Interferometric Testing of the AOptix Deformable Mirror

David Horsley[1], Hyunkyu Park[1], Sophie Laut[2] & Jack Werner[2]
[1]Berkeley Sensor & Actuator Center &
Department of Mechanical Engineering
[2]Department of Ophthalmology
University of California, Davis

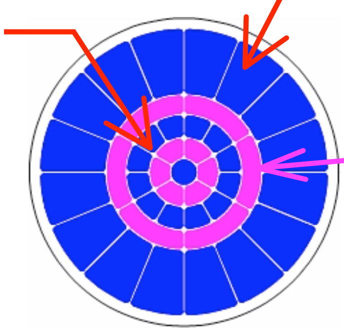
BSAC

Overview

- Description of mirror structure
- Global characteristics
  - Roughness
  - Static actuation characteristics
  - Dynamics
- Reconstruction of Zernike mode-shapes from influence matrix
- Conclusions

AOptix Mirror Structure

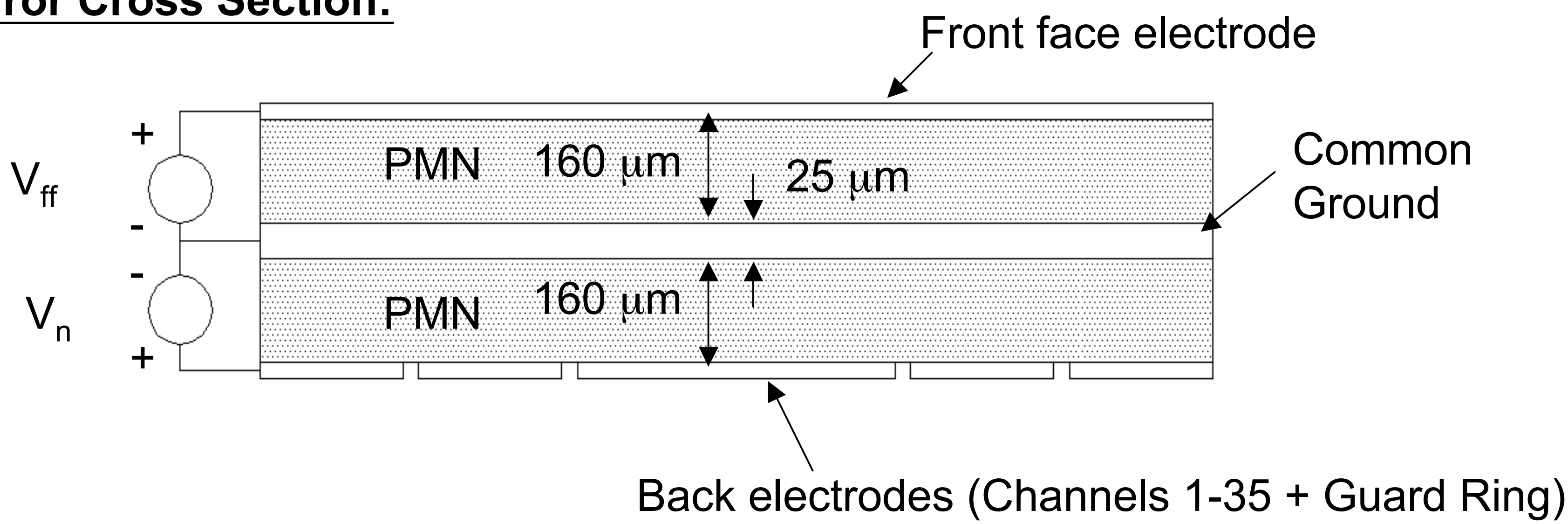
Plan View of Electrode Layout:



# of Actuators:

35 + 1 (Guard Ring)

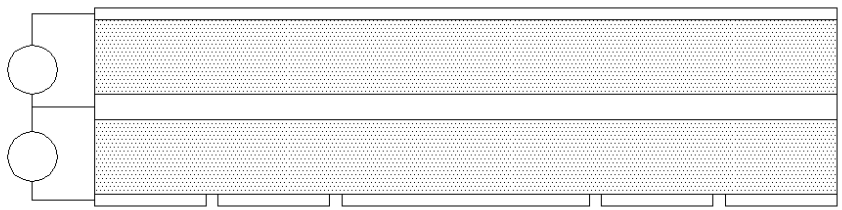
Mirror Cross Section:



