AOSLO Update: imaging a distortion grid using a model eye

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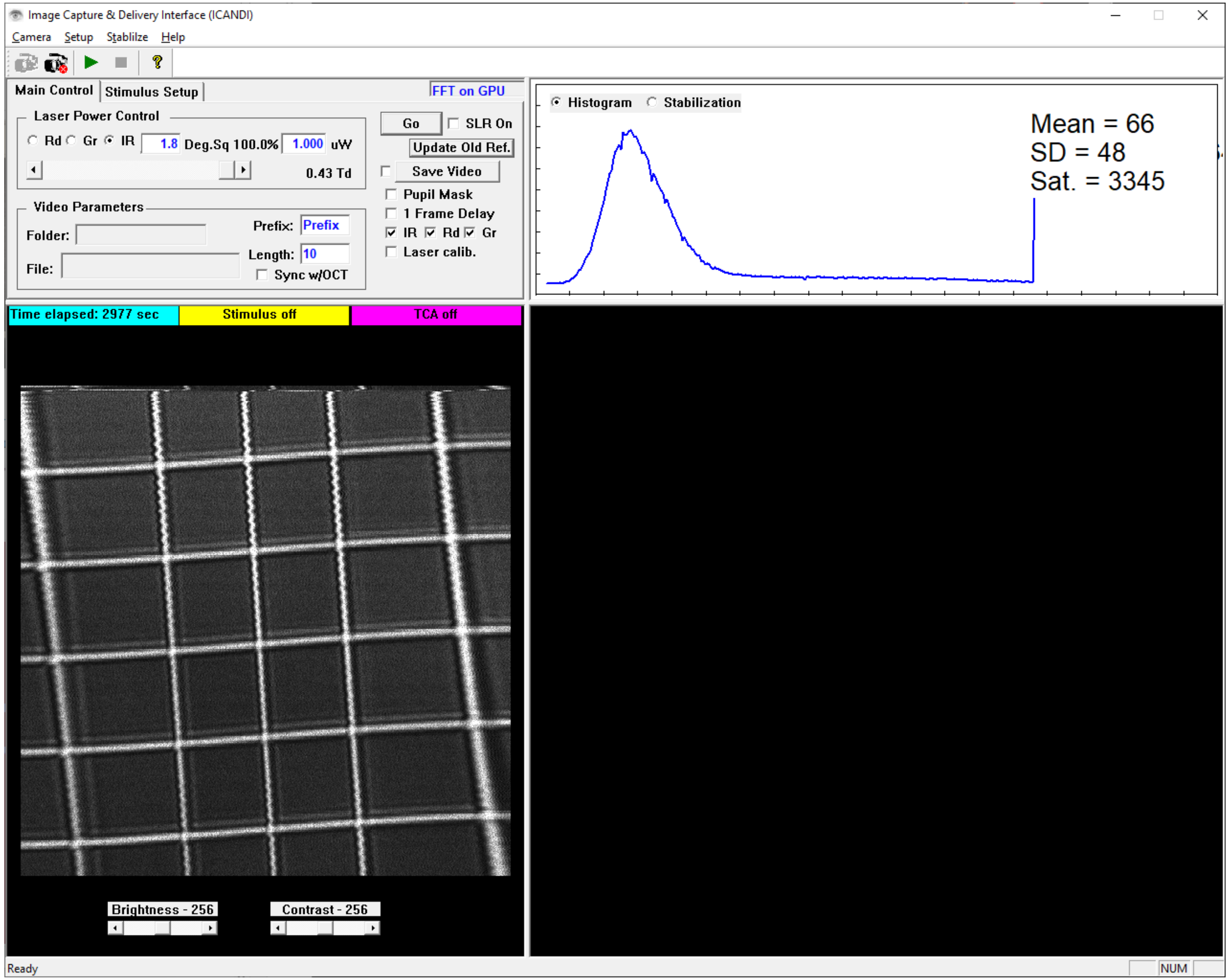
September 10, 2021

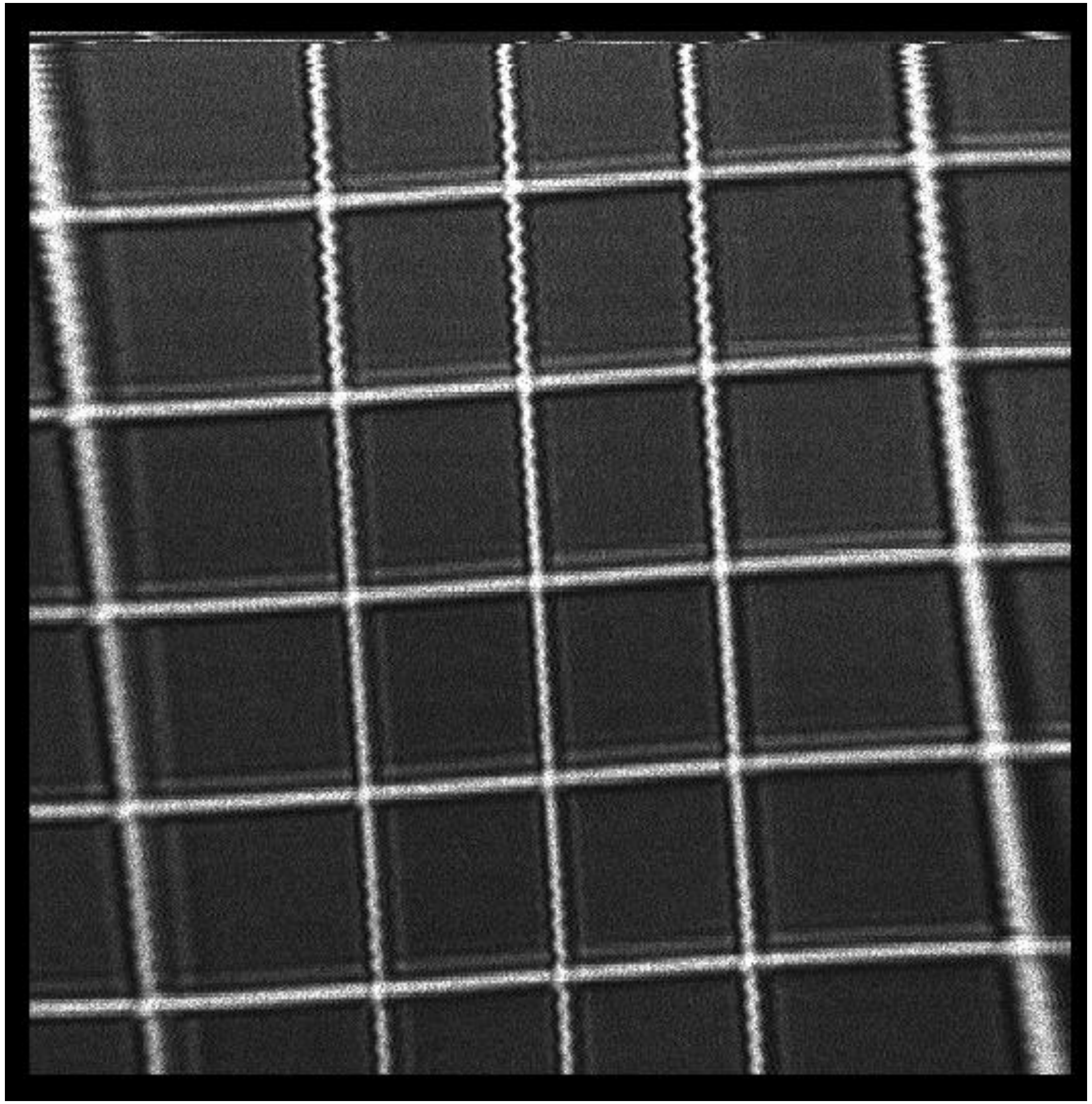
AP Lab Technical Meeting

Removing shear in image



- Captured with the 840 nm imaging channel
- Full field of view is about 500 µm x 500 µm, or 0.6° x 0.6°
- The shear is caused by the two scanners not being orthogonal to each other: requires optical adjustment
- The waviness in the vertical lines is caused by a timing issue: needs electrical adjustment

