Update on Adaptive Optics Scanning Laser Ophthalmoscope (AOSLO) for retinal imaging

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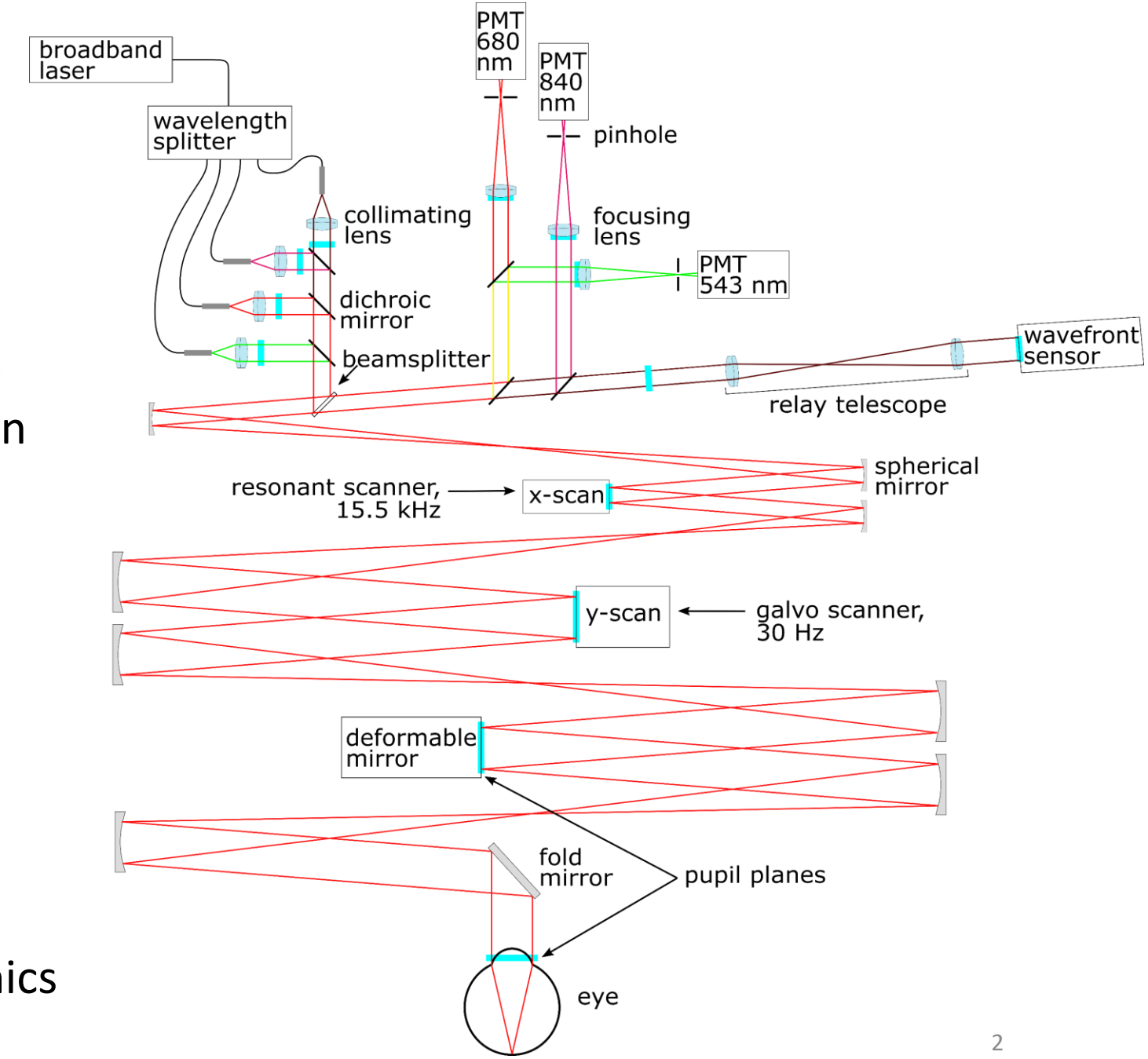
Friday, July 9, 2021

