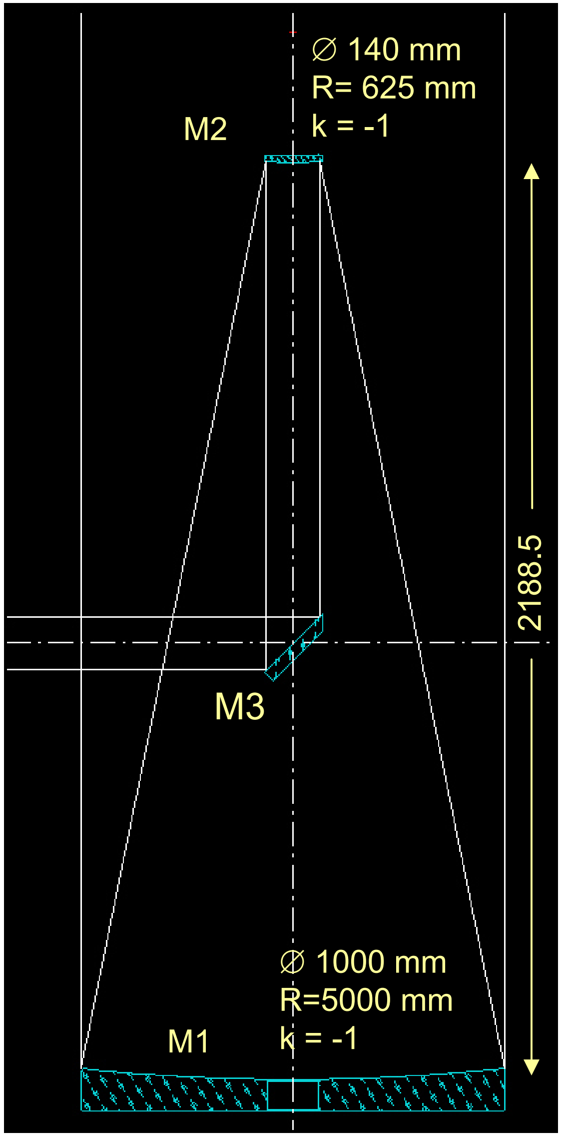
CHARA Telescope Alignment

By Laszlo Sturmann

Mersenne (Cassegrain type) Telescope



M1/M2 provides an afocal optical system
1 m input beam and 0.125 m collimated output beam

