Adaptive Optics for Wavefront Correction of High Average Power Lasers

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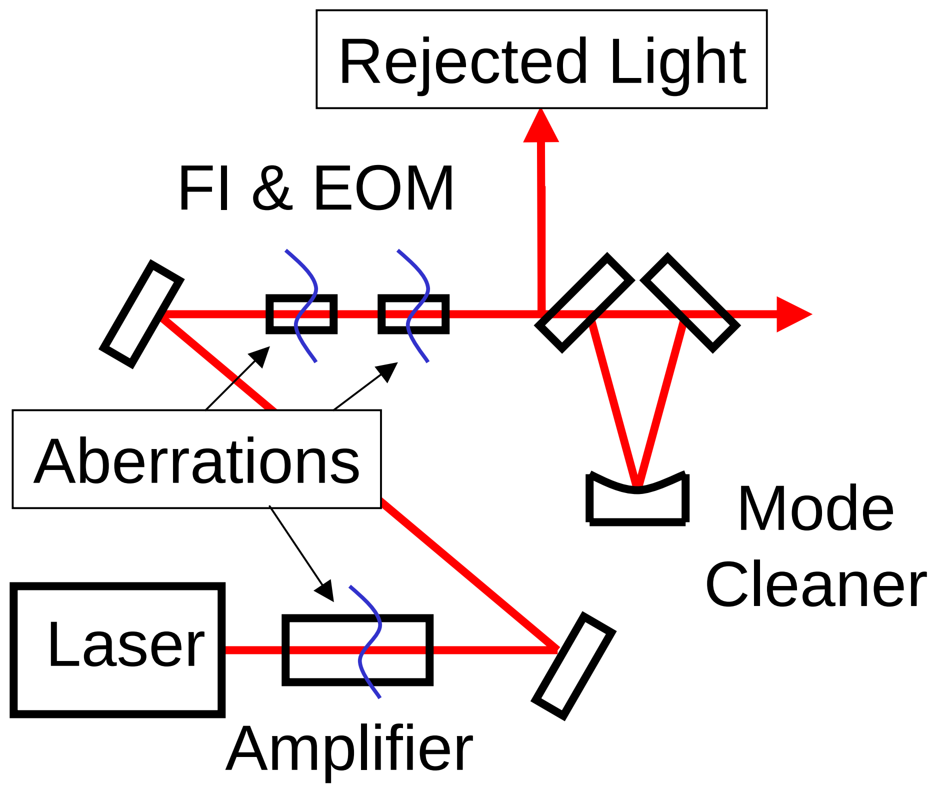
Outline

- Motivation – Laser Aberration Removal
- Effects of Zernike Aberrations on Laser Beam Quality
- Measured Laser Aberrations
- New Micromachined Deformable Mirror
- Laser Aberration Compensation Experiment
- Conclusions and Future Work

Motivation

- Aberrations remove light from the interferometer
- “Quasi-Static” - diode failures and power fluctuations change the aberration shape and amplitude.

