CHARA AO Calibration Process

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CHARA AO Project Overview

Phase I. Under way

- WFS on telescopes used as tip-tilt detector

Phase II. Not yet funded

- WFS and large DM in place of M4 on telescopes

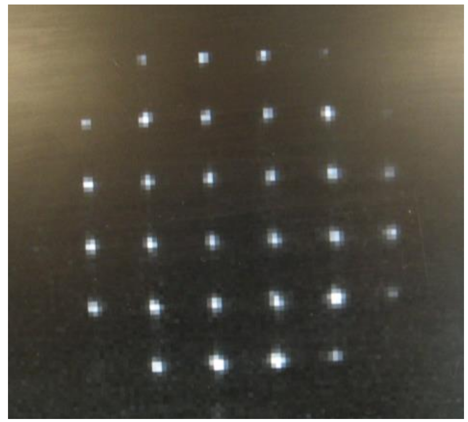
- In the lab slow WFS and DM to correct static aberrations

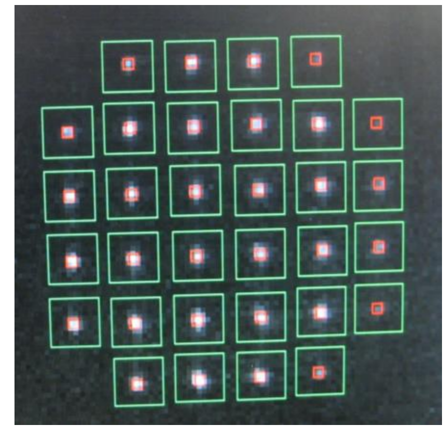
This talk focuses on the calibration of the LabAO

The Lab AO

A Shack – Hartmann Wave-Front Sensor

Lenslet array
10 x 10 mm square grid
Lens Pitch 150 μm
Lens Diameter 146 μm





Deformable Mirror

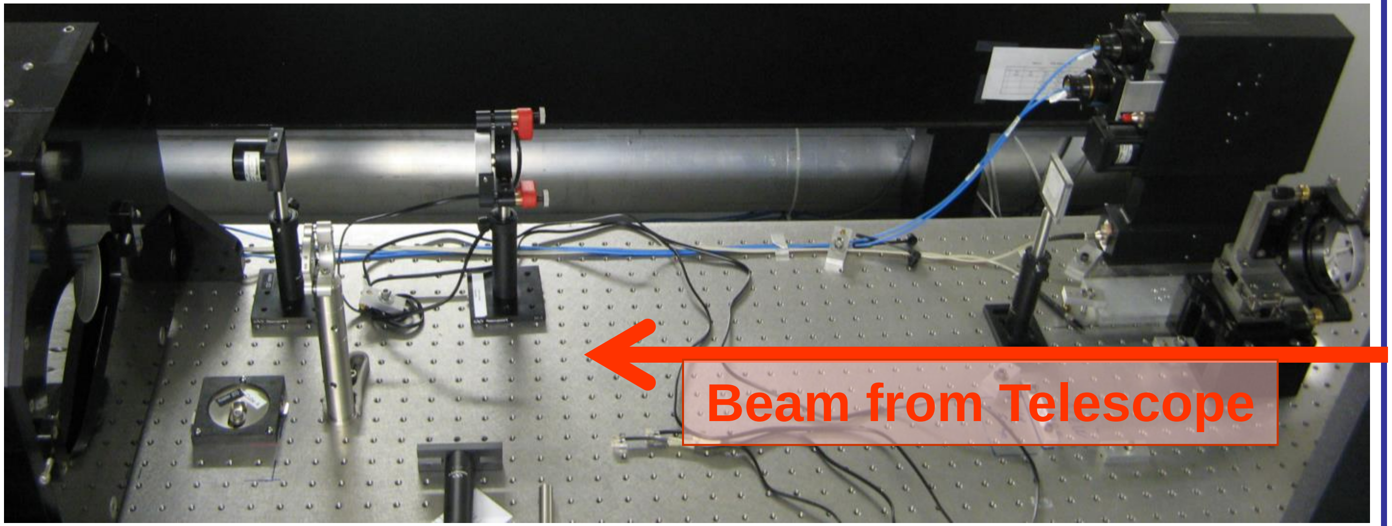
Aperture 15 mm diameter
Max deflection of center 9.4 μm
Always concave

