First results from a bench demonstrator of a novel Wide Field of View Wavefront Sensor

Lazar Staykov, Nazim Ali Bharmal, Timothy Morris, Lisa Bardou, Matthew Townson, David Bramall, Ariadna Calcines-Rosario

Durham University

CfAI
Centre for Advanced Instrumentation

Outline

- Wide Field Wavefront Sensing, short intro
- Our approach
- The bench
- The results
- Discussion

Wide Field of View WFS

Wide field-of-view astronomical imaging using wavefront sensor deconvolution with a Laser Guidestar Reference

J.D. Gonglewski and D.C. Dayton

Author Information ▾ Find other works by these authors ▾

Get PDF | Email | Share ▾ | Get Citation ▾ | Save article

Abstract

It was recently suggested that a simple atmospheric distortion correction method using a laser guidestar reference (LGR) produces a potentially simpler compensation method than adaptive optics (AO) systems, with some loss in performance.[1] In addition, there are several advantages other than simplicity and cost, including the possibility of widening the field of view (FOV) of the compensations system, and compensating for multiple layers of turbulence. This paper extends this earlier work to the wide field of view problem in astronomical imaging.

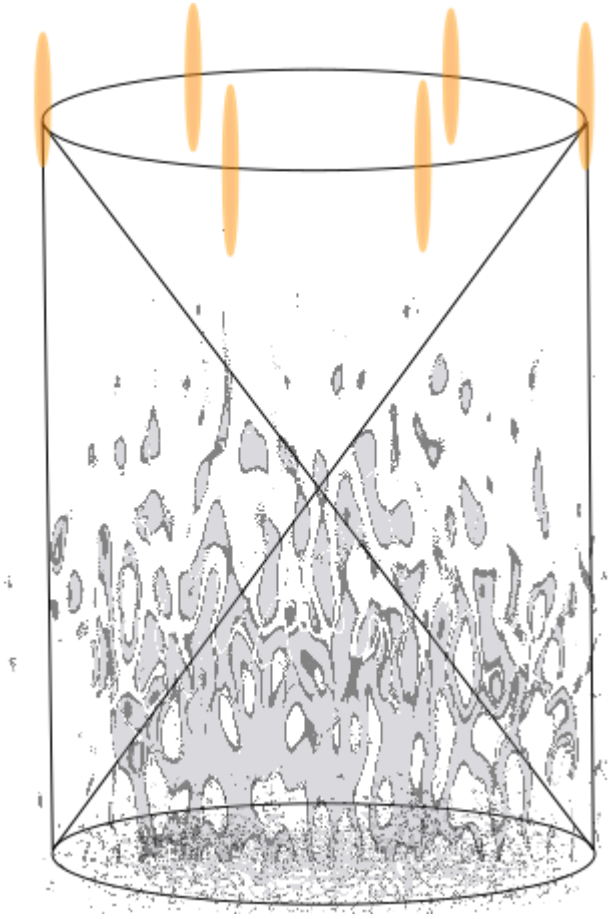
It all begins with a dream:

- improve performance
- lower the cost
- widen the corrected area

Notable applications:

- Solar AO, from way back when
- MAVIS – Cedric's talk yesterday
- MORFEO – ELT's FL WFoV WFS

