



Programmable Phase Nulling Interferometer for Giant Mirrors Phase I SBIR

Mirror Tech Days 2018

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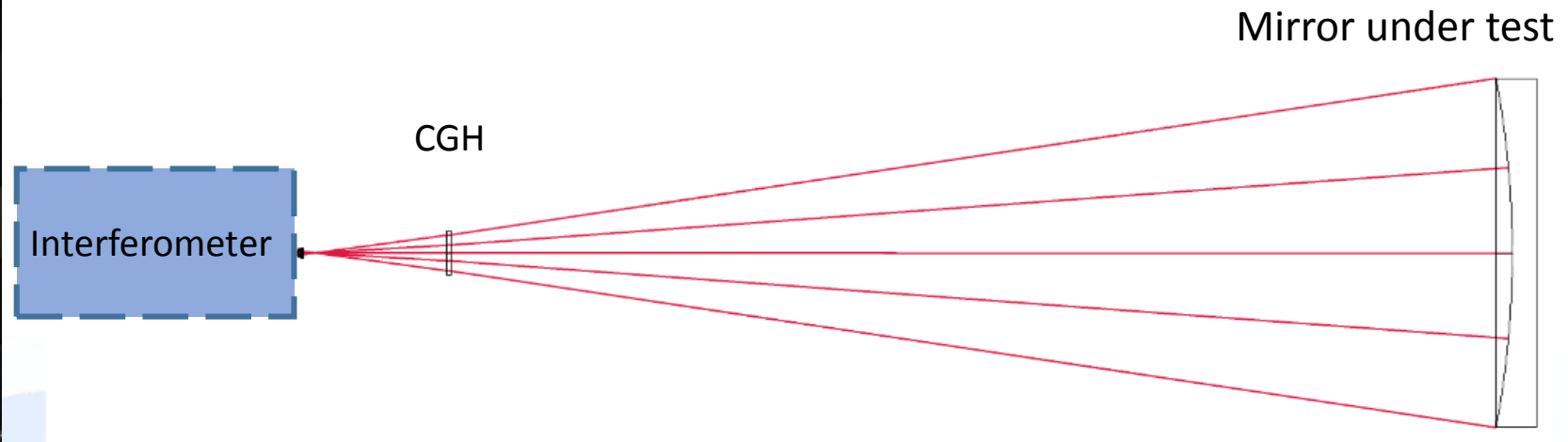
Boulder Nonlinear Systems, Inc.

450 Courtney Way

Lafayette, CO 80026

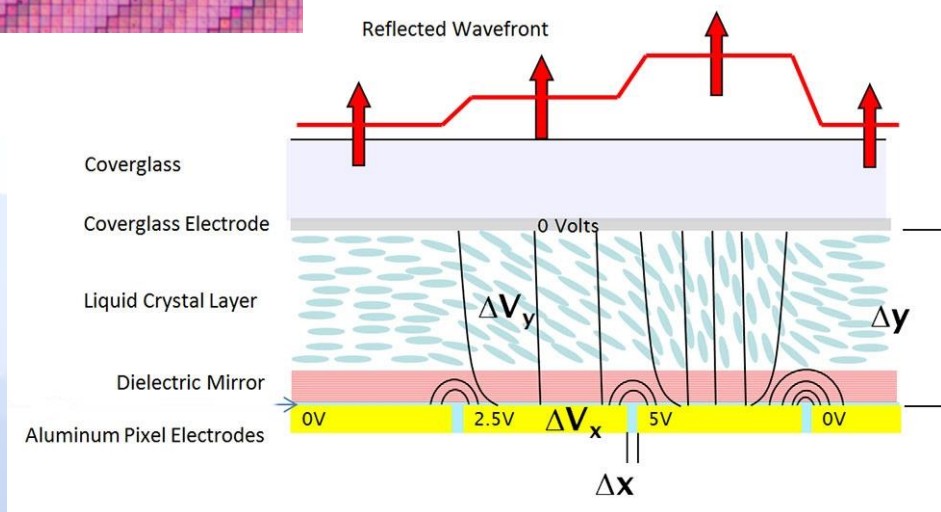
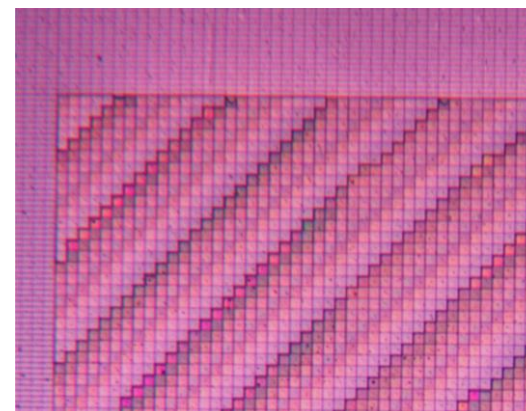
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Motivation: mirror characterization



