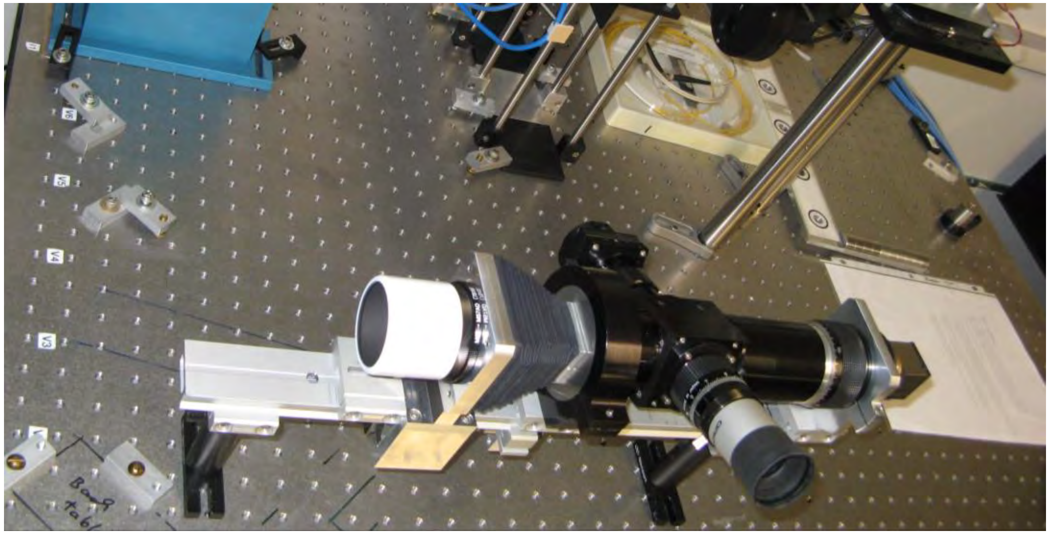
# Evaluation of the Lab Sources

## Procedure

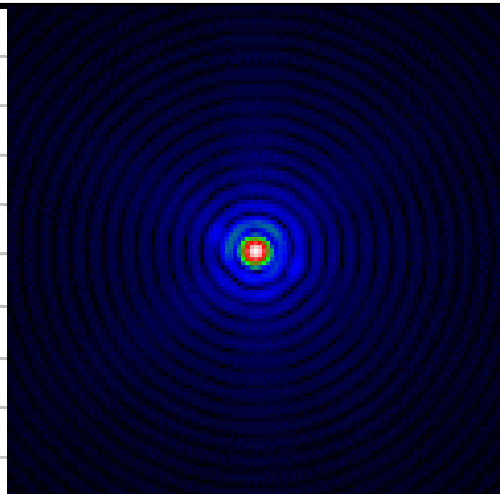
Having the Test-WFS focused on sky, I used to test the beam quality of the

- Green lab laser
- CHARA white light source
- New fiber collimator (white LED-light was injected into the fiber)

The Test-WFS was set up on the metrology table looking toward the lab sources in beam 4. Both the engineering path, and the normal path through the VIS beam combiner were tested with all sources.

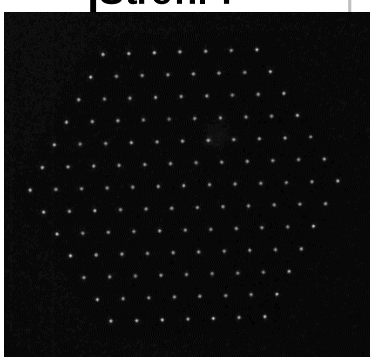


# Test-WFS Focused on Sky



**Full aperture** **D=50 mm**

**Strehl : 0.94**



$D_{lenslet}$~3.9 mm

8/12/2015

**Source: Vega**

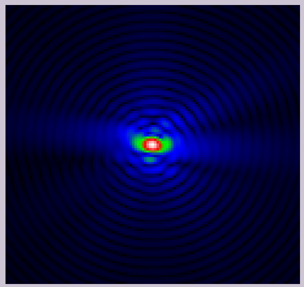
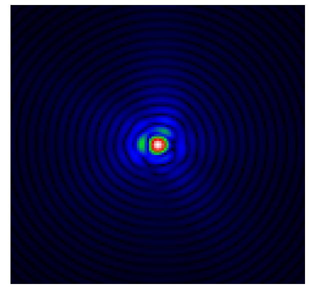
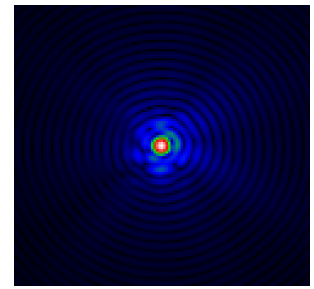
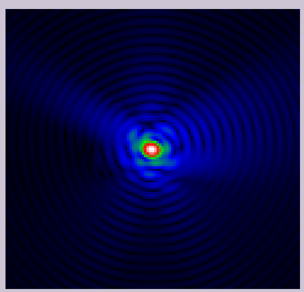
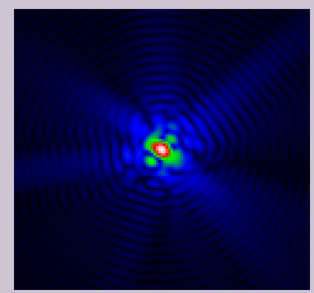
File names: focused-Vega___

| zernikes [µm] | Front Surfer Report [wave@550nm] | |
|---|---|---|
| -0.0044 | -0.0080 | focus |
| 0.0266 | 0.0484 | astigmatism |
| -0.0258 | -0.0469 | astigmatism |
| 0.0185 | 0.0337 | coma |
| 0.0021 | 0.0039 | coma |
| 0.0074 | 0.0134 | trifoil |
| -0.0063 | -0.0115 | trifoil |
| 0.0193 | 0.0350 | spherical ab. |
| -0.0072 | -0.0131 | |
| 0.0013 | 0.0024 | |

At the time of focusing, the Test-WFS had a green filter in it: peak at 550 nm.