Removing shear in image



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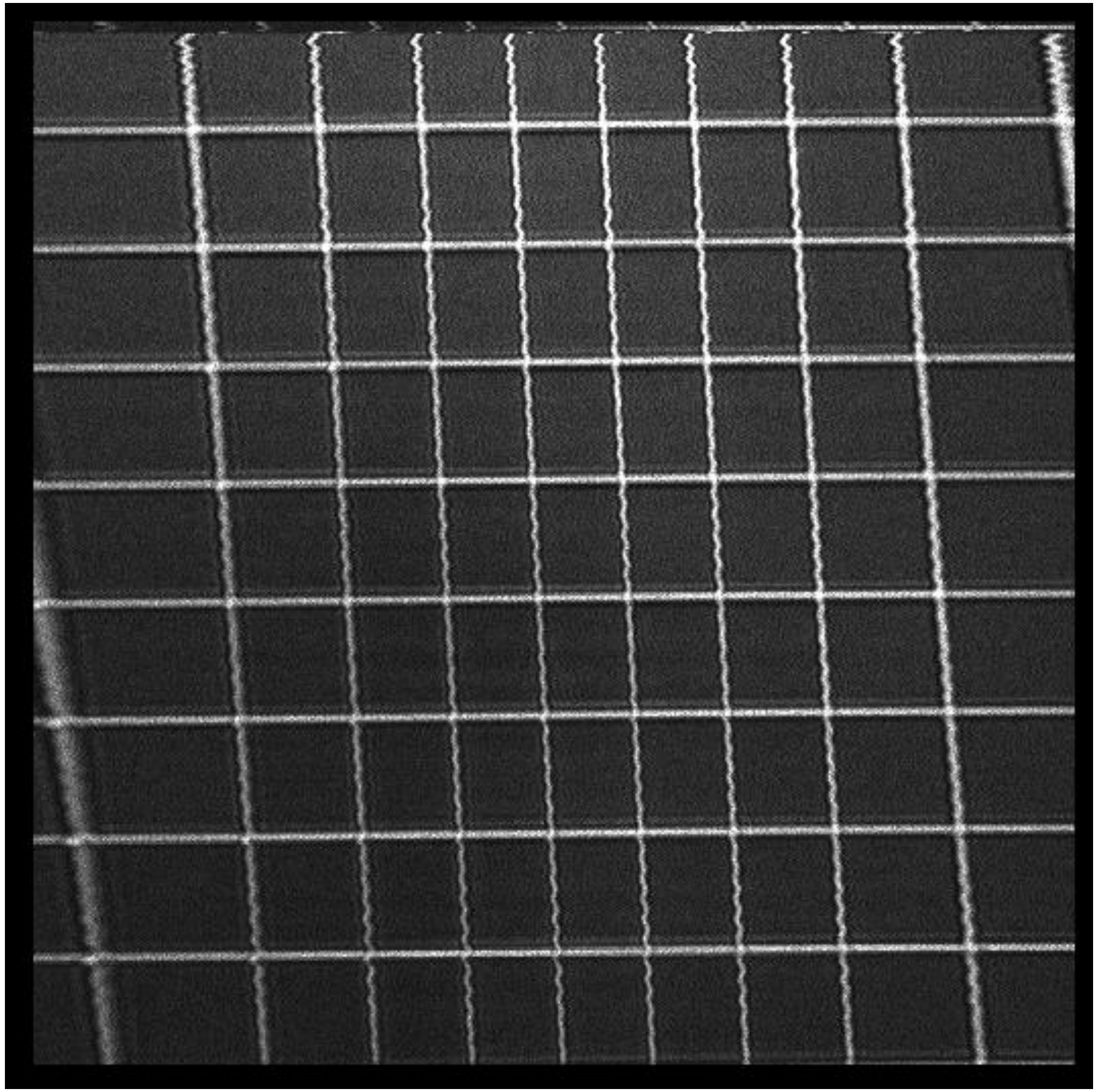
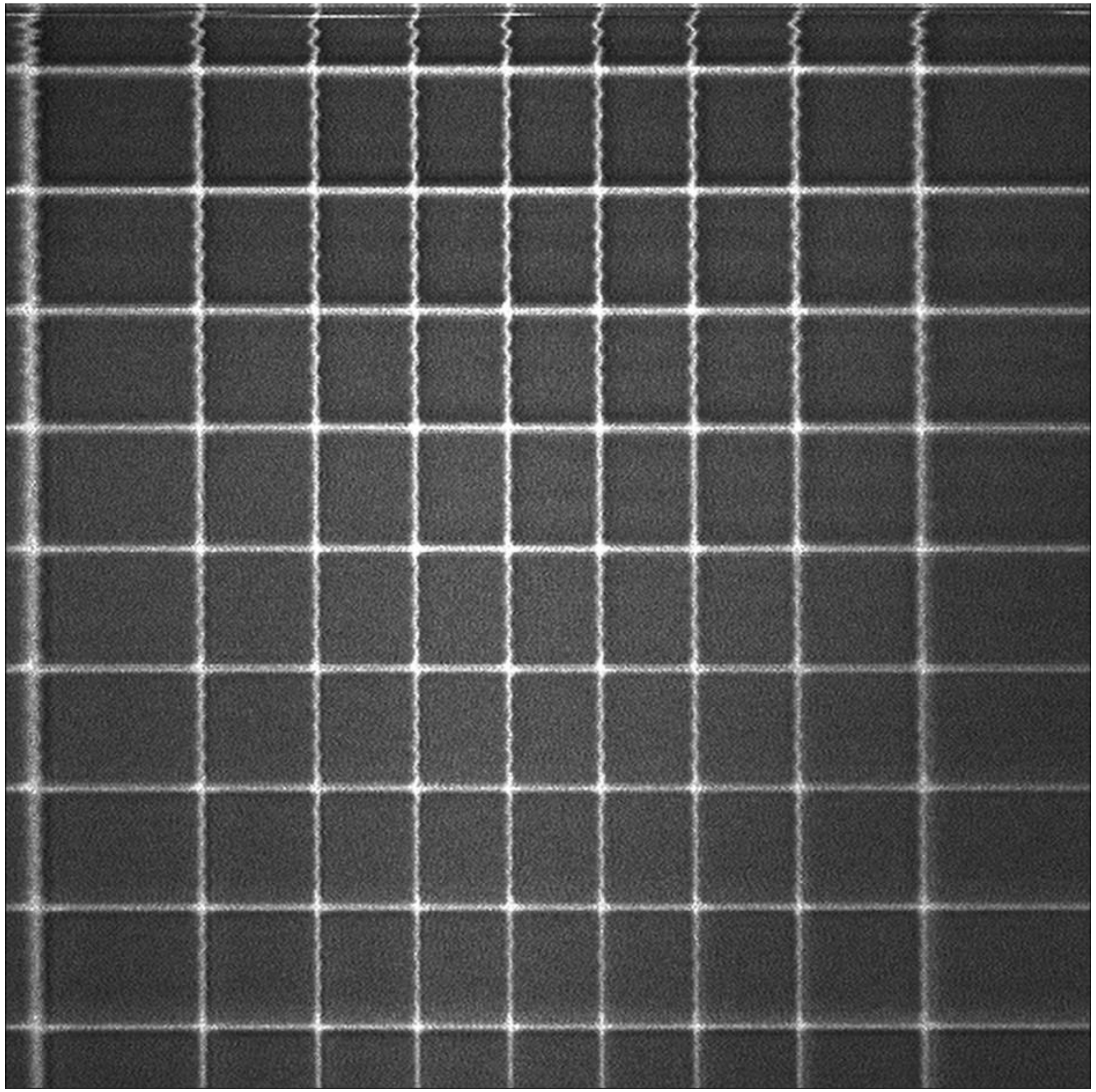
Vertical shear removed by tilting resonant scanner



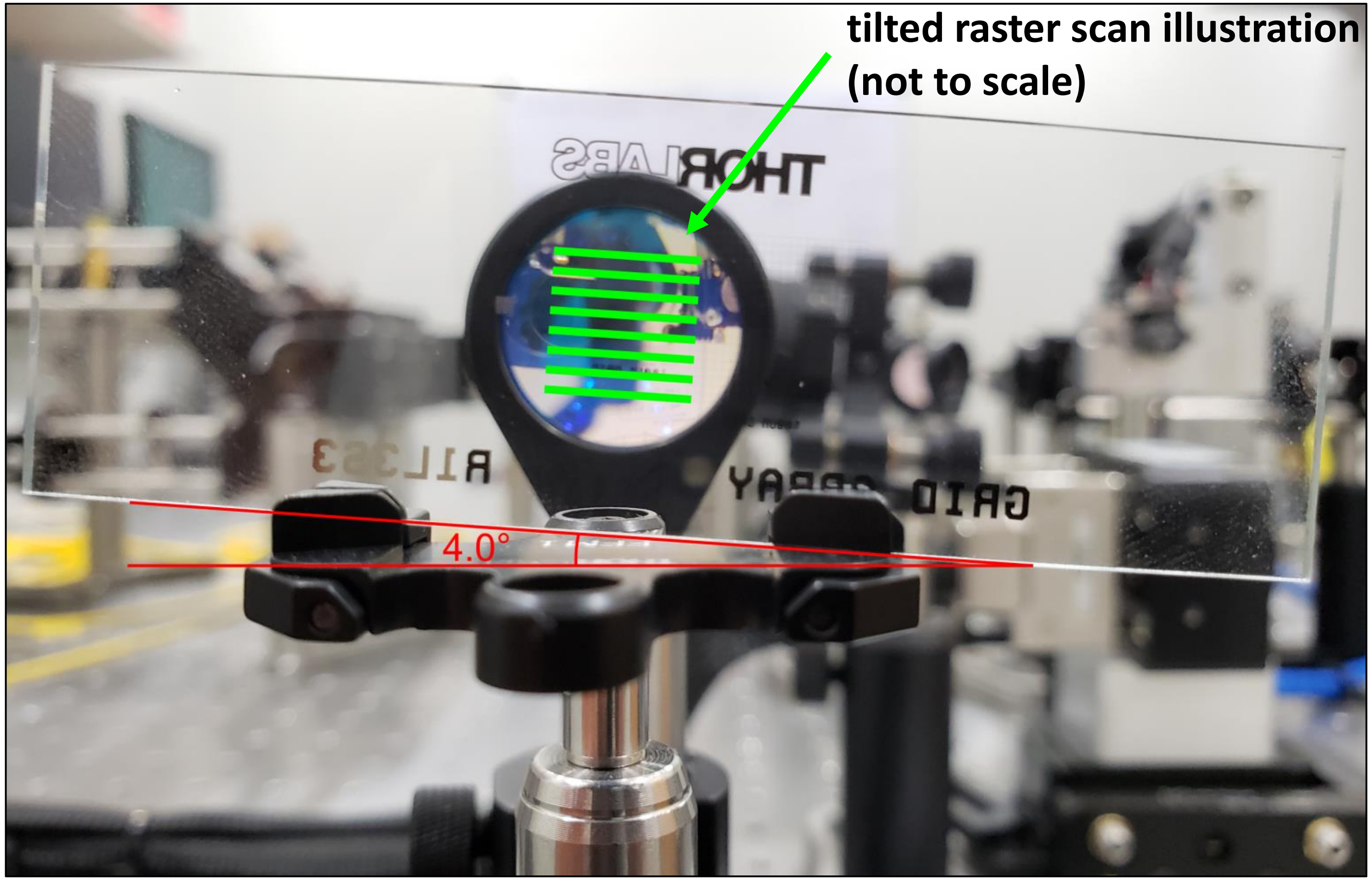
- Full field of view for this image is about 900 µm x 900 µm, or 1.0° x 1.0°
- This is comparable to the field of view that we will use in human imaging
- Tilting the resonant scanner (mounted on a precision tip/tilt mount) removed the vertical shear, but there is still horizontal shear
- To remove horizontal shear, would need extra degrees of freedom on the galvo scanner (or allow the raster to be slightly tilted in the room coordinate frame)

Horizontal shear removed by tilting the grid



- The distortion grid was tilted by a few degrees
- After reoptimizing the resonant scanner tilt, all shear was successfully removed
- This is the approach that Austin Roorda uses: they don't worry about the absolute orientation of the raster scan in the room coordinates

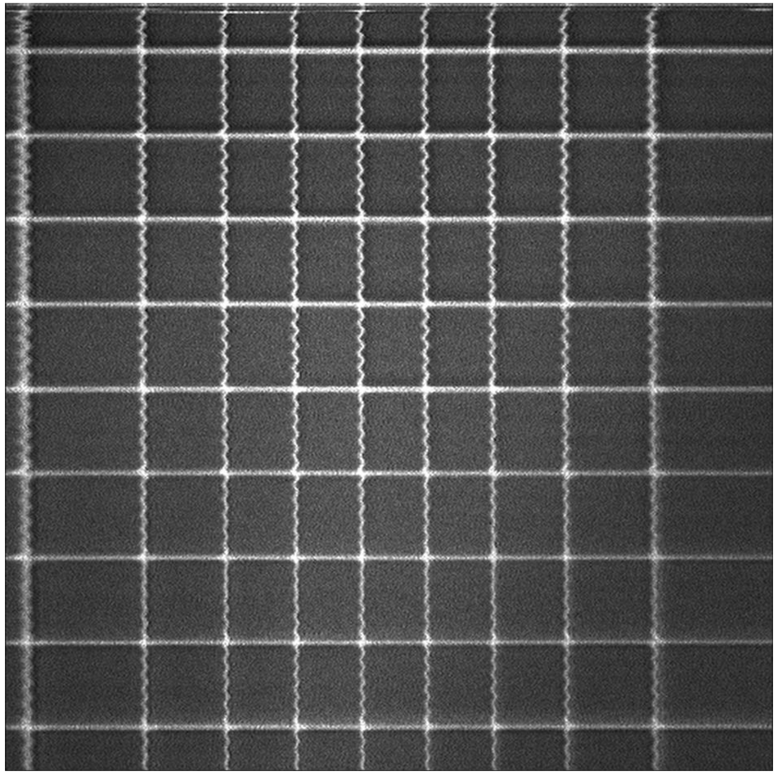
Is the tilt of the raster scan a problem for us?