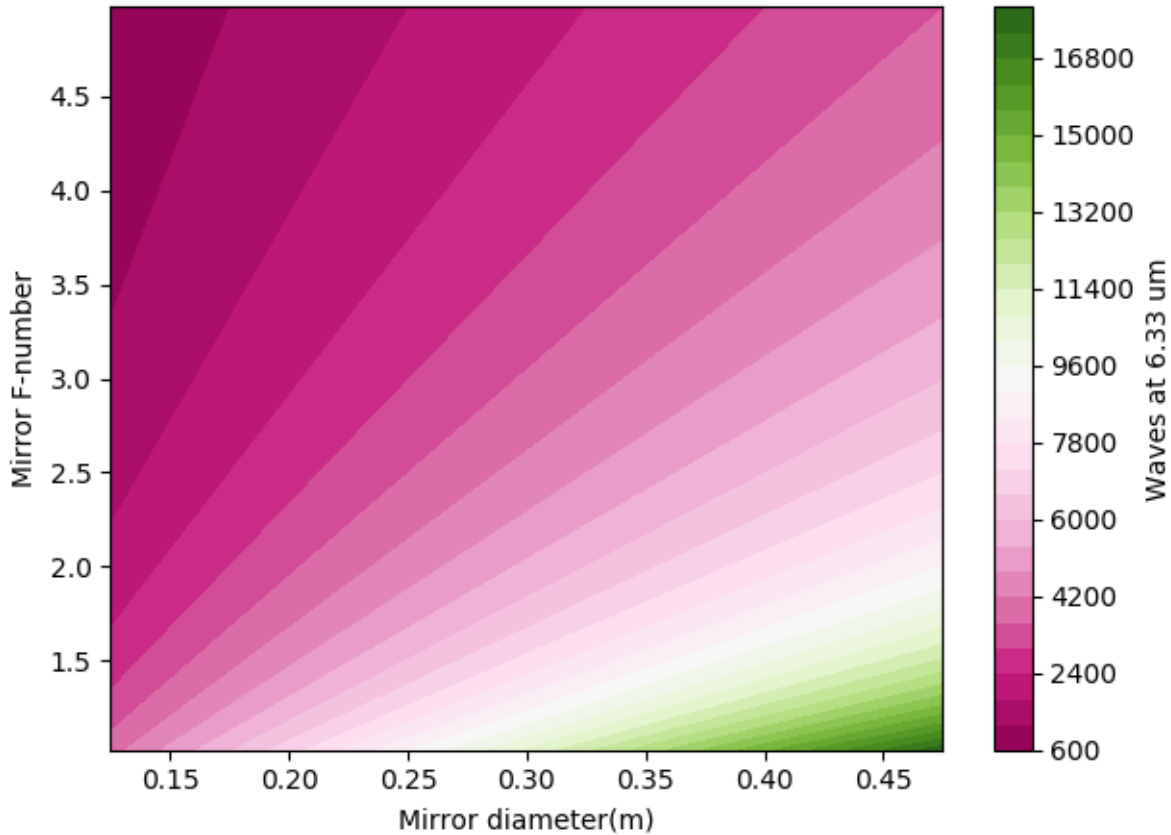
LCoS Spatial Light Modulators

Liquid Crystal on Silicon (LCoS) Spatial Light Modulators (SLMs)