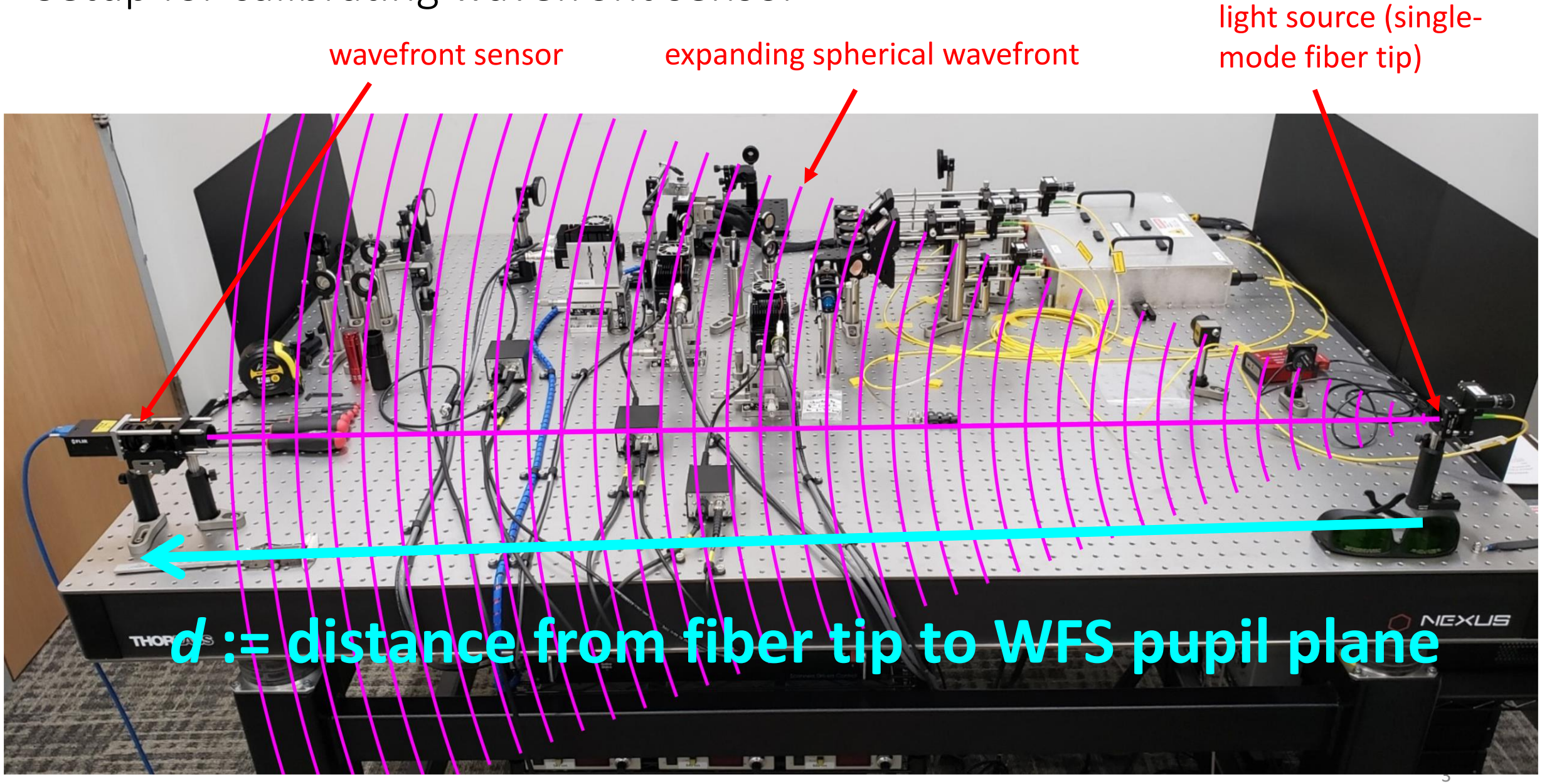
AP Lab Technical Meeting

Hardware is nearly complete

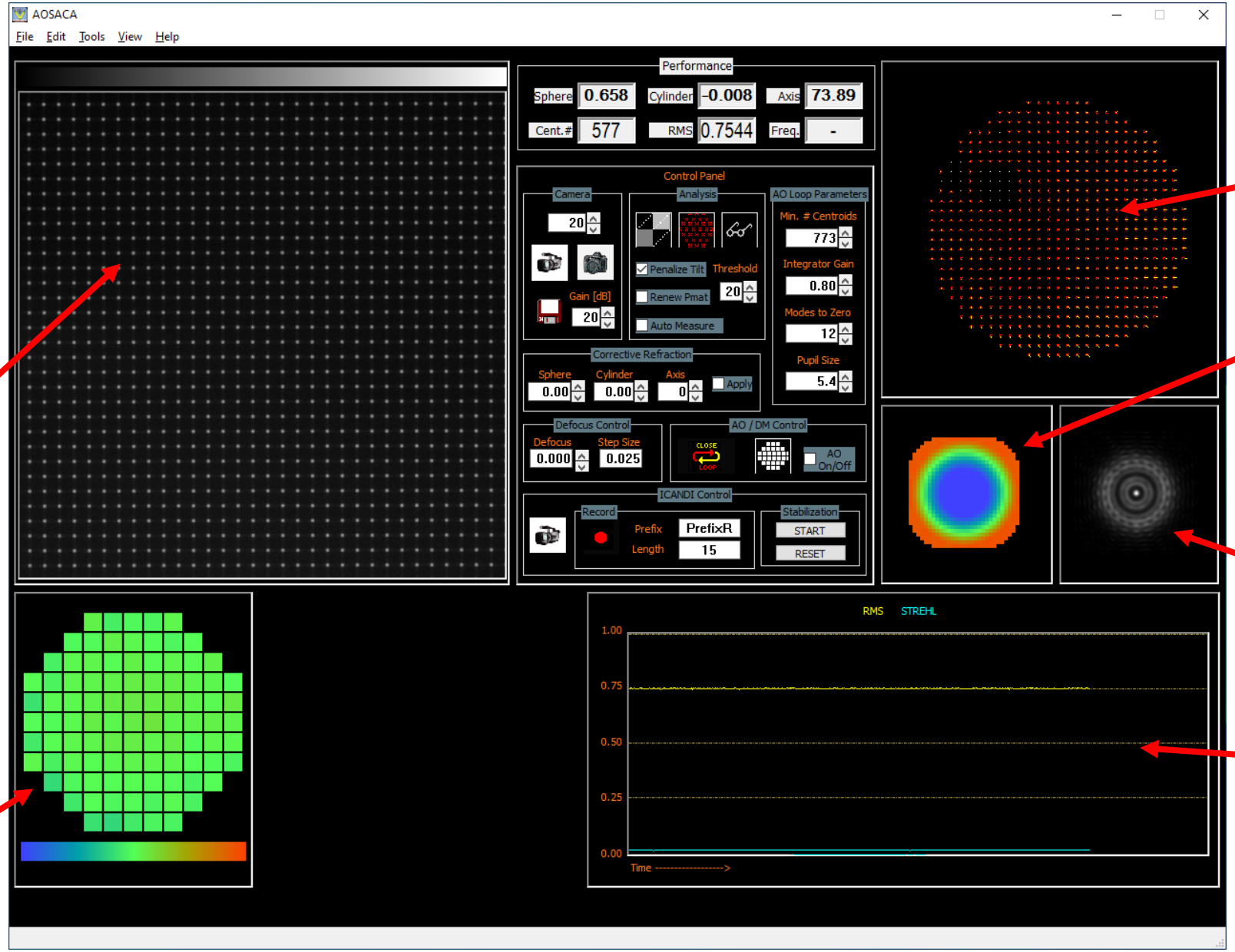
- Wavelength splitter was recently realigned to improve the power output
- Scanning system was realigned to ensure optimum beam position on all surfaces
- Wavefront sensor has been calibrated and installed
- AO system works in closed-loop mode
- Pinholes have been aligned
- Timing signals are being properly generated by the control electronics



Setup for calibrating wavefront sensor



Sample measurement with WFS software



focal spots

centroid deviations

wavefront map

PSF

RMS WFE and Strehl ratio over time

DM surface

Calibration measurements

- WFS measures wavefront curvature, P, and reports it as Diopters of sphere
- First measurement taken with $d = 1.634\ \mathrm{m}$, which corresponds to $P = \frac{1}{d} = \frac{1}{1.634\ \mathrm{m}} = 0.612\ \mathrm{D}$ of sphere
  - WFS reported 0.515 D of sphere
  - lenslet axial position was adjusted to achieve the correct value: 0.610 D
- Next, measurements were taken at other distances:

Distance (m)	Wavefront curvature (D)	WFS measurement (D)
1.634	0.612	0.610
1.189	0.841	0.841
0.668	1.50	1.508

Lenslet adjustment

- For the closest distance, the measurement was too high by 0.008 D, and for the furthest distance, the measurement was too low by 0.002 D