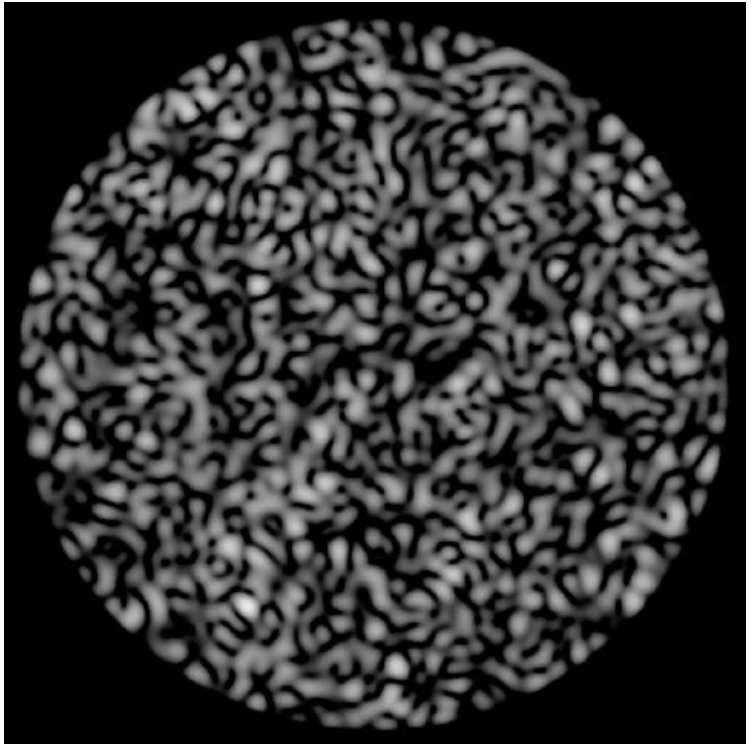
Wide Field of View WFS – concept

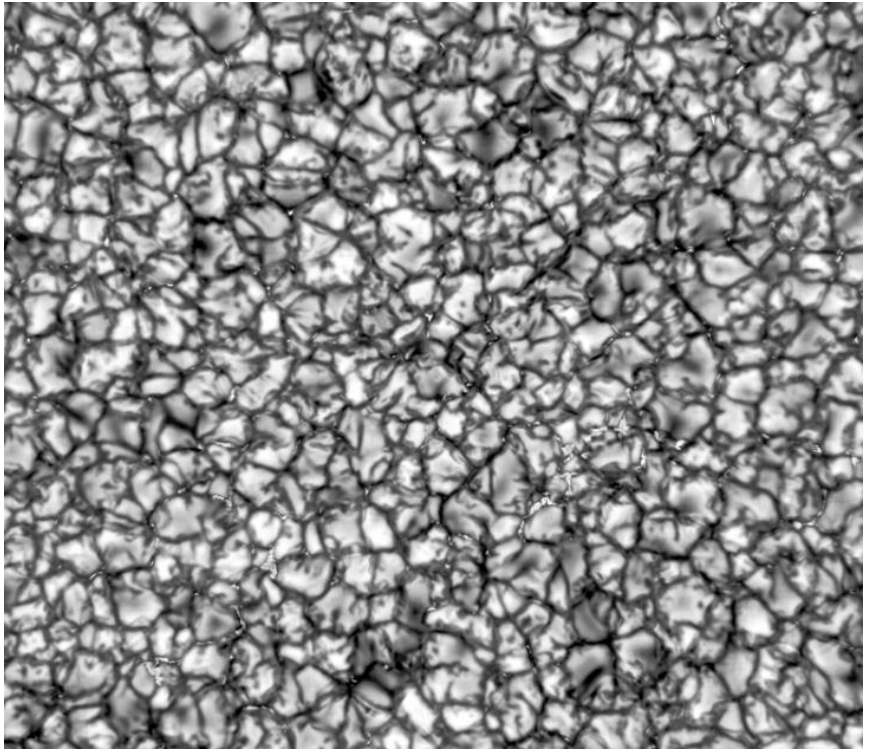


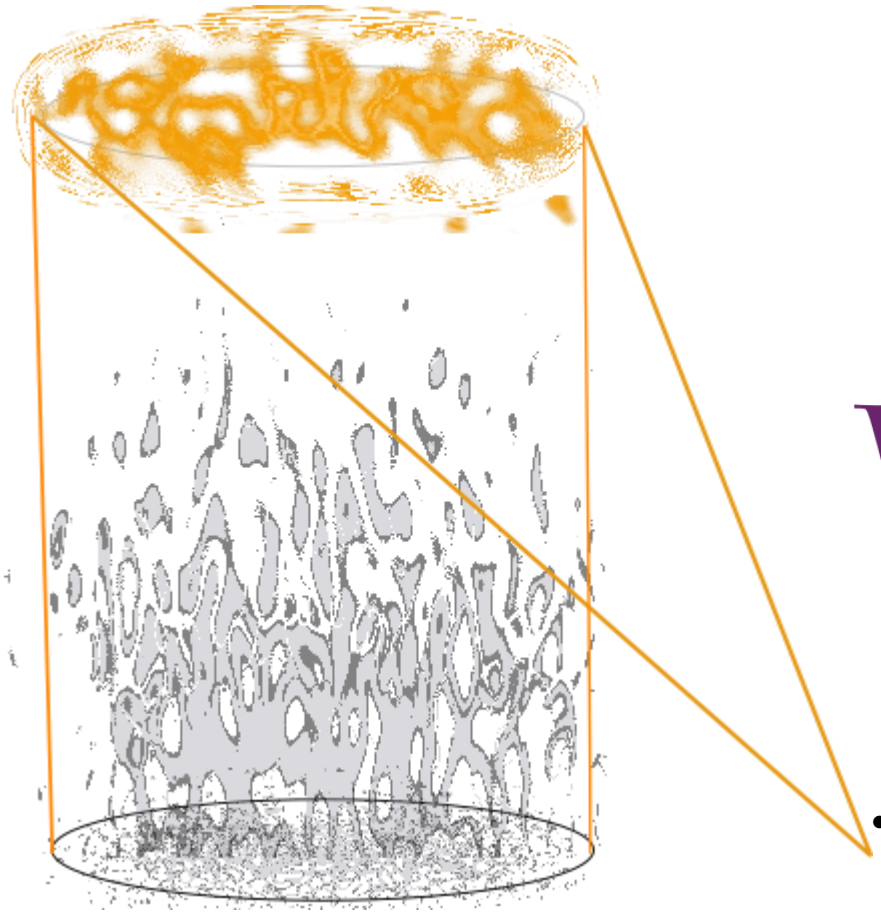
classic case

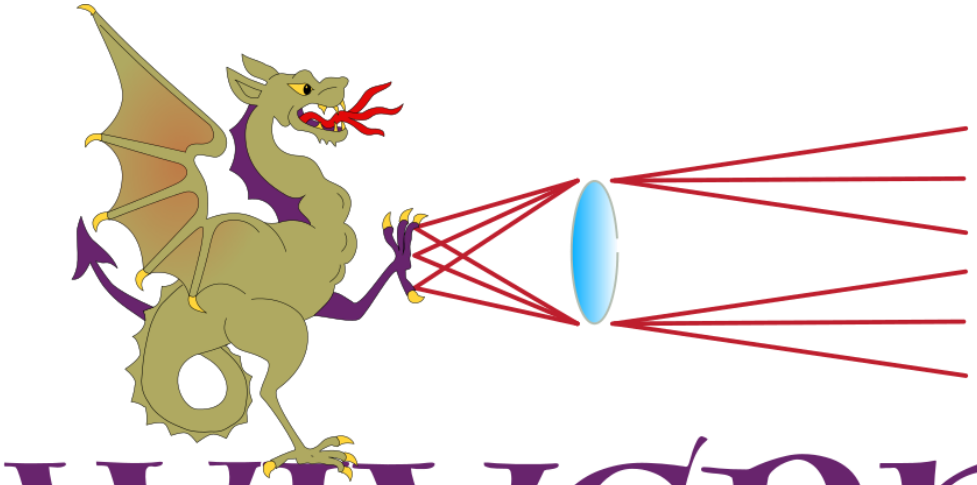
- Laser light propagated in multiple directions around the target. Provides different projections of the turbulent volume.
- Each LGS is observed by a dedicated WFS.
- The information from the different WFS is then cross-correlated to reconstruct the 3D shape of the turbulence.
- Problem is:
  - not all of the volume is sampled simultaneously.
  - need multiple lasers and WFS, MORFEO 6, MAVIS 8

WF WFS – Solar AO





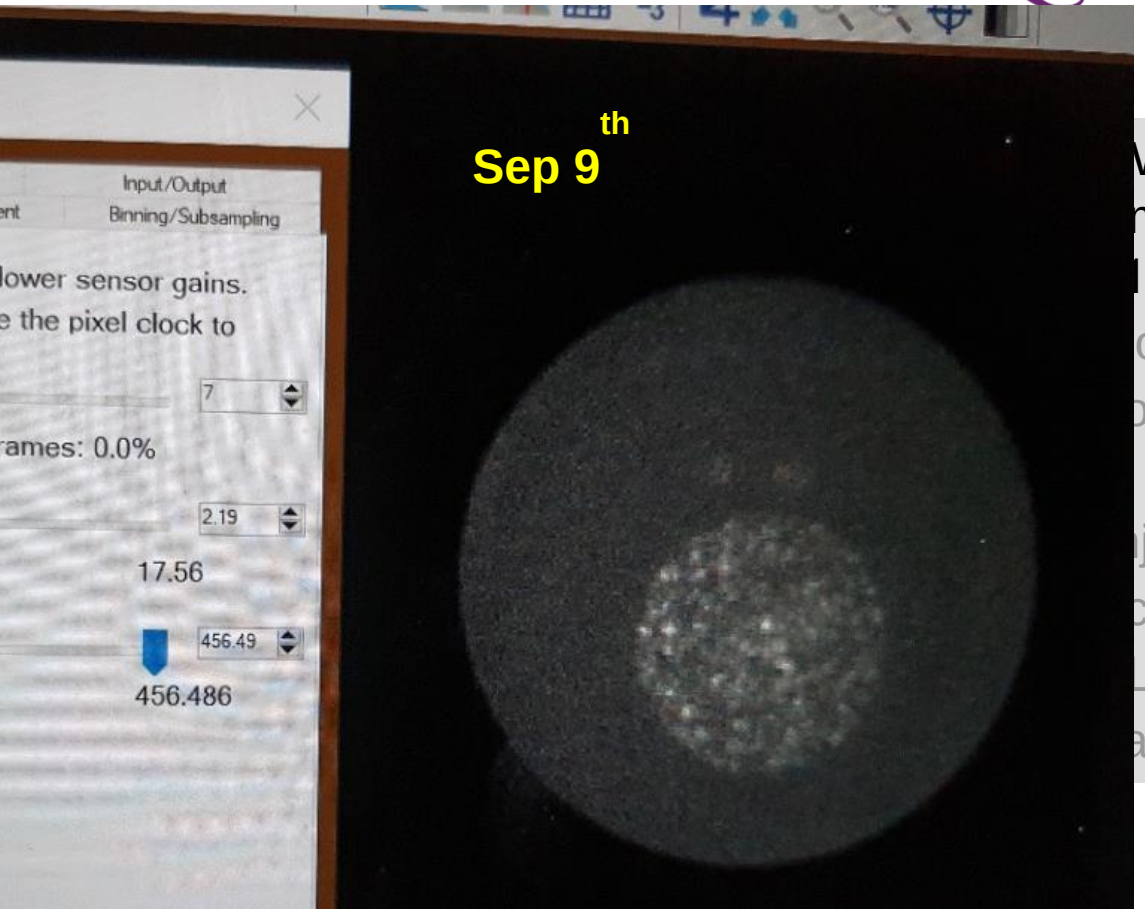




Short form

- Create a structured illumination using a single laser
- Sense it with a single correlating WFoV WFS
- Improve tomography errors