# Lab Sources in the Test-WFS

Green filter in the Test-WFS (550 nm)

| | Green Laser | CHARA WL | New Fib.Collim.+White LED |
|---|---|---|---|
| Engb 4 |  |  |  |
| Focus term* | -0.068 μm | +0.013 μm | +0.008 μm |
| Strehl | 0.69 | 0.91 | 0.86 |
| VIS B4 |  | No data |  |
| Focus term* | -0.090 μm | | -0.049 μm |
| Strehl | 0.69 | | 0.60 |

* Corrected with the on sky focus term

These data were taken on 8/14/2015 with the on-sky-focused Test-WFS using the same green filter in the Test-WFS (550 nm)

Zernike coefficients* in μm measured in the lab

| | A | B | C | D | E |
|---|---|---|---|---|---|
| | Engb 4 | Engb 4 | VIS B4 | Engb 4 | VIS B4 |
| | CHARA WL source | Fib. launcher White LED | Fib. launcher White LED | Green laser | Green laser |
| focus | 0.013 | 0.008 | -0.049 | -0.068 | -0.090 |
| astigmatism | -0.004 | 0.010 | 0.102 | 0.010 | 0.009 |
| astigmatism | 0.023 | -0.026 | -0.003 | -0.077 | -0.024 |
| coma | 0.012 | -0.005 | -0.009 | 0.002 | 0.003 |
| coma | -0.037 | 0.046 | 0.026 | 0.026 | 0.055 |
| trifoil | -0.018 | 0.003 | -0.007 | 0.026 | 0.046 |
| trifoil | -0.036 | 0.015 | -0.014 | 0.012 | 0.038 |
| spherical ab. | -0.035 | -0.025 | -0.029 | -0.039 | -0.062 |
| | 0.007 | 0.003 | 0.005 | 0.021 | 0.008 |
| | 0.023 | -0.019 | -0.012 | -0.009 | -0.043 |

A: CHARA white light source → Engineering beam 4
B: New collimator + white LED → Engineering beam 4
C: New collimator + white LED → VIS B4
D: Green lab alignment laser → Engineering beam 4
E: Green lab alignment laser → VIS B4

* Corrected with the on sky terms

# Evaluation of Lab Sources Summary

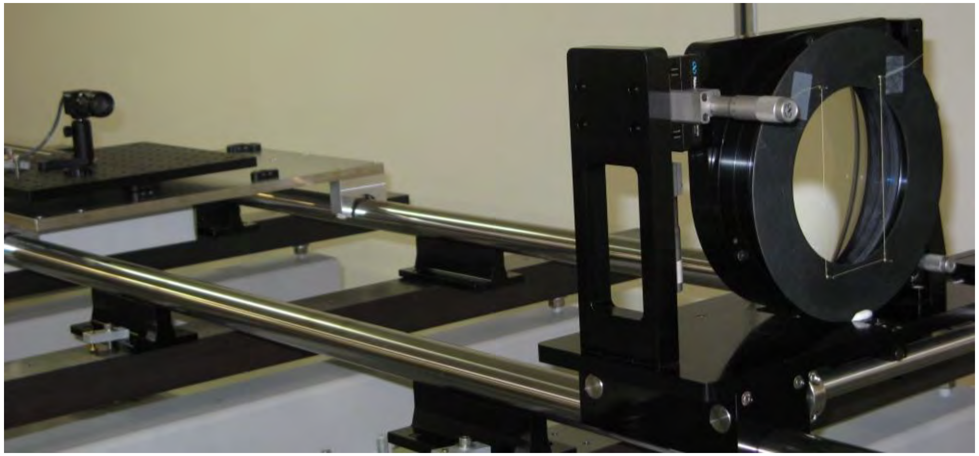
1. The wave front quality through the engineering path is better than through the VIS beam combiner.
2. Both collimators in the WL-path are well focused.
3. The first 10 terms of **wave-front aberrations** from both WL-path collimators are **under 50 nm through the engineering path** in front of the beam samplers.
4. The focus of the green alignment laser is not stable. (It was focused ~ 6 months before this test.)

For LabAO calibration
use the engineering beam with the blue LED

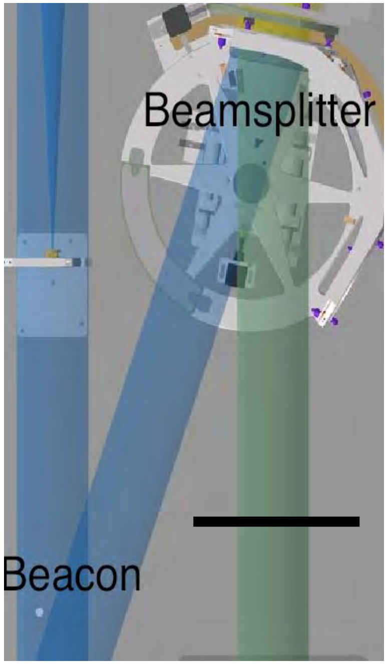
# The Rail Camera

This setup could be used to check the focus of the beacon or the telescope.