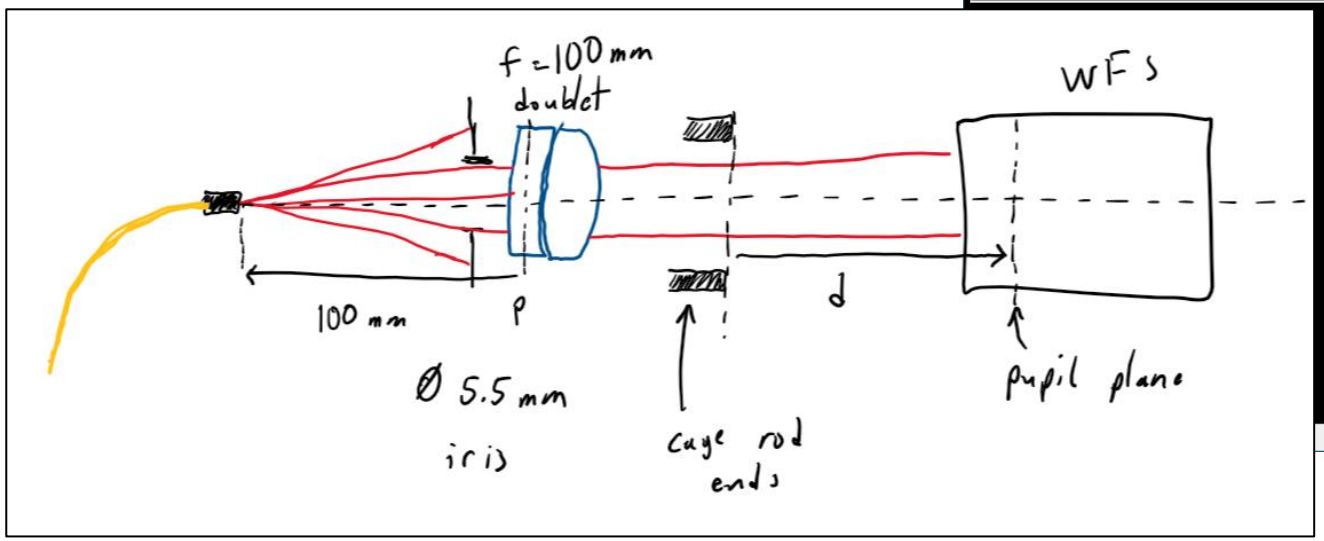
Distance (m)	Wavefront curvature (D)	WFS measurement (D)	Difference (D)
1.634	0.612	0.610	-0.002
1.189	0.841	0.841	0.000
0.668	1.50	1.508	+0.008

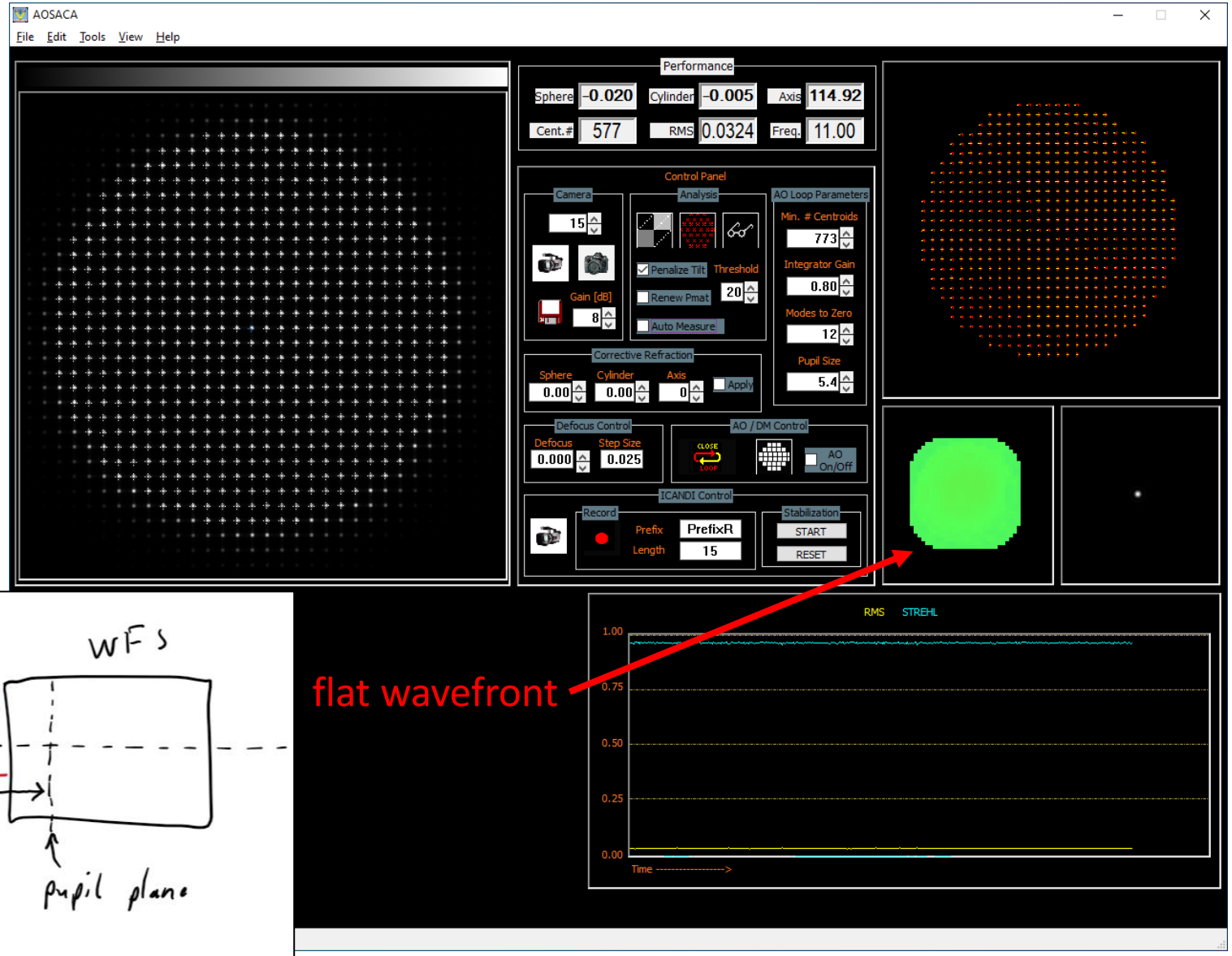
- The lenslet axial position was adjusted by 0.02 mm to achieve better accuracy across this measurement range