WIVERN



Sep 9th

July'22

WIVERN

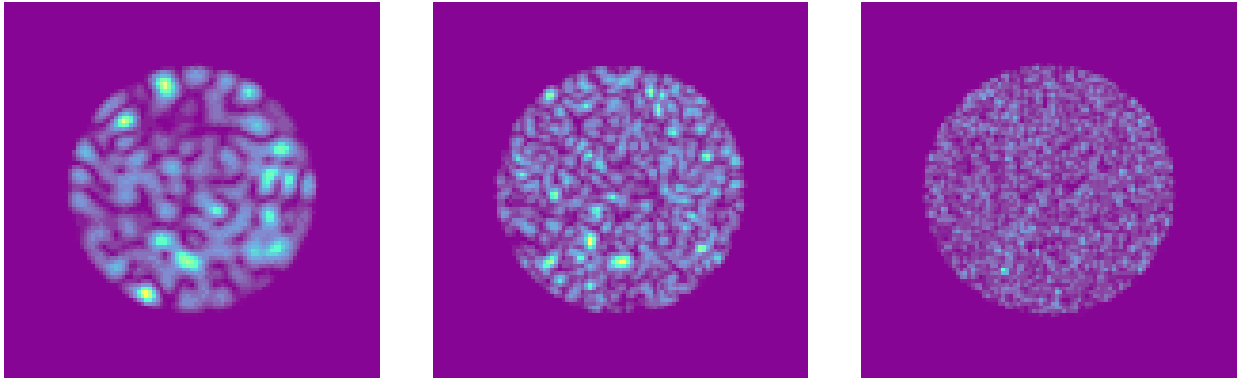
Pattern transportation

- 8m telescope
- Single layer of turbulence at the ground (r_0 of 0.12m)
  - Pessimistic case
- 532nm laser projected to 20km
  - Uses angular spectrum propagator
- Full aperture monostatic launch of collimated beam
  - Not the best/easiest way to implement in reality
  - Definitely the easiest to simulate
- Uplink/Downlink paths not fully reciprocal

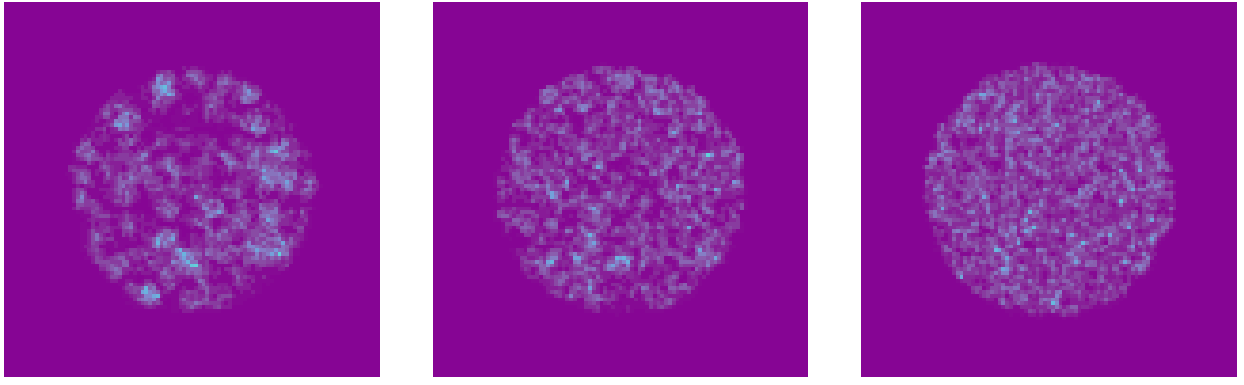
WIVERN

Pattern transportation

Launch intensity



Intensity @ 20km

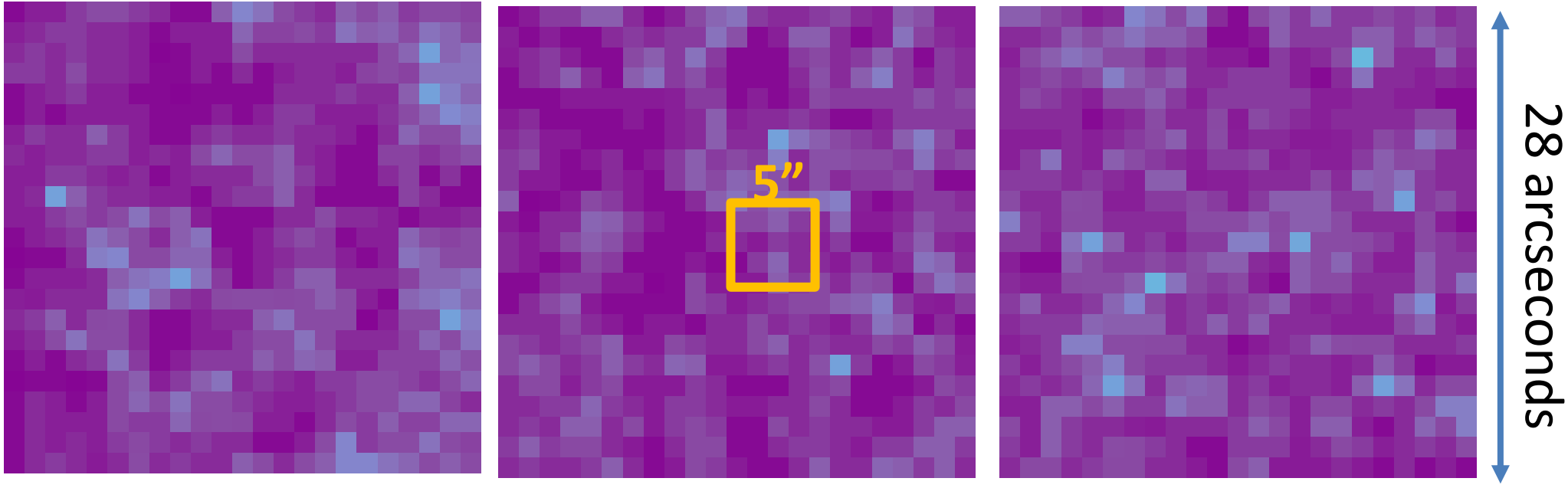


150 modes | 550 modes | 1550 modes

WIVERN

Pattern transportation

Sub-aperture images



150 modes

550 modes

1550 modes

WIVERN

Pattern transportation subaperture flux

- 100 independent turbulence realisations
- Investigate flux and contrast within every 5” subaperture
- Predicted photon return from 265W pulsed 532nm laser
  - 50cm subapertures, 800 Hz frame rate
- Values are photons/subaperture/frame