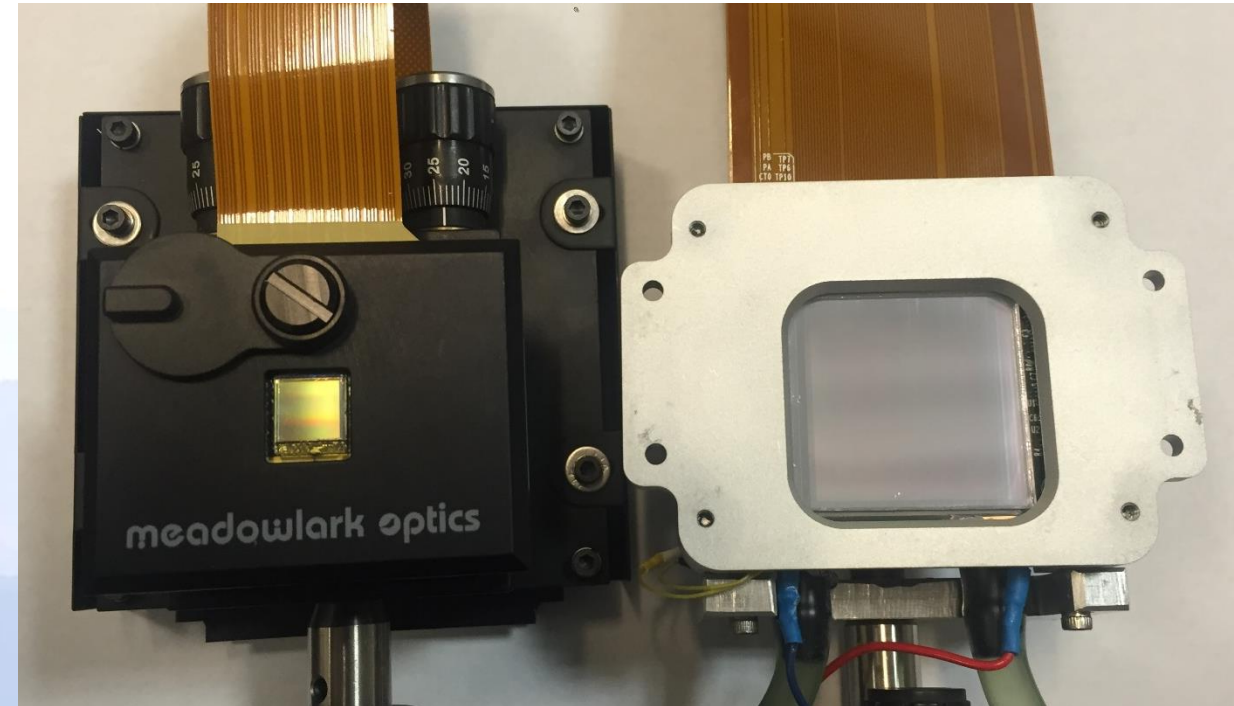
SLM nulling range

Paraboloid mirror max deviation at wavelength 6.33 μm



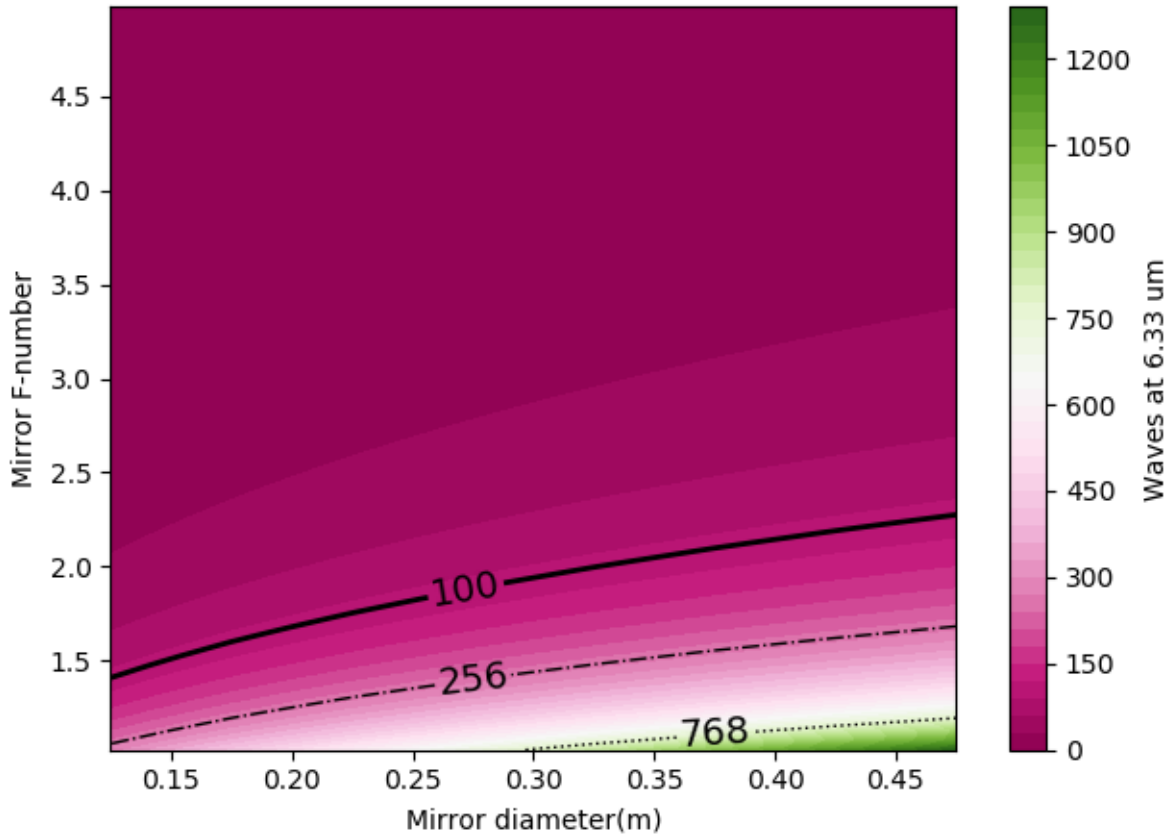
Phase I 512x512 SLM
Binary range: < 256 waves
15 μm pixels