Distance (m)	Wavefront curvature (D)	WFS measurement (D)	Difference (D)
1.515	0.660	0.658	-0.002
0.668	1.50	1.500	0.000

Measuring collimated beam of light with WFS

- Doublet with focal length of 100 mm was used to collimate light from the fiber tip
- Thorlabs WFS was used to measure test setup and ensure proper collimation



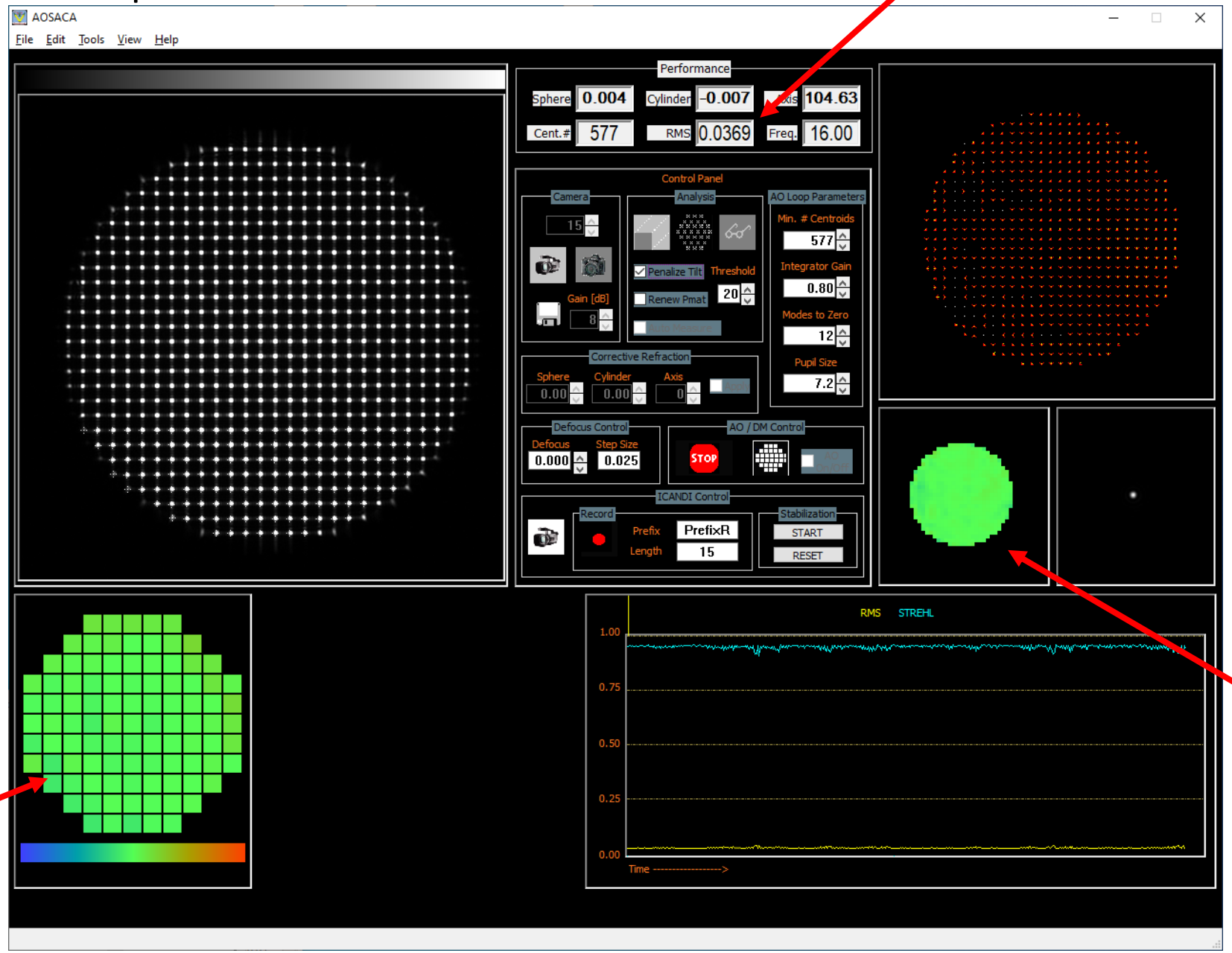


Collimation test results

- Measurements of the collimated beam were similar between the Thorlabs WFS and the custom AOSLO WFS
- In both cases, the RMS WFE was much less than 0.07 waves
- There seems to be a small bias in the sphere measurement of about -0.010 D between the two wavefront sensors
- This difference is very small, and is likely related to the different calibration wavelengths for the two wavefront sensors (633 nm for Thorlabs, 940 for AOSLO)