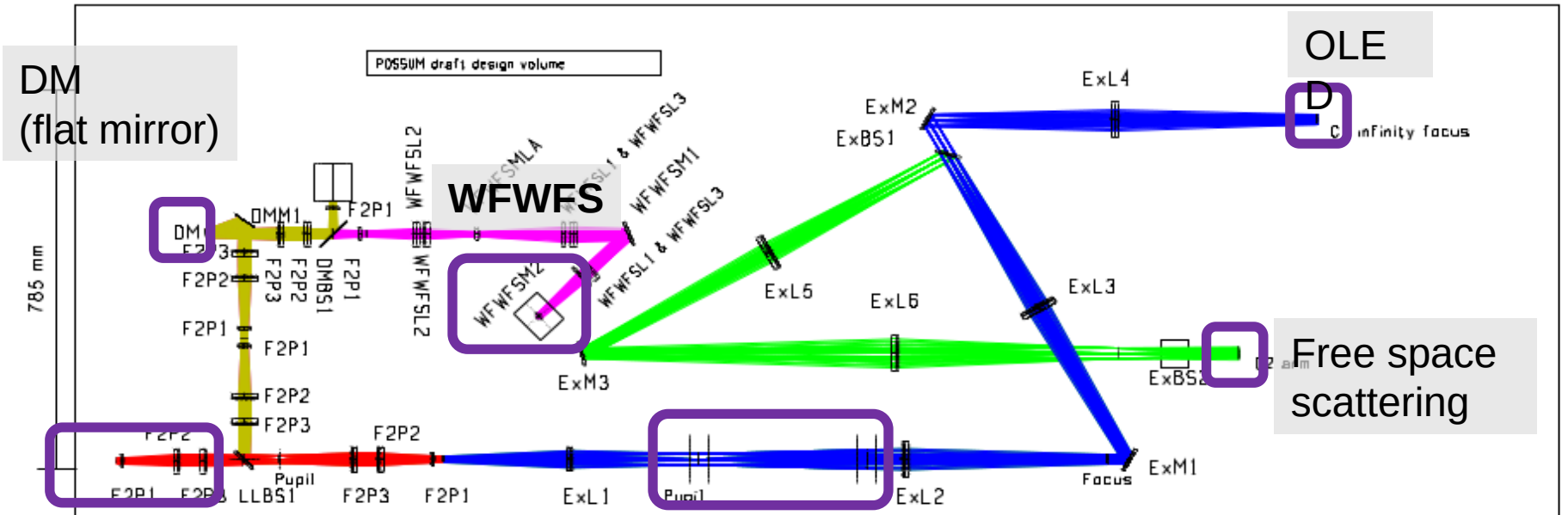
		150 modes	550 modes	1550 modes
Flux	Mean Max Std	648 3050 422	617 2121 267	593 1488 198
Contrast	Min	0.981	0.984	0.993

Pattern transportation
Laser feasibility

- Photon return and contrast pattern appears suitable for correlation based wavefront sensing
- Fibre modes (i.e. fibre core diameter) gives some flexibility to tune flux vs number/distribution of guide regions
  - Modal structure broadly preserved on propagation
- High-power pulsed multimode fibre lasers are commercially available
  - Not completed a full market survey however

