CHARA Lab-AO

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With lots of help from: Theo, Judit, Laszlo and the whole CHARA-AO team

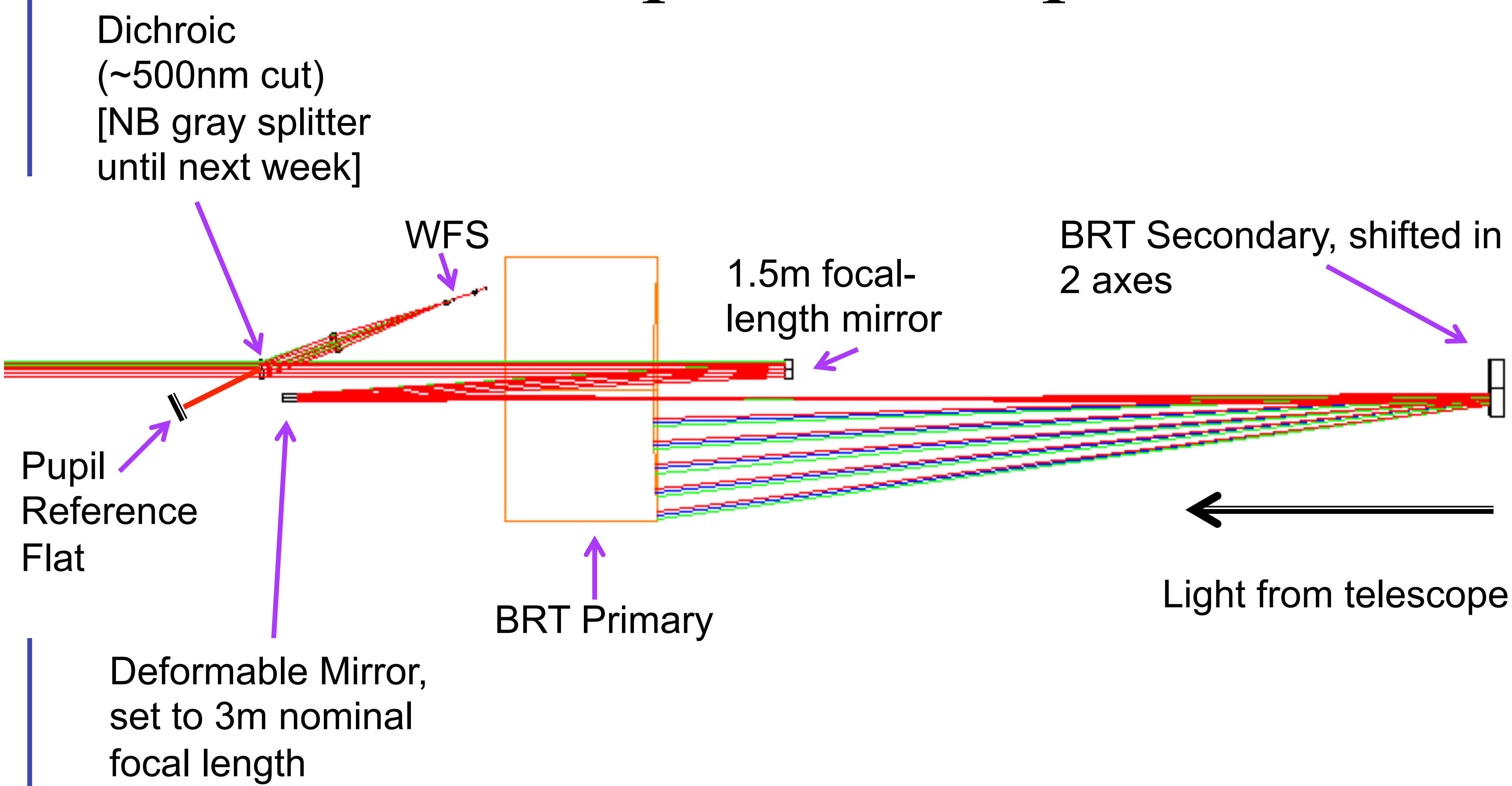
Motivation

- Ideally, an AO system is operated in feed-back mode, with the deformable-mirror (DM) before the wavefront sensor (WFS). For CHARA, this is expensive and so-far unfunded.
- It is possible to operate as a “feed-forward” or open-loop system. The problem with this is that there is no knowledge of if the wavefront is actually flat.
- A hybrid system is possible, where a slow “truth” wavefront sensor operates in a slow feedback loop, to track open-loop errors (like LGSAO tracking focus) or to at least record them for later analysis.