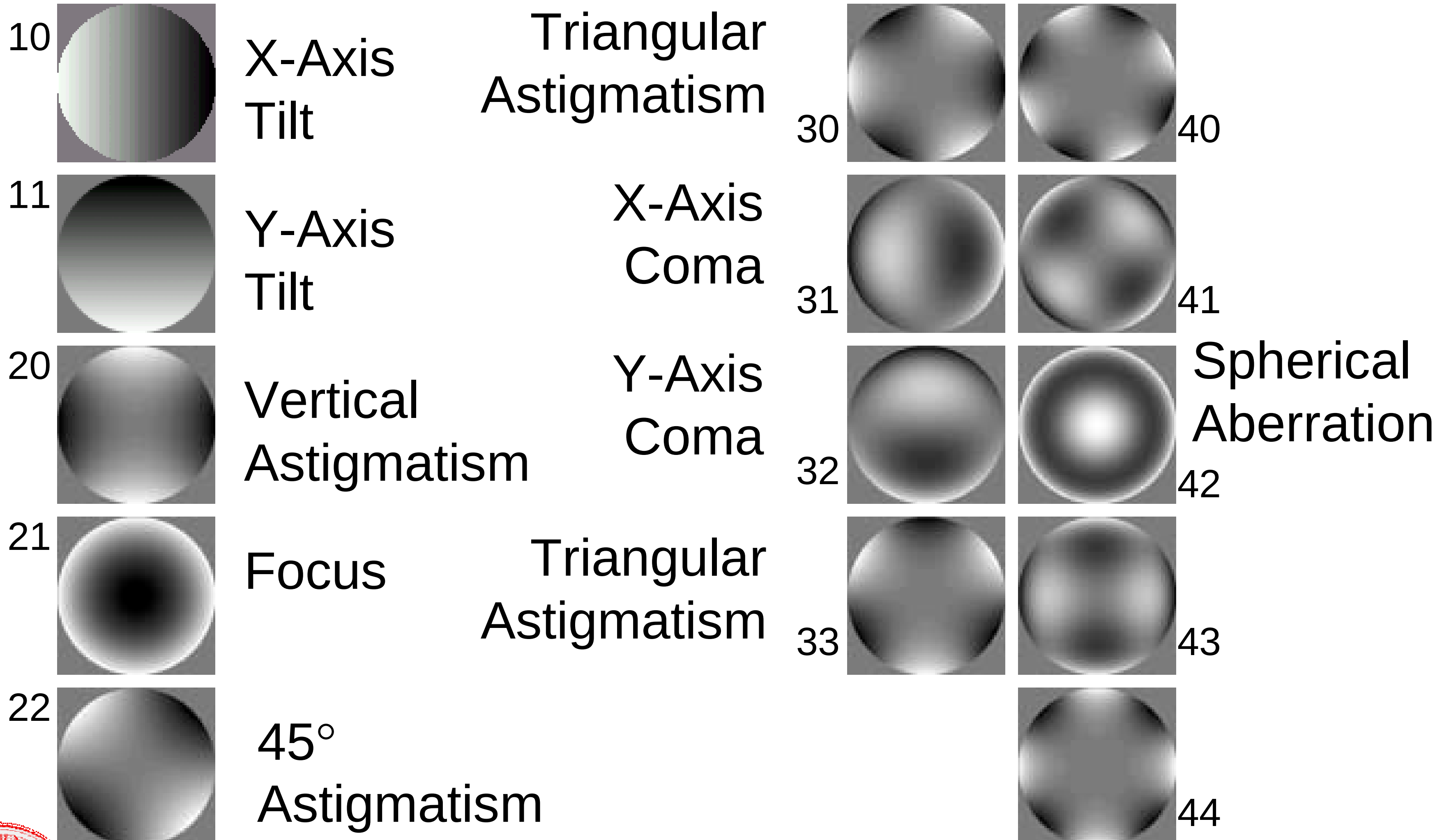
LIGO Front End



Effects of Zernike Aberrations

- **Zernikes** - a set of orthogonal polynomials defined about a unit circle used to describe wavefront aberrations in optical metrology
- Effect of Zernikes can be understood by performing the overlap integral (a.k.a., inner product) of the perfect and aberrated electric field distributions.
  - Mansell *et al*. “Evaluating the Effect of Transmissive Optic Thermal Lensing on Laser Beam Quality With a Shack -Hartmann Wave-Front Sensor” Applied Optics **40,** p.366.