Measurement	sphere (D)	cylinder (D)	RMS wavefront error (waves)
Thorlabs WFS	-0.001	-0.003	0.040
Thorlabs WFS, repeated	-0.005	-0.003	0.042
AOSLO WFS	-0.020	-0.005	0.032
AOSLO WFS, repeated	-0.015	-0.007	0.030

AO in closed-loop mode



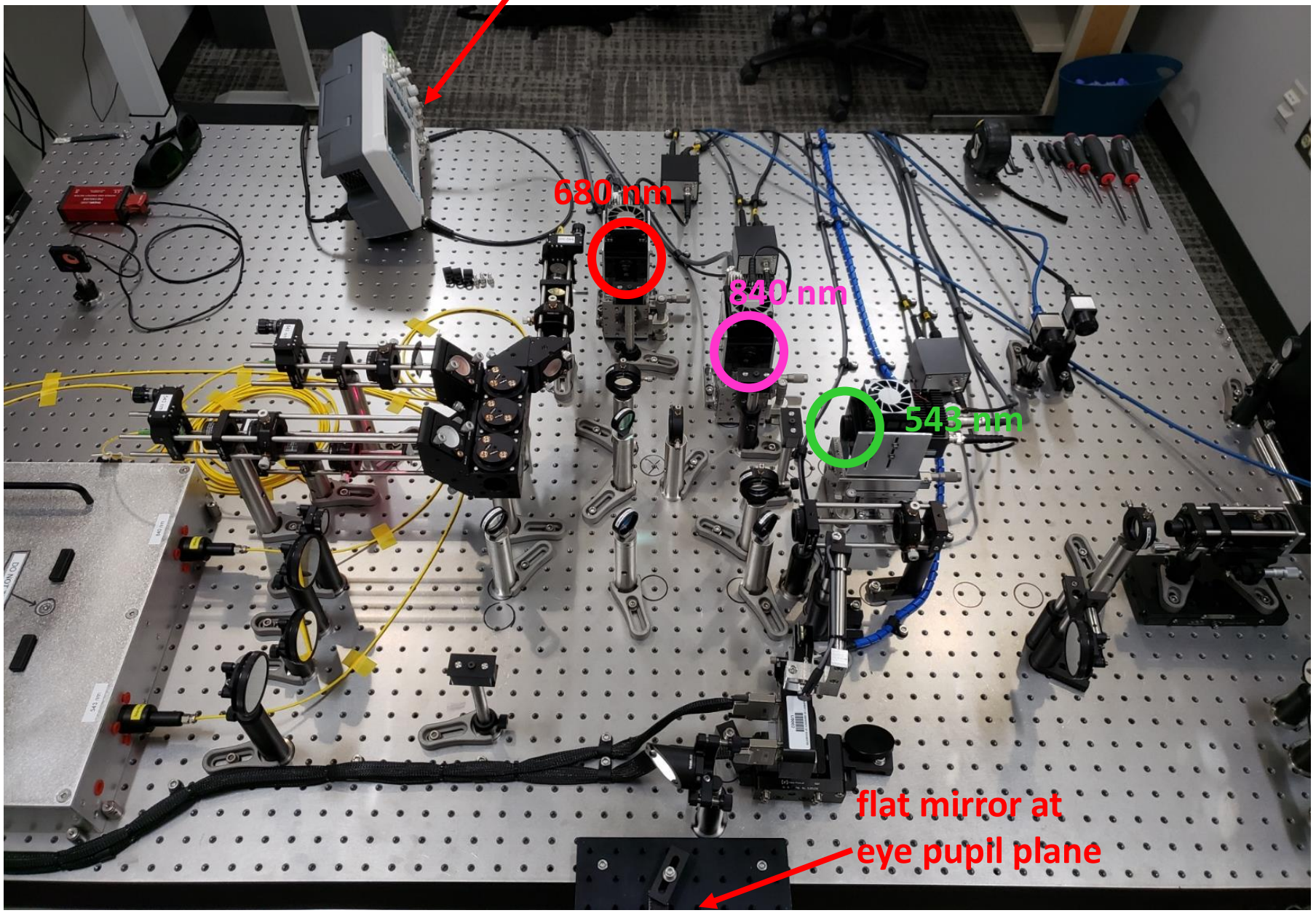
diffraction-limited wavefront error (RMS < 0.07 waves)