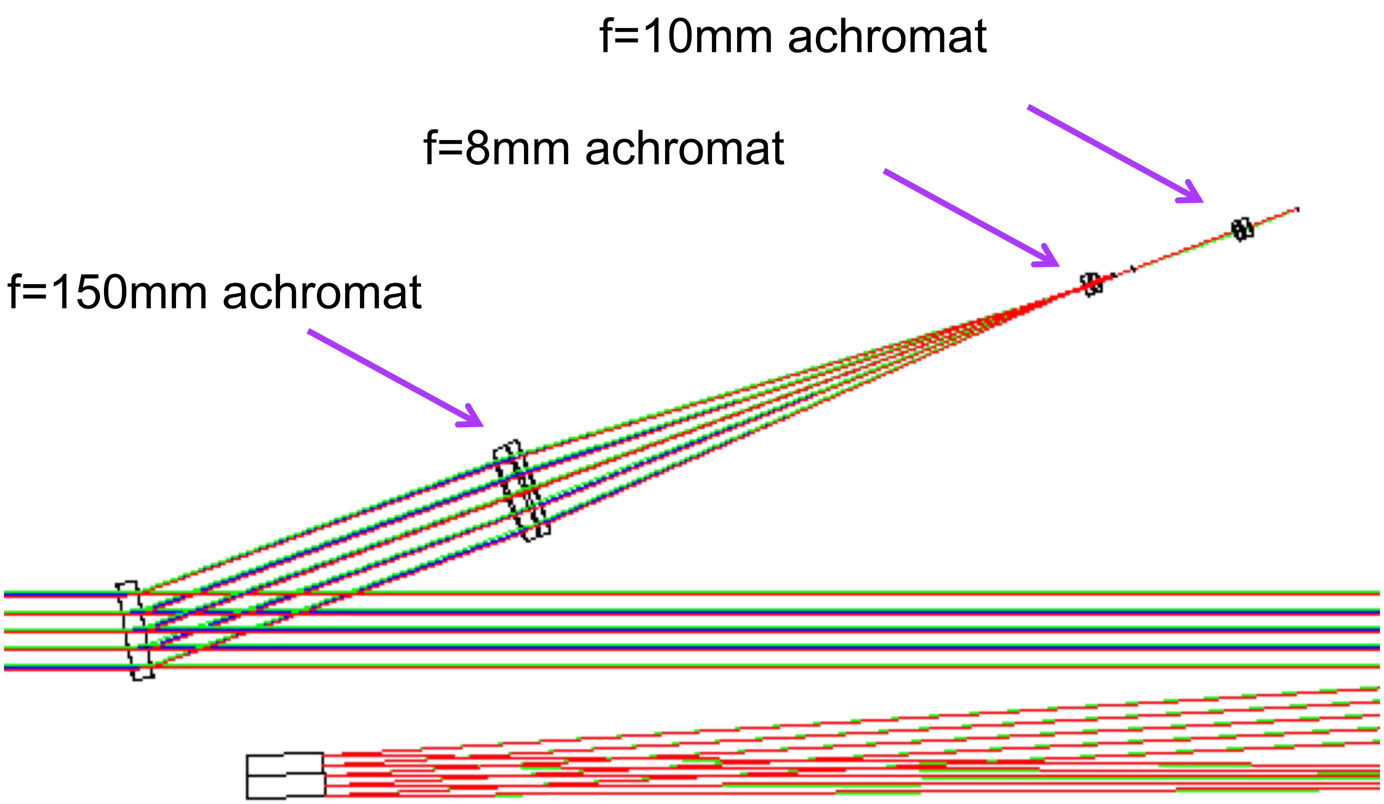
LabAO Purposes at CHARA

1. Enable the possibility of open loop AO using the on-telescope WFS.
2. Correct static aberrations, including the (rotating) aberration from the telescope.
3. Track the pupil, enabling M10 alignment using starlight.
4. Correct lab seeing and tilt (a minor need).