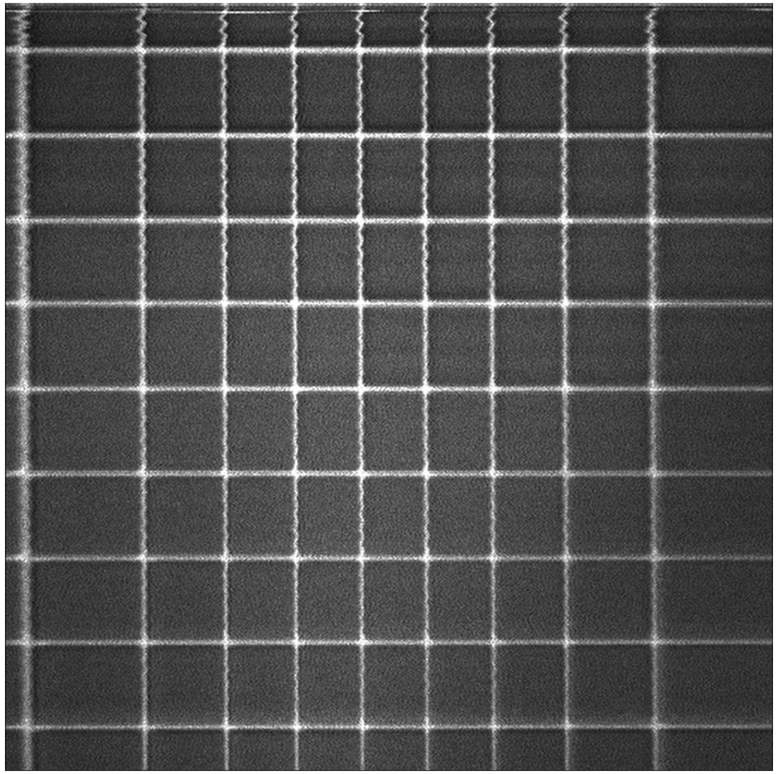
- The tilt required to remove the shear is 4°
- This means the raster scan is not perfectly aligned with the room (or the subject)
- Can we tolerate this amount of tilt?
- If not, we need to design a new galvo mount to give us the required degrees of freedom for removing the tilt

Fixing the waviness in the vertical lines

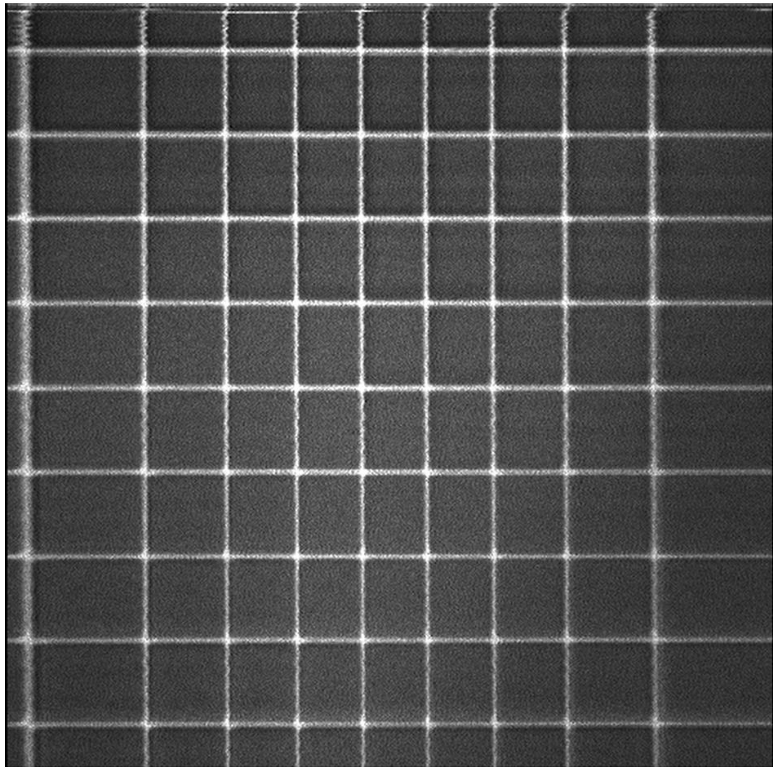
- Waviness comes from jitter in the hsync signal: needs to be tuned in hardware
- Pictures below are from before the adjustments were made (1° square FOV)



bad frame

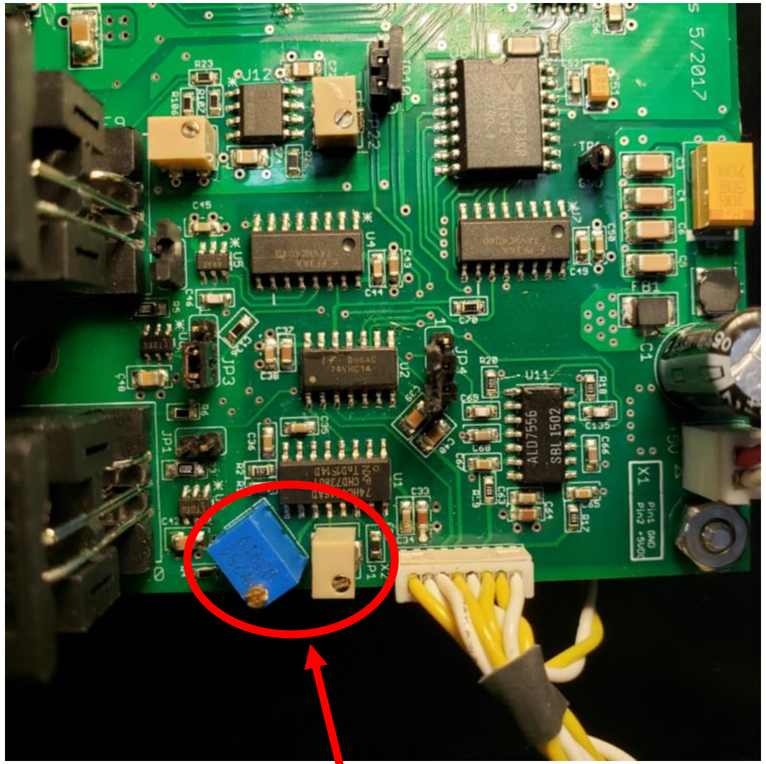


typical frame



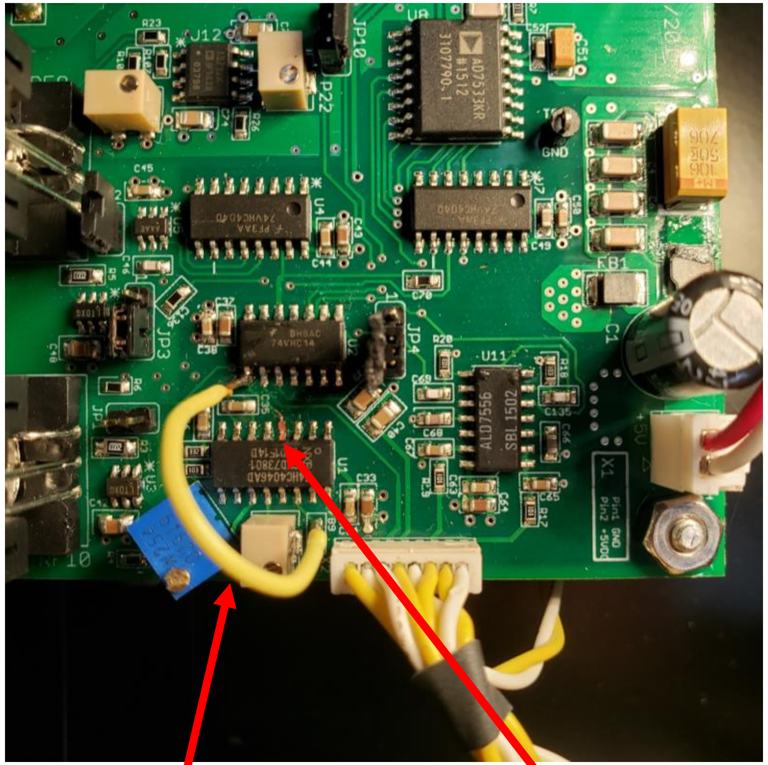
good frame

First approach did not work but workaround was found



these two potentiometers were adjusted to try to remove the jitter, but this did not fix the problem

- Custom electronics assembly from UCB has two adjustment potentiometers for tuning out the jitter
- These adjustments did not remove the jitter: they just made it worse
- Workaround involved disconnecting a pin on one IC and bypassing the adjustment pots using a wire