Zernike Polynomials



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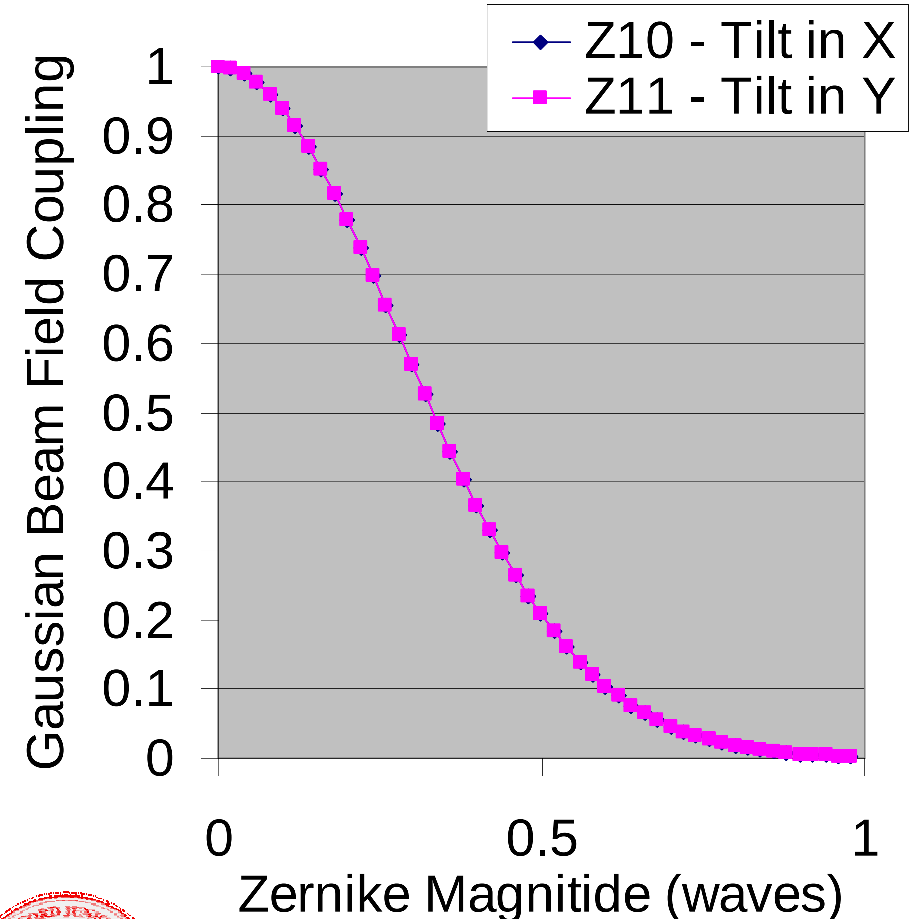
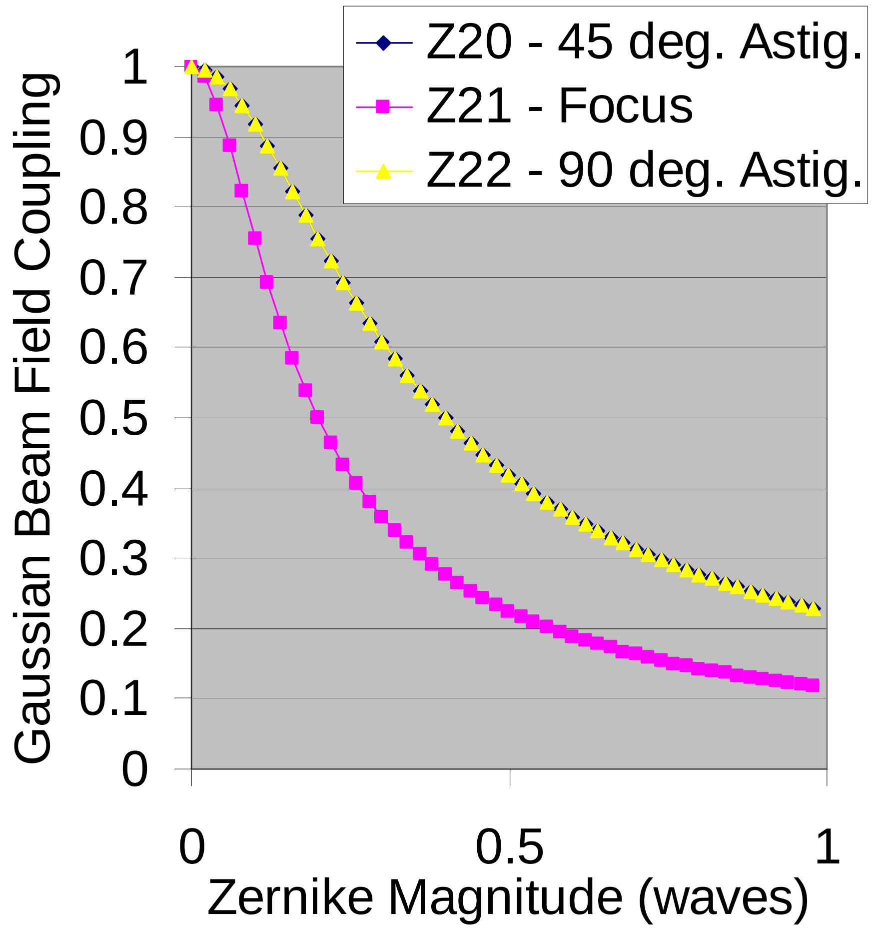
Effect of 1st and 2nd Order Zernikes on TEM_{00} Mode Content