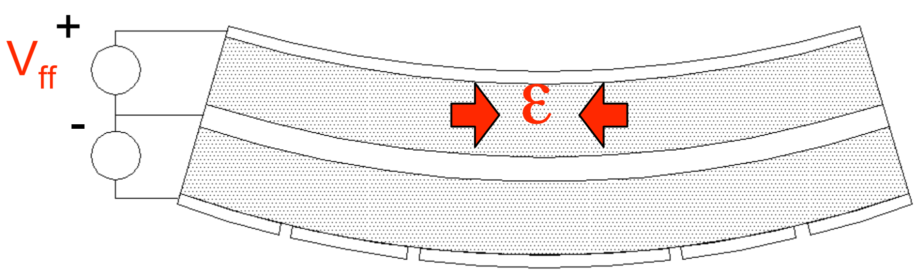
Actuation Principle

- PMN is an electrostrictive ceramic
  - Strain is proportional to square of electric field.
  - Unlike piezoelectrics, cannot generate compressive stress.

Relaxed state



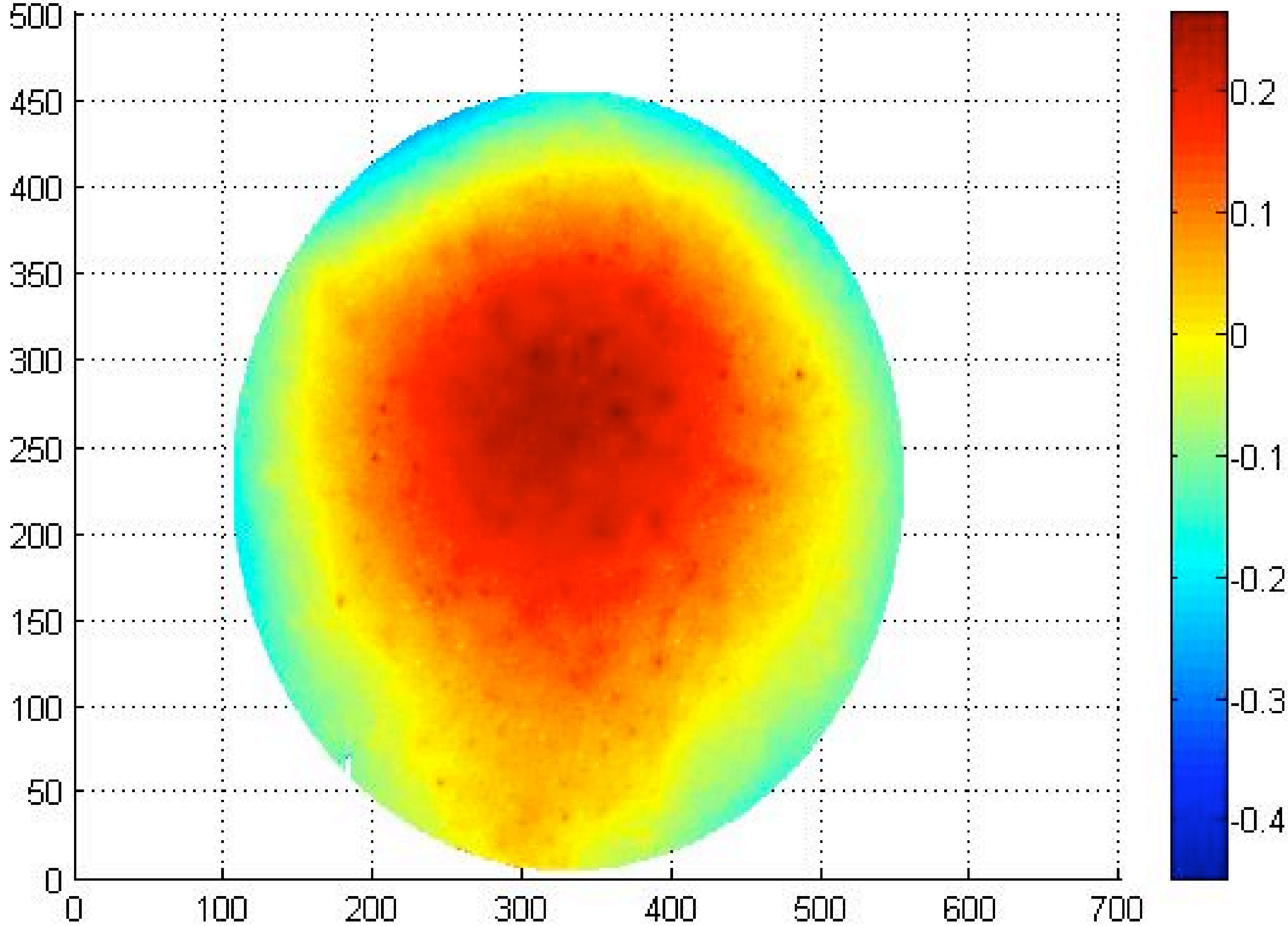
Actuated state



Actuation Details

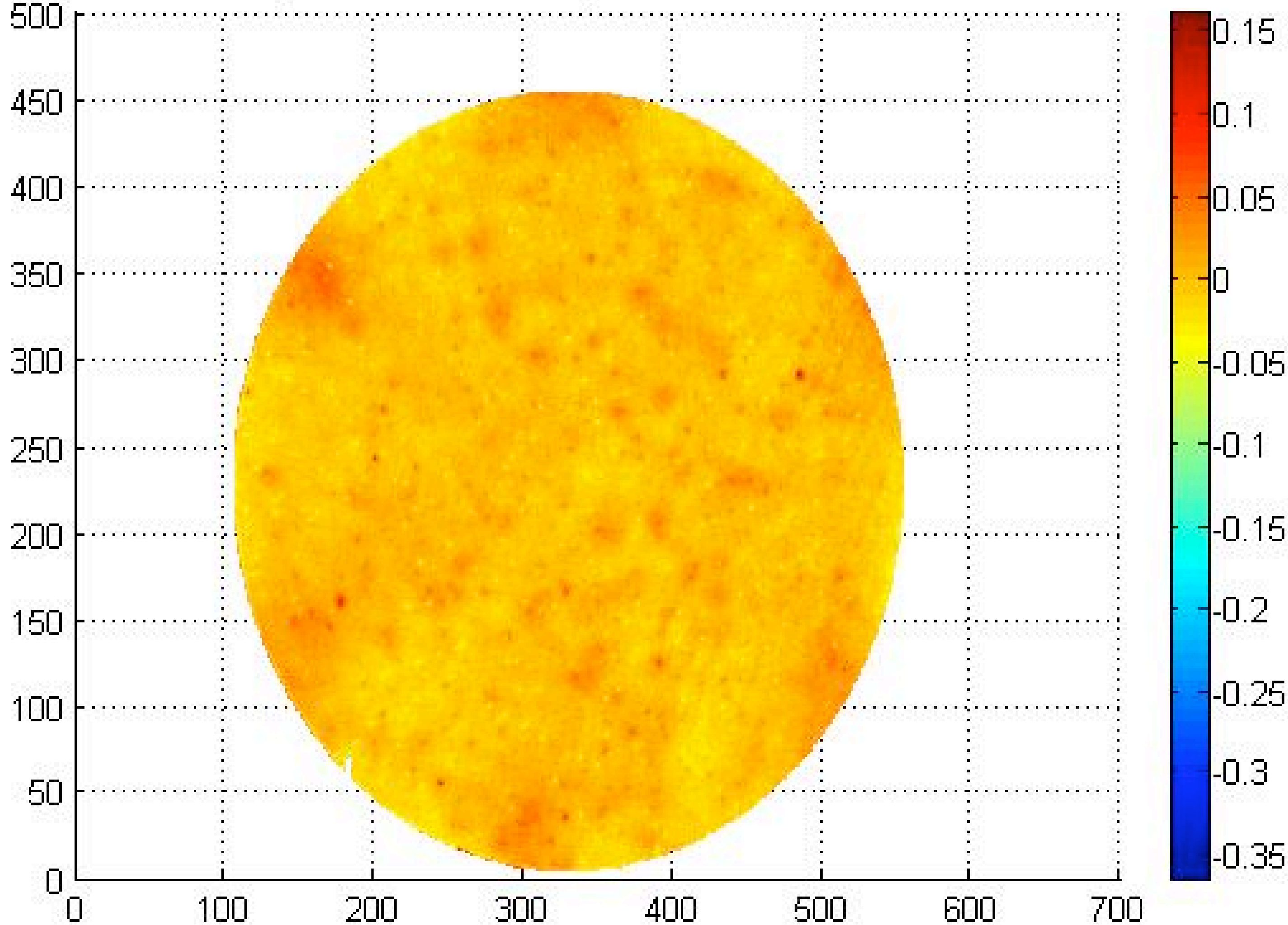
- Symmetric bimorph structure:
  - Front-face biased at 100V.
  - When back electrodes are at 100V, mirror is nominally flat.
  - Back electrodes < 100 V results in concave shape
  - Back electrodes > 100 V results in convex shape
  - Max full-scale voltage = 300V
- Advantages
  - Lower remanent polarization than piezo results in low hysteresis.
  - Lower tempco than a simple bimorph.