On the delay line



On the AO board




<u>The beacon on the AO board:</u>

F/8 on-axis parabolic mirror (F = 1.2 m )

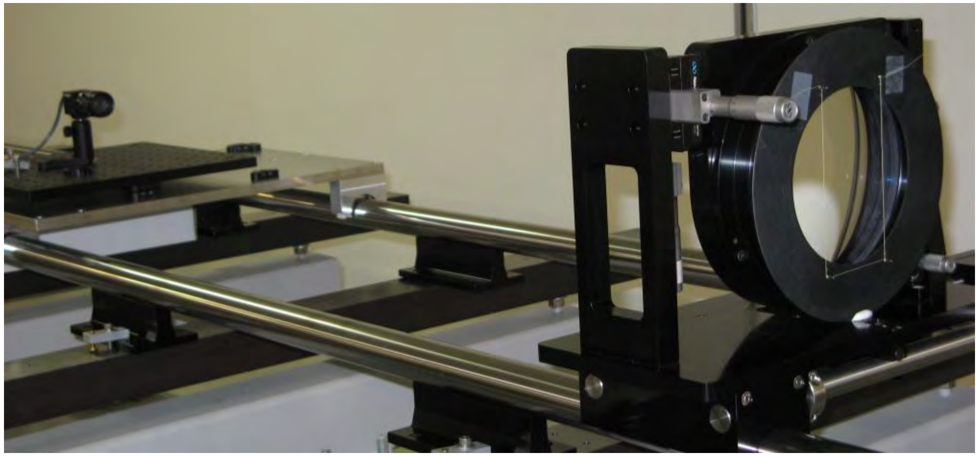
Single mode fiber tip in focus

Once the fiber tip is on-axis → the wave-front should be good, except the focus is temperature dependent.

# The Rail Camera

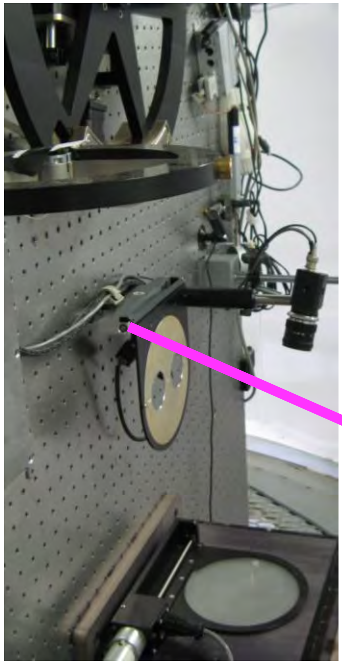
This setup could be used to check the focus of the beacon or the telescope.

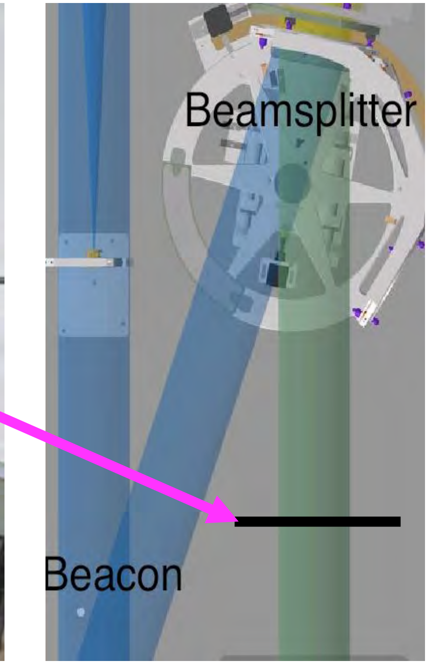
On the delay line



The rail telescope aperture is D=125 mm. (The CHARA beam size.) There are strings in front of the big objective at the distance of the two holes in the Hartmann mask. The camera is mounted on a separate platform on the rail.

On the AO board

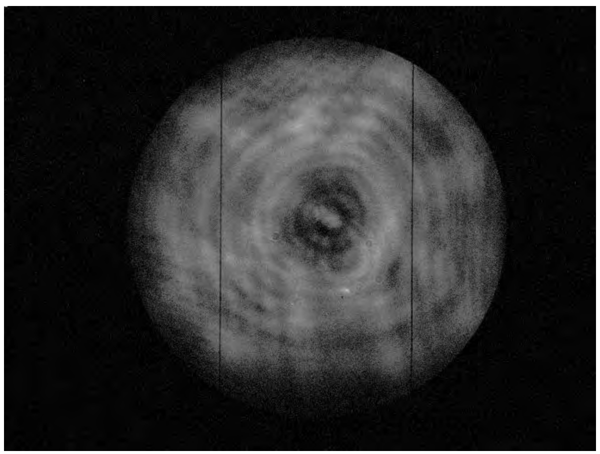




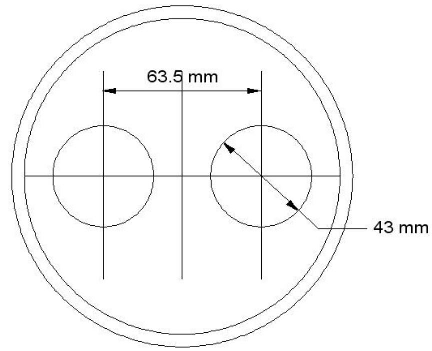

The 2-hole mask can be remotely moved in/out of the beam.