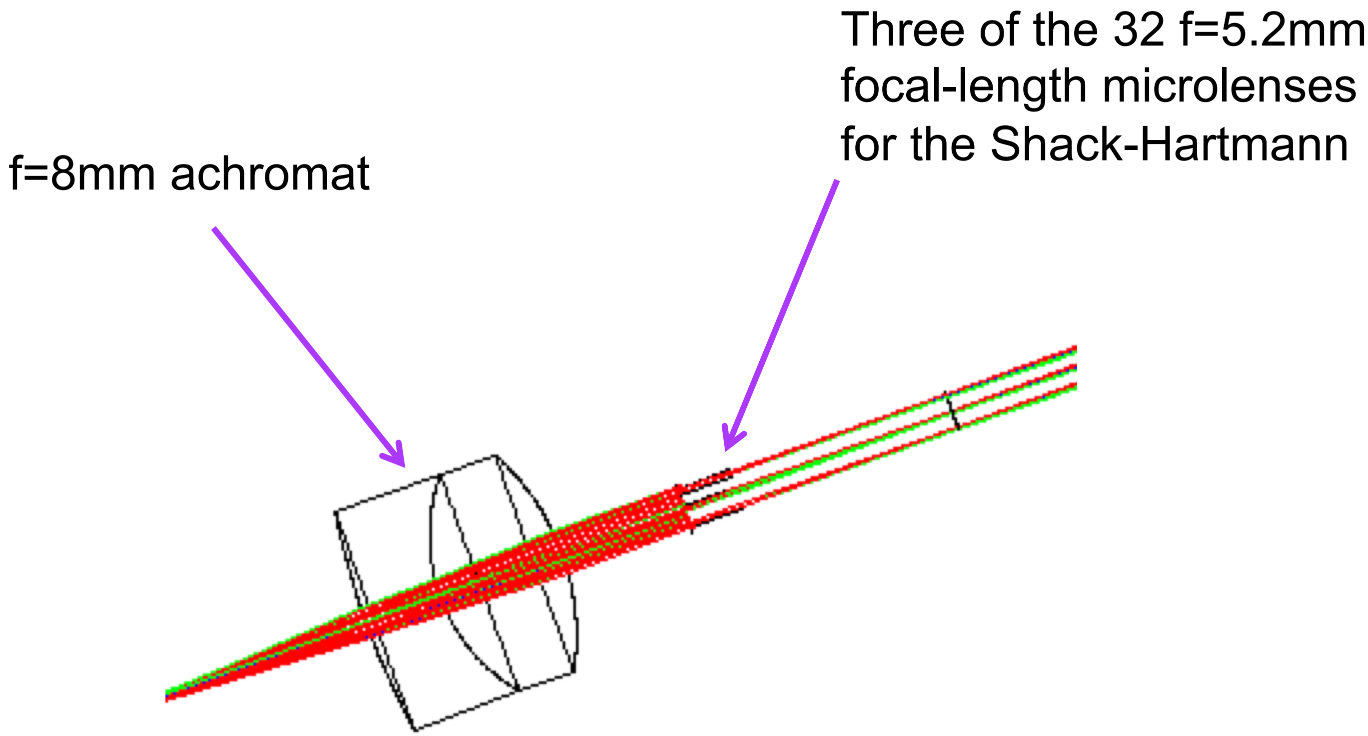
Optical Setup

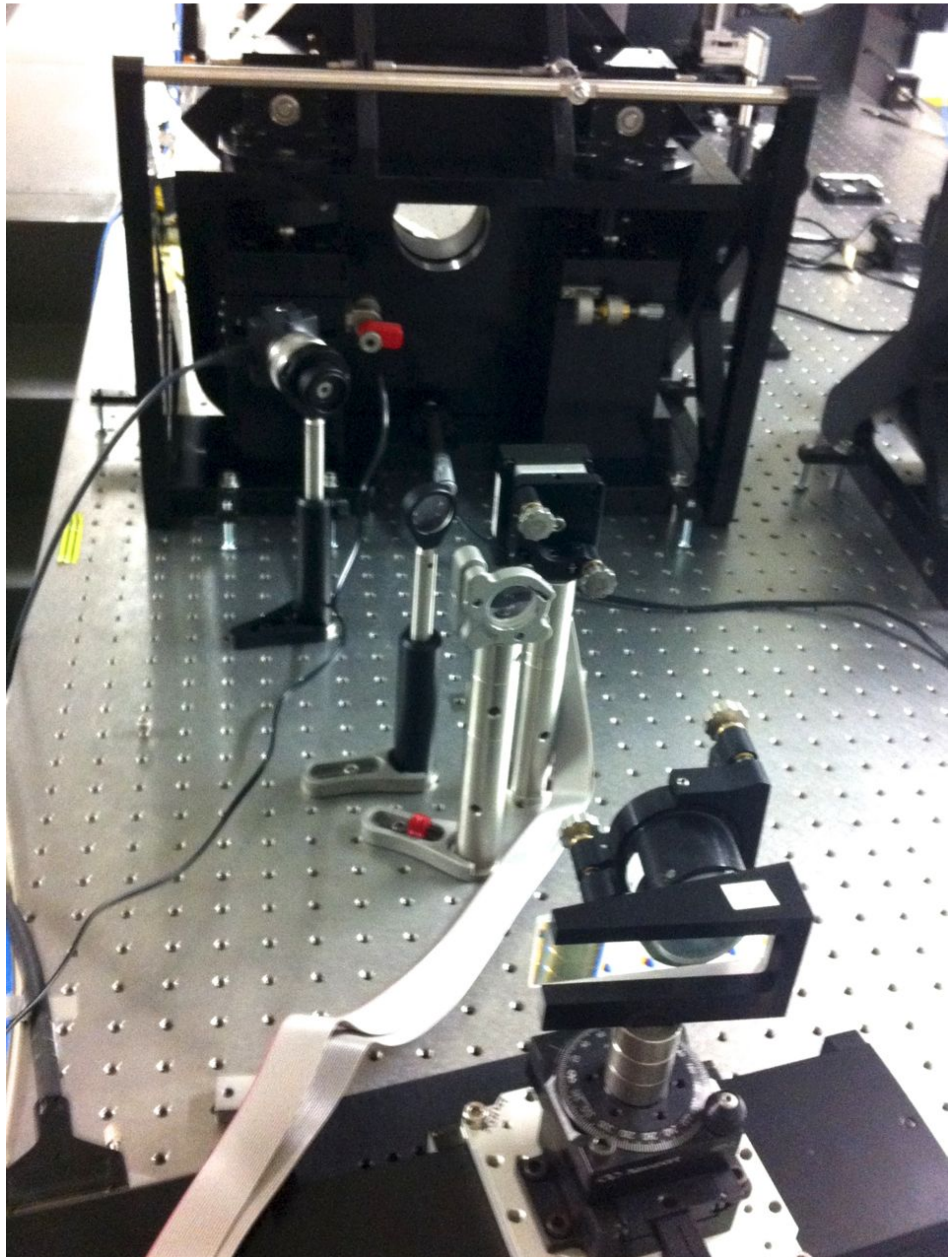


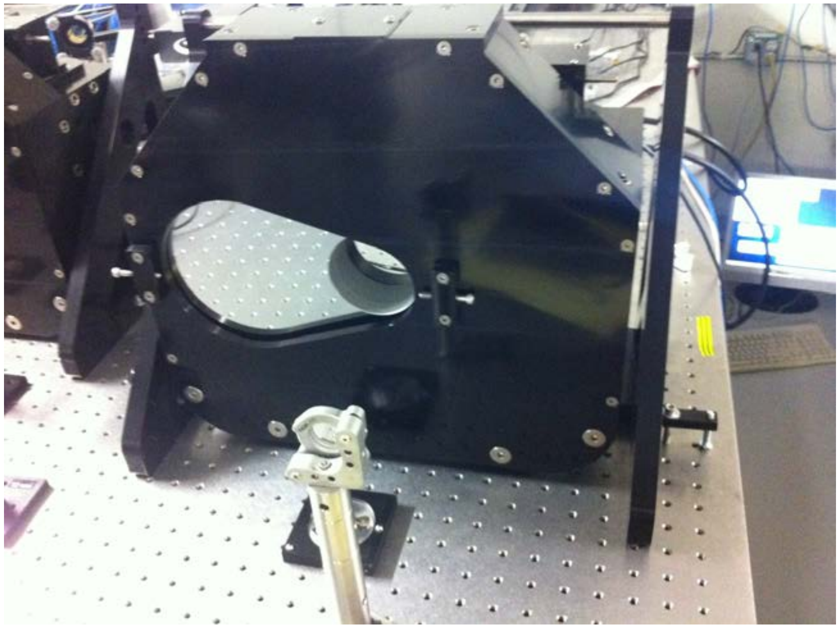
Optical Setup – Zoom 1



Optical Setup – Zoom 2







Adjustments

- Each of the large reflective optics has tilt adjustments – expect to only tilt the DM in week to week alignment.
- The camera has a focus adjustment.
- Pupil conjugation and WFS scale are set by measurements of the optical components when mounted in the lens tube.
- The pupil scale is set by translating the lens tube in its mount.
- WFS pupil alignment is set by tilting the beamsplitter.