Surface map of "flat" mirror



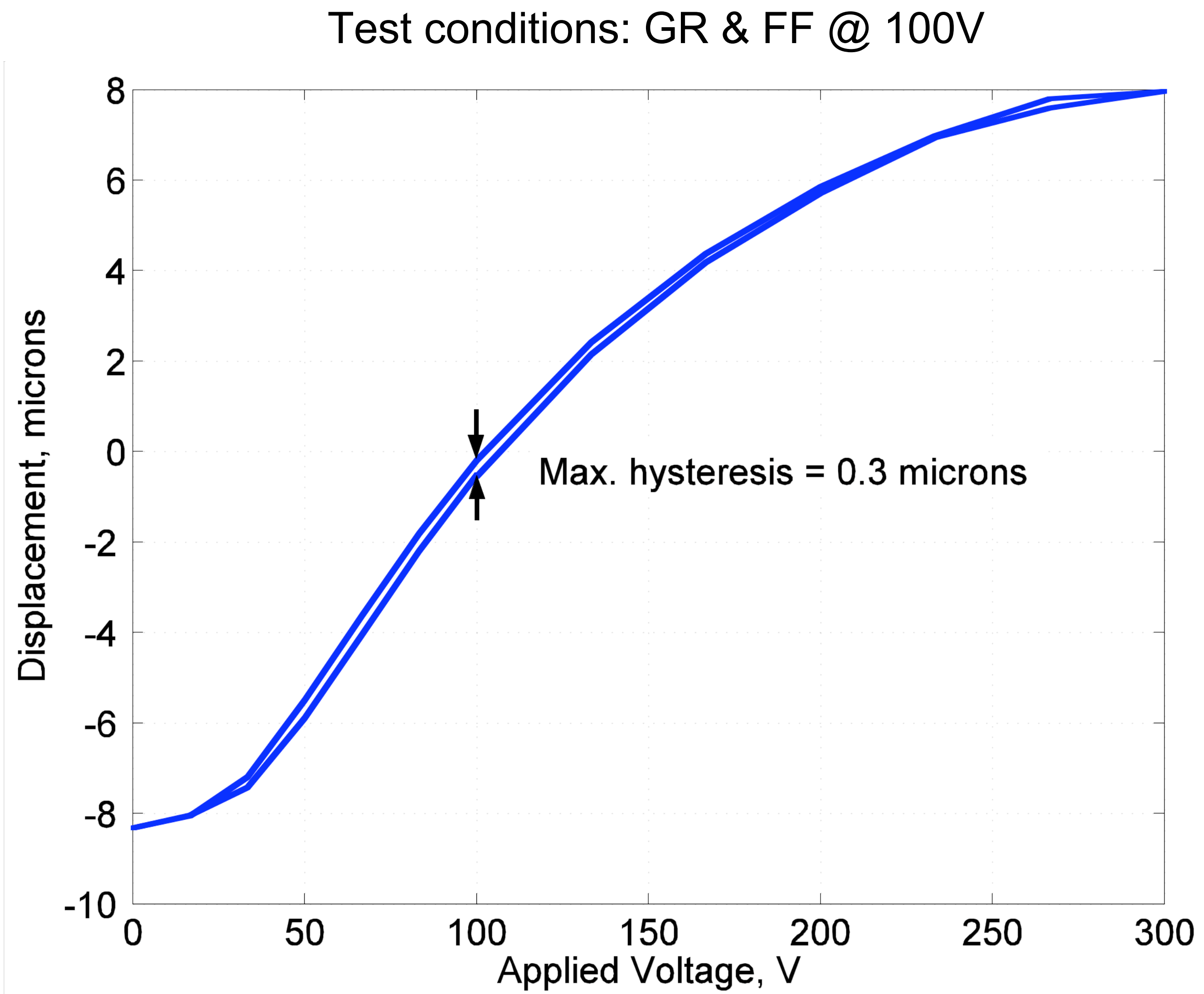
RMS = 120 nm, P-V = 0.6 microns

Residual error after 5th order Zernike Fit