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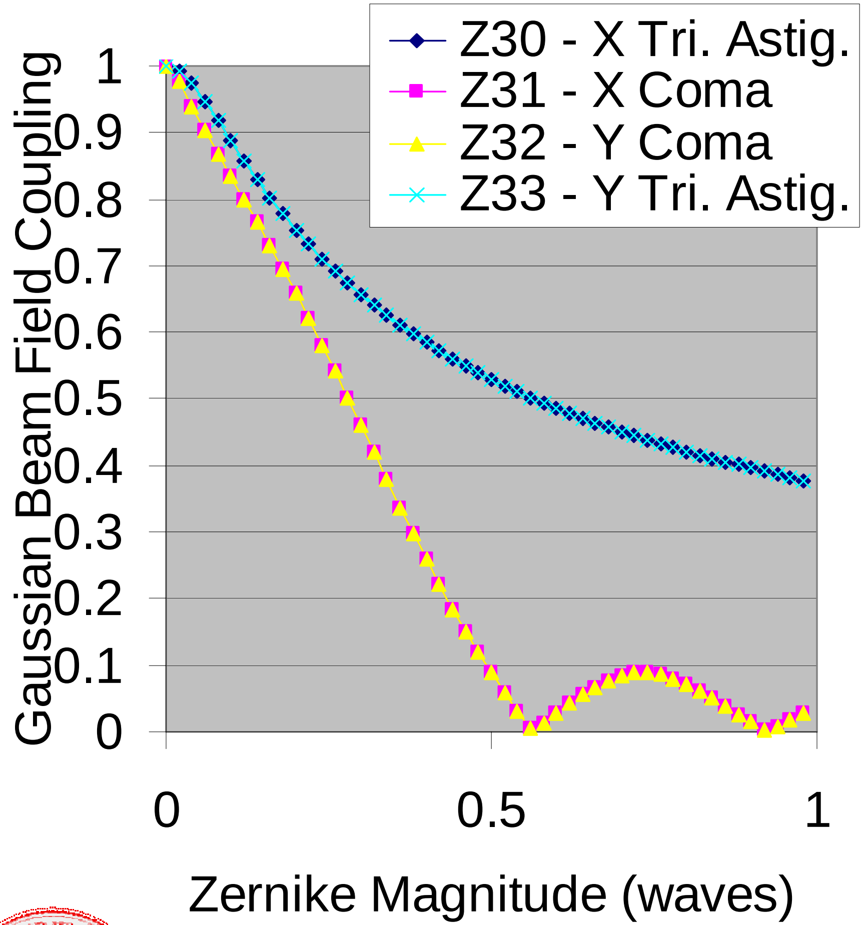
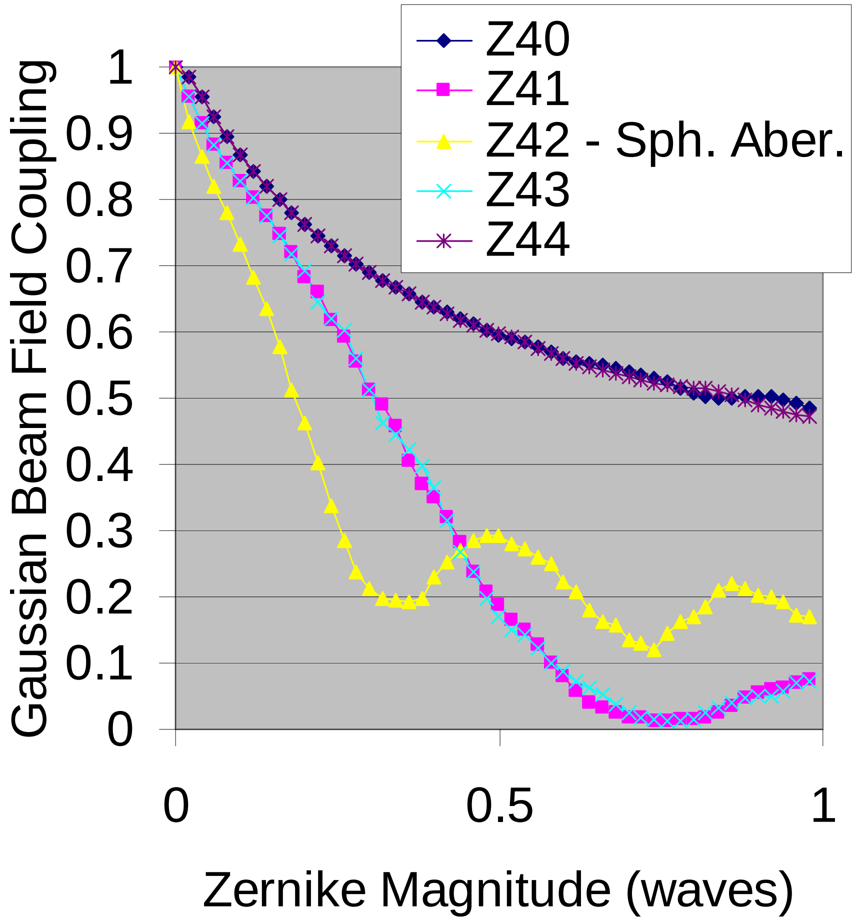
Effect of 3rd and 4th Order Zernikes on TEM$_{00}$ Mode Content