Aplanatic design

spherical aberration = 0
Coma = 0
Astigmatism = 0
on-axis

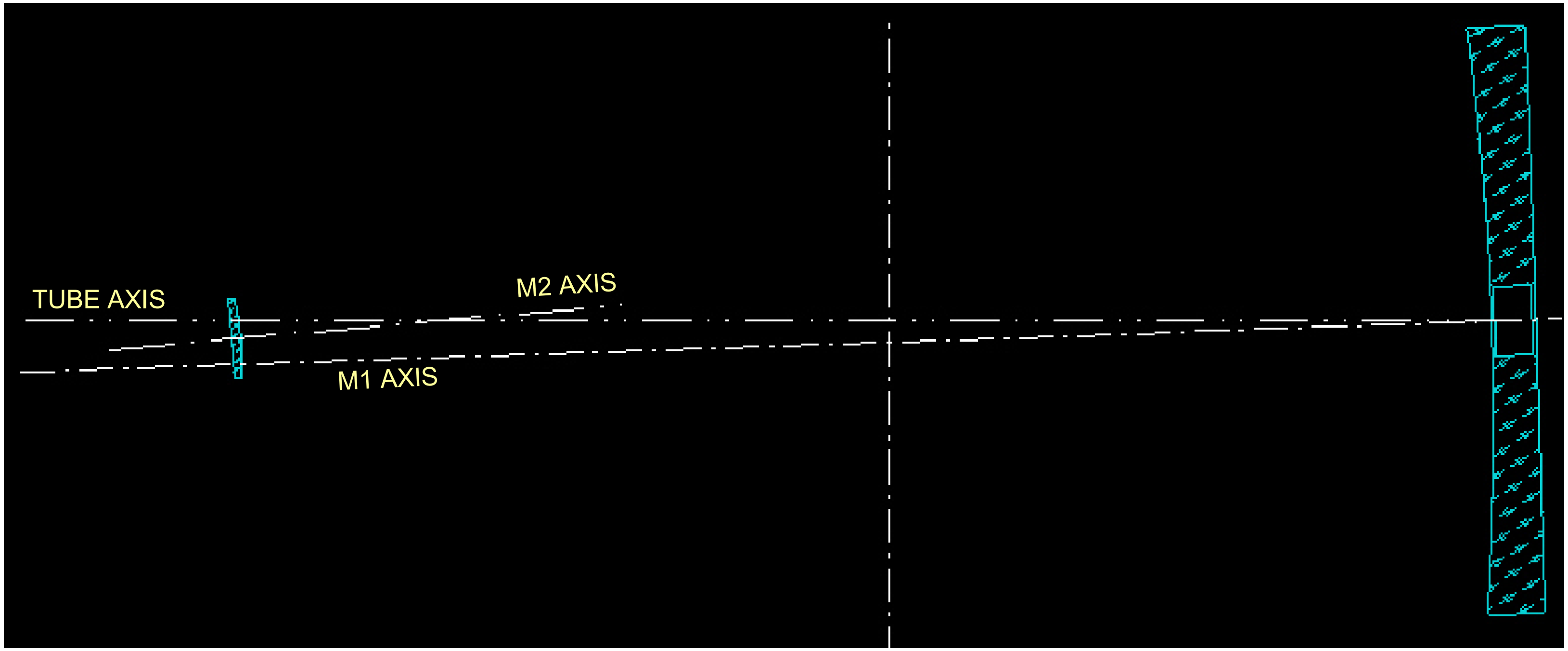
FOV - small (few arcsecs)

Perfect Alignment

The axes of M1 and M2 as well as their focal points are coincident and the output beam intersects the elevation axis at the center of M3

is an abstraction!

The situation with slight exaggeration



- many degrees of freedom
- the exact positions of the vertices and the direction of the axes of the mirrors are not known