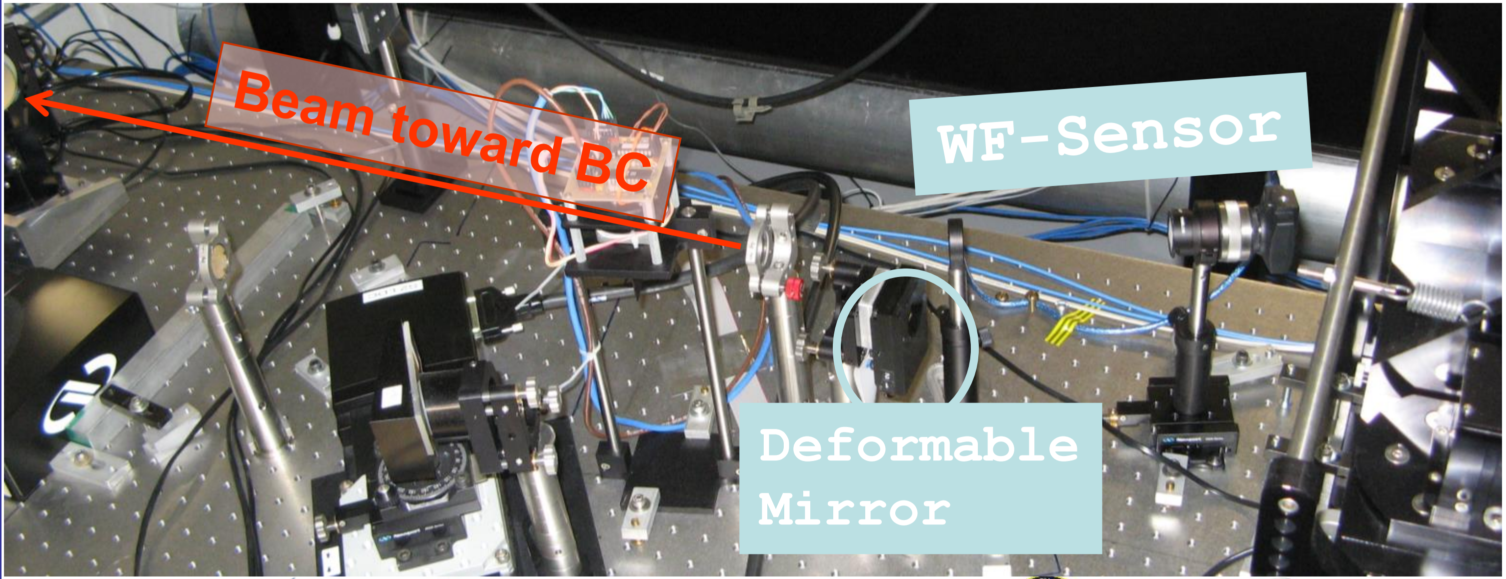
The Road Ahead

could be tricky, so I thought in early 2014

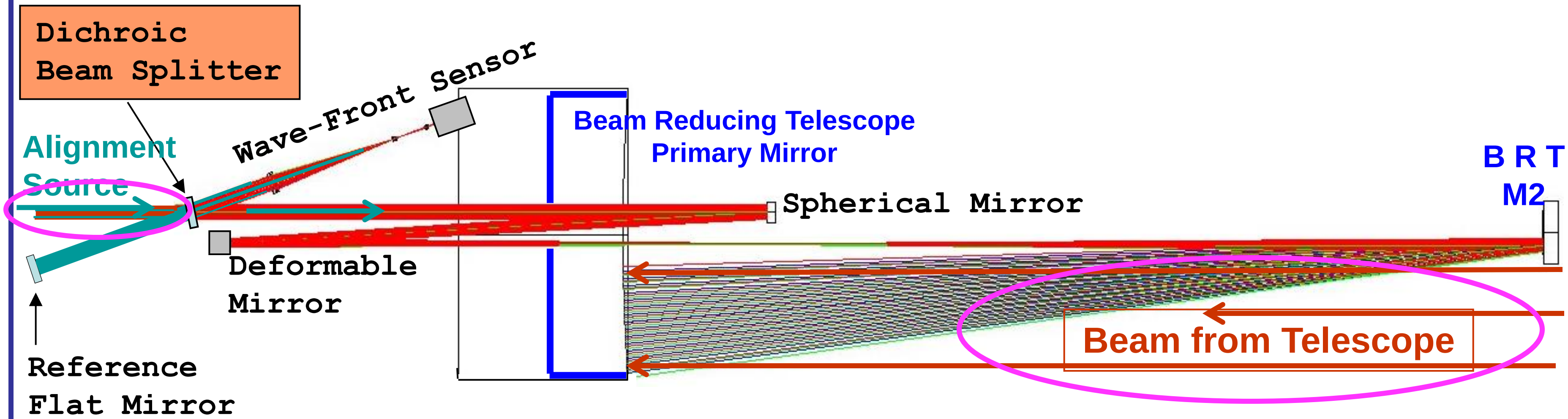
We came upon a few tricks and twists so far.

AO Setup in the Laboratory





Calibration in the Laboratory



To keep the original CHARA beam parameters:

- Collimated beam, D = 19 mm toward the beam combiners
- Collimated beam, D = 125 mm on the rail and toward the telescopes

Calibration steps:

I. The "flat" wave front, or collimated beam, has to be defined for the WFS

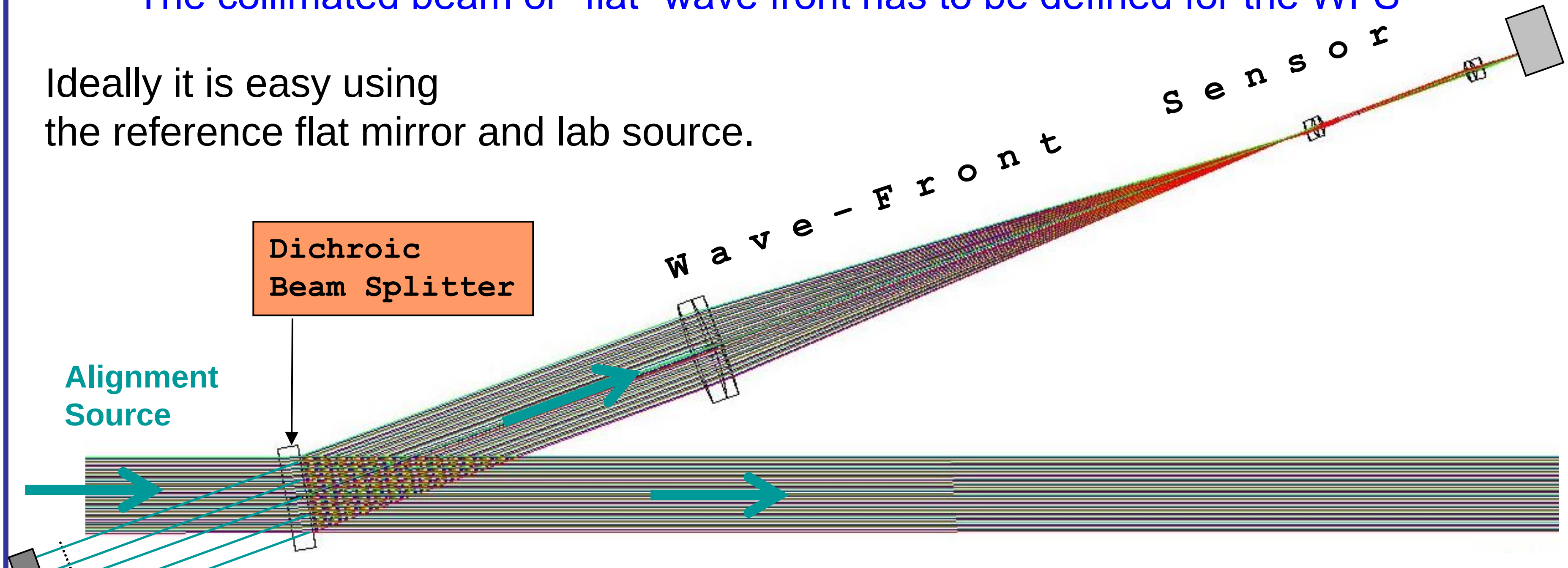
II. The default shape of the DM has to be set to produce the required collimated beam

III. Relating telescope aberrations to lab WFS, work in progress

Calibration Step I.

The collimated beam or “flat” wave front has to be defined for the WFS

Ideally it is easy using
the reference flat mirror and lab source.