5mm lenses glued in mounts

WFS Parameters

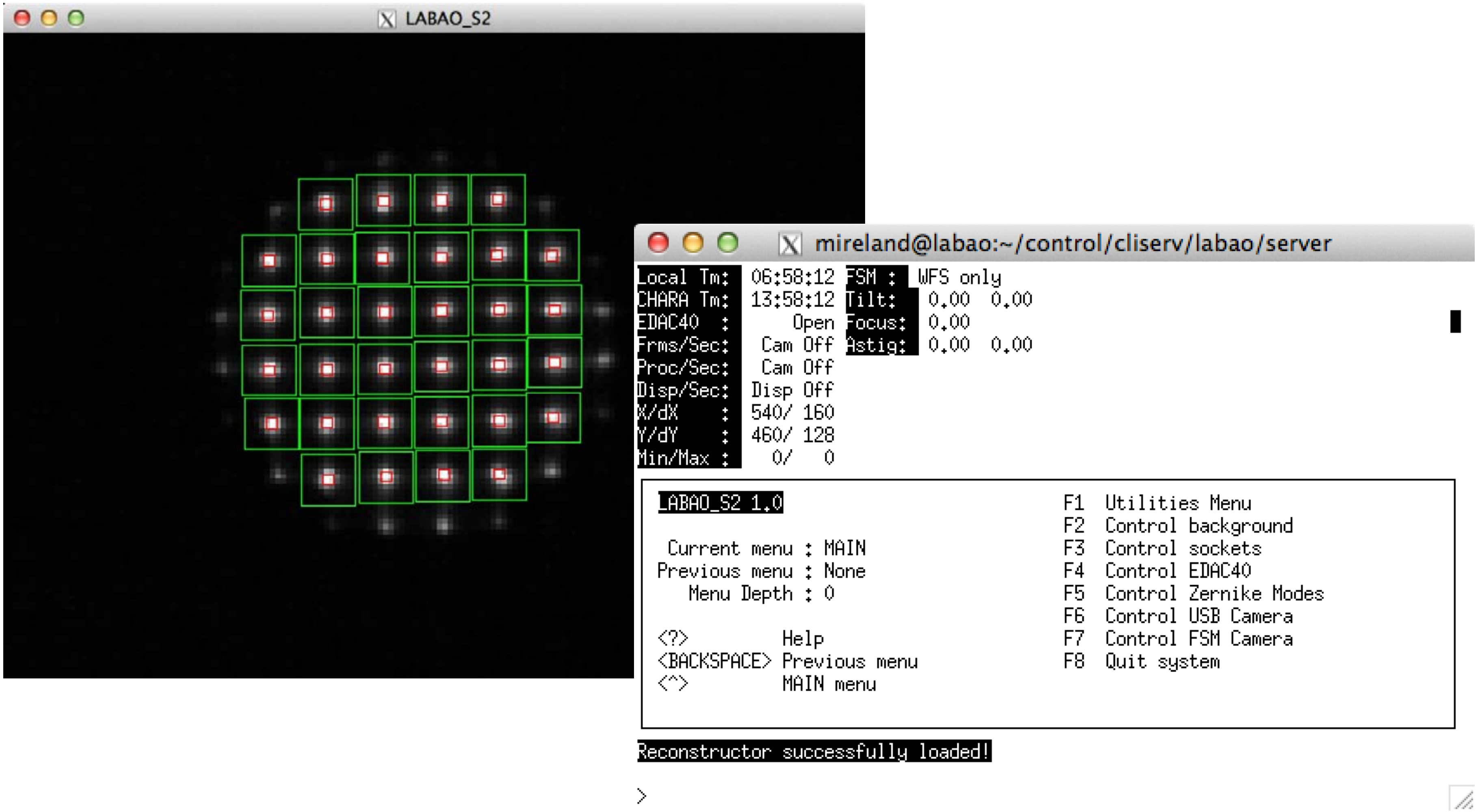
- The wavefront sensor operates in the collimated 19mm beam.
- A pupil of 0.95mm diameter is imaged onto an array of microlenses with 0.15mm pitch and 6.7mm focal-length.
- This gives a +/- 2.3 arcsec field of view only per microlens.
- Pixel scale is nominally 0.30 arcsec/pix, with 15 pixels nominally between neighboring images. The scale appears to be out by a factor of 0.7 from this (11 pixels and 0.43 arcsec/pix – a lens in the wrong place by 1.2mm).