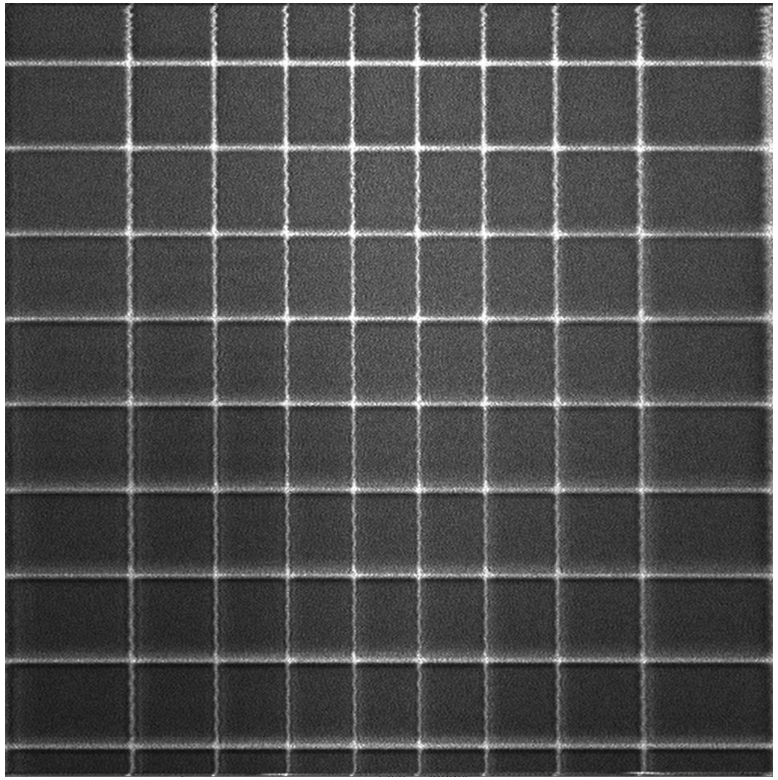


this wire was added

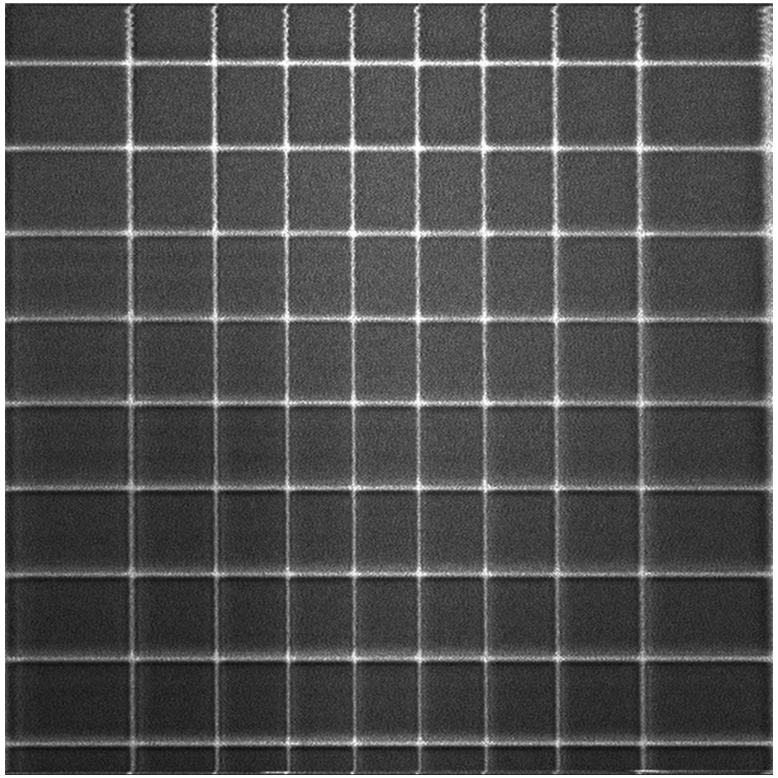
this pin was disconnected

The modification drastically reduced the jitter

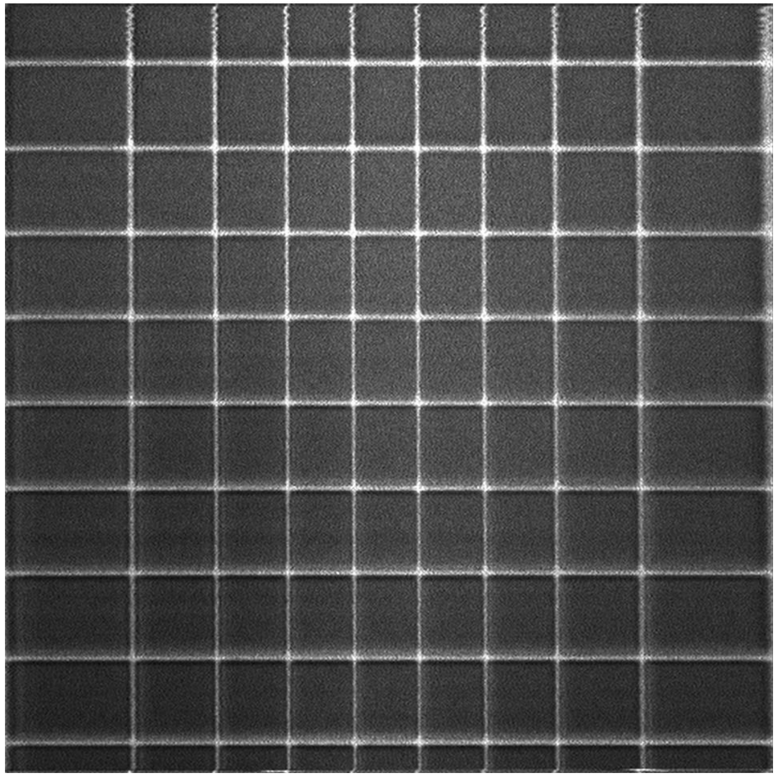
- Waviness is barely perceptible in a typical frame
- Pictures below are from after the adjustments were made (1° square FOV)