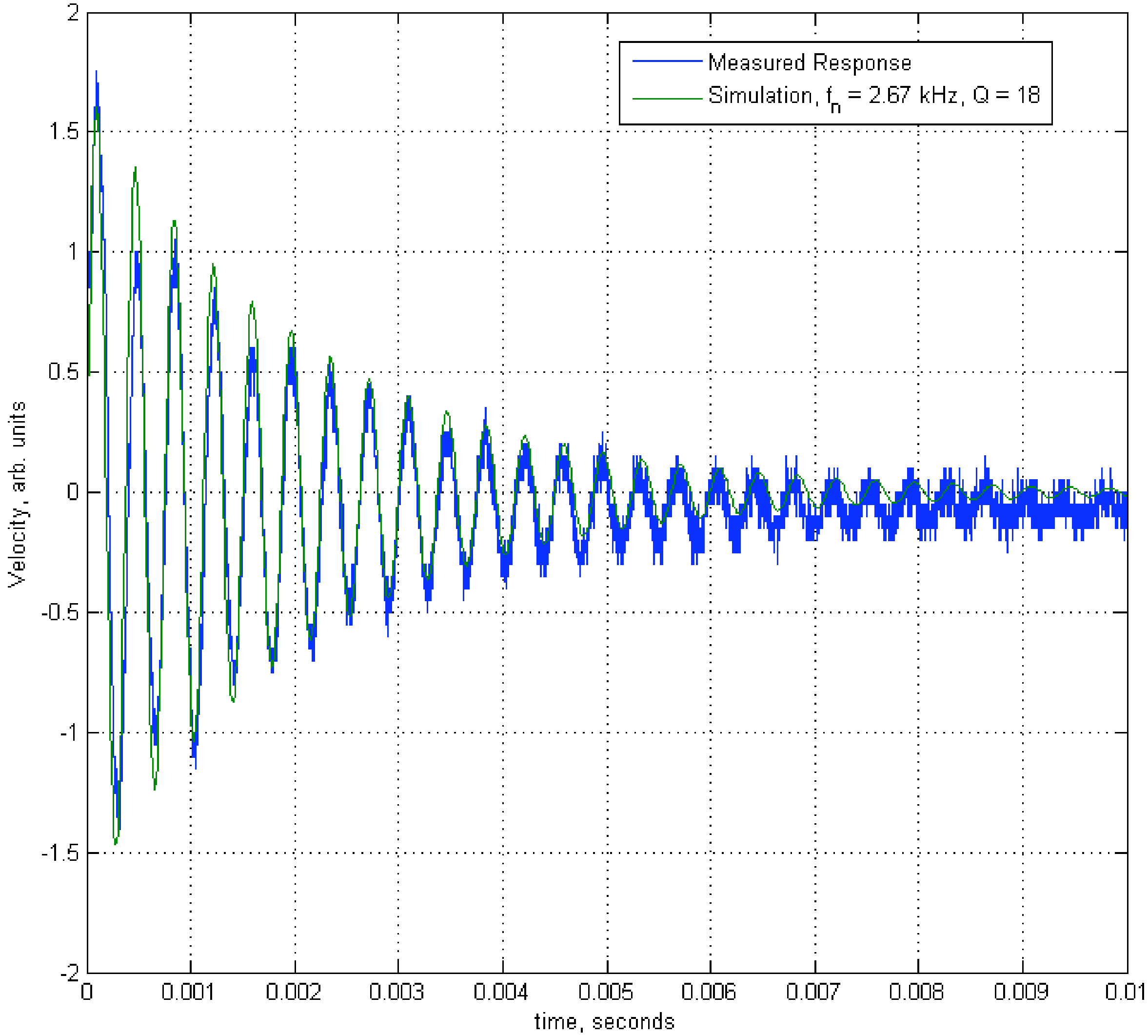


RMS = 13 nm, P-V = 200 nm

Defocus Vs. Applied Voltage