(in retrospect, this is probably not ideal. Sticking with Thorlabs parts, we can increase this FOV to +/- 3 arcsec.)

Detector

- The detector is the DCC1545M CMOS camera from Thorlabs (actually the monochrome UI-1540LE from uEye).
- Has 9 electrons readout noise, about 50% QE and can read at 500Hz in an appropriate sub-array (price: $345).
- USB2

As seen by the server…



DM Parameters

- The DM is a 37 actuator OKO DM, with a 10.5mm diameter from actuator to actuator.
- This conjugates 150m upstream of the BRT – which only matches the telescope pupil for W2 POP1. A cost effective DM of appropriate size for typical conjugation was not available.

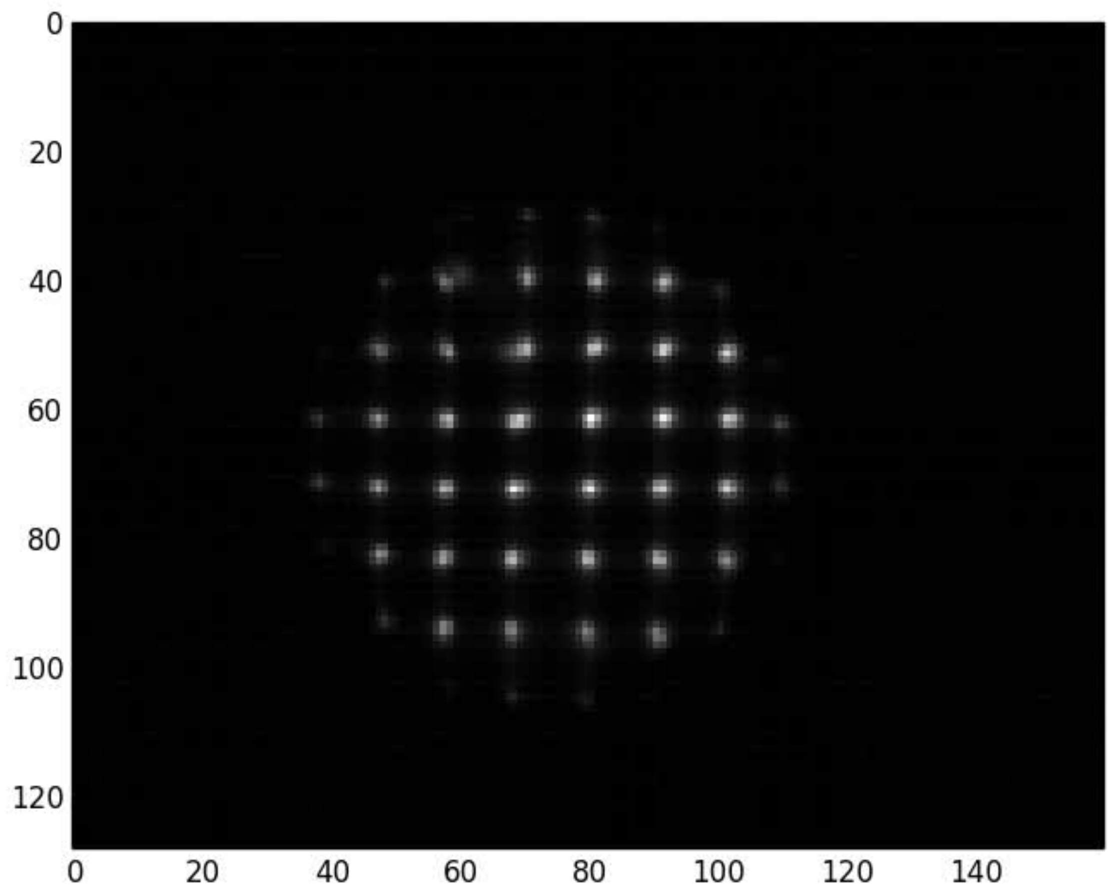
Table 1: Technical parameters of the mirror.