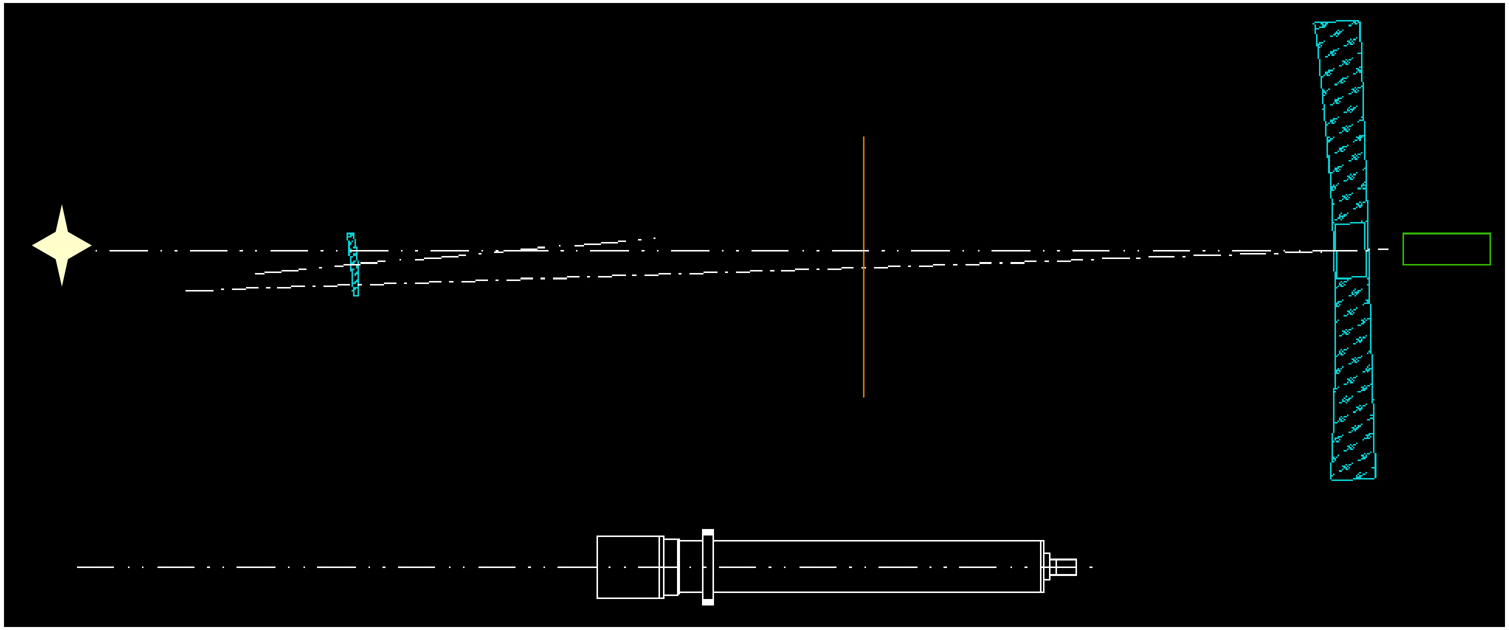
Step 1 Initial alignment

Slightly modified version of Steve Ridgway's procedure

Purpose: Center and tilt M1, M2 and M3 to approach their ideal position and direction

secondary centering error on tube axis : ~1-2 mm
secondary tilt error with respect to the tube axis : ~20 arcsecs
primary tilt error with respect to the tube axis : ~3 arcmin

All could be improved with a better alignment telescope

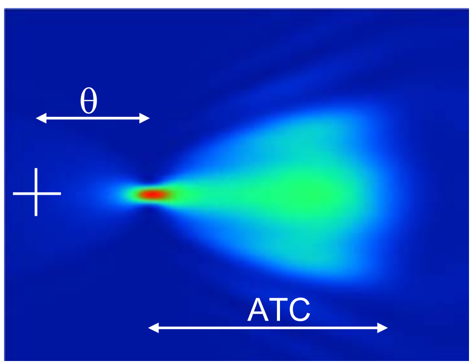


Step 2 refining the initial alignment and focusing the telescope

coma has linear field dependence compared with the quadratic dependence of astigmatism → Close to the axis coma is the dominant effect when the secondary is tilted or decentered

For the CHARA telescope the third-order angular tangential coma (ATC) is:

$$ATC[arc\sec] = 0.0525\theta[arc\sec] + 0.0075\alpha[arc\sec] - 2.475l[mm]$$



α – M2 tilt

l – M2 decenter

It is possible to eliminate coma due to decenter by tilting M2

Tilting M2 is easy but it causes beam tilt and defocus

The telescope is afocal → an auxiliary telescope is needed aligned to the laser from the lab

Procedure:

1. watch the extrafocal image of a bright star with high magnification (>1000x)
2. look for asymmetries in the pupil image
3. tilt the secondary and repoint the telescope until the image is symmetric

When coma is close to zero astigmatism becomes dominant

Astigmatism can not be eliminated by tilting the secondary in a decentered telescope.

Either the primary needs tilting or the secondary needs centering

Step 2 focusing the telescope

Despace results in spherical aberration and defocus
1 mm despace decreases the focus from ∞ to ±781 m and produces 7.4 wave p-v wavefront error.

Focusing currently is done by eye.
The auxiliary telescope is focused to infinity
M2 is moved until the image is sharp in the aux. telescope.