DM shape is continuously updated

flat wavefront

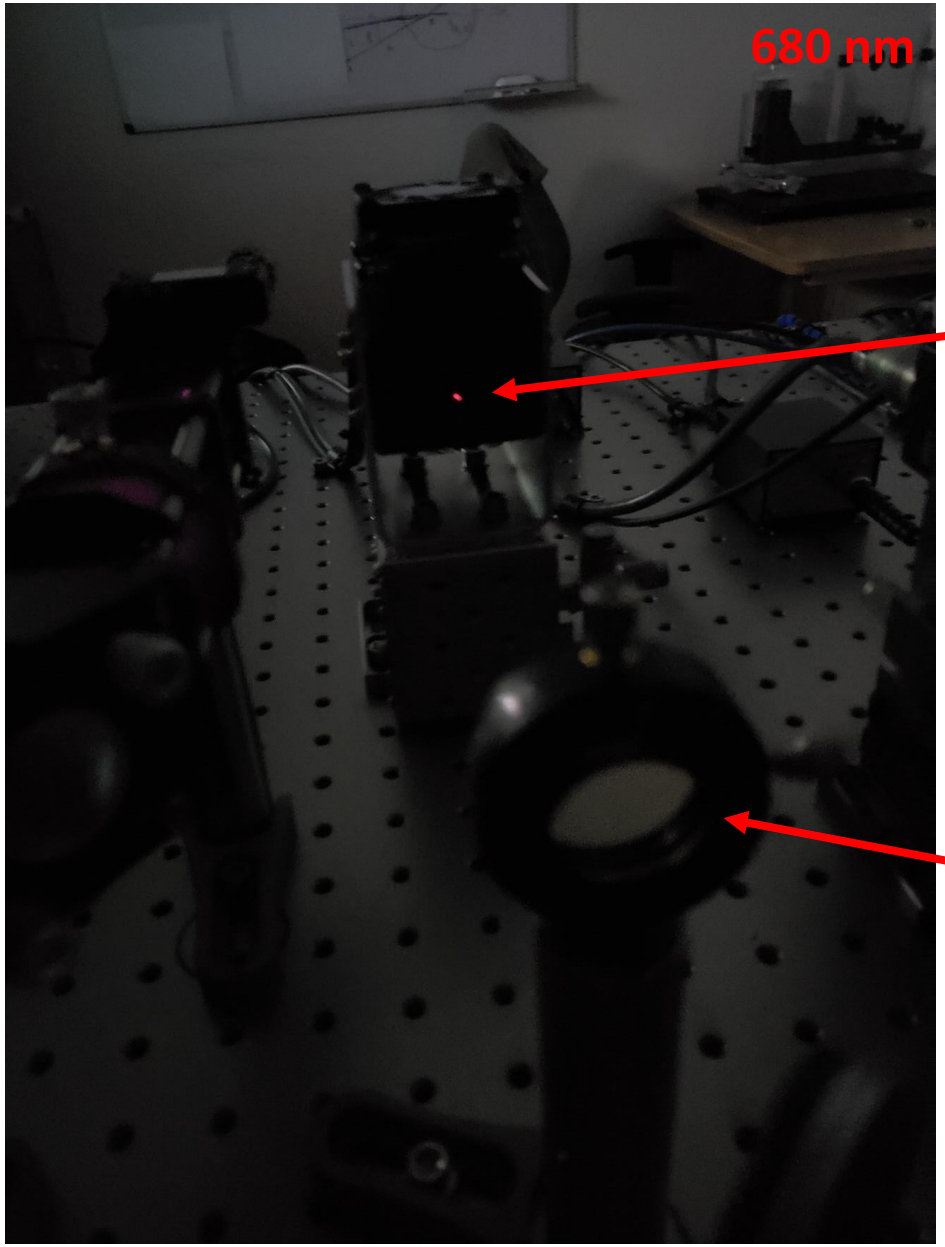
Pinholes have been aligned

- Pinholes are 40 – 50 µm in diameter
- Attached to PMTs (detectors) for 543, 680, and 840 nm channels
- To ease alignment, flat mirror placed at eye pupil plane
- PMT output signal monitored with oscilloscope
- x-y-z position of pinholes optimized