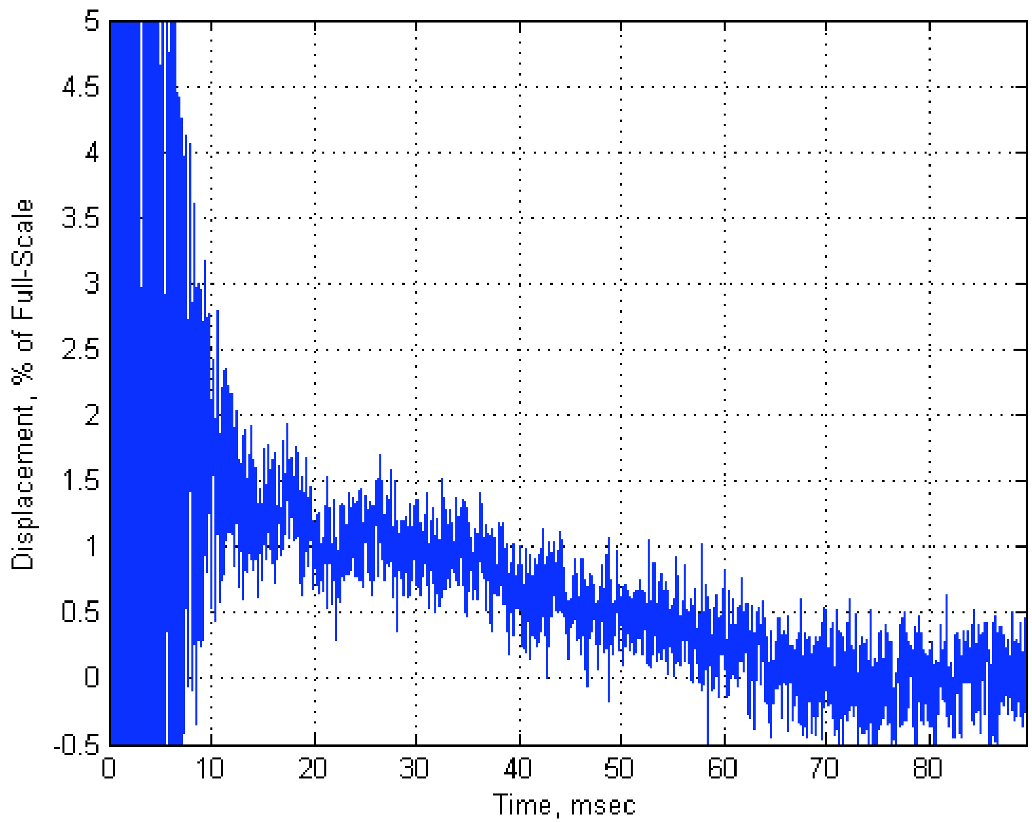
Step Response



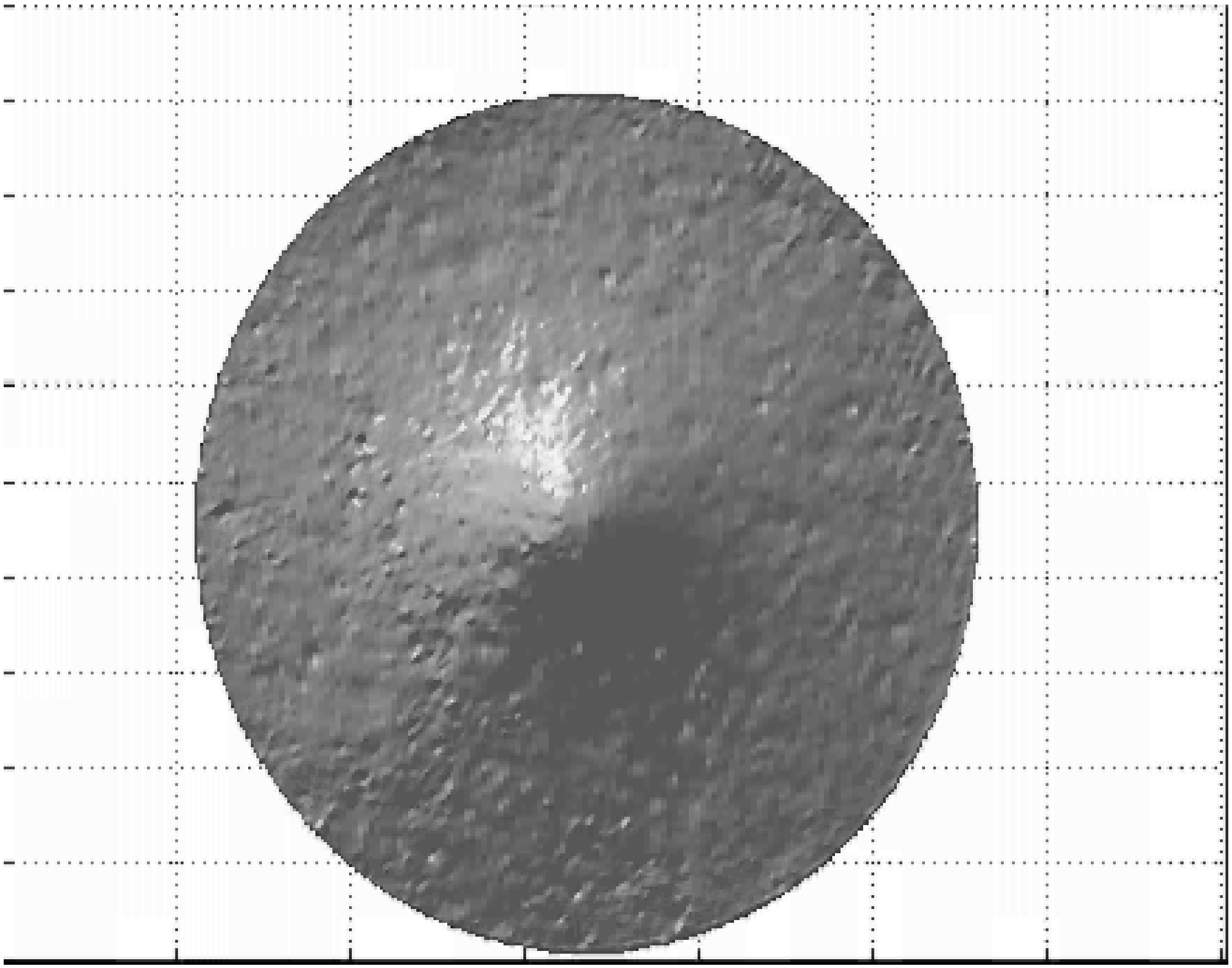
- f_n = 2.67 kHz
- Q = 18
- 1% settling time = 10 ms