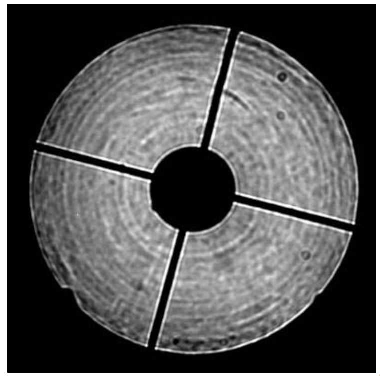
Focusing error in the aux. telescope $\Rightarrow$ bias in focusing the main telescope

The effect of 0.1 mm defocus in the aux. telescope is that the focus of the main telescope will be set to ± 15 km (1.2 μm p-v).

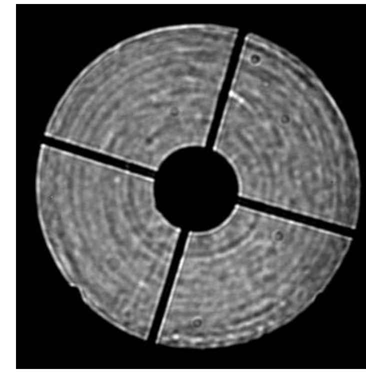
Step 4 quantitative beam quality evaluation is needed

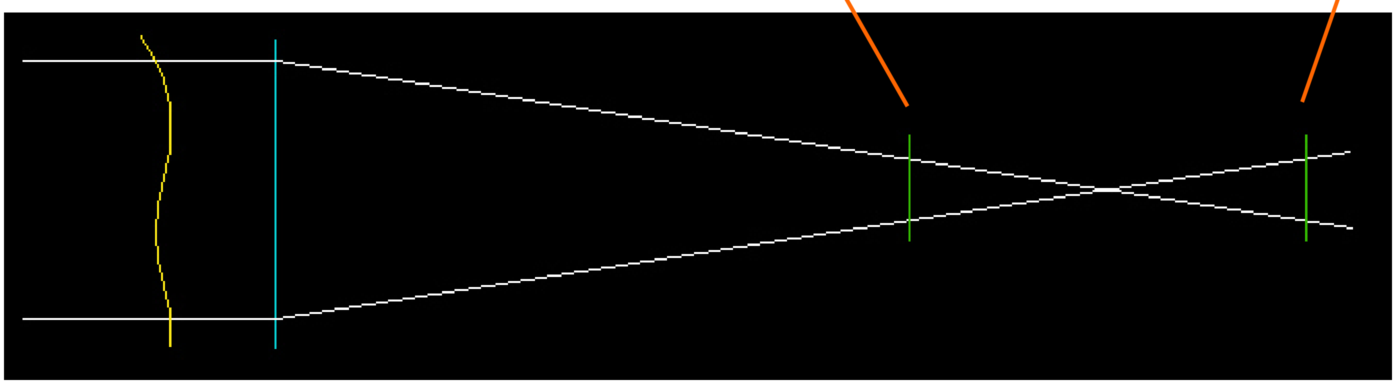
Wavefront Curvature Sensing (Roddier & Roddier)