Pinhole alignment pictures

fluorescent target was used during alignment of 840 nm channel



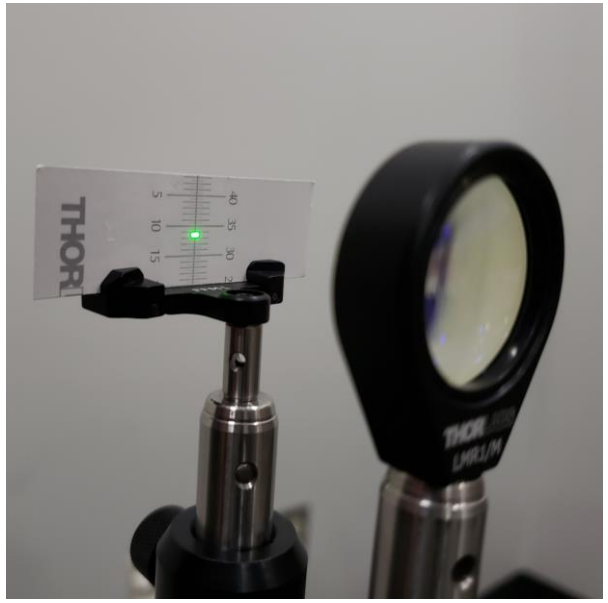
small spot of light visible at pinhole plane

focusing lens

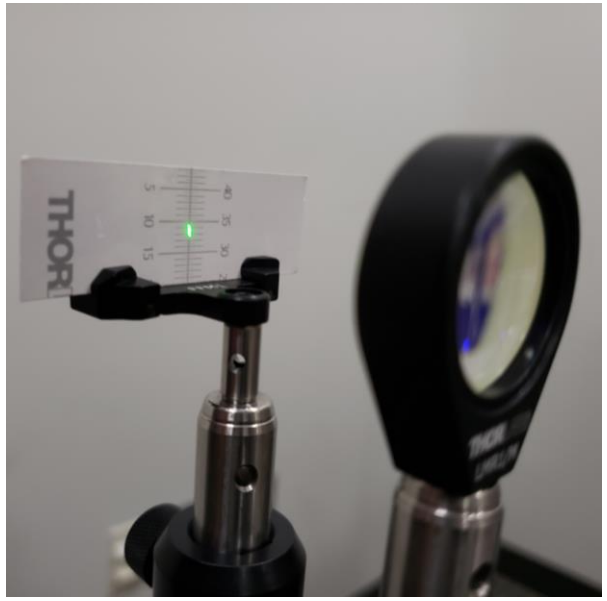
Demonstration that both scanners are working well

- Doublet lens with focal length of 50 mm was placed at the eye pupil plane
- Piece of paper was placed at rear focal plane of lens
- Scanners were turned on and adjusted using the digital control interface
- Next, I will need to calibrate the scanners so we can set the angular scan range

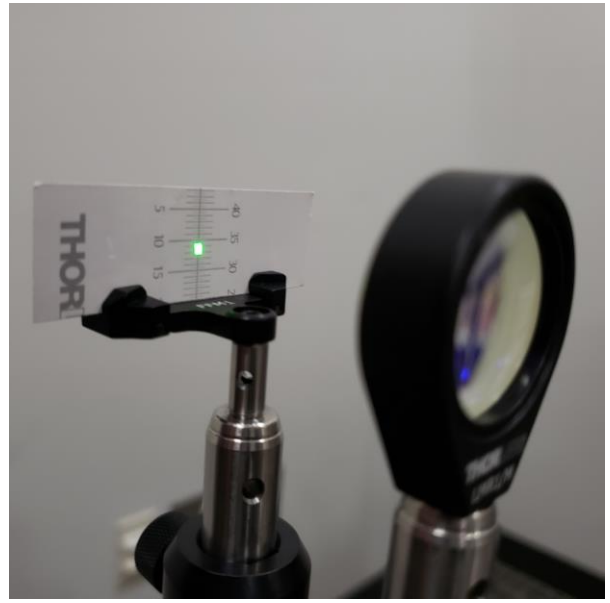
Spot of light
(both scanners off)



Horizontal line
(resonant scanner on)



Vertical line
(galvo scanner on)



Square
(both scanners on)

Schedule updates

- About 1 week behind schedule due to issues with the data acquisition software
  - The goal was to have some images of a resolution target by now, but that did not happen
  - The issue seems to be driver-related: FPGA is receiving the timing signals from the hardware, but fails to run the data acquisition sequence
  - Working with Pavan to troubleshoot the issue (met last week to discuss, and have been emailing back and forth this week)
- Next steps:
  - Fix the issue with the data acquisition software
  - Image a resolution target using the model eye setup
  - Install AOMs (acousto-optic modulators) to give us dynamic control of the stimulus
  - Send power meter to Thorlabs for recalibration
  - Make adjustments to ensure that light levels are well below the maximum permissible exposure
  - Develop procedures for human subject imaging

IRB updates

- Needed to make small changes to all 3 documents (protocol, info sheet, and consent form)
  - Updating the location
  - Updating our on-call ophthalmologist
  - Making sure everything is correct for the specifics of this new system
- Planning to submit the continuing review and these modifications at the same time
- Still trying to figure out whether we need an ophthalmologist to do the initial eye exam or if someone from the lab can be trained to do this
- Deadline for continuing review submission: July 29
- Just submitted our response to the internal quality check findings, so there may be additional follow-up

End