Phase II 1536x1536 SLM
Binary range: < 768 waves
25 μm pixels



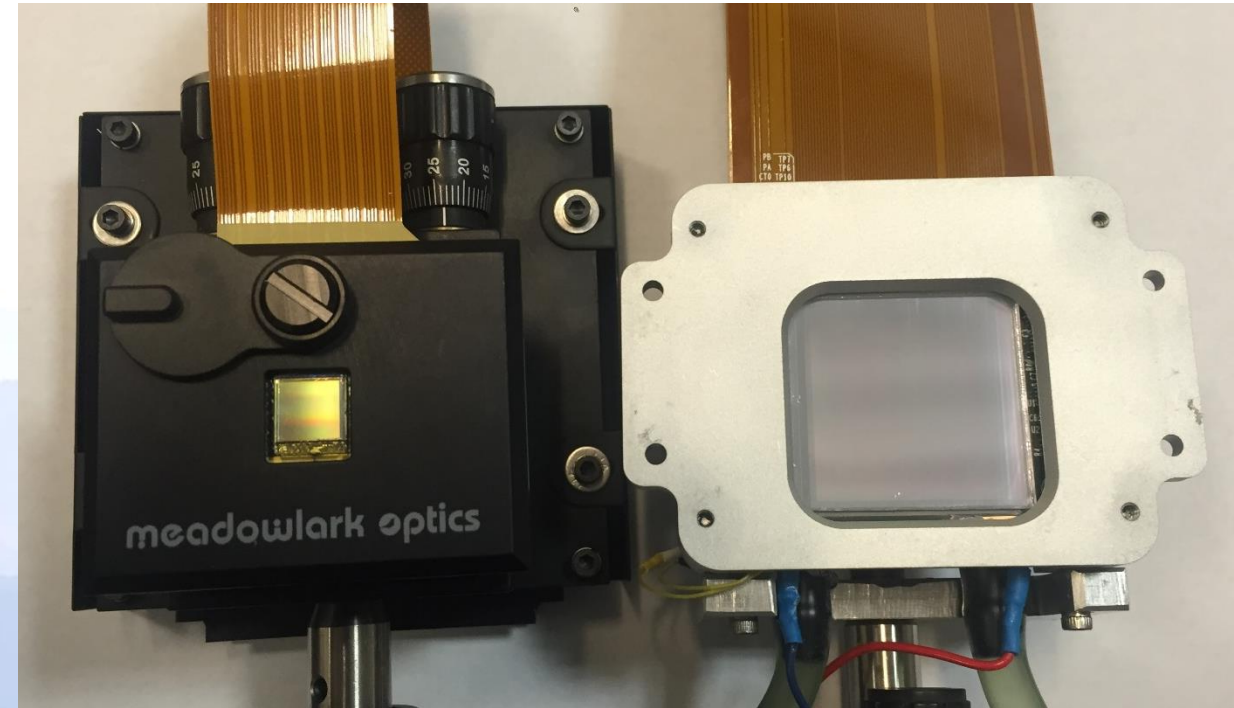
SLM nulling range

Paraboloid - sphere mirror pv at wavelength 6.33 μm



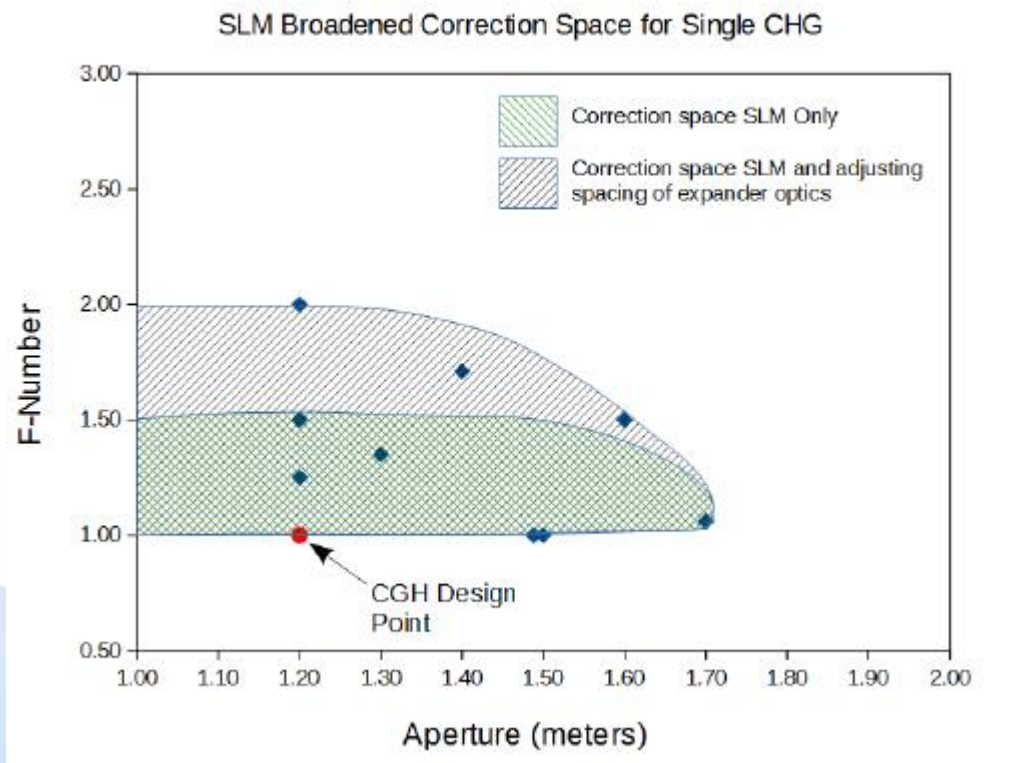
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Use of SLMs to extend CGH range