ef -software to compute *W* in terms of Zernike polynomials is in hand



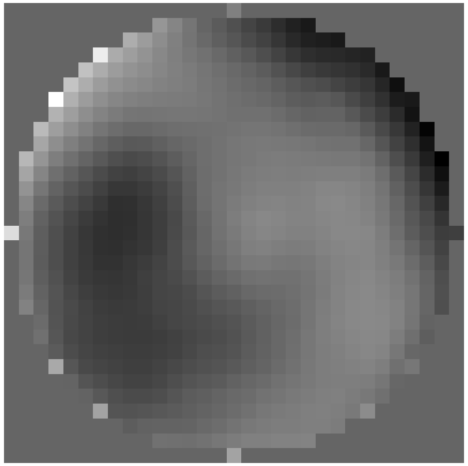
W1

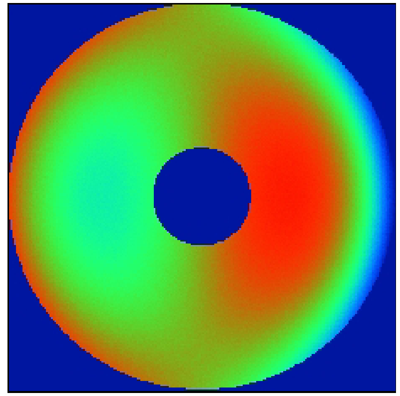




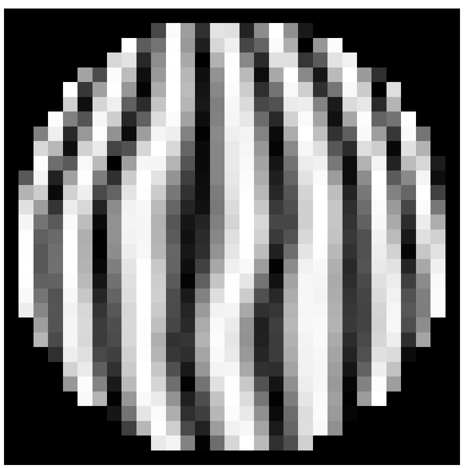
$W(x,y)$

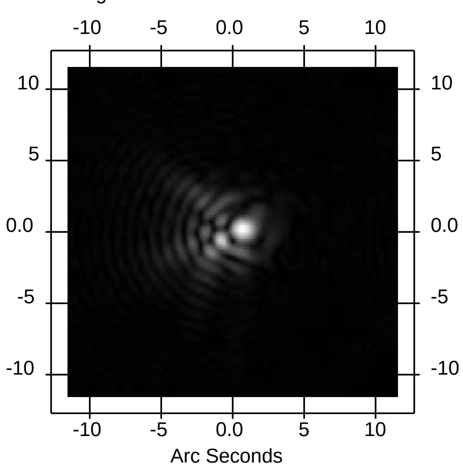
computed wavefront for W1





M2 1mm decentered



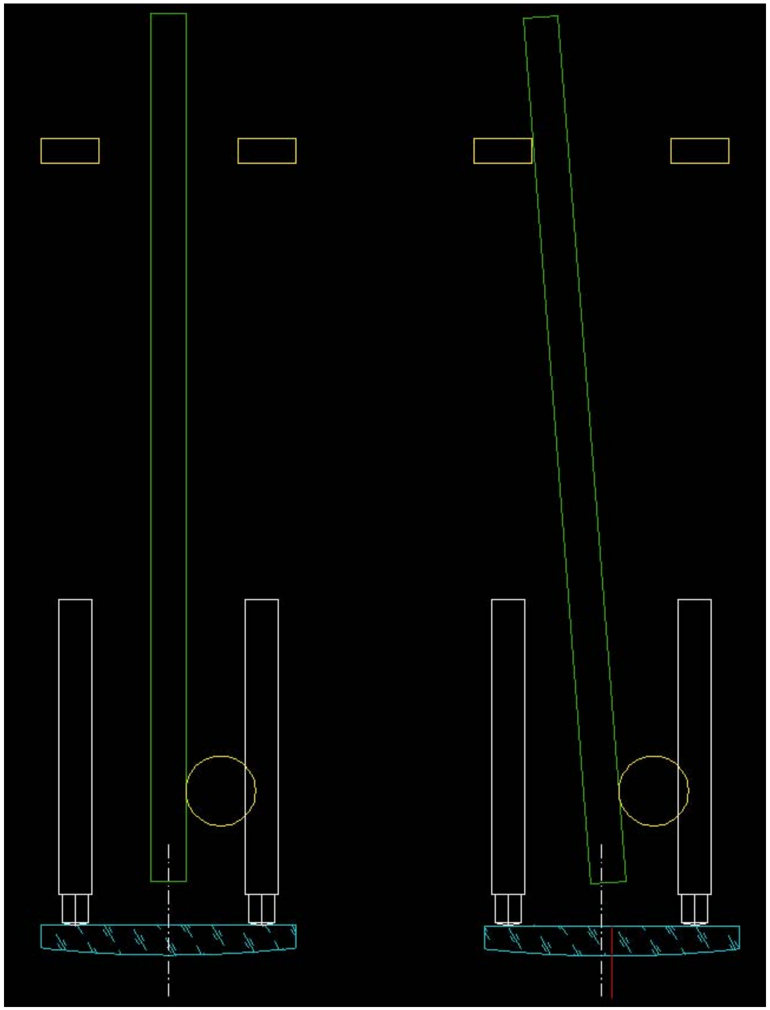


Synthetic image

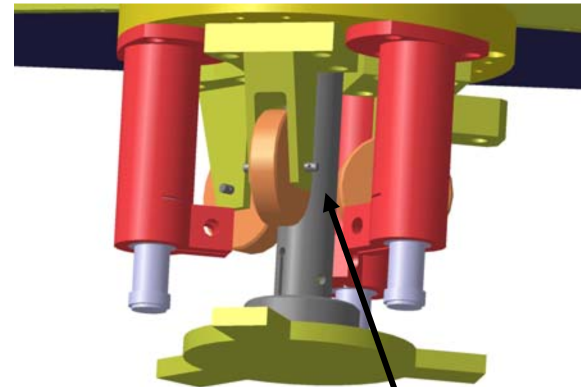
WL_100mm

Zernike	Name	RMS nm
4	focus	660
5	astigmatism (sin)	-86.2
6	astigmatism (cos)	-11.8
7	coma (sin)	-27.2
8	coma (cos)	-97.4
9	trefoil (sin)	8.79
10	trefoil (cos)	11.7
11	spherical	18.9
12	sph astig (cos)	5.66
13	sph astig (sin)	-8.96
14	quad astig (cos)	-8.27
15	quad astig (sin)	6.03
16	r^5cos(1)	-9
17	r^5sin(1)	5.79
18	r^5cos(3)	-9.53
19	r^5sin(3)	7.12
20	r^5cos(5)	-4.43
21	r^5sin(5)	-11.4