<u>Issues when dealing with a real system</u>

- Alignment source collimation error

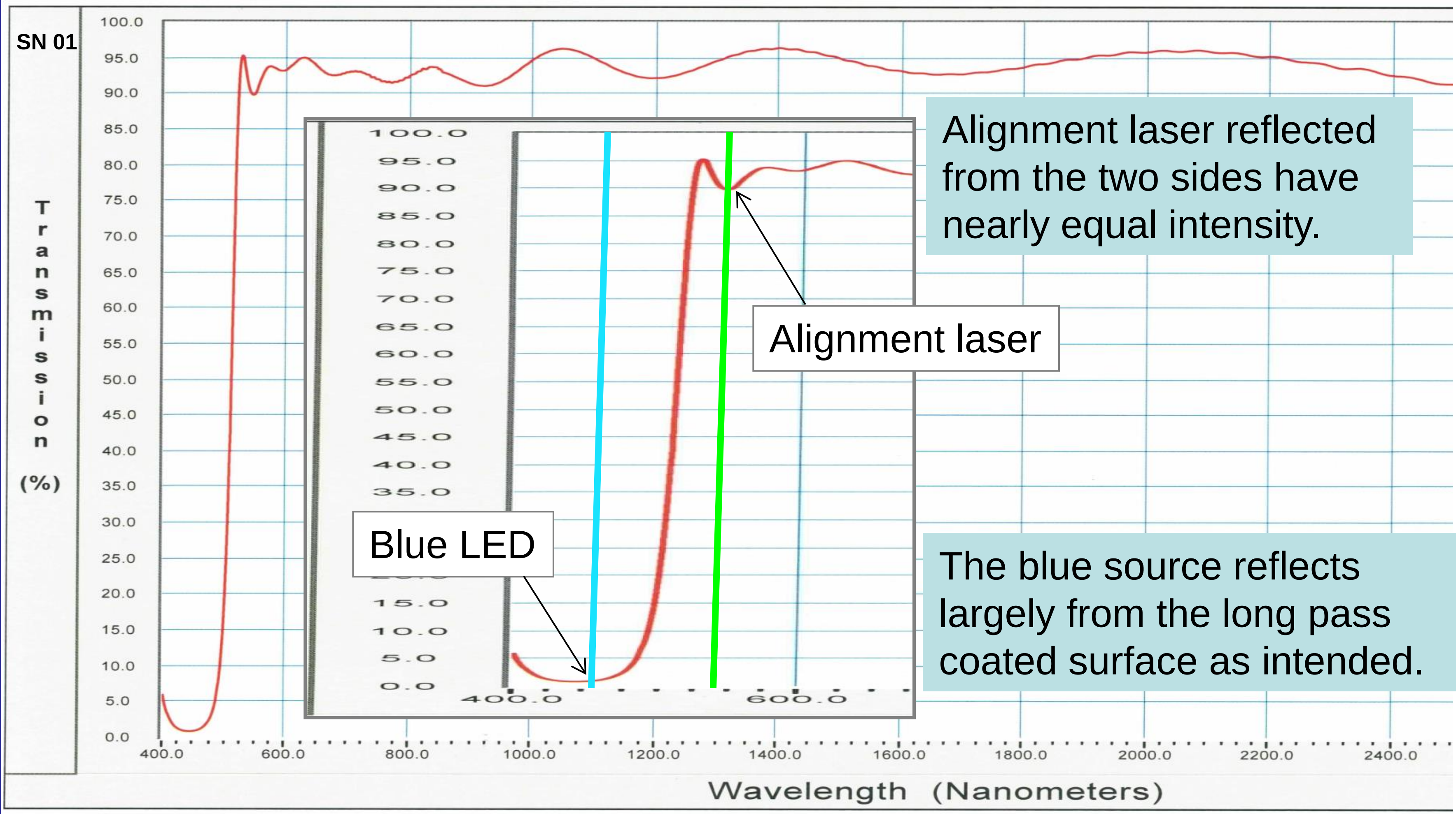
Auxiliary findings:

- We found with 2-hole Hartmann check that PAVO beam splitters significantly alter the green laser focus !
- The green laser itself in 2014 was no longer well collimated.

Lab AO Dichroic Filter

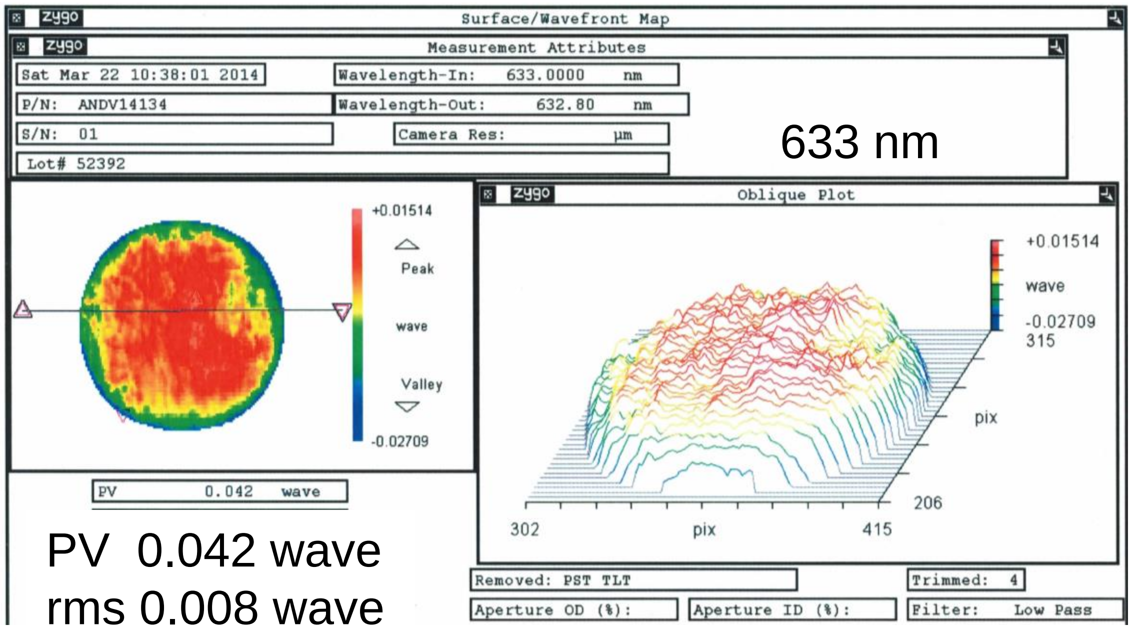
One side long pass coating,
AR coating on the other side

Andover Corporation



Lab AO Dichroic Filter Surfaces

Zygo Wavefront Map Provided by the Manufacturer
Filter Installed at S2 Lab AO (S/N: 01)



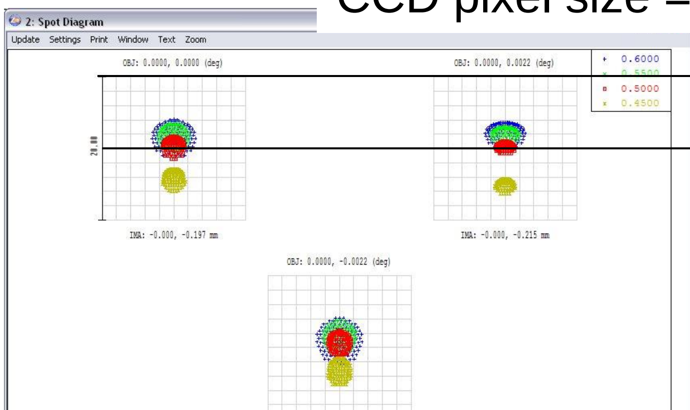
S/N	PV wave at 633nm
01	0.042
02	0.075
03	0.056
04	0.041
05	0.083
06	0.055
07	0.073
08	0.052
09	0.033
10	0.072

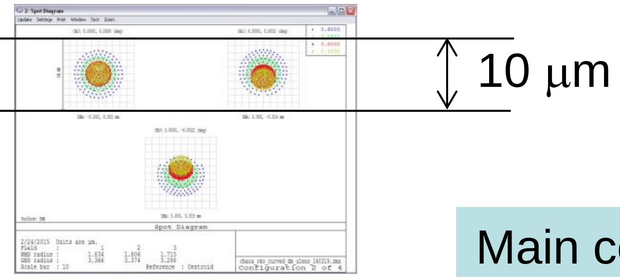
PV is better than the substrate specification (PV < λ/8 633 nm)

No information were provided on individual surfaces.
My Hartmann test showed different curvatures of the two sides in reflection.