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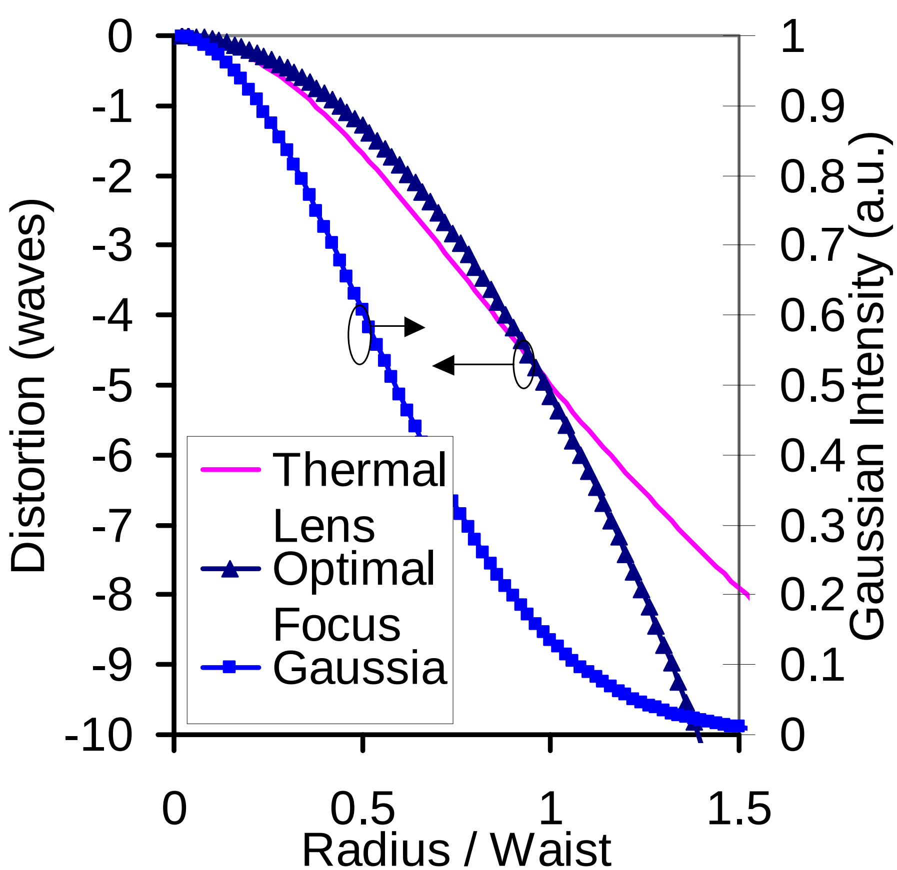
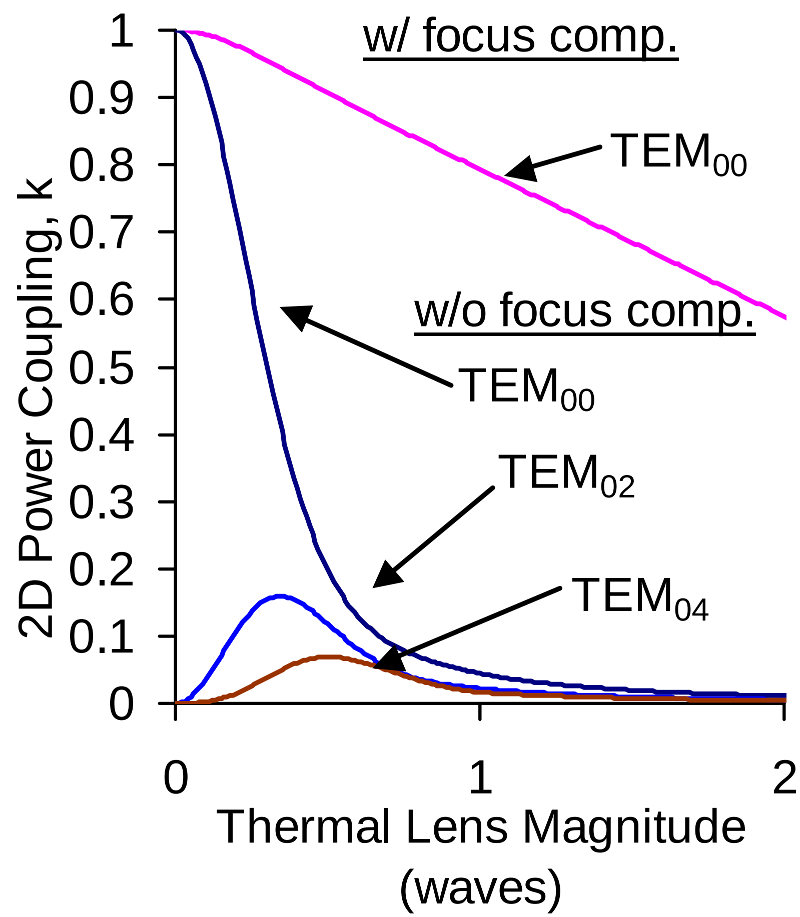
Transmissive Optic Thermal Lensing