New mode for centering M2

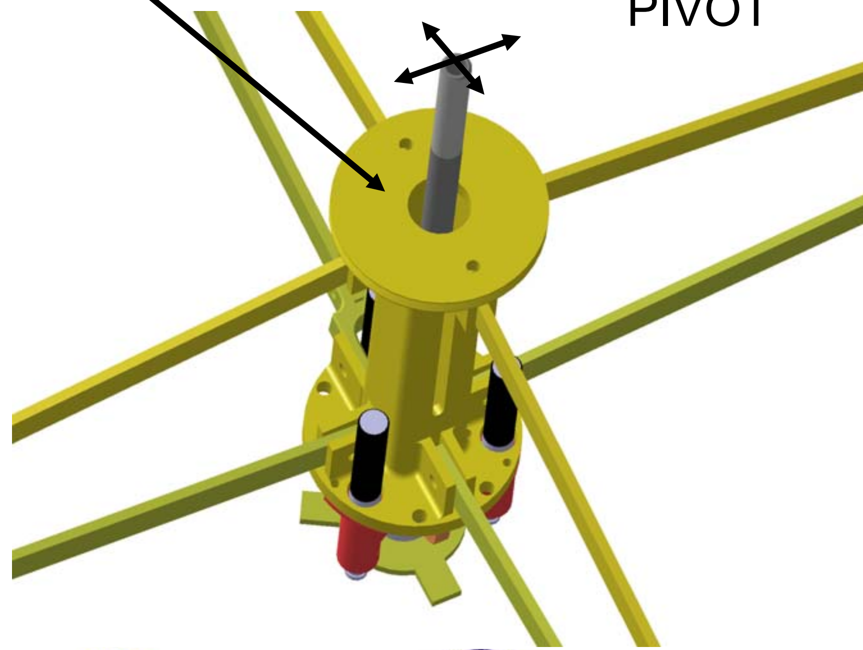


$\cong 2mm$



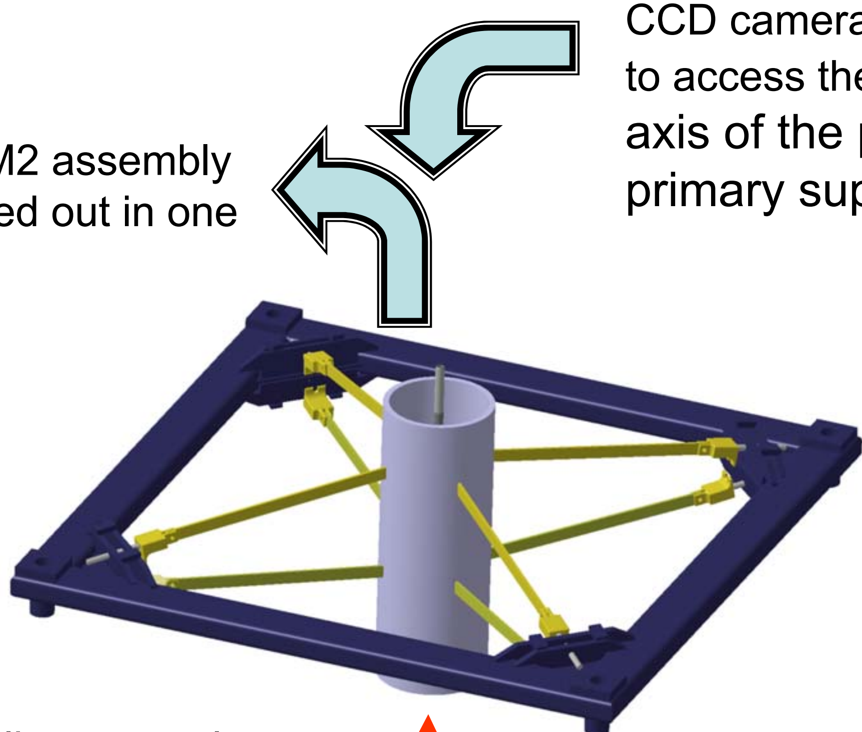
PIVOT

2 MOTORS



CCD camera can be mounted in the tube to access the prime focus for finding the axis of the primary and checking the primary support structure

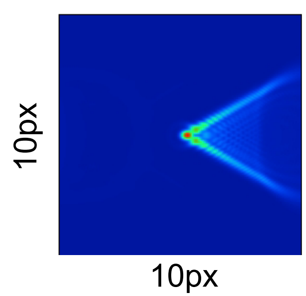
the whole M2 assembly can be pulled out in one piece



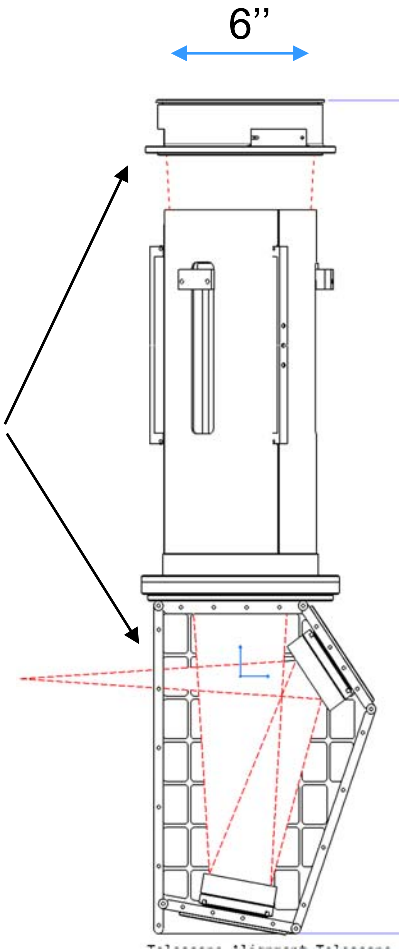
alignment telescope can see through better