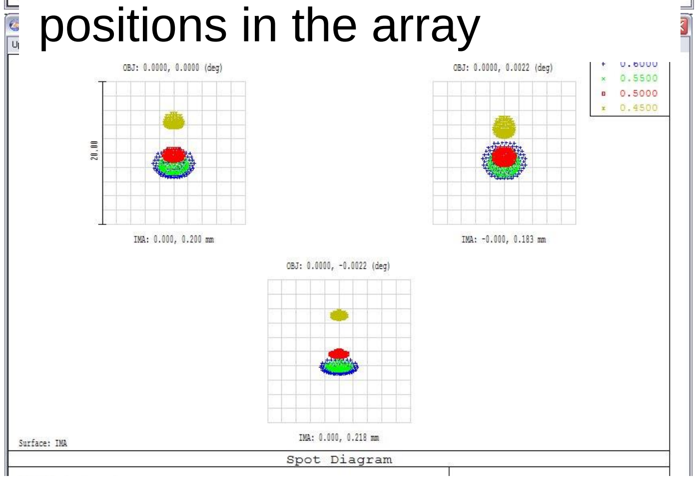
WFS Chromatic Aberration

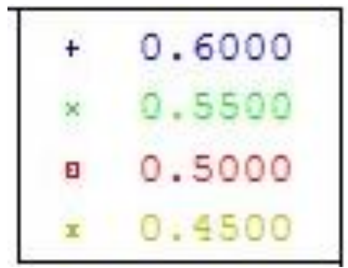
CCD pixel size = 5.2 μm x 5.2 μm



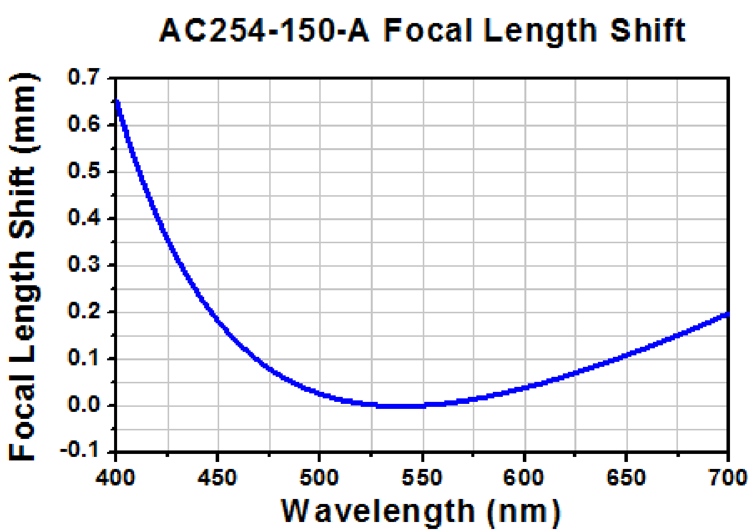


Zemax spot diagrams on the CCD by lenslets at various positions in the array

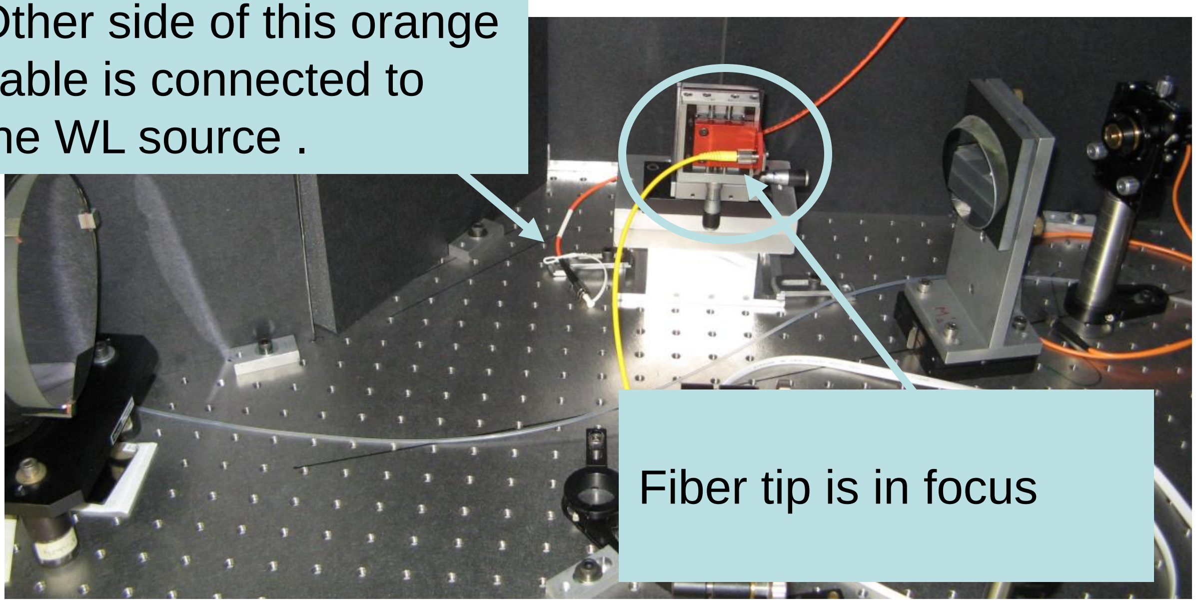




Main contributor is the first lens in the WFS setup.



From White Light Source to Versatile Lab Source



Alignment sources:

1. Green laser "LASER"
2. Versatile source "WL"

One can inject anything through a patch cable with FC connector into the known WL path.

After the rearrangement, shown here, the beam quality of laboratory sources can be reliably checked with 2-hole Hartmann test, and are good to use for LabAO calibration.