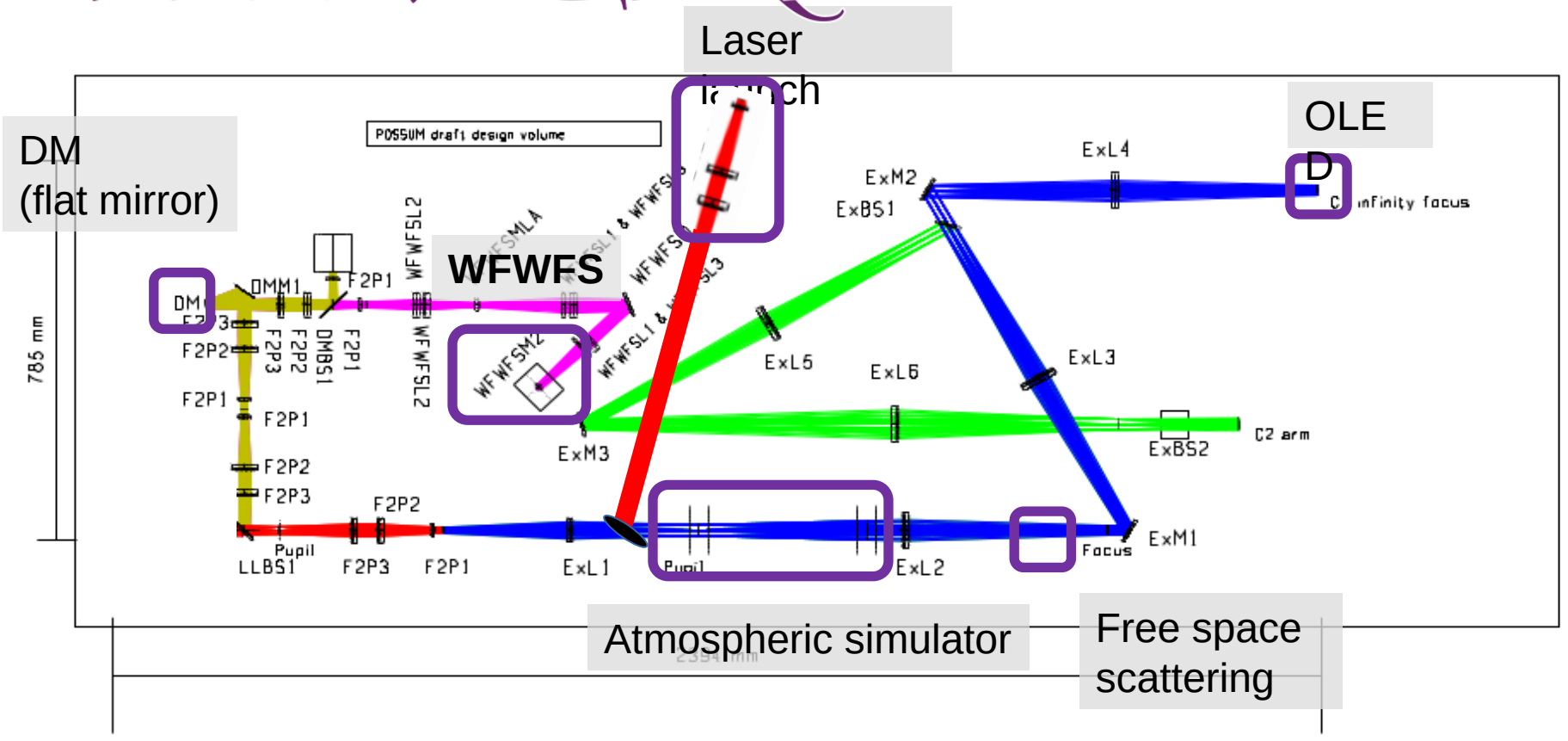
WIVERN

Optical layout, designed



WIVERN

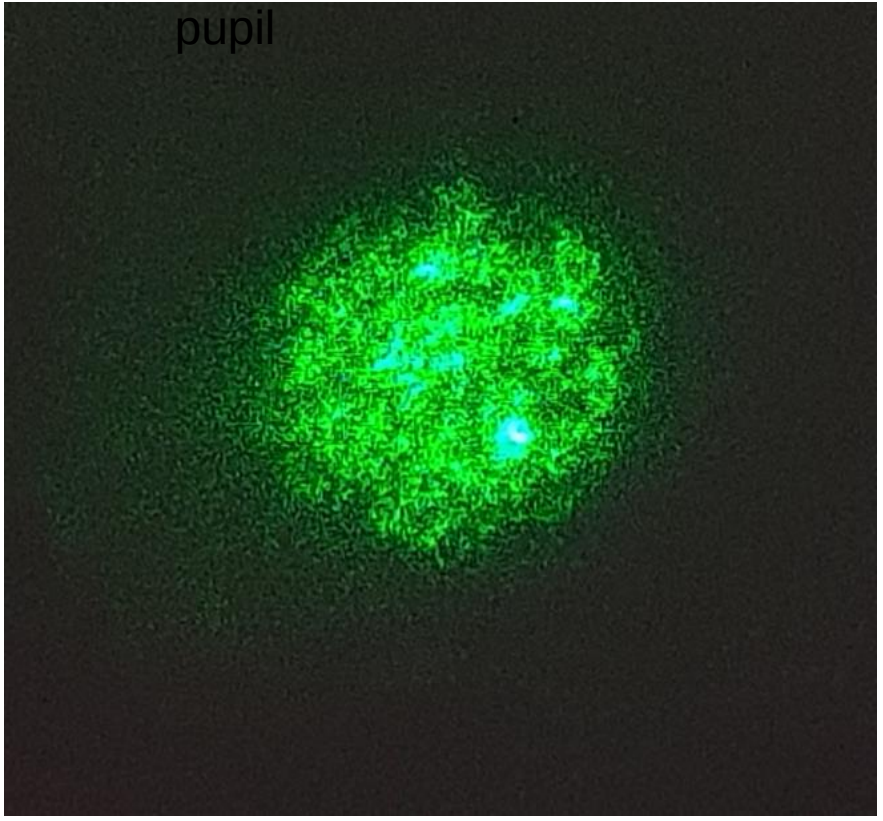
Optical layout, current



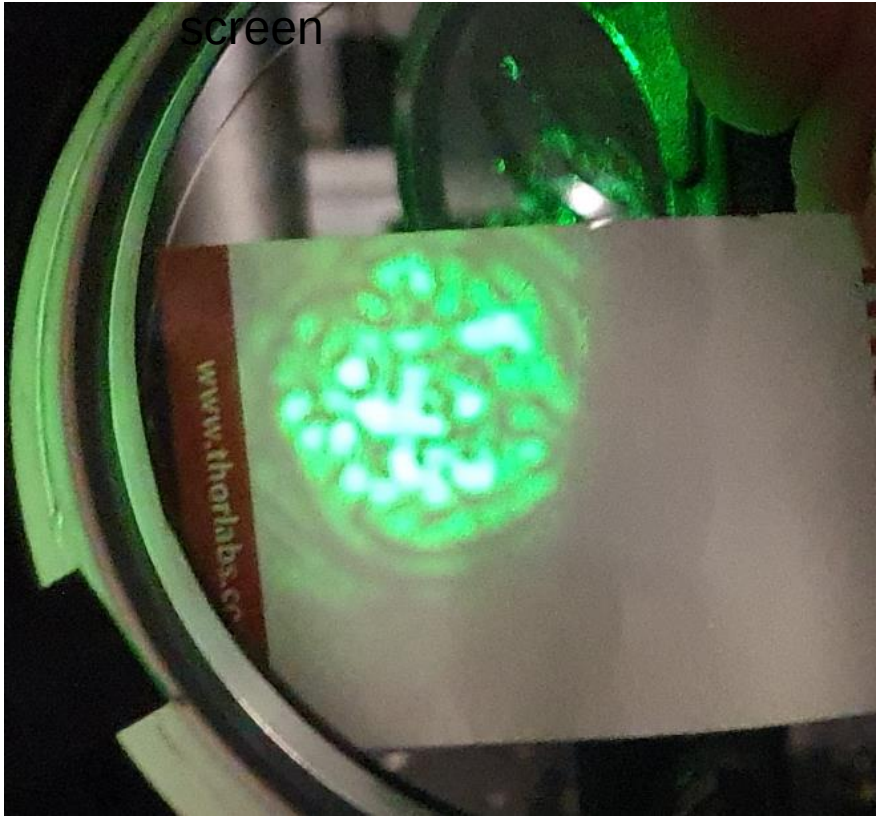
WIVERN

Pattern transportation

With phase screen@ pupil



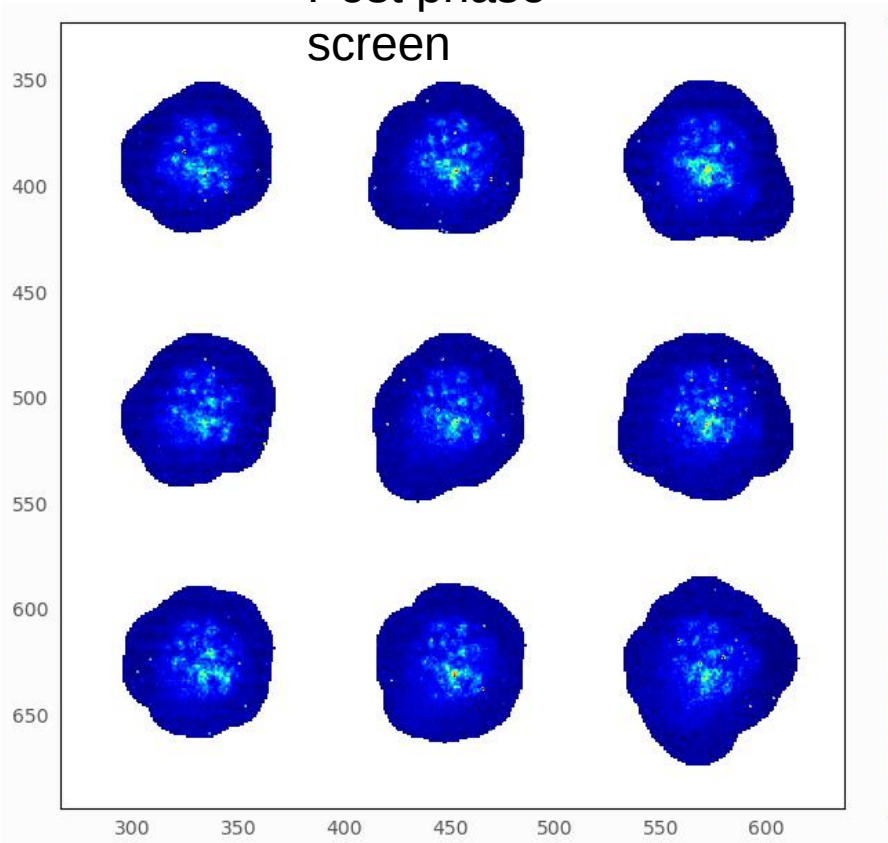
Without phase screen