F/2.5 Primary
field coma can be used to find the focal point

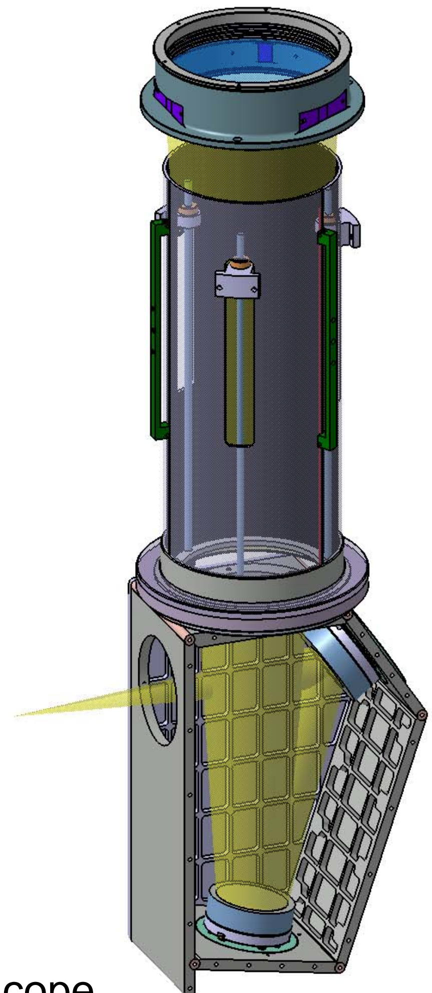
6 mm off axis

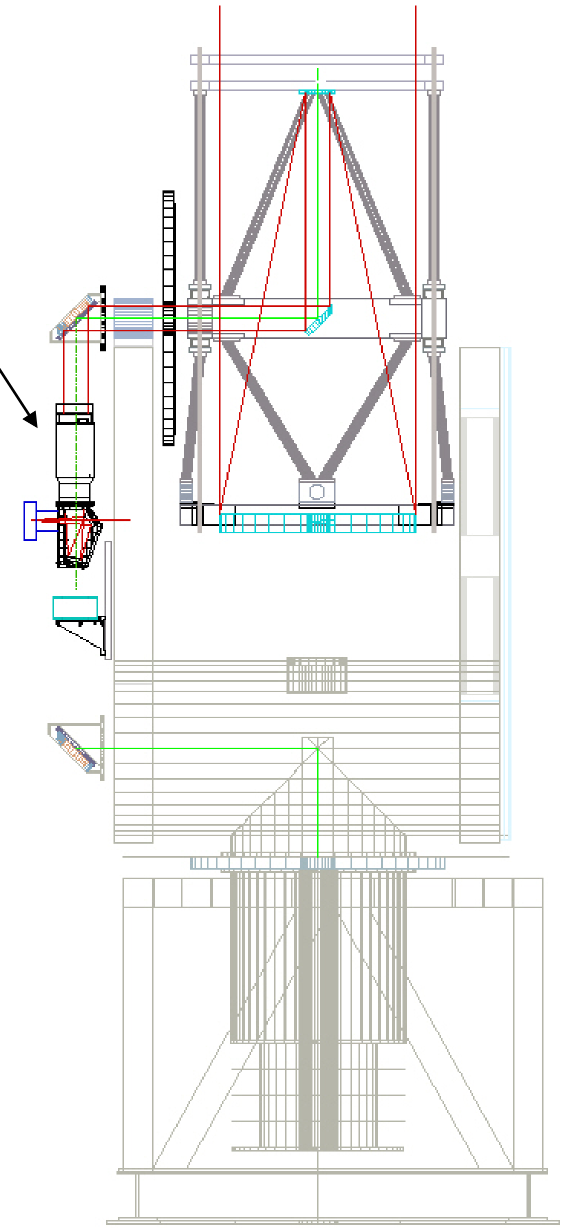


Folded 6’’ F/9 Refractor (TAS)
for wavefront curvature sensing



built





Prealigned mounts on each telescope
for easy and repeatable mounting