SLM: 100 wave range



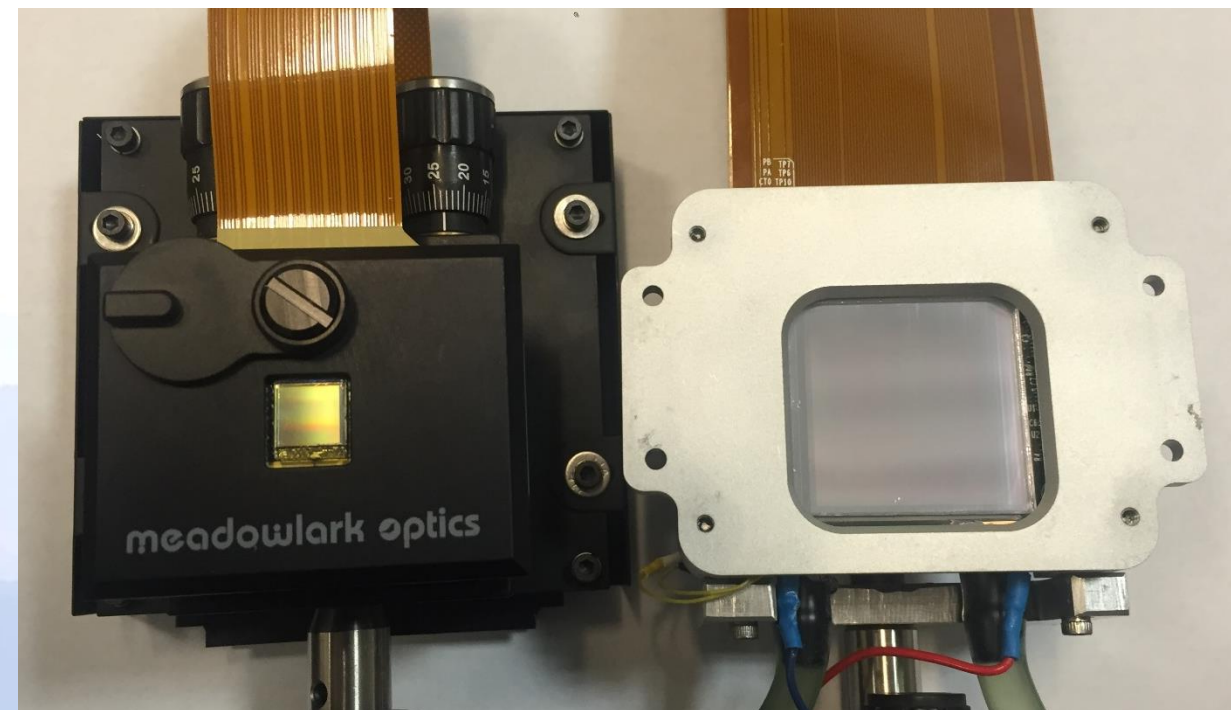
Temperature, gravity, similar segments

Phase I 512x512 SLM

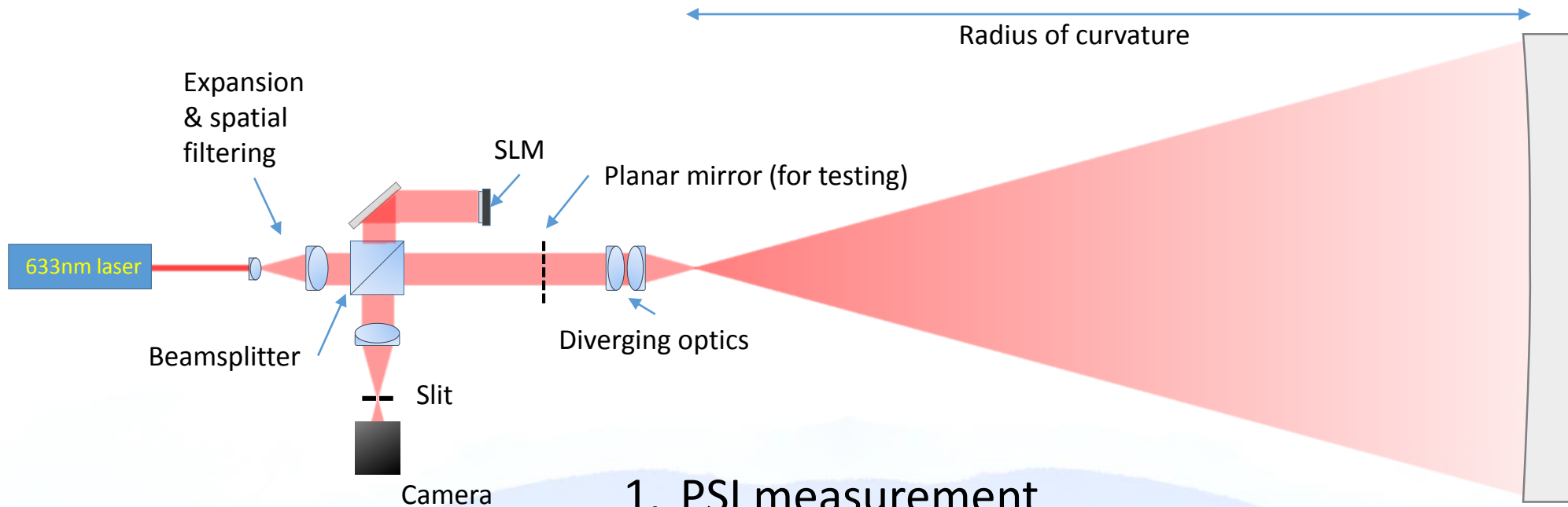
Binary range: < 256 waves
15 μm pixels

Phase II 1536x1536 SLM

Binary range: < 768 waves
25 μm pixels



Optical setup

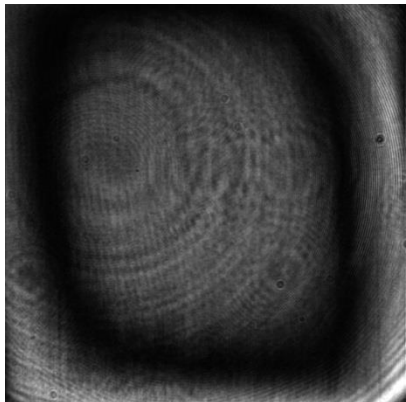


1. PSI measurement
2. Invert measured phase
3. Apply with SLM to null

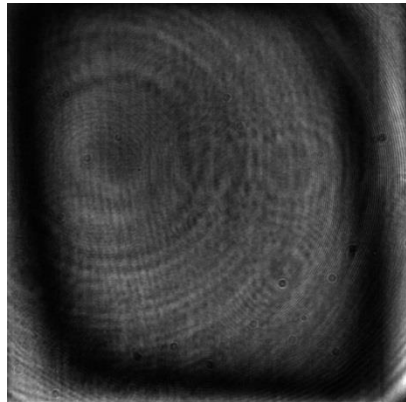
PSI Measurement: planar mirror

SLM piston applied (4-step PSI):

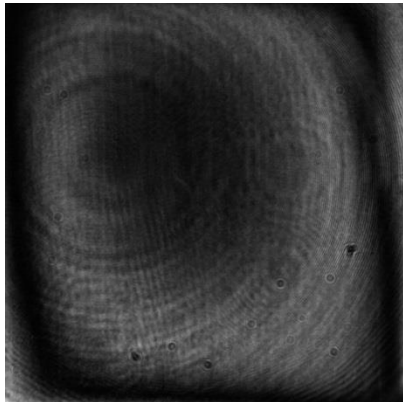
0



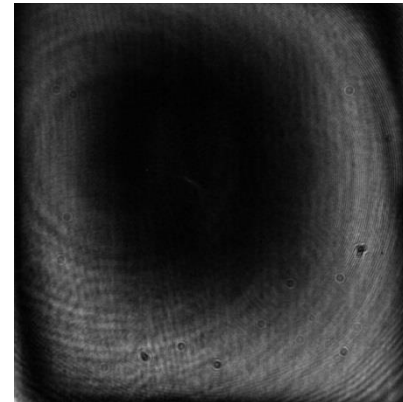
$\pi/2$



π



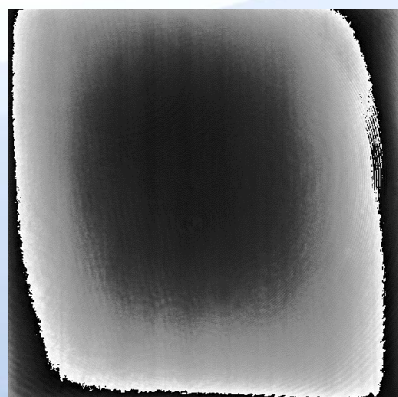
$3\pi/2$



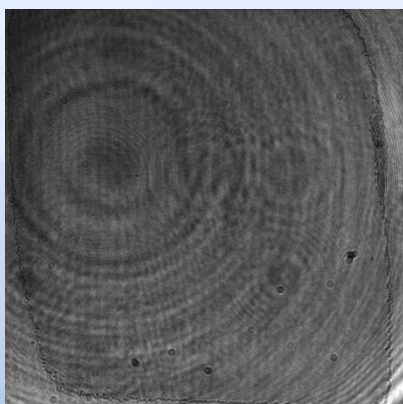
Retrieved phase:



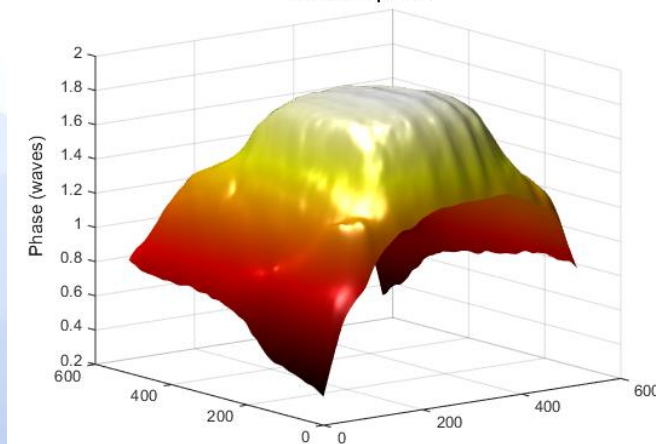
Correction phase:



Null

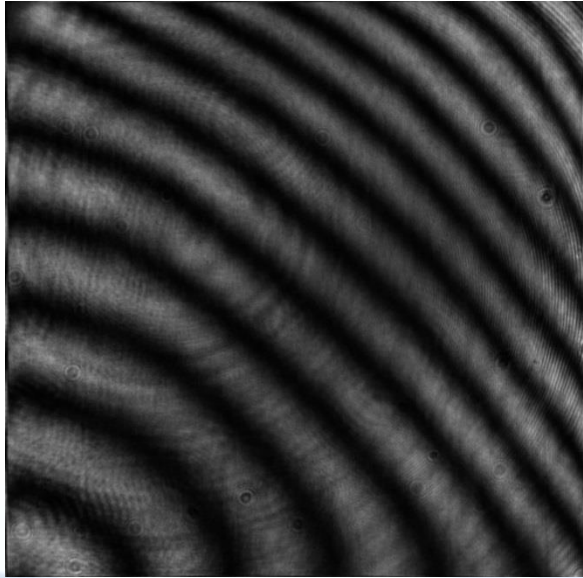


Retrieved phase

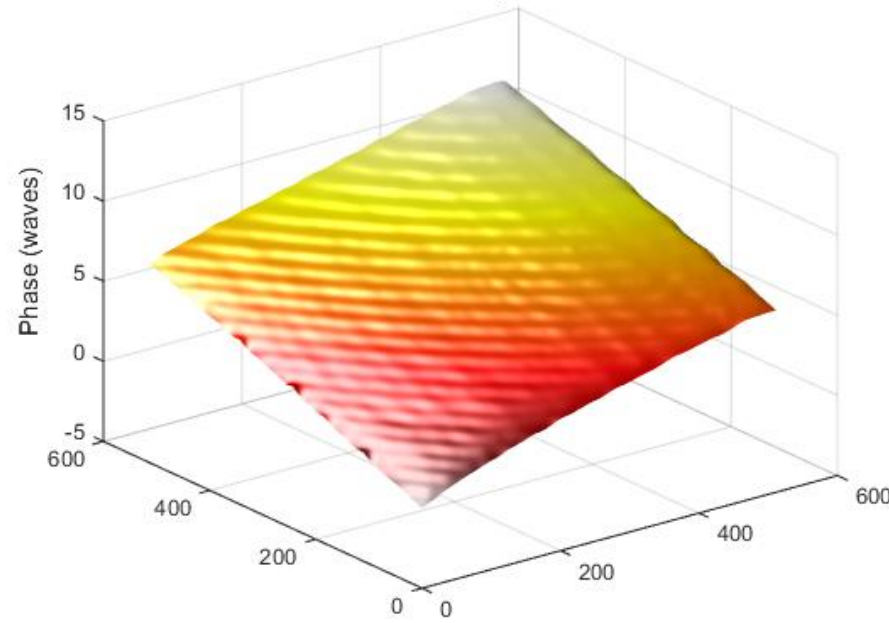


Nulling results: planar mirror w/ tilt

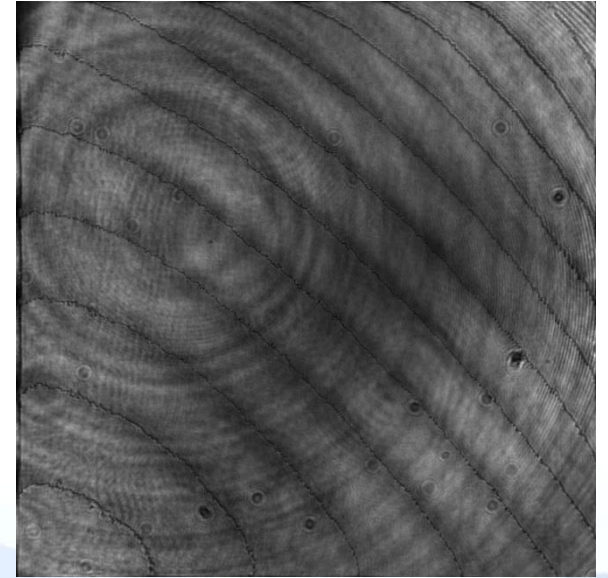
Interferogram before nulling



Retrieved phase



System nulled



Nulling results: adaptive null

Moving optic in the test arm
Nulling time: 0.9s

SLM rate: 400 Hz
Camera rate: 15 Hz

w/ triggered fast camera &
GPU accelerated calculation,
100 Hz nulling is possible

The screenshot displays the BNS software interface with the following components:

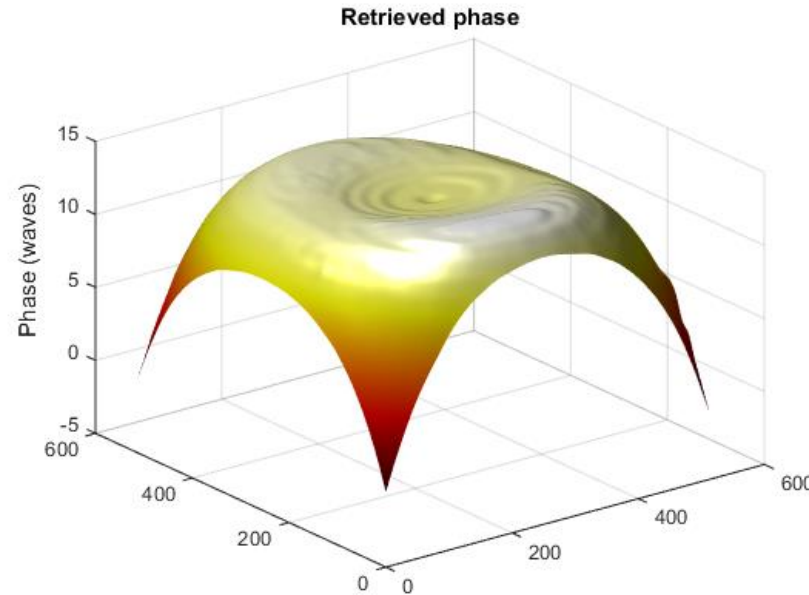
- SLM controls:** Includes a 'STOP' button, 'SLM power' set to 'ON', and file selection options for 'Zernikes from file' and 'Zernikes from list'. The 'Image file' is set to 'C:\Image_files\512x512\512black.bmp'.
- Nulling controls:** Features a 'START' button, 'PSI measurement' set to 'Continuous', and 'Number of PSI steps' set to 4. A status box indicates 'No correction phase applied. Continuous PSI measurement starts from blank.'
- SLM Pattern:** A 512x512 pixel grid showing a solid blue field, labeled '(does not include correction phase)'. The x and y axes range from 0 to 525.
- Camera image:** A grayscale image of a circular pattern, labeled '732x732 0.61X 32-bit RGB image 45,45 (54,162)'. Above it are buttons for 'Save camera image', 'Save next null', and a 'Nulled' indicator.
- SLM status:** Shows 'Number of SLM boards found' as 1 and 'SLM version' as 'BNS Overdrive_SDK version 3.3.1'. It includes an error message: 'Error initializing SLM: No board exists at index 4294967295. invalid vector<T> subscript'. A 'use_GPU' checkbox is checked, and 'board' is set to 1.
- Initialization controls:** A section for 'Regional LUT file' with a path 'C:\LUTs\SLM_4996_nonmirrored_635nm\SLM4996_nonmirrored_635_fm_flat_lut.txt' and a 'max_frames' setting of 20.
- Correction Phase:** A vertical plot on the right showing a blue curve, with 'PSI time' at 0.88768s.
- Cursors and ROI:** A 'Cursors' section with 'Cursor 0' and an 'ROI' section with 'Global Rect' at 234 and 'Contours' at 0.

Nulling results: Custom SLM-applied phase

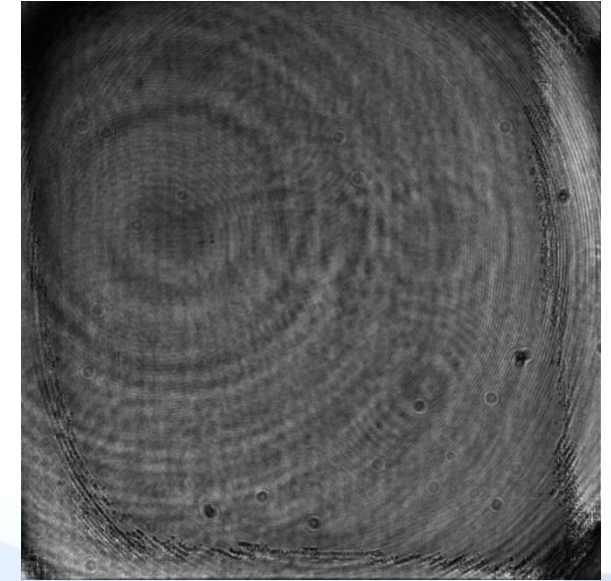
Interferogram before nulling



PSI retrieved phase



System nulled



X tilt: 0.5
Y tilt: 0.25
Oblique astigmatism: 0.25
Defocus: 1
Horizontal coma: 1

Future work

Speed

Speed limited by 15fps camera rate
SLM speed: 400fps; 500fps w/next-gen
>100 Hz nulling

Commercial-grade hardware

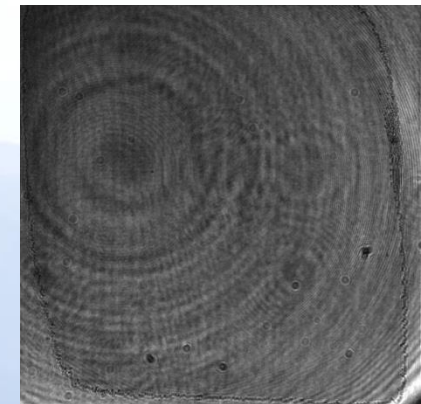
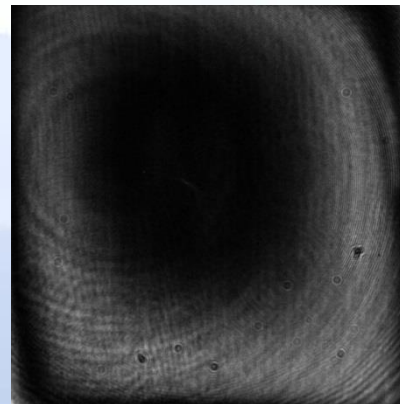
Vibration management
Quality of optics
Integration w/ commercial interferometer