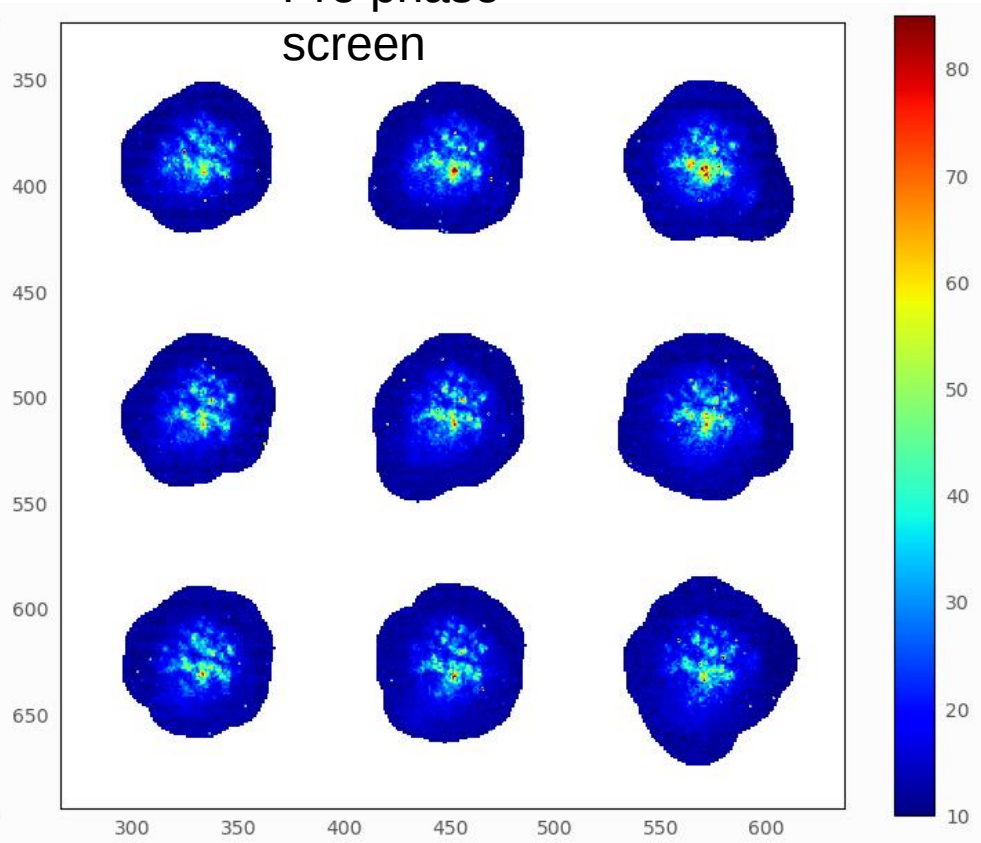
WIVERN

Pattern on WFS

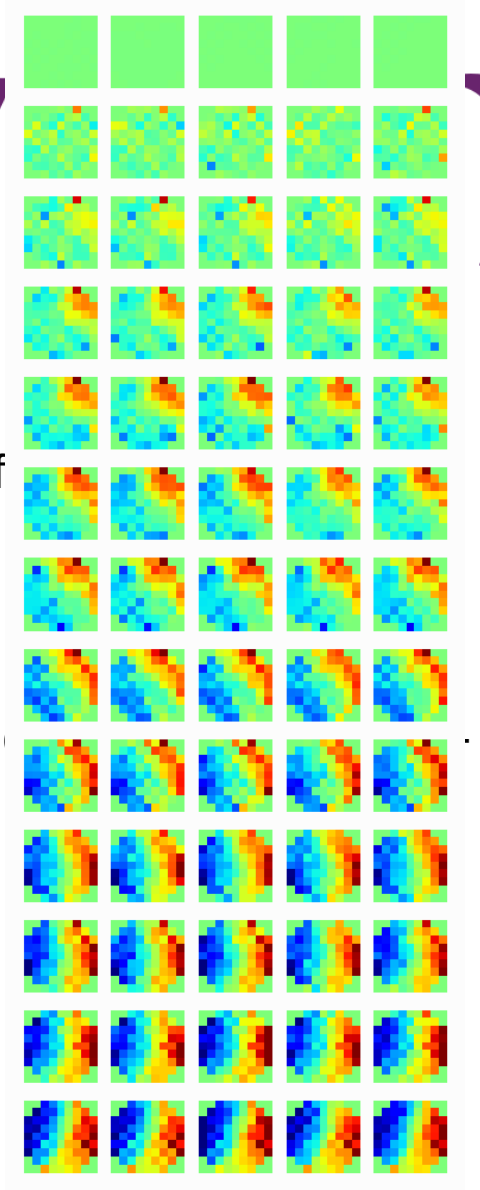
Post phase screen



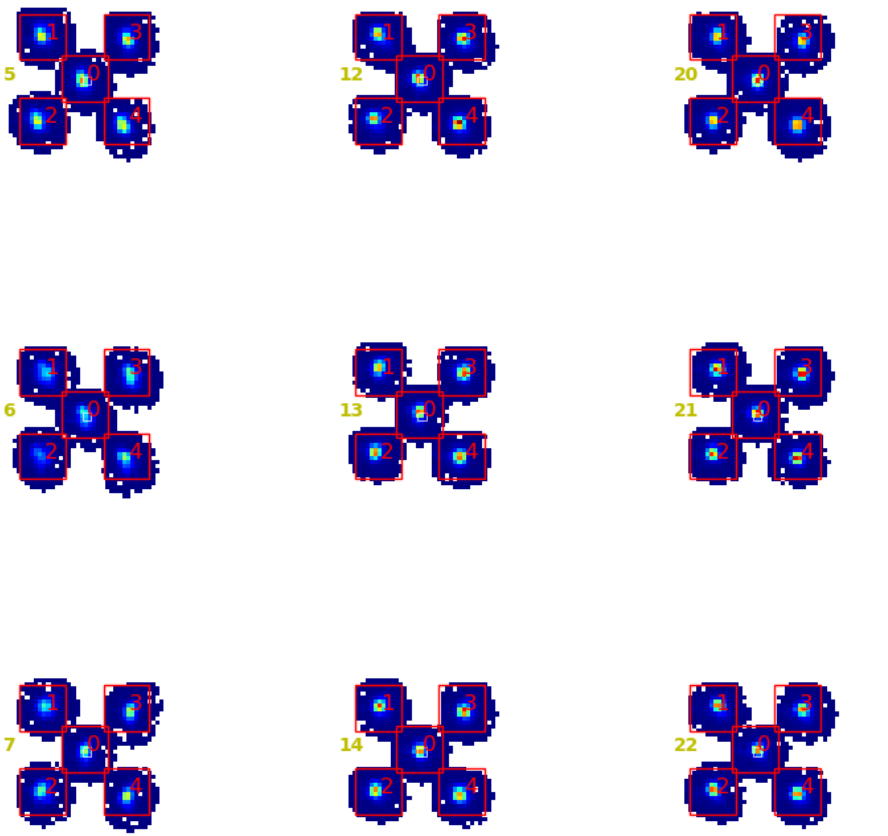
Pre phase screen



- Five dots generated using
- Same type of analysis perf
- The ‘turbulence’ is applied
- The screen is rotated 1.5° grab
- The distance between the axii is ~13”