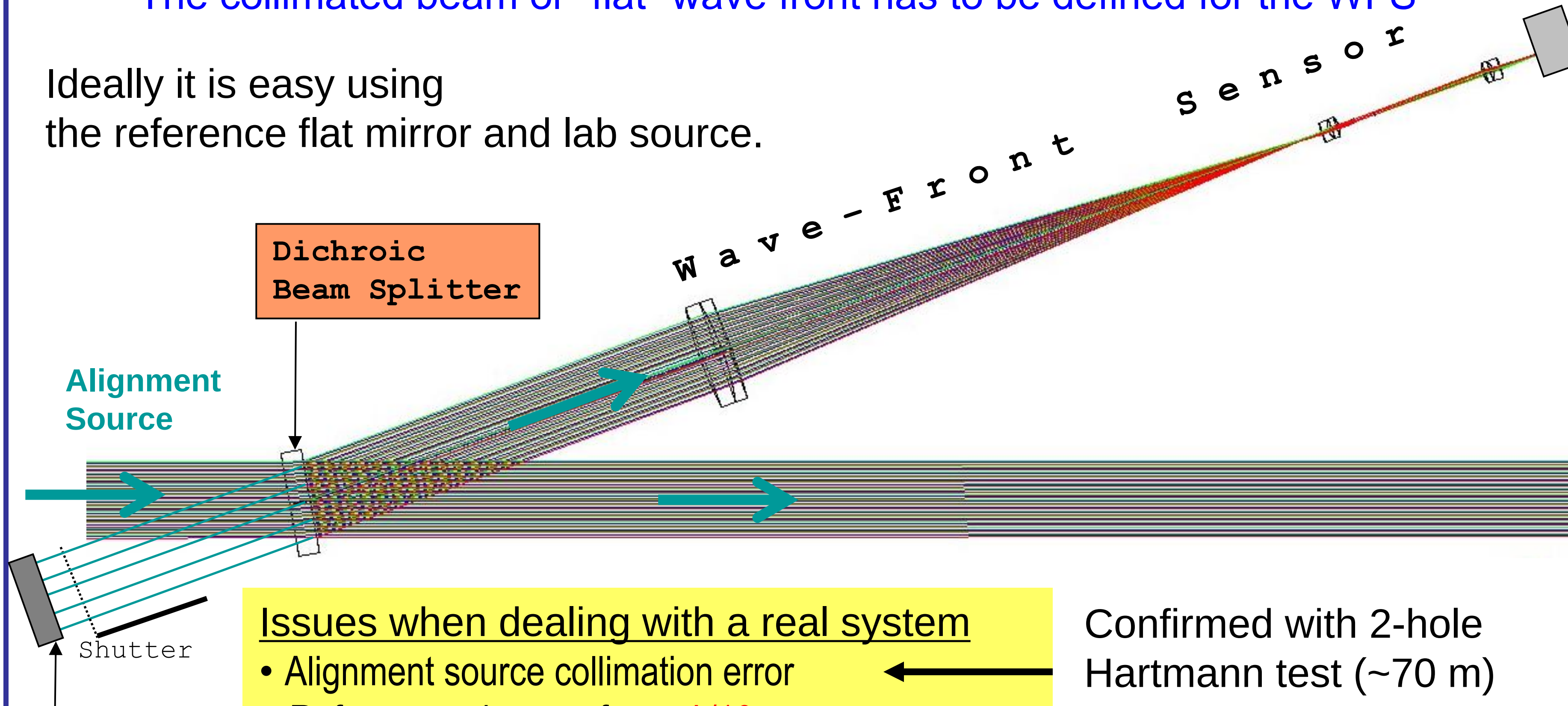
Holes 12 mm apart, mask to screen can be ~70 m,
if spot distances judged with 1 mm accuracy

→ sources P-V wavefront error < 20 nm

Calibration Step I.

The collimated beam or “flat” wave front has to be defined for the WFS

Ideally it is easy using
the reference flat mirror and lab source.



<u>Issues when dealing with a real system</u>

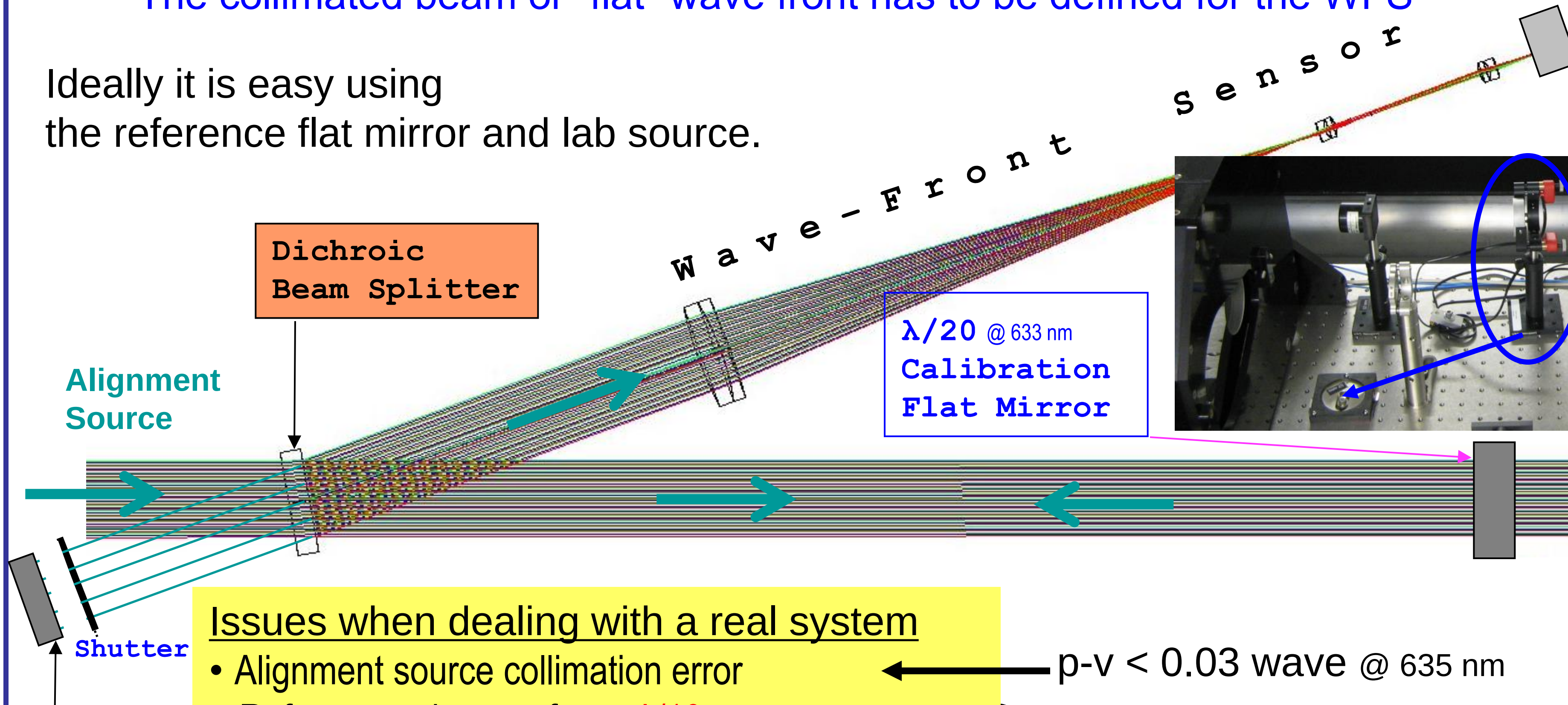
- Alignment source collimation error
- Reference mirror surface λ/10 @ 633 nm
- Beam splitter makes strong ghosts λ > 500 nm
- Two splitter surfaces have different curvatures
- Chromatic aberration of the WFS

Confirmed with 2-hole
Hartmann test (~70 m)
the wave front error
due to defocus
is now reduced to
P-V < 0.03 wave @ 635nm

Calibration Step I.