Creep

- Mirror response varies by approximately 1% after the first 10 ms of settling.
- This response lasts for approximately an additional 60 ms.

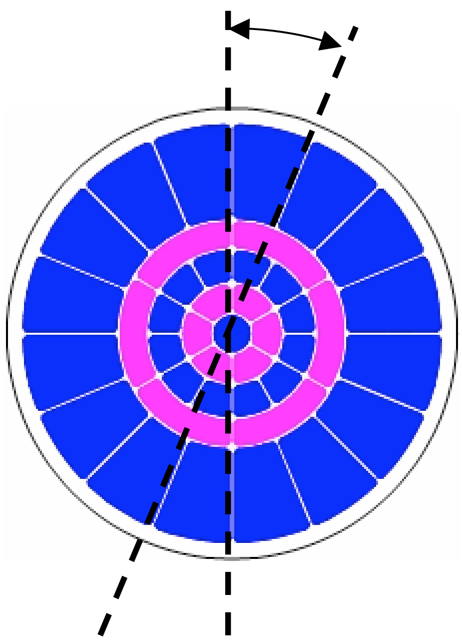


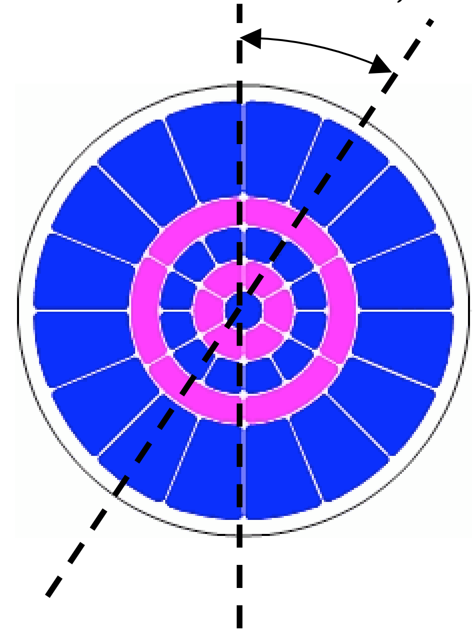
Influence Functions



Reproducing Zernike Mode Shapes

- Motivation: characterize ability of mirror to reproduce "interesting" combinations of aberrations.
- Started with astigmatism at arbitrary angles:





Zernike Modeshapes

Approach:

- Model wavefront surface as a weighted combination of influence functions:

$$W(x,y) = f(\overrightarrow{V})\overrightarrow{\Phi}^T$$

- Approximate influence functions with a finite number of Zernike polynomials:

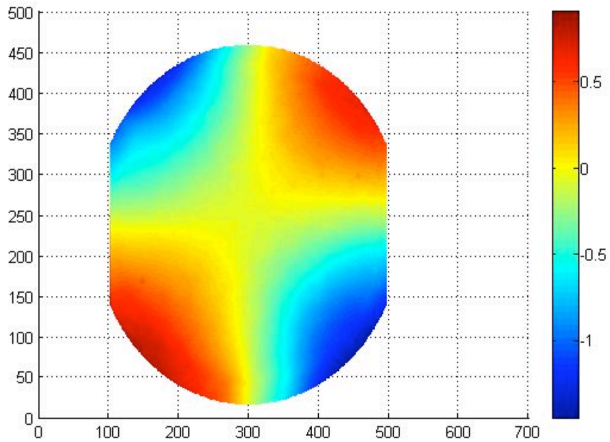
$$\overrightarrow{\Phi}^T = \frac{1}{Z_0} A \overrightarrow{Z}^T$$

- The voltage required to generate an arbitrary combination of Zernike polynomials , e_i, is computed from the pseudo-inverse of ***A***:

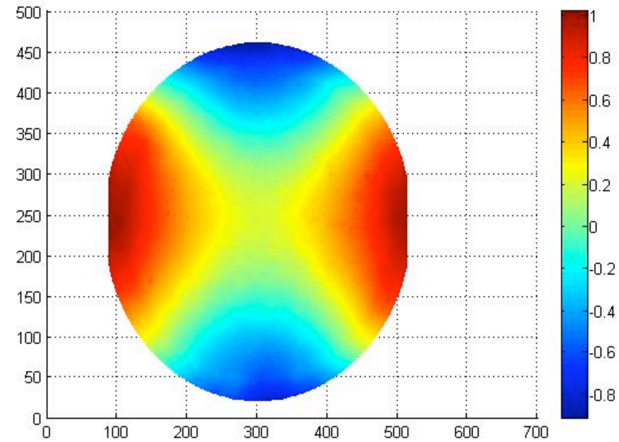
$$\overrightarrow{V} = f^{-1}(Z_0 \overrightarrow{e_i} A^*)$$

Measured Results

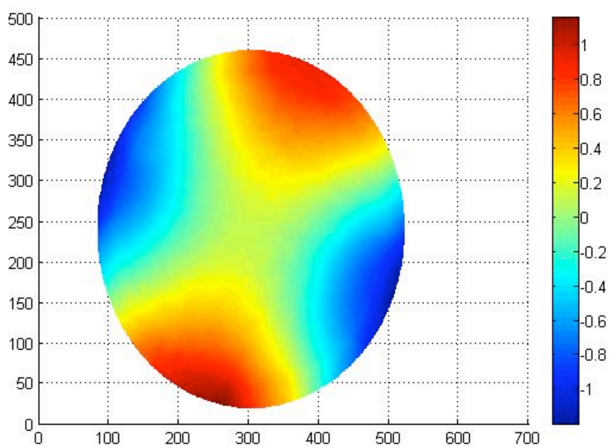
45º, RMS error = 170 nm



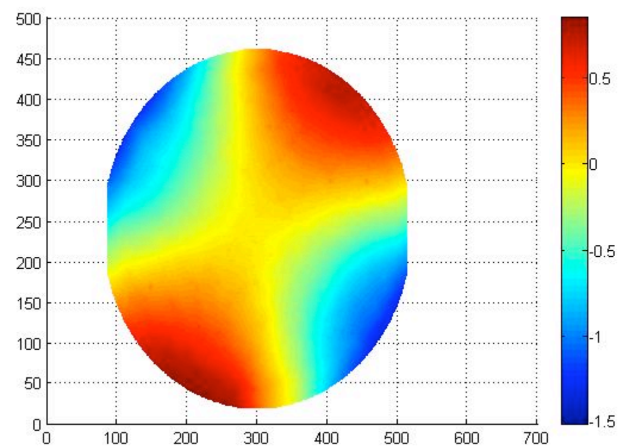
90º, RMS error = 86 nm



22.5º, RMS error = 103 nm



33.75º, RMS error = 106 nm



Summary of Results

Parameter	Value
Max Stroke	± 20 um
Max Defocus	± 3 D
Creep	1% of FS
Hysteresis	2% of FS
Settling (1%)	10 msec

- Correction of 2nd-order aberrations is clearly feasible.
- Study of correction of 3rd and 4th order aberrations in progress.
- Simple mirror structure may result in future low-cost DM's.