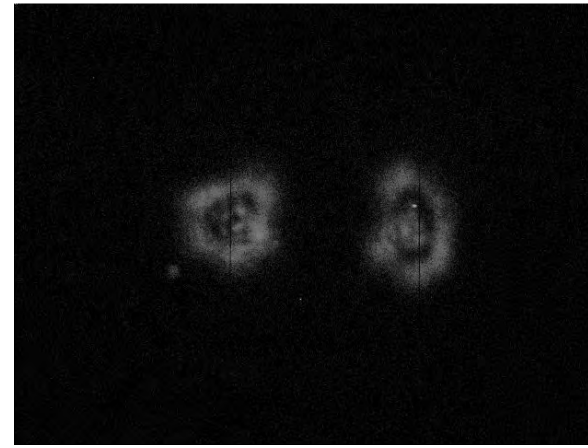
# Beacon in the Rail Camera

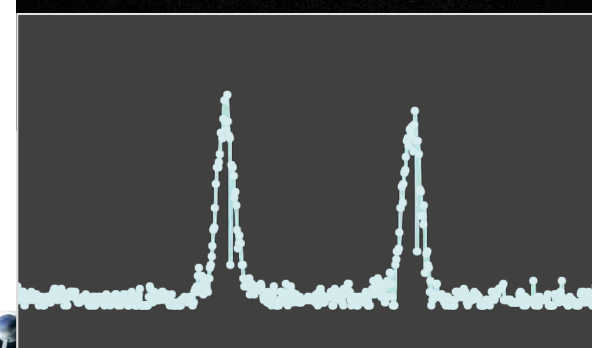
S2 beacon
Mask out



Mask

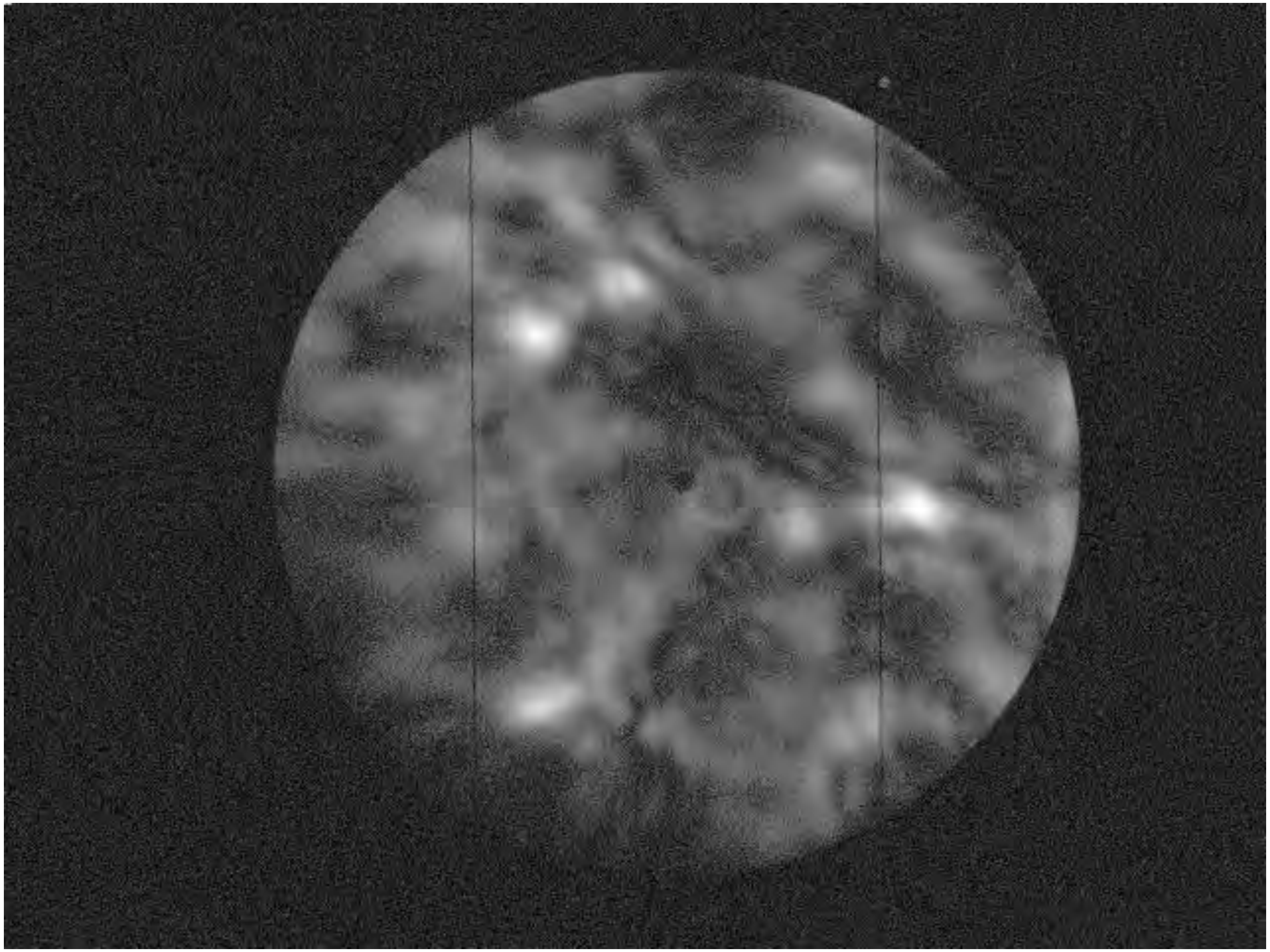




Recently changed to smaller holes
[ d~16mm ]
for easier image processing.