The collimated beam or “flat” wave front has to be defined for the WFS

Ideally it is easy using
the reference flat mirror and lab source.



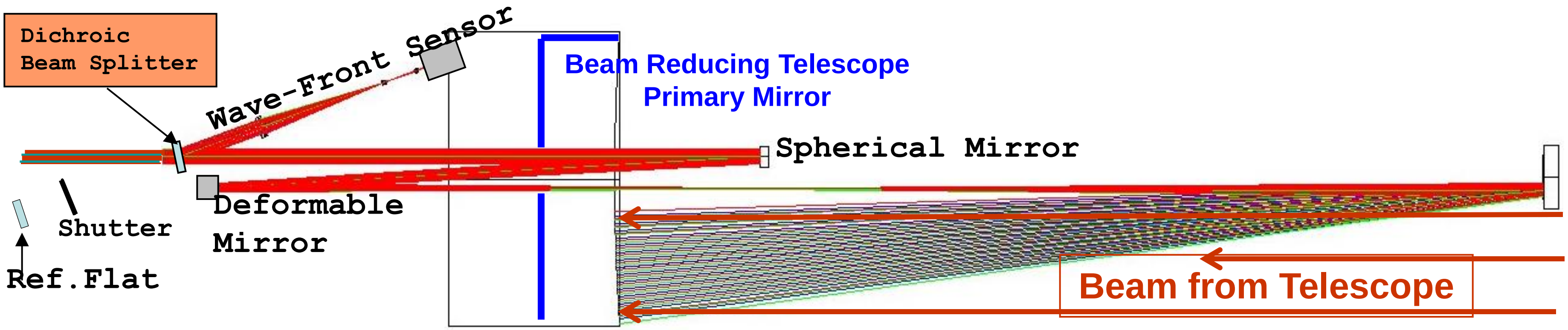
Issues when dealing with a real system

- Alignment source collimation error ← p-v < 0.03 wave @ 635 nm
- Reference mirror surface λ/10 @ 633 nm
- Beam splitter makes strong ghosts λ > 500 nm
- Two splitter surfaces have different curvatures
- Chromatic aberration of the WFS

Defined flat from “star side” by inserting a calibration flat and using 465 nm LED

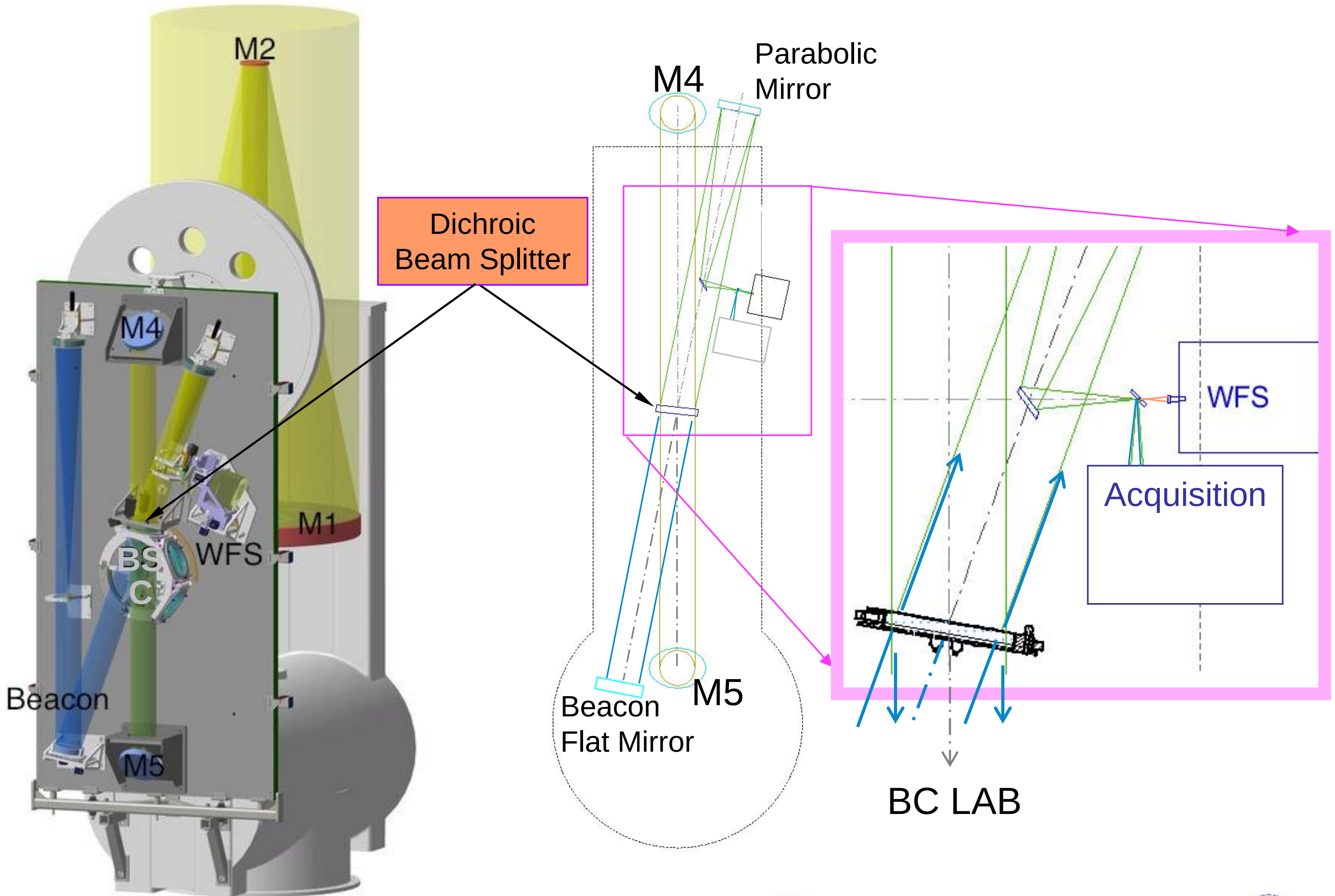
Calibration Step II.

The default shape of the DM has to be set to produce the required collimated beam



1. Send well collimated beam to the BRT primary

AO Setup at the Telescope



Calibration Step II.