bad frame

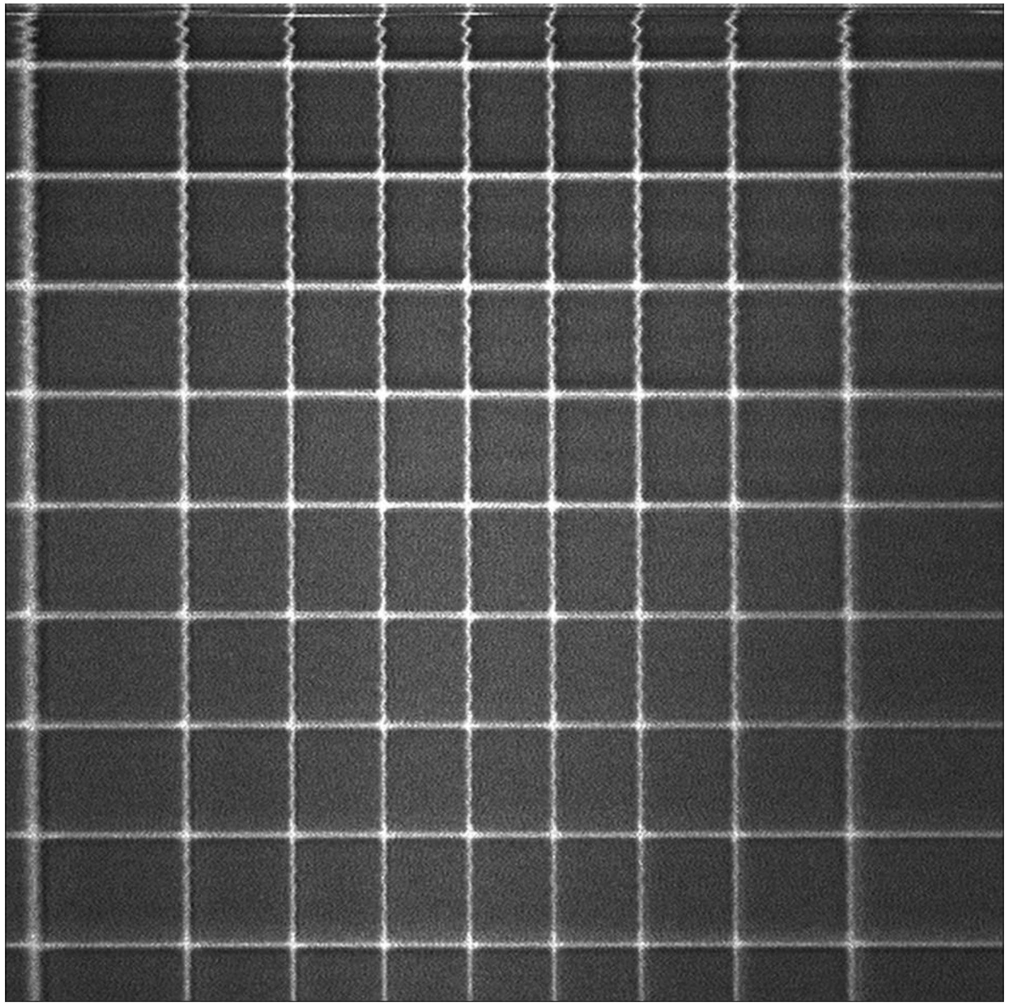


typical frame

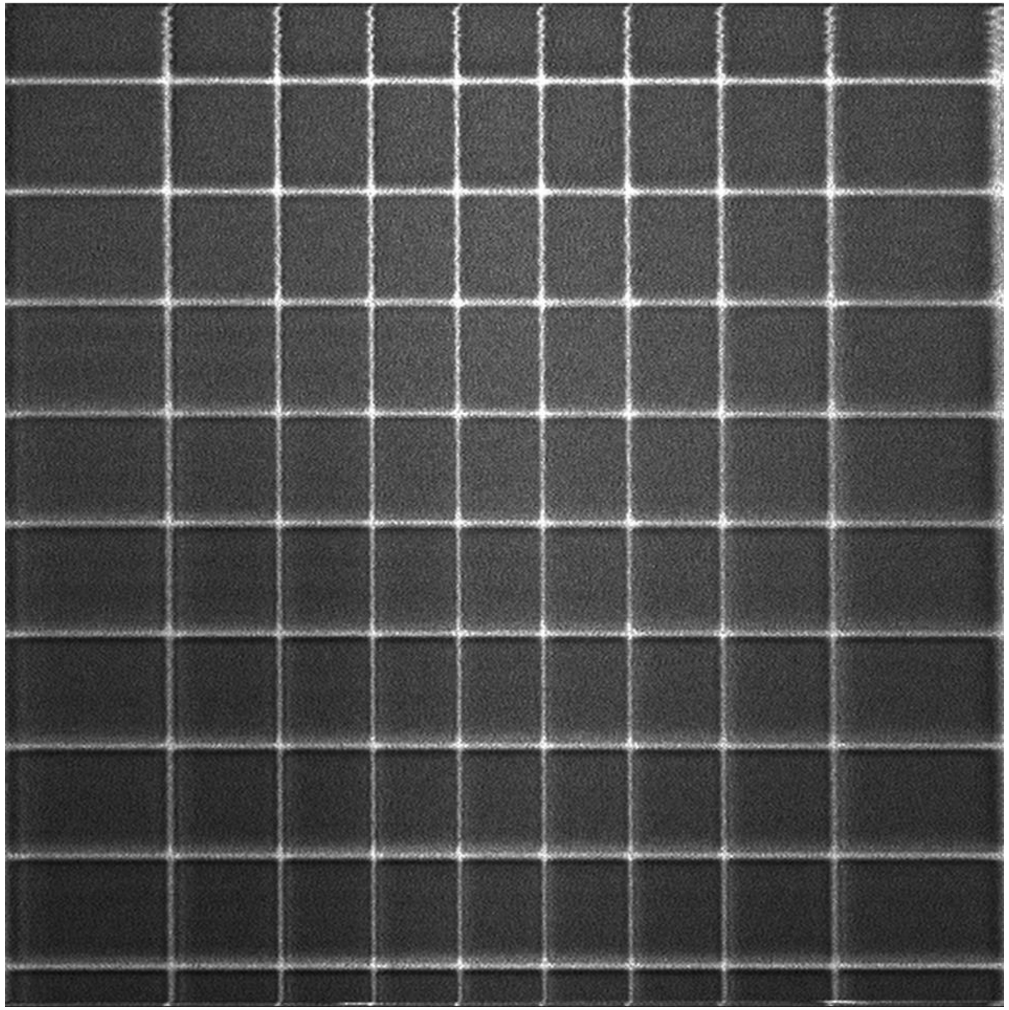


good frame

Side-by-side comparison of typical frames



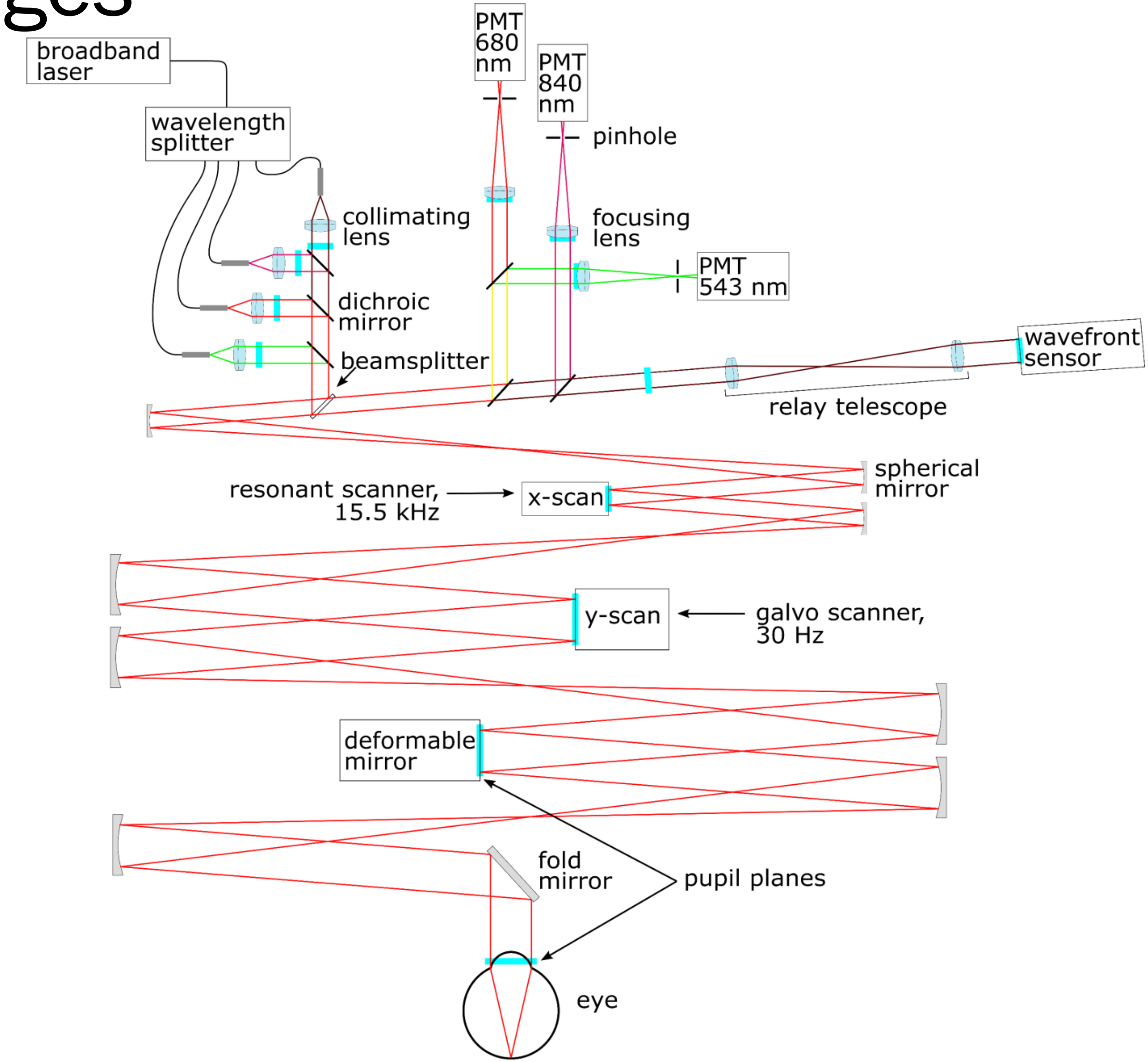
before



after

Desinusoiding the images

- Resonant scanner (horizontal scanner) traces out a sinusoidal motion profile
- This causes the images to be stretched at the edges
- Correction is done in ICANDI software (Image Capture and Delivery) from UCB
- Initial attempt to desinusoid the images failed because of the polarity of our distortion grid