# Capella in the Rail Camera



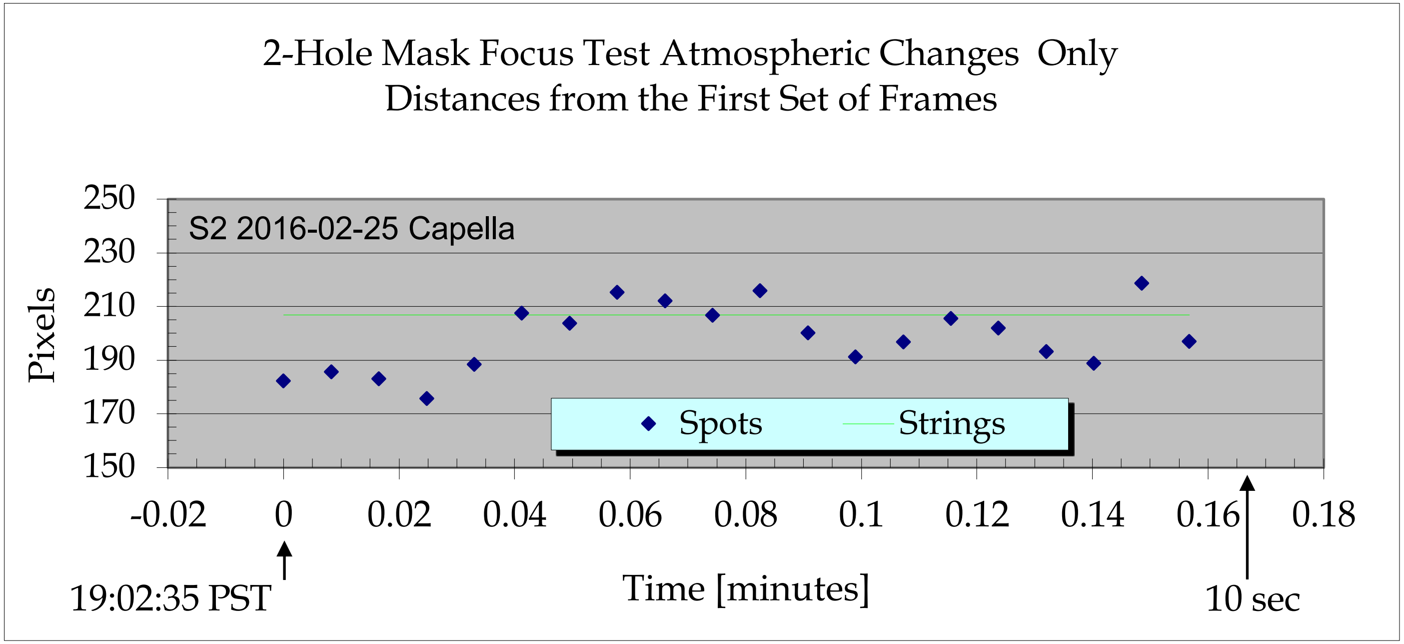
# S2 Focus Test using Capella

A set of frames captured

Files to

Mathematica.nb

Spot distances




The effect of our control over focus:

$\Delta D_{M1\text{-}M2} = 0.020 \text{ mm} \rightarrow \Delta d_{\text{RailCam spots}} \sim 10$ pixels*

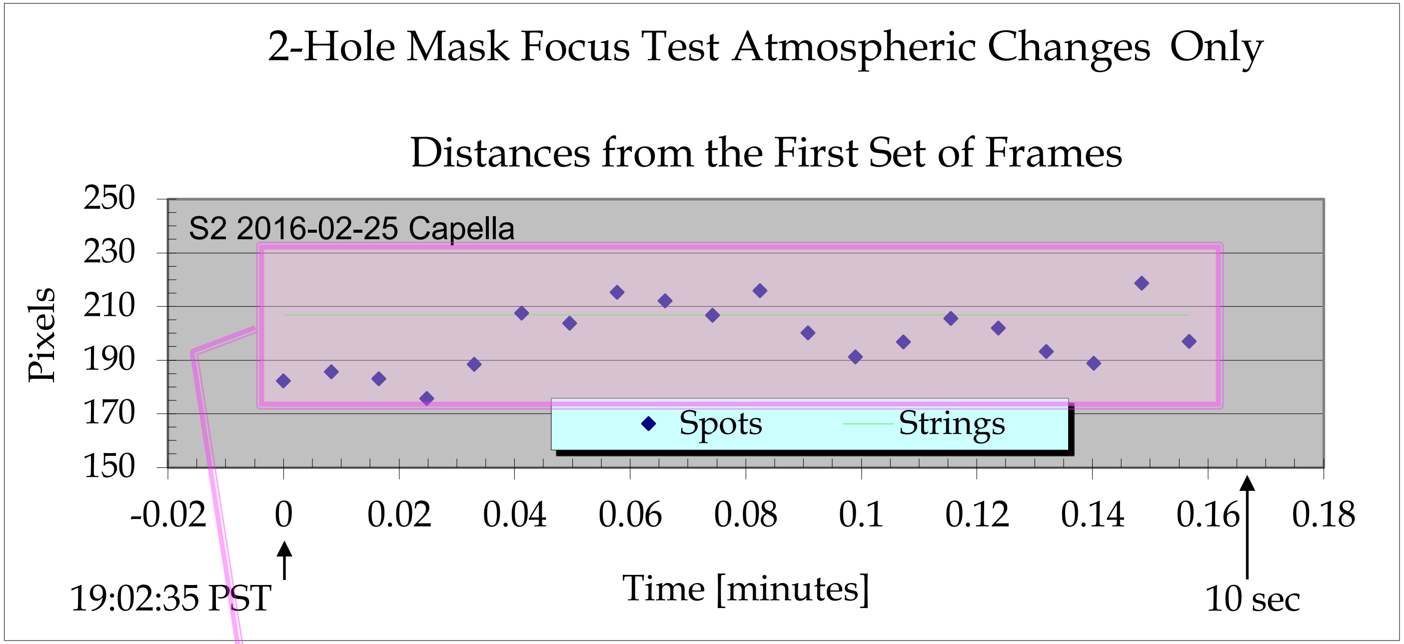
* Based on few observations so far.