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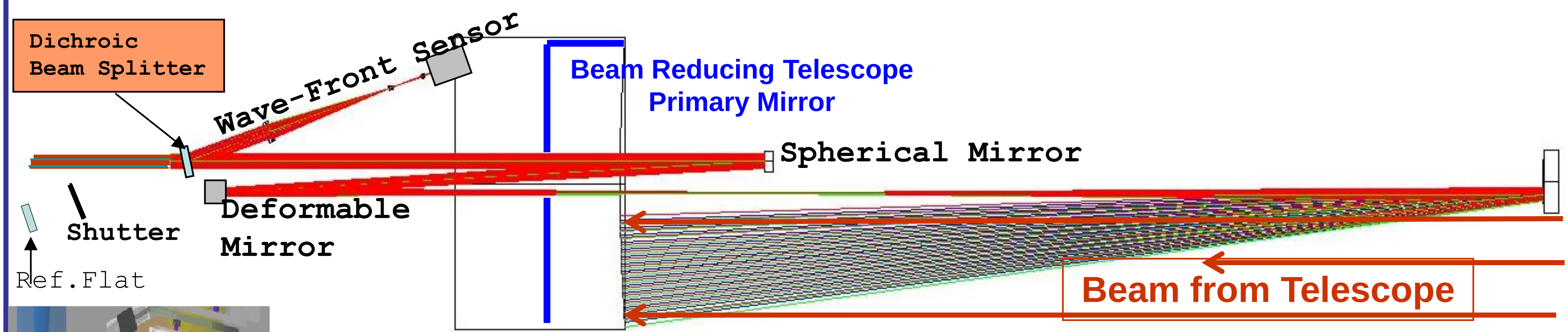
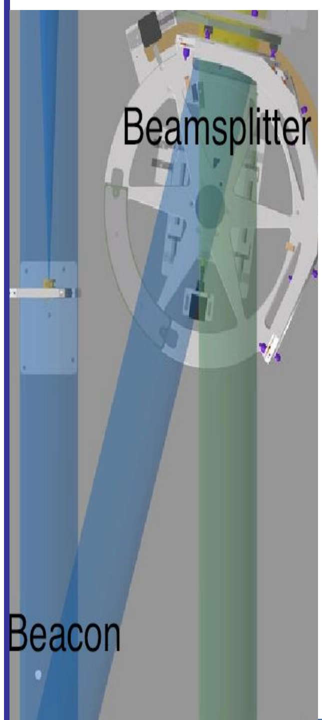
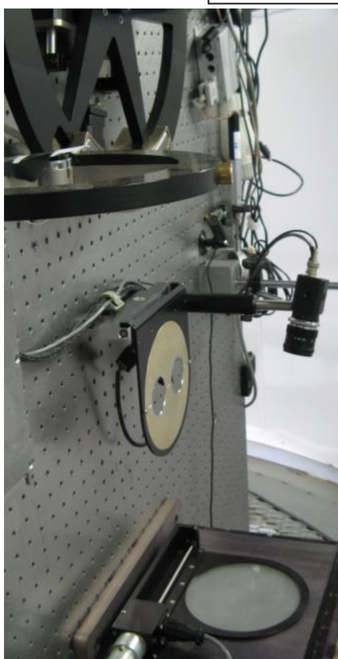


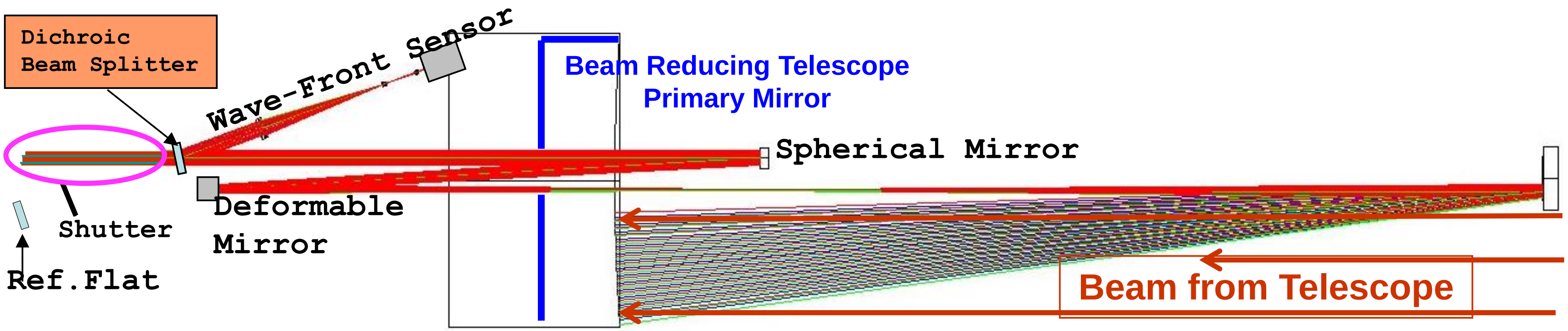




1. Send well collimated beam to the BRT primary
   a) Beacon focus checked just out of the periscope in the lab and adjusted based on 2-hole Hartmann using red alignment laser, and visual check of spot distance.
   b) Spot distances including the delay line cart checked in front of BRT, cart focus adjusted if needed.
2. Take out 2-hole mask, switch to blue beacon LED, fine adjust splitter at telescope to center on lab WFS
3. Adjust DM shape until lab WFS finds it “flat”
4. Save DM default shape

Calibration Steps I. and II.

are the best we can do to ensure flat wavefront toward the beam combiners, since :



1. we defined “flat” in Lab WFS with a well collimated beam from BC lab side

2. the beam used for calibration and the beam from telescope both
   a) reflect from the same surface of the splitter
   b) pass the splitter once
   c) similar in wavelength

3. the transmitted wavefront error caused by the AO dichroic splitter is pretty small (< 1/15 wave at 633 nm)

Calibration Step III.

Relating telescope aberrations to lab WFS, work in progress

- In principle the static aberrations of the wave coming to the BRT primary can be made flat actively by the lab DM, up to the range of the DM.

- Static aberrations have to be kept small by independently adjusting the alignment of delay line, cart, and BRT in the lab, if necessary. Annual adjustments proved adequate so far.

- Optics and mounts at the telescope due to temperature changes are subject to possibly too large variations over a single day or night for the DM to handle. The beacon focus should be checked few times during the night.

- For telescope check on lab WFS, bright blue stars are necessary. Ideally no DM shape change is needed between the beacon and star. It is important to establish a point when the main telescope needs adjustment, focus only.

Calibration Step III.

Relating telescope aberrations to lab WFS, work in progress

<u>Issues when dealing with a real system</u>

- Beacon collimation error << temperature
- Beam splitters different spectral characteristics >> different set of ghosts >> picking the right surface (spot) when aligning
- Beam splitter surfaces 32 nm < PV < 63 nm measured by manufacturer