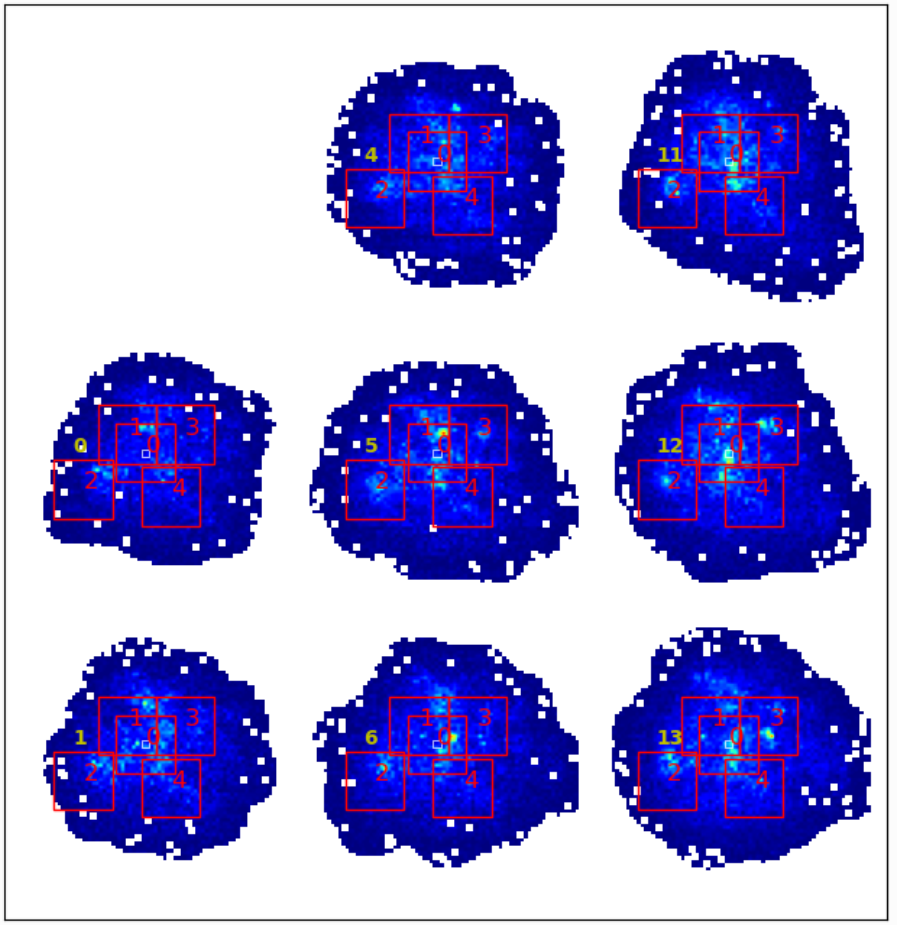
Pattern on WFS



WIVERN

- Speckle pattern in each subaperture is subdivided to various areas of interest (AoI)
- Cross correlation is then performed on each one of them
- However:

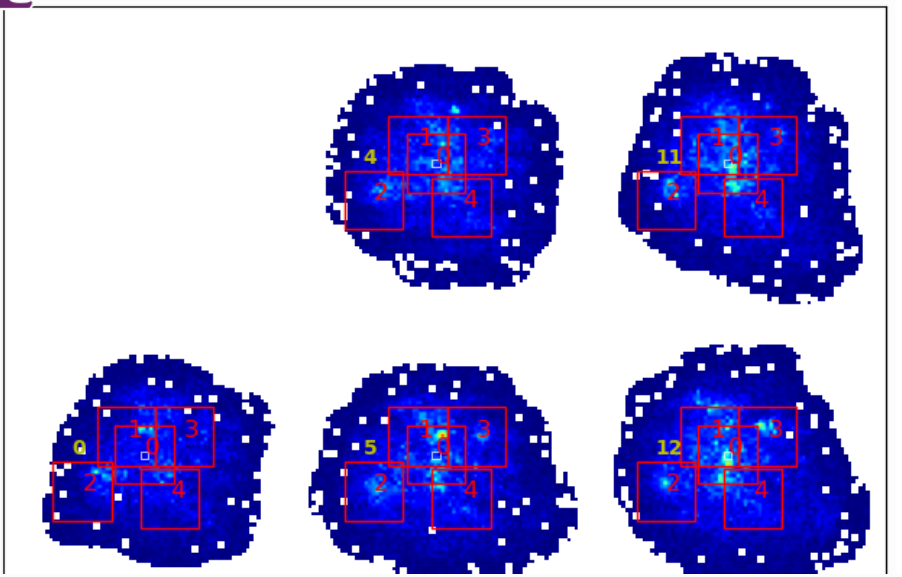
Pattern on WFS

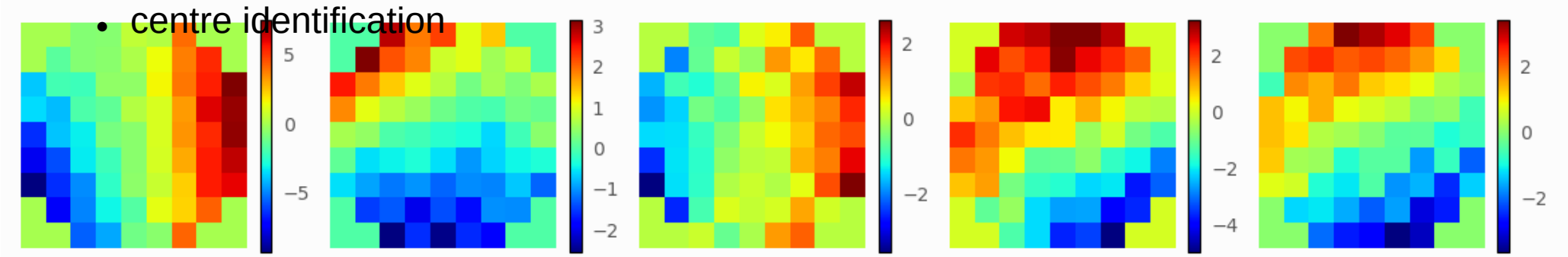


WIVERN

- Speckle pattern in each subaperture is subdivided to various areas of interest (AoI)
- Cross correlation is then performed on each one of them
- However:
  - resulting WF disagree
  - possibly due to:
    - low SNR
    - centre identification