Characterization

Accuracy, range
Results w/ known optics & CGH

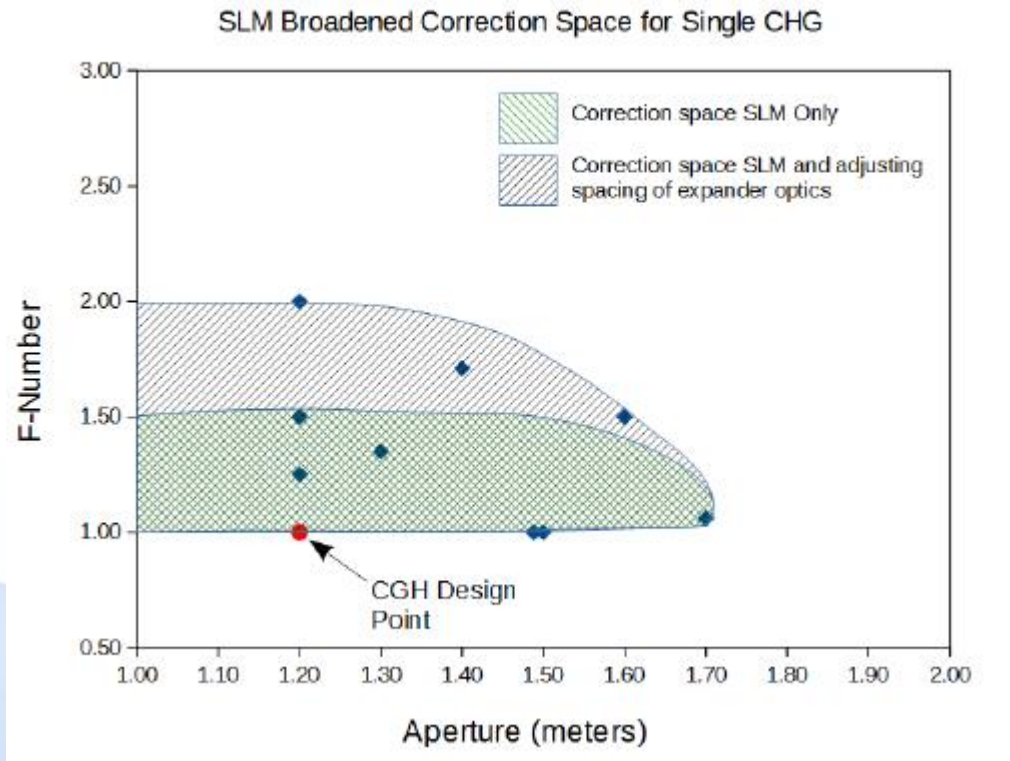
Regional SLM calibration

Accounts for nonuniform SLM surface



Future work – expanded range

SLM: 100 wave range

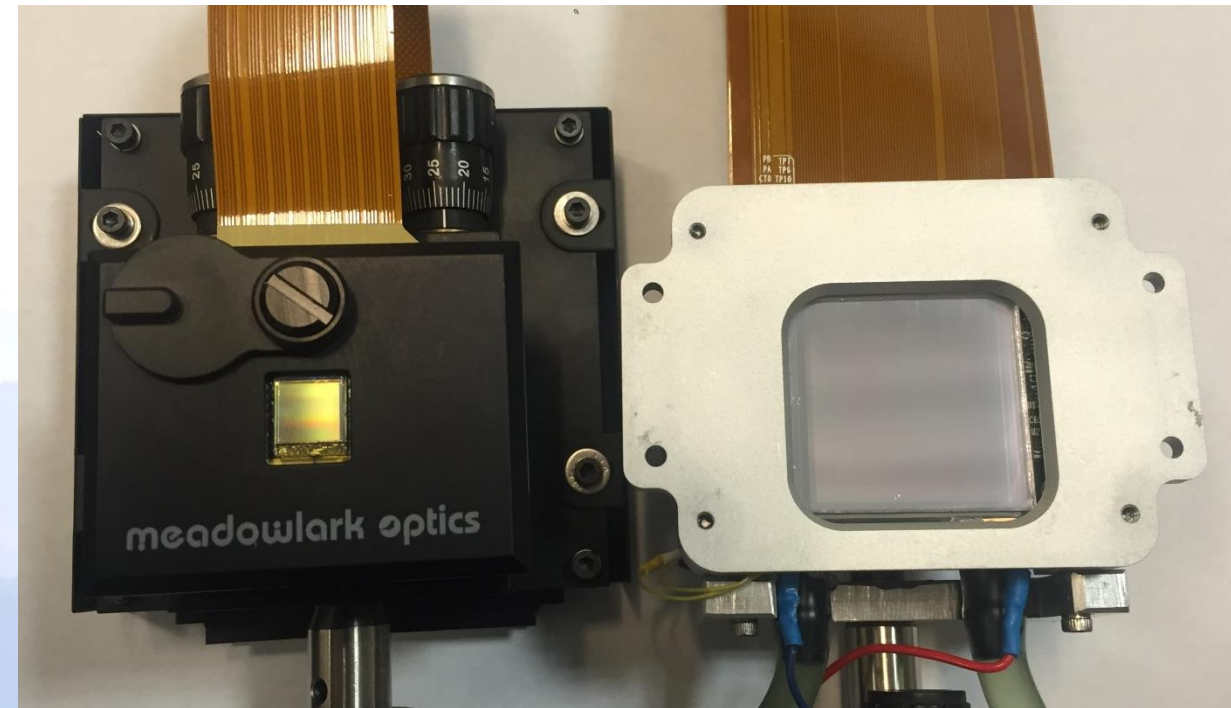


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Conclusions

- LCoS can apply arbitrary phase, incl. piston for PSI
- Can extend the range of a CGH
- 1 Hz nulling shown; 100 Hz nulling likely
- Phase 2: larger SLM, commercial interferometer

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