Example of Beacon focus adjustment from one day to next : ~300000 steps

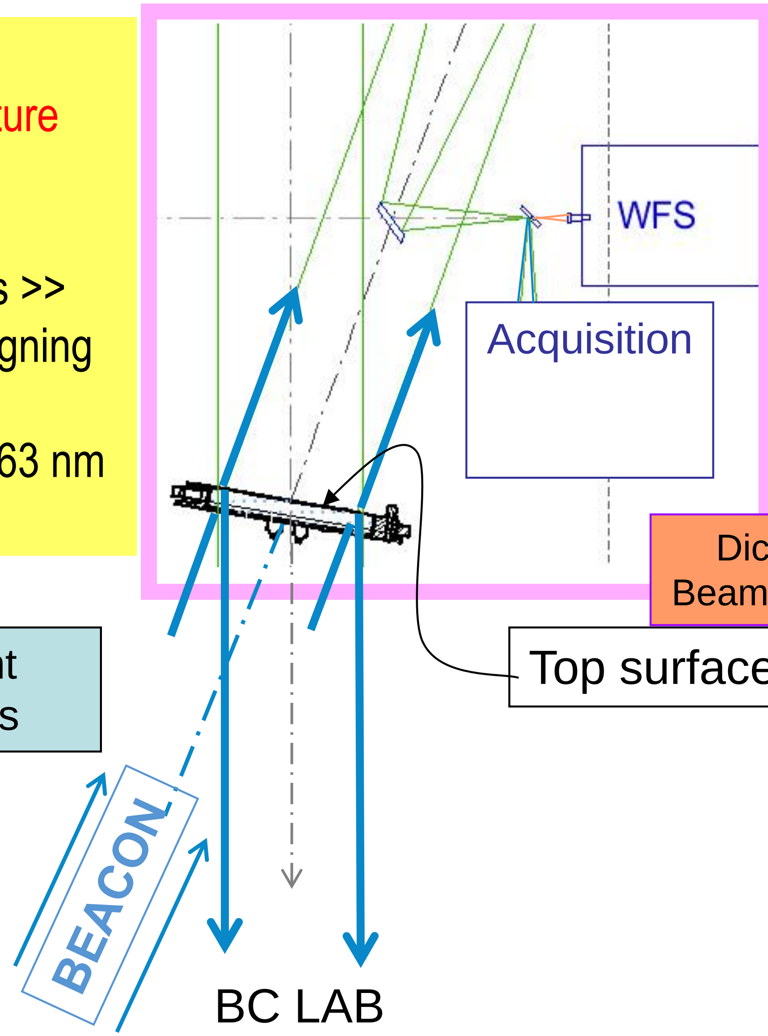
<u>PV of actual dichroic surfaces in S2</u>

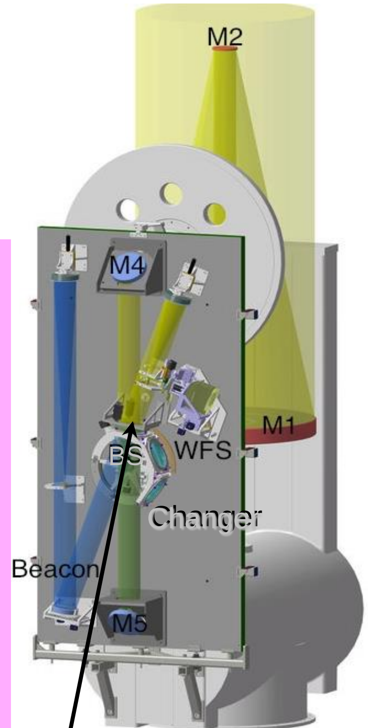
Uncoated "SPARE" PV_{s1}= 37 nm

PV_{s2}= 53 nm

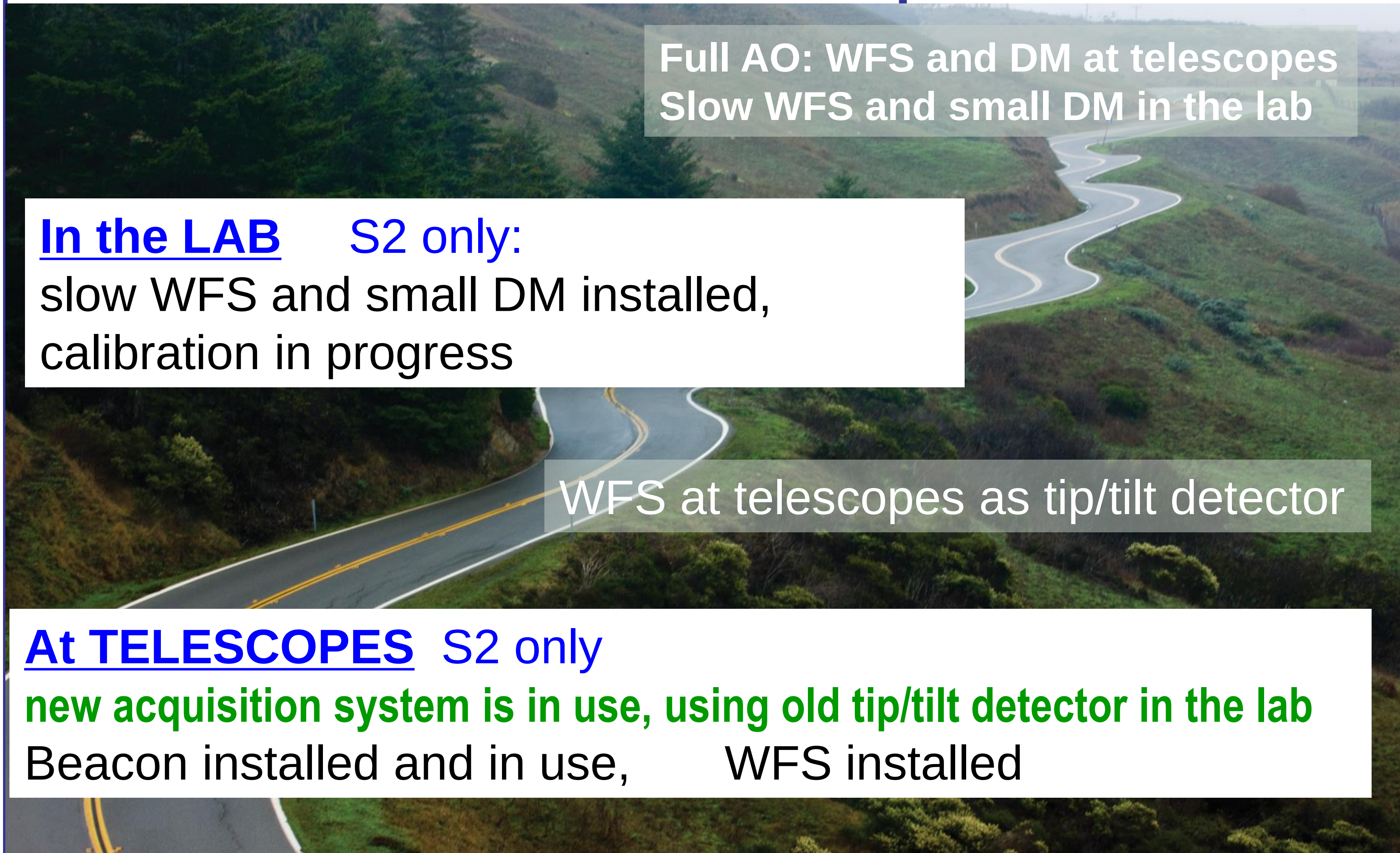
Dichr. coated "YSO" PV_{s1}= 62 nm

AR coated PV_{s2}= 60 nm





On the Road Update



Full AO: WFS and DM at telescopes
Slow WFS and small DM in the lab

In the LAB S2 only:
slow WFS and small DM installed,
calibration in progress

WFS at telescopes as tip/tilt detector

At TELESCOPES S2 only
new acquisition system is in use, using old tip/tilt detector in the lab
Beacon installed and in use, WFS installed