Pattern on WFS





WIVERN

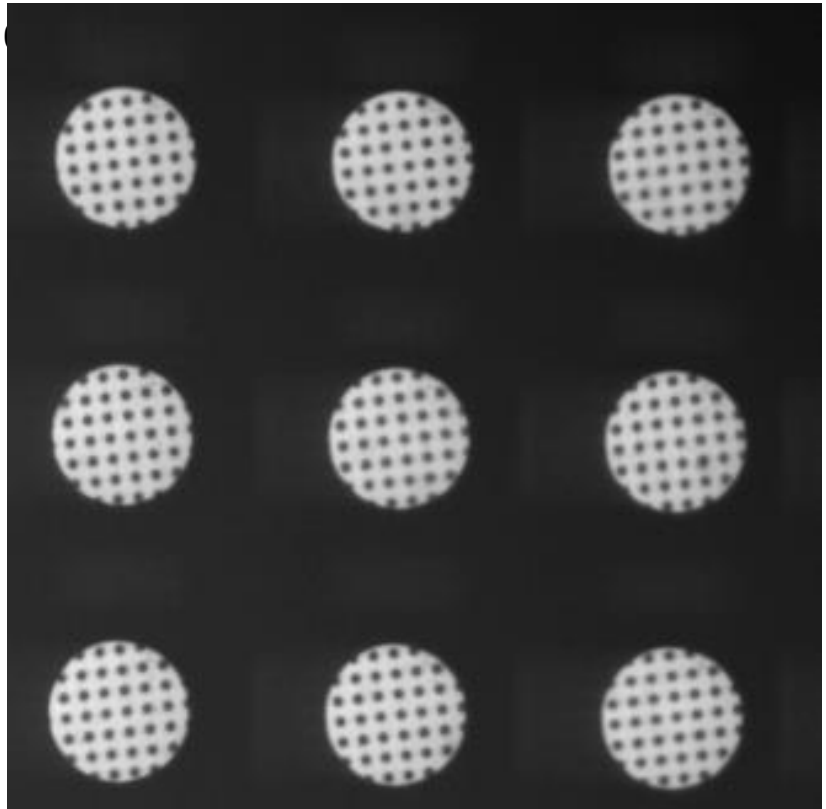
Conclusion

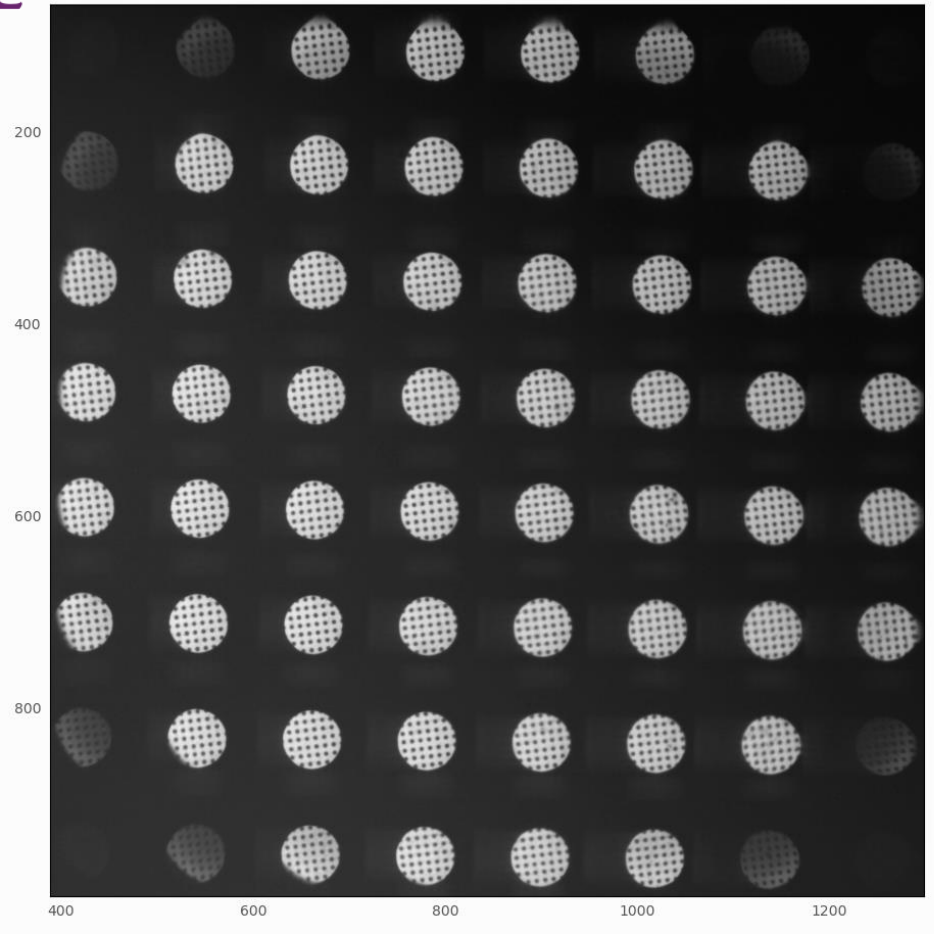
- Can we improve wide-field wavefront sensing using a LGS
  - LGS = Laser Guide Sun
- Simulations show it’s feasible using current technology
  - High-powered laser coupled into multi-mode fibre
  - Creates high contrast speckle pattern
- Optical bench setup that simulates two-way LGS propagation
  - Started in July, very first results presented here
- Wide-field correlating WFS works on calibration OLED
- Issues with SNR degrading 2-way LGS sensing
  - Side-launch and modifications to optical path should help here

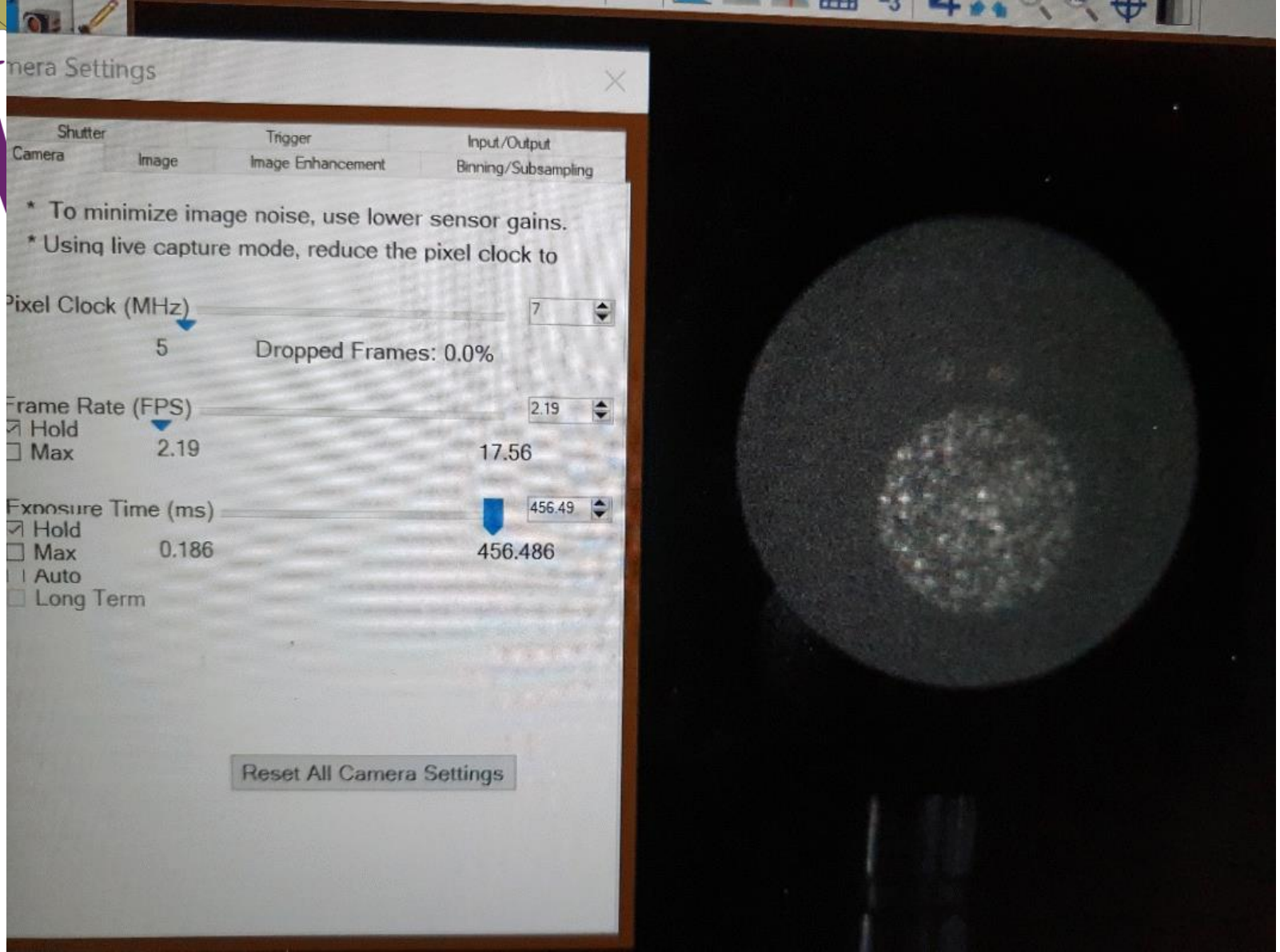
Thank You!

WIVERN

Calibration






nera Settings
Shutter
Camera
Image
Trigger
Image Enhancement
Input/Output
Binning/Subsampling
* To minimize image noise, use lower sensor gains.
* Using live capture mode, reduce the pixel clock to
Pixel Clock (MHz)
7
5
Dropped Frames: 0.0%
Frame Rate (FPS)
2.19
Hold
Max
2.19
17.56
Exposure Time (ms)
456.49
Hold
Max
0.186
456.486
Auto
Long Term
Reset All Camera Settings