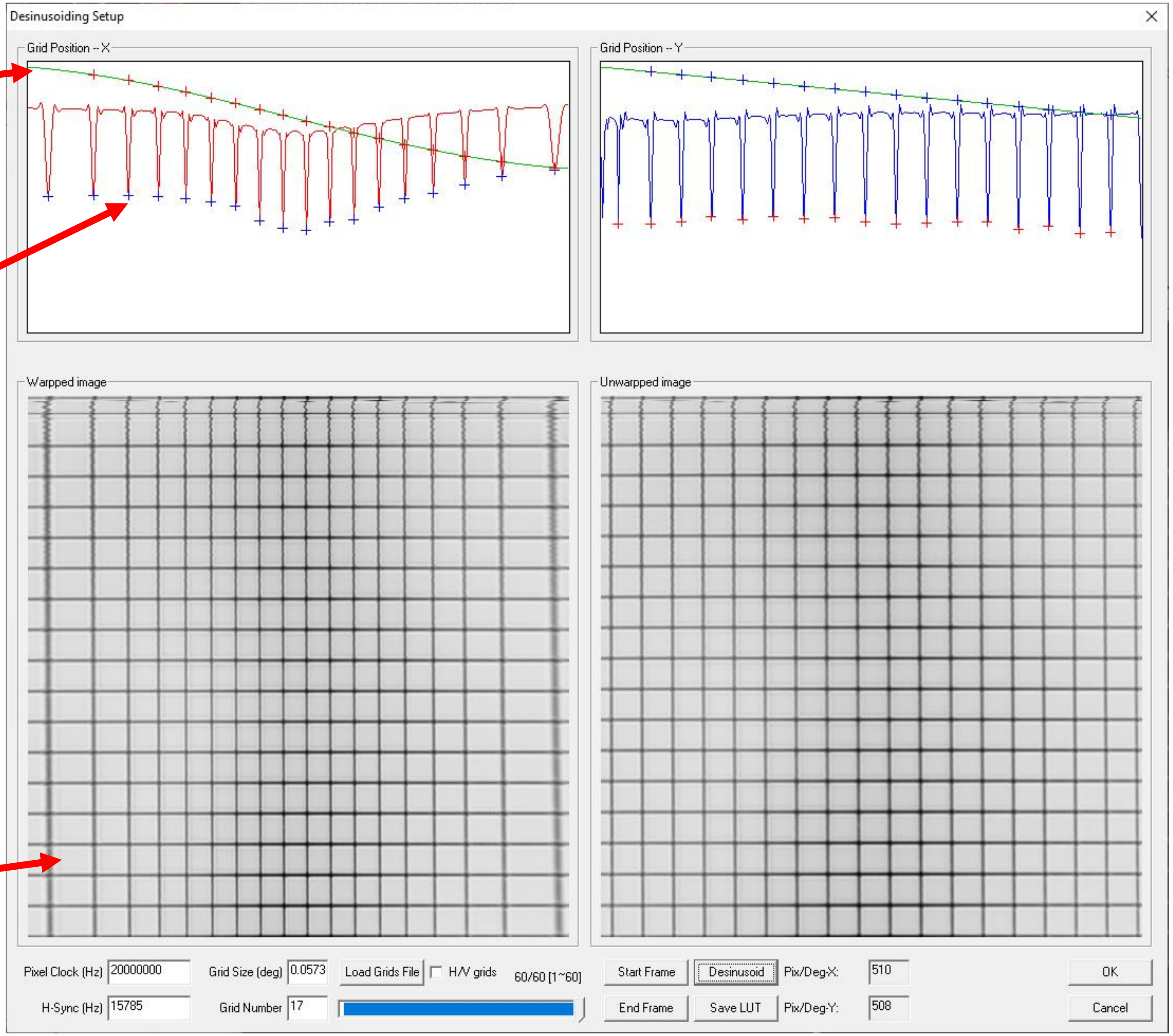


Interface for generating desinusoid look-up table

automatic curve fitting

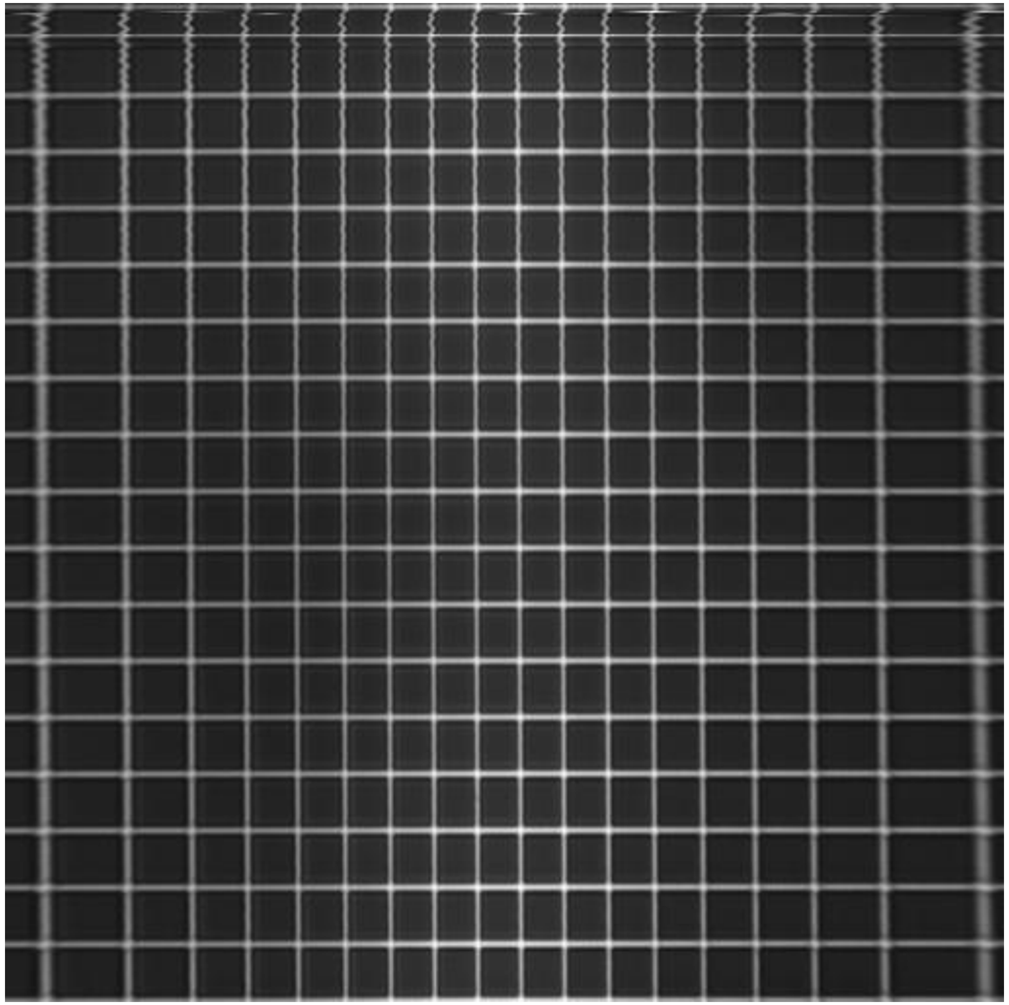
selecting minima in contrast-reversed image

stretching at edges

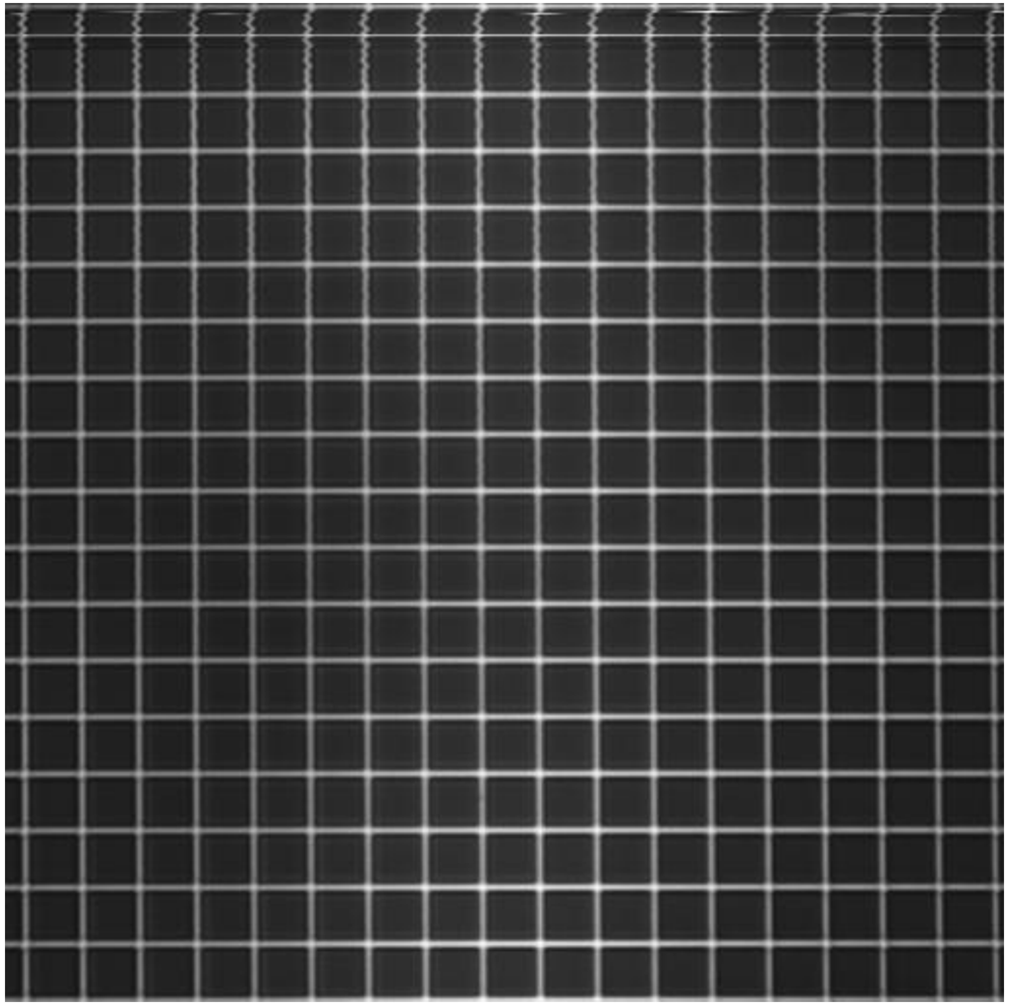


- After desinusoiding, the stretching at the edge of the frame is removed
- A unique look-up table (LUT) should be generated for each field of view we want to use
- After saving and applying the LUT, the live image and saved videos are desinusoided

Side-by-side comparison of frames



before desinusoid correction

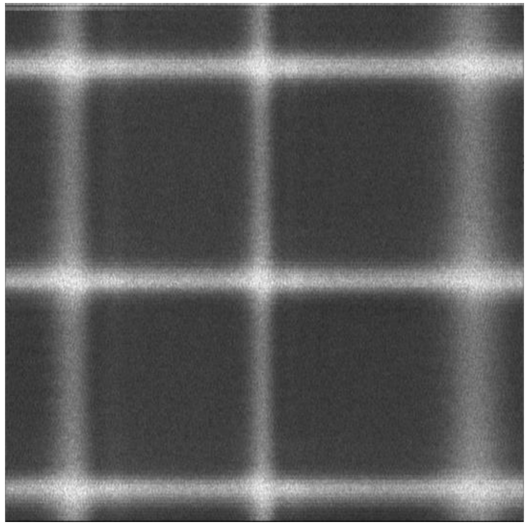


after desinusoid correction

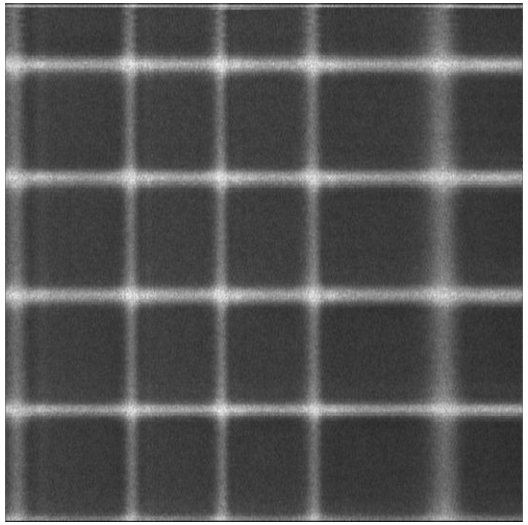
(60-frame average, 1° square FOV)

Calibrating the field of view

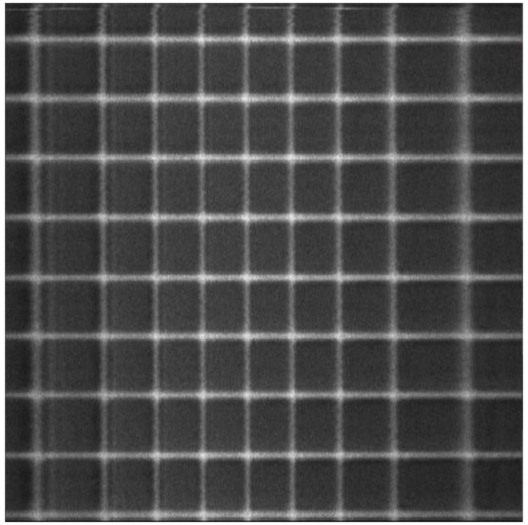
- The digital inputs for the scanners were recorded for each of these square FOVs
- The grid lines have 3.44 arcmin spacing (50 μm)



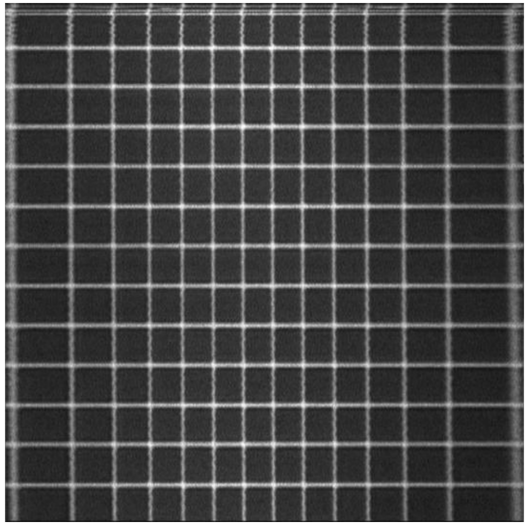
0.13° (min)