Parameter	Value
Aperture shape	approximately circular
Mirror coating	Al
Aperture dimensions	15mm diameter
Number of electrodes	37 (19) (see Fig. 3)
Control voltages V_c	0 . . . 260 V
Initial RMS deviation from plane	less than 0.45 μm
Main initial aberration	1.5 fringes at 630nm
Maximum deflection of the mirror center	9.0 μm

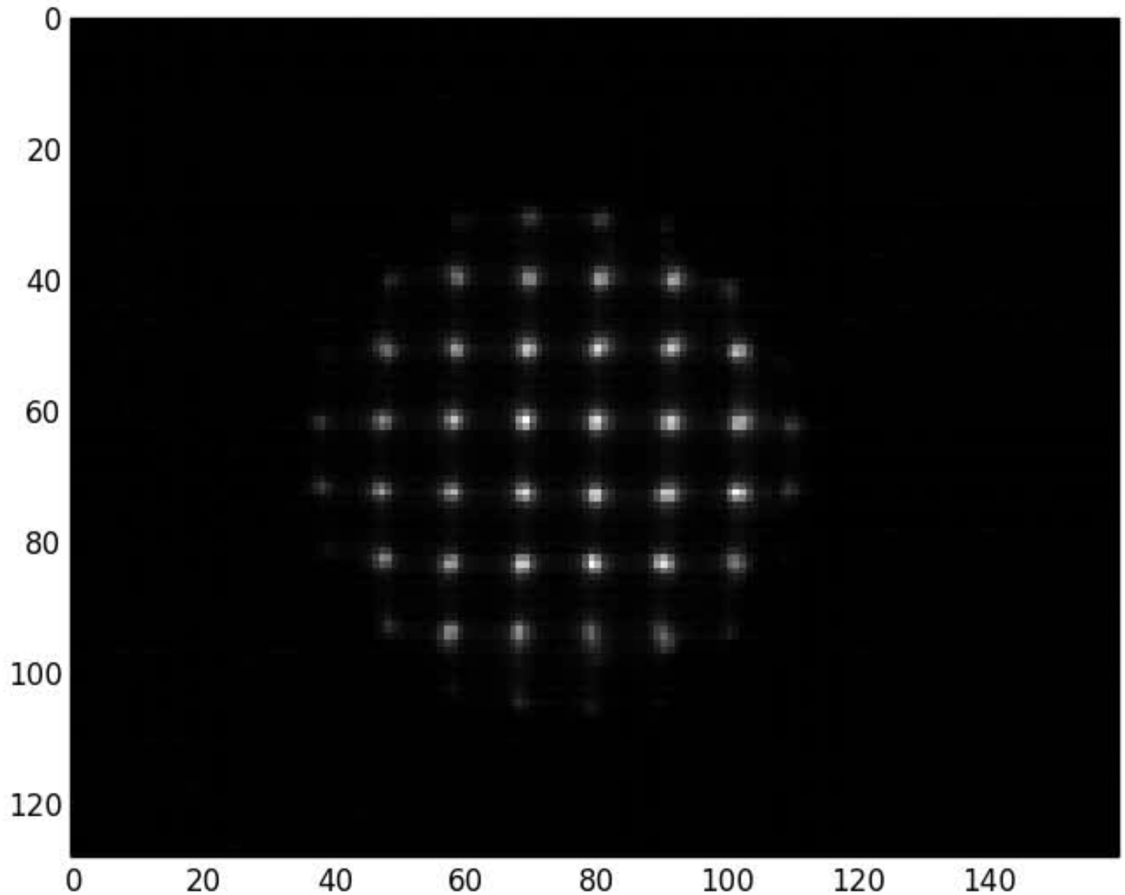
Operating Modes

1. Flat wavefront measurement (requires lab source)
2. Reconstructor computation (requires beacon)
3. Closed-loop AO
4. Fast starlight passive measurement (telescope AO calibration).
5. Slow starlight "truth" wavefront sensor and pupil tracker.
6. Beacon tracker (tilt and pupil).

Open loop with artificial "Seeing"



Close loop with artificial "Seeing"



θ Aur

(system misaligned : data for flux only)