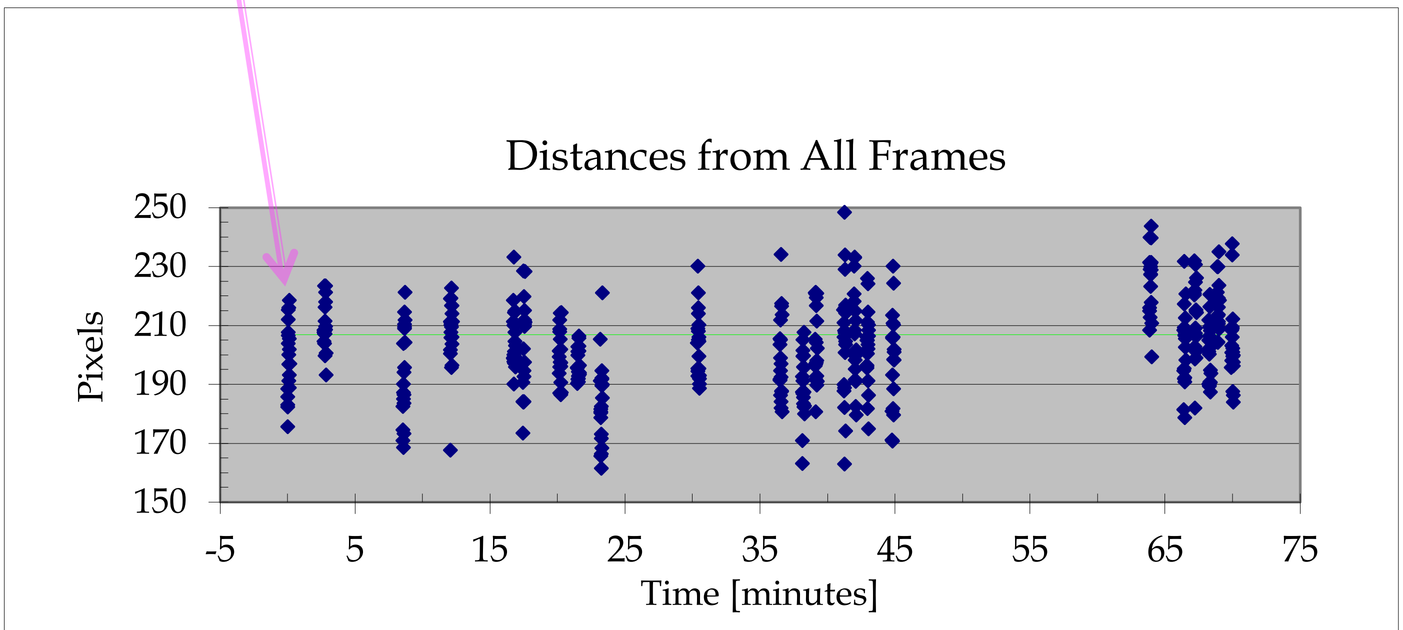
A set of frames captured

Files to

Mathematica.nb

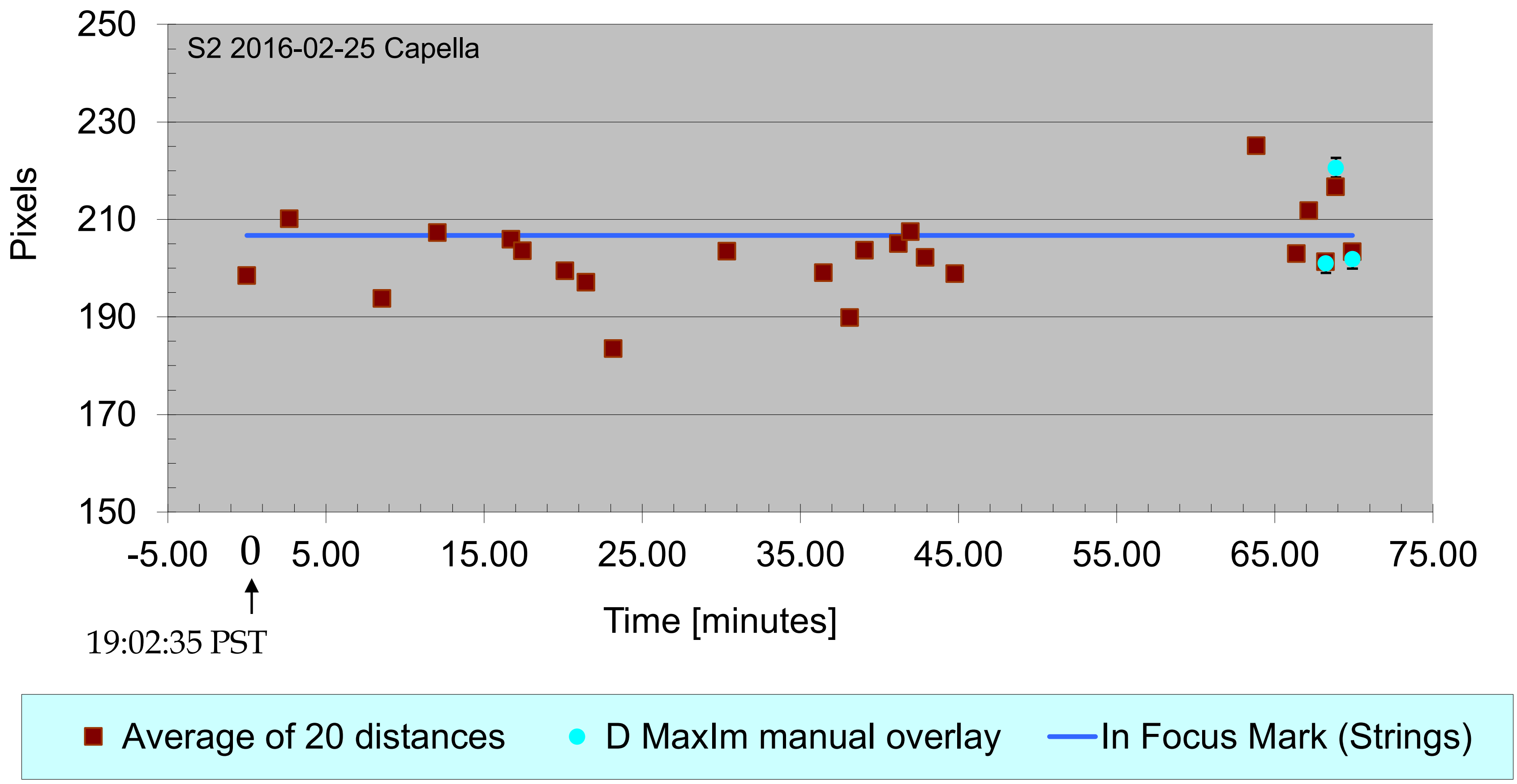
Spot distances



# Telescope Focus Test with 2-Hole Mask

No adjustments were done to any of the optical components.




Note: The telescope is designed to be athermal. Any change should be due to the atmosphere, including dome seeing.

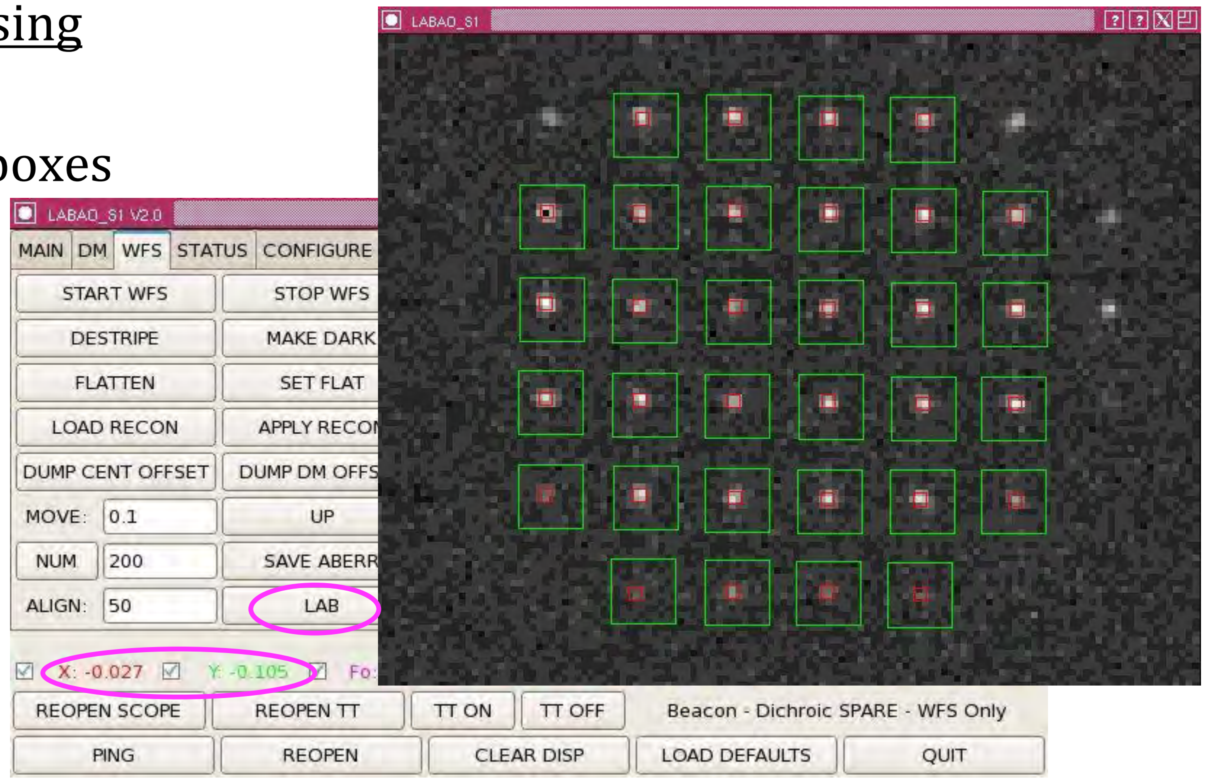
# Beam Switching Toward Automation

1. The laser is aligned to the target on the E table as usual. No automation yet.

2. Auto alignment of BS dichroic splitters can be done using LabAO WFS

when all spots are in their boxes

- The alignment-laser spots not yet well centered in the boxes
- LAB button pressed, and the beam sampler dichroic tilt will be automatically optimized until |X| and |Y| < 0.01