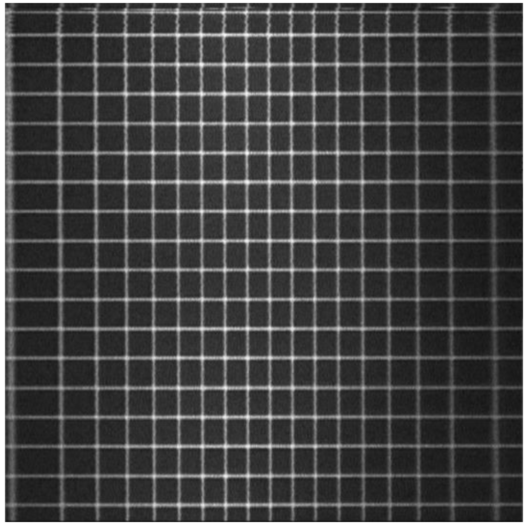
0.25°



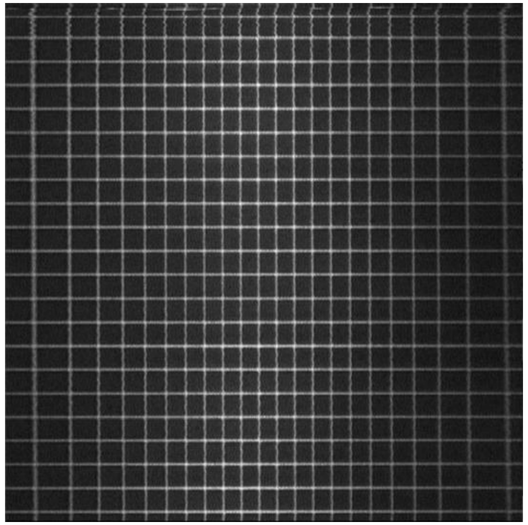
0.50°



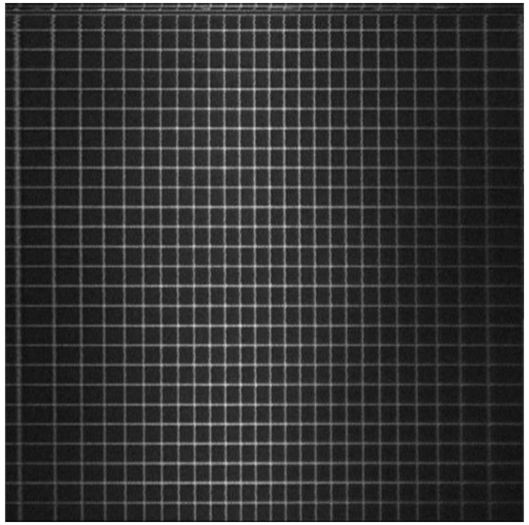
0.75°



1.00°

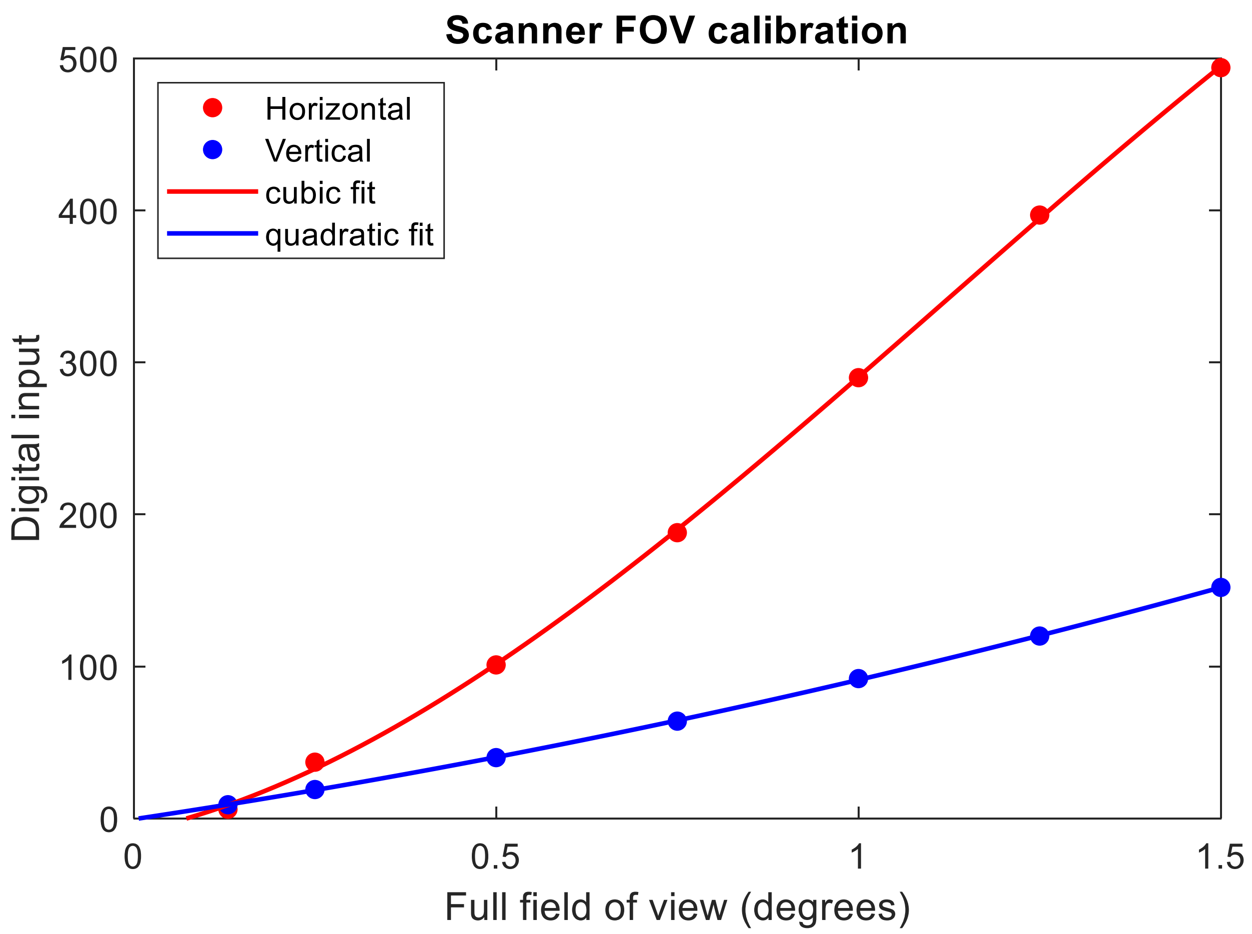


1.25°



1.50°

Field of view calibration curves



- Quadratic fit works well for vertical field of view:

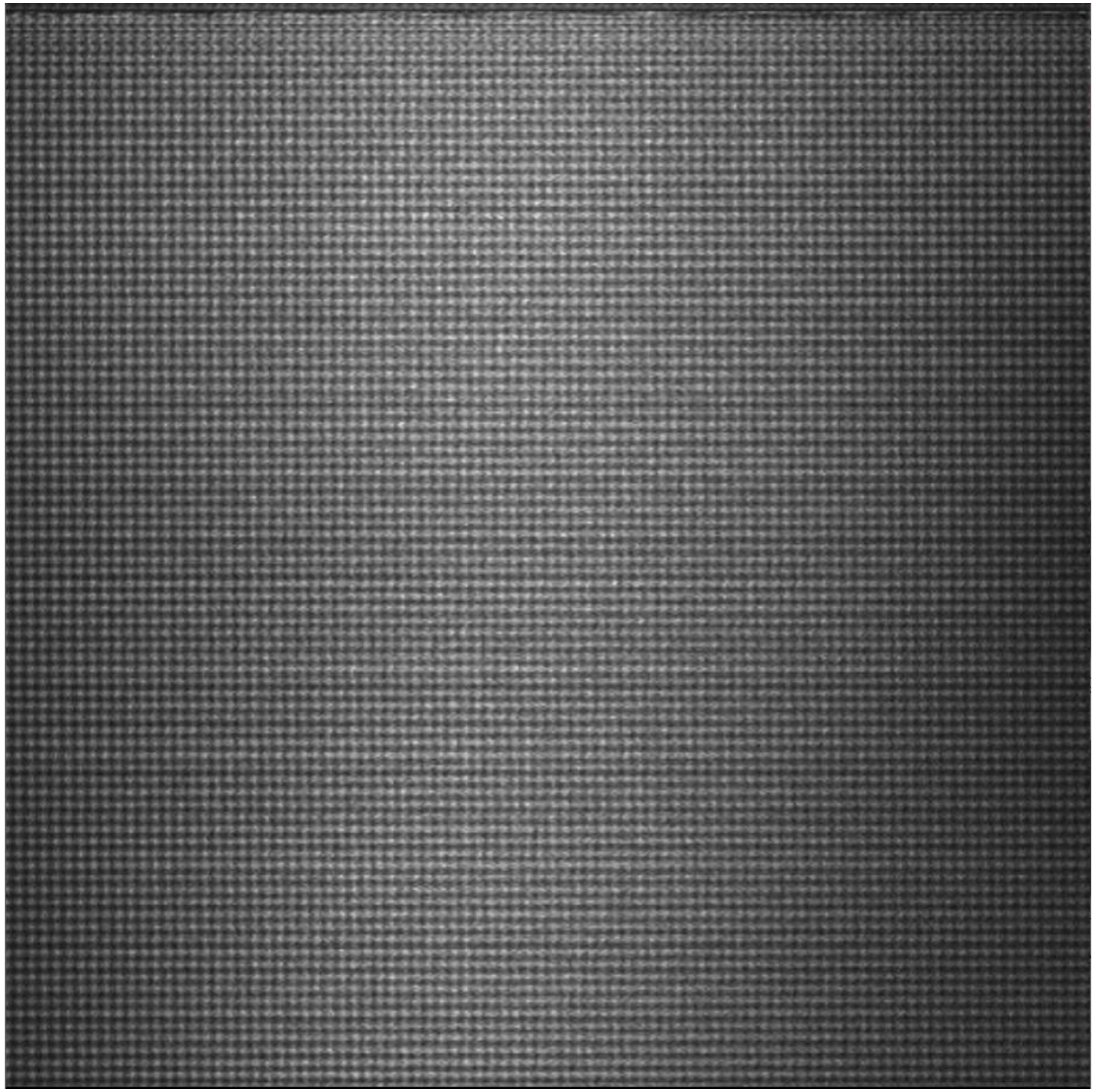
$$V = 20.0x^2 + 71.7x - 0.5$$

- Cubic fit works well for horizontal field of view:

$$H = -83.9x^3 + 283x^2 + 100x - 8.8$$

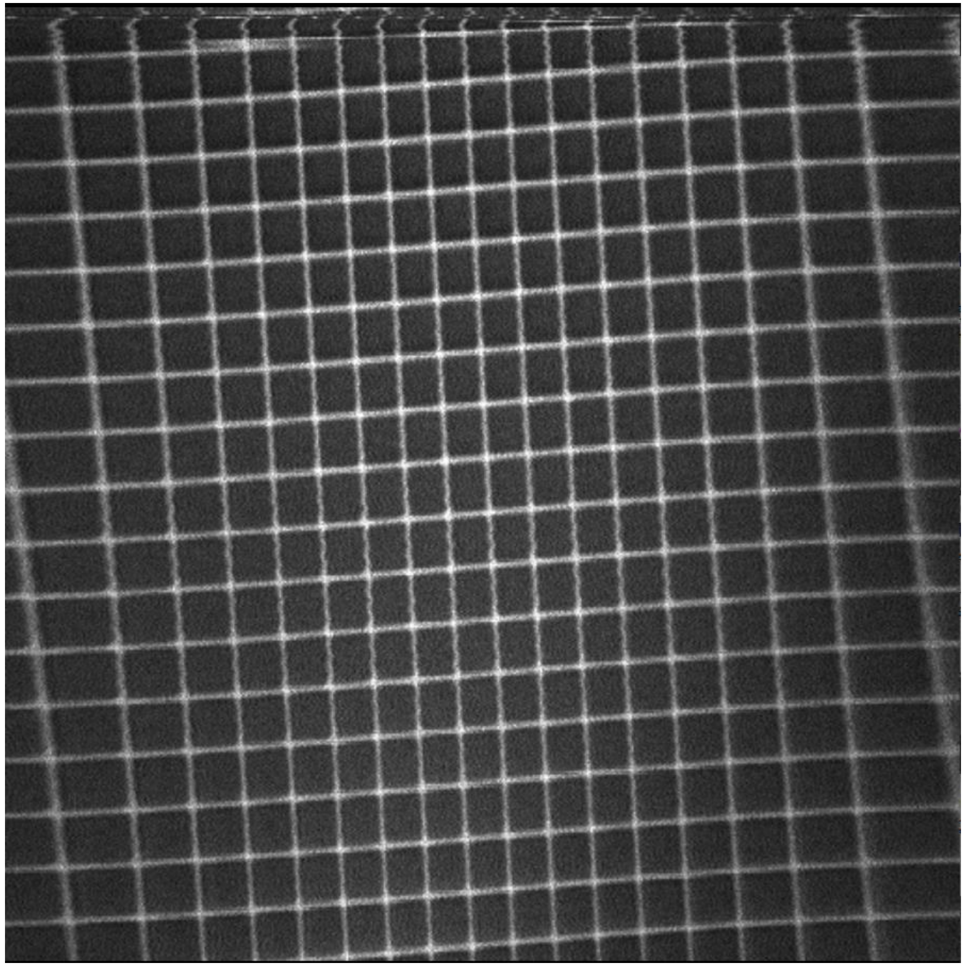
- This calibration will allow us to select a custom FOV in the future if we want to

Finest grid pattern is resolved



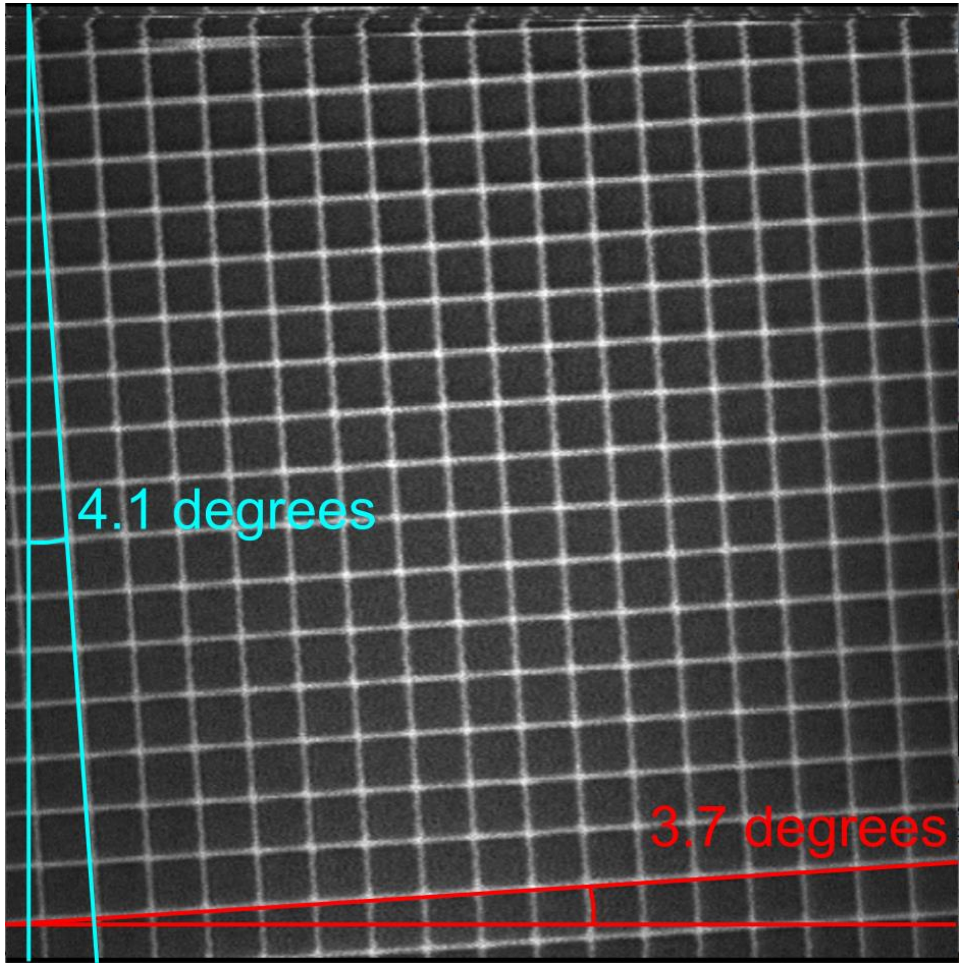
- Field of view is 1° square
- 512 x 512 pixels → 8.5 pixels per arcmin
- Image has been desinusoided
- Grid line spacing is 0.69 arcmin (10 μm)
- The angular resolution limit (by the Rayleigh criterion) is 0.49 arcmin for this configuration
- Being able to easily resolve the grid lines is a good sign, and it means the system is well corrected: at or near the diffraction limit

After desinusoiding, rotation appears normal



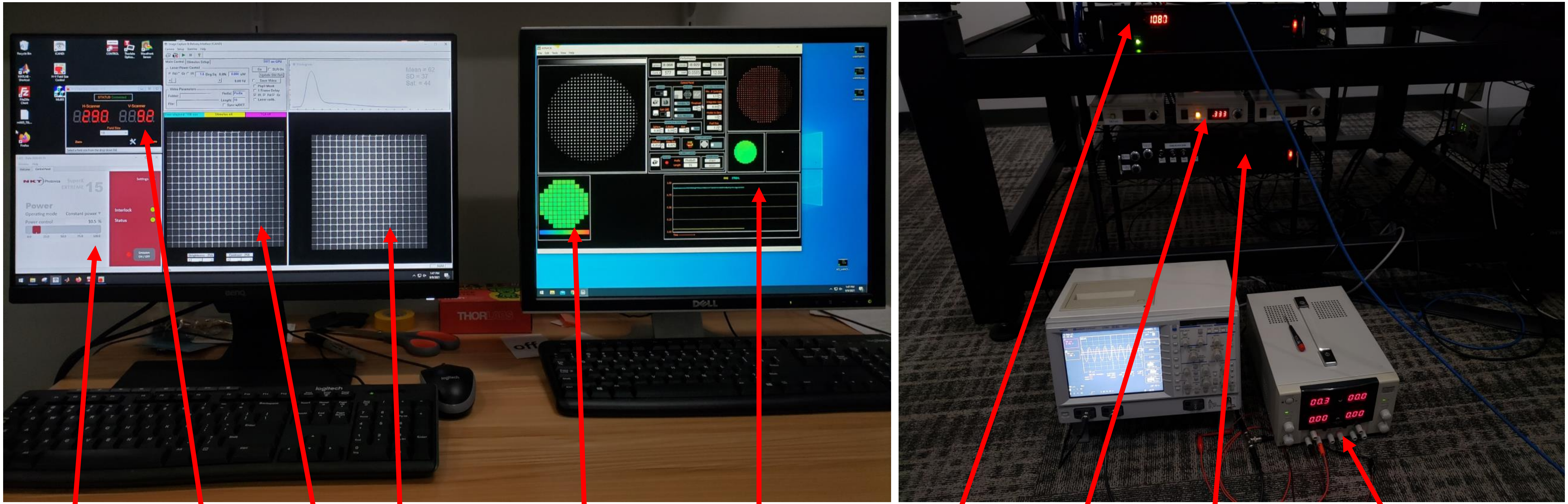
without desinusoid correction

- Grid was rotated by 4° to be aligned with the room coordinates
- Without desinusoiding, the stretching of the tilted grid looks like shear
- Desinusoiding makes the rotated grid look normal



with desinusoid correction

System in operation during calibration imaging



Ongoing challenges

- Custom DAC card for controlling Acousto Optic Modulators (AOMs) had one channel that was unstable, making it unusable. It was sent back to UCB for repairs, and is currently being shipped back to us
- There is a small amount of residual defocus between the imaging channel (840 nm) and the wavefront sensing channel (940 nm) due to the chromatic aberration of the model eye lens
- This will need to be optimized by adjusting the PMT and input fiber locations
- Visible channels (for stimulus delivery) will also need to be optimized to account for chromatic aberration of the lens
- Output power levels need to be reduced to make the system eye safe
- Power meter calibration: does anyone need to use it in the next two weeks?

Next steps and open questions

- I have no previous experience using an AOSLO for human subject imaging, so I think it would be helpful if I could shadow an experienced user before attempting to use the system on my own and train other lab members. Does anyone have a recommendation for someone I could reach out to? Maybe someone from the ARIA group?
- What will the first human subject imaging task be? Will this be to collect foveal images for subjects who have already done eye tracking experiments in the lab?
- We should spend some time researching and developing our image processing pipeline. There are multiple toolboxes available, and I do not have a good understanding of what the strengths and weaknesses of various options are.