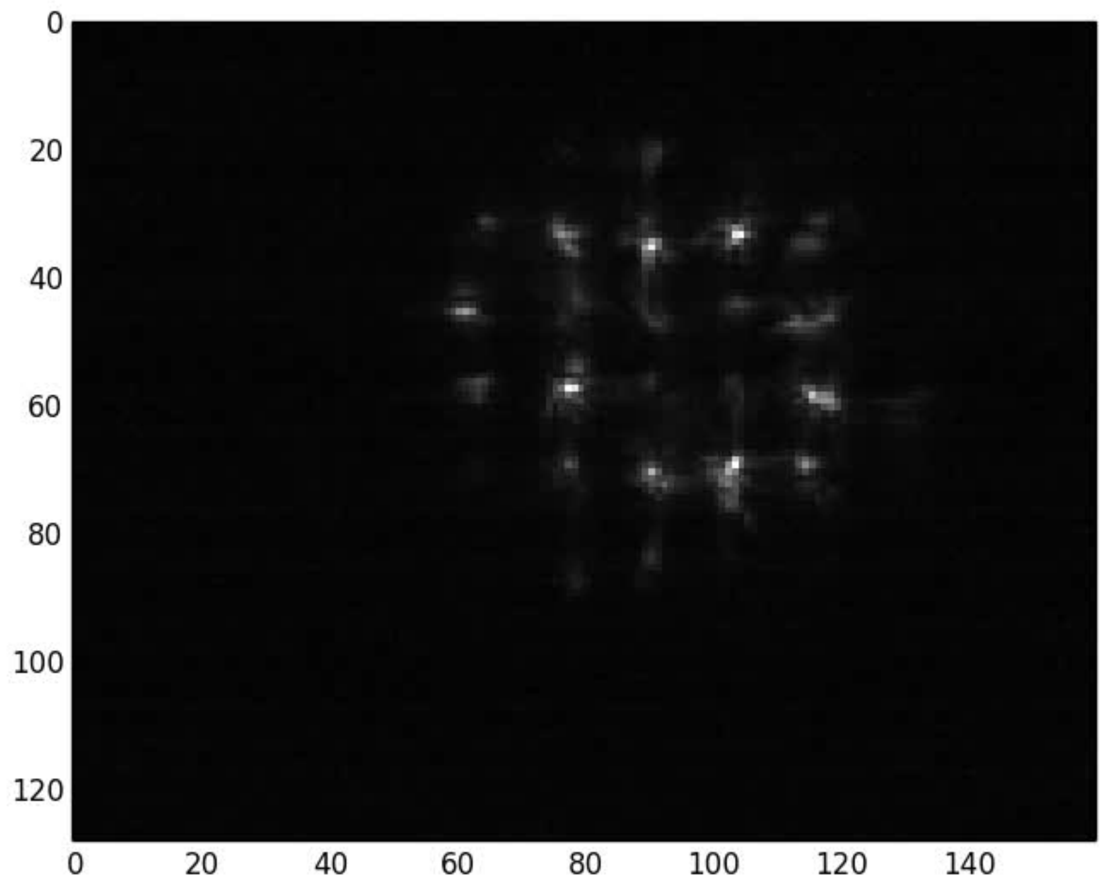
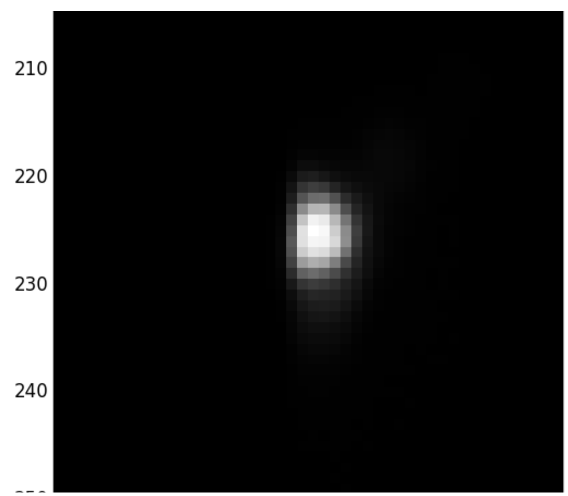


Image of (resolved) fiber source

- With the current 50 micron core fiber system mounted on the rail, I can only say that the image is less than 1 arcsec and consistent with the fiber core size (measured with PAVO).
- More testing needed with S2 beacon when installed.



Where to Next?

- The real dichroics should arrive today (poor timing!) The procedure for their alignment can be carried out by staff on the mountain.
- With only 1 dichroic in the beam, the 5mm of CaF2 is the equivalent of 5m of air. This is negligible for IR combiners (PAVO tracks dispersion anyway).

Fast Passive WFS Calibration…

- With N_l lab WFS measurements and N_t telescope WFS measurement, we can create a (N_l x N_t) correlation matrix C.
- Multiplication by this matrix translates the lab WFS measurements to the telescope WFS, enabling a new reconstructor to be made from the interaction matrix, projected to the telescope WFS coordinate system (i.e. a matrix multiplication $T_t = C \,.\, T_l$, with T the inTeraction matrix.
- Works better with finer lab WFS sampling than telescope WFS sampling (as we have – 28 lenslets).