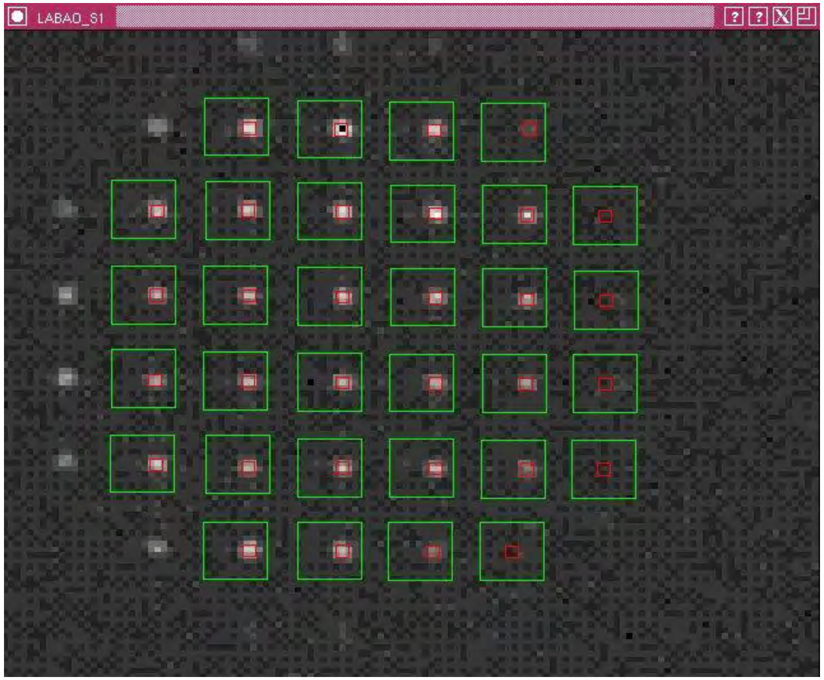


# S1 Beam Switching

1. The laser is aligned to the target on the E table as usual. No automation yet.

2. <u>Auto alignment of BS dichroic does NOT work</u>

when laser spots fall outside their boxes on LabAO WFS display.

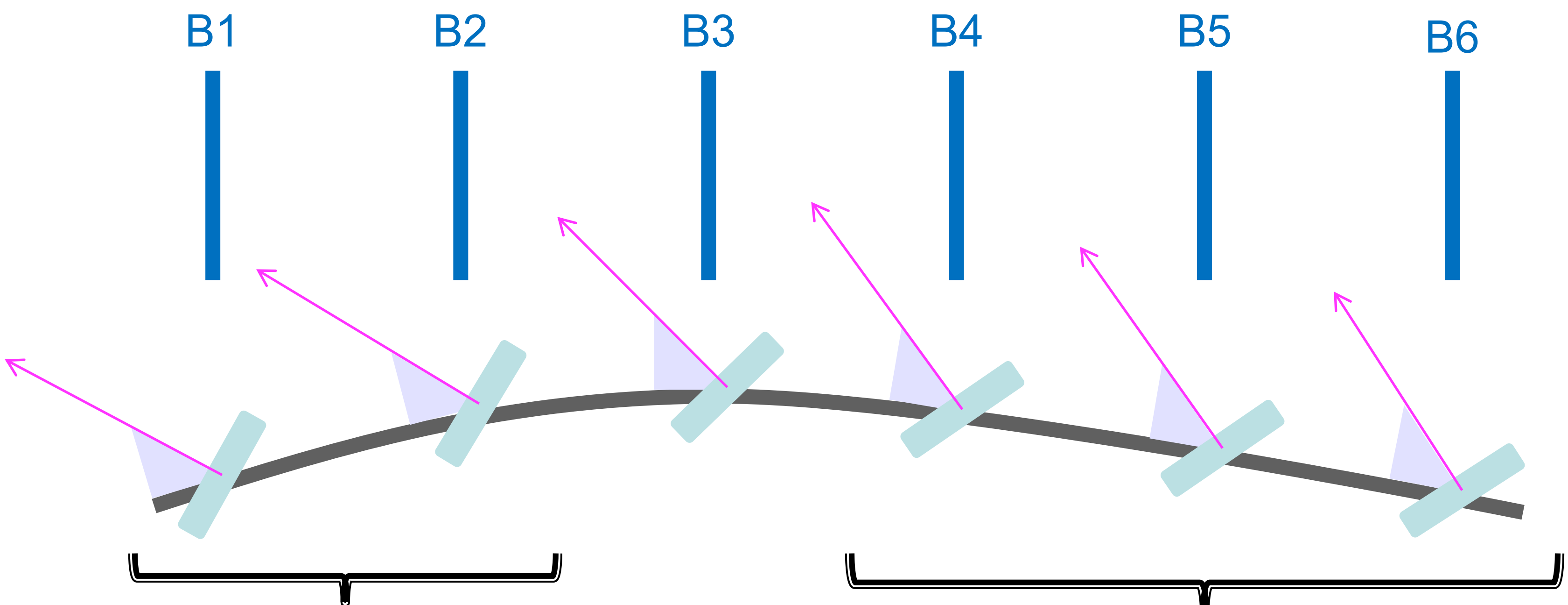



Switching S1 from B1 to B6

- One has to continue the old fashioned way: stand next to S1 table and look at the small BRT target, use the hand paddle to adjust. → The spots should go to their boxes.
- Let LabAO do the final adjustments.

# S1 Beam Sampler

It is a long (>60cm) translation stage with much more yaw deviation than the other beam samplers. Recent beam switching tests suggest a bent rail with an apex around beam 3.




Auto alignment works between B1–B2

Auto alignment works between B4-B5-B6