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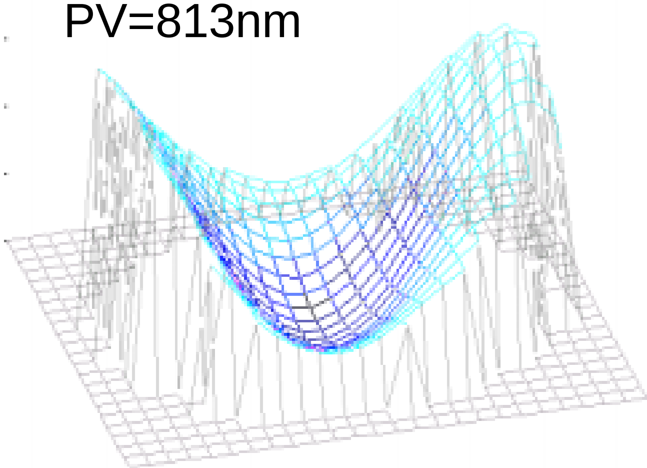
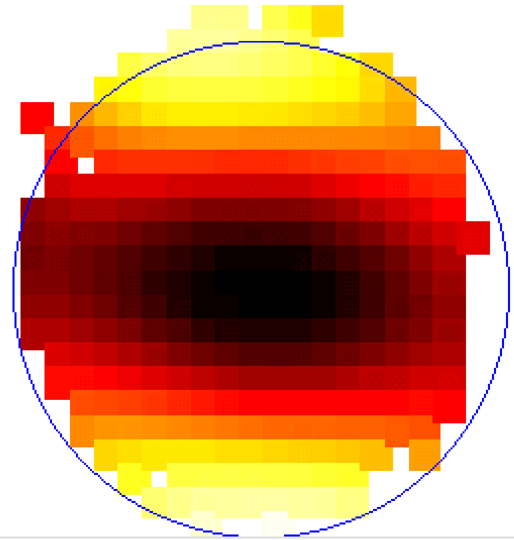
Slab Laser Amplifier Aberrations

PV=813nm



Tilt-Removed Aberrations for 175W Pump



Term	Norm Coeff	Coeff(µm)	Description
Z11	4.26E-04	0.84	tilt about z axis
Z10	4.08E-04	0.806	tilt about y axis
Z22	1.78E-04	0.352	astigmatism with 0 or 90 axis
Z21	1.16E-04	0.23	focus shift
Z42	-3.80E-05	-0.075	third order spherical aberration
Z43	-2.73E-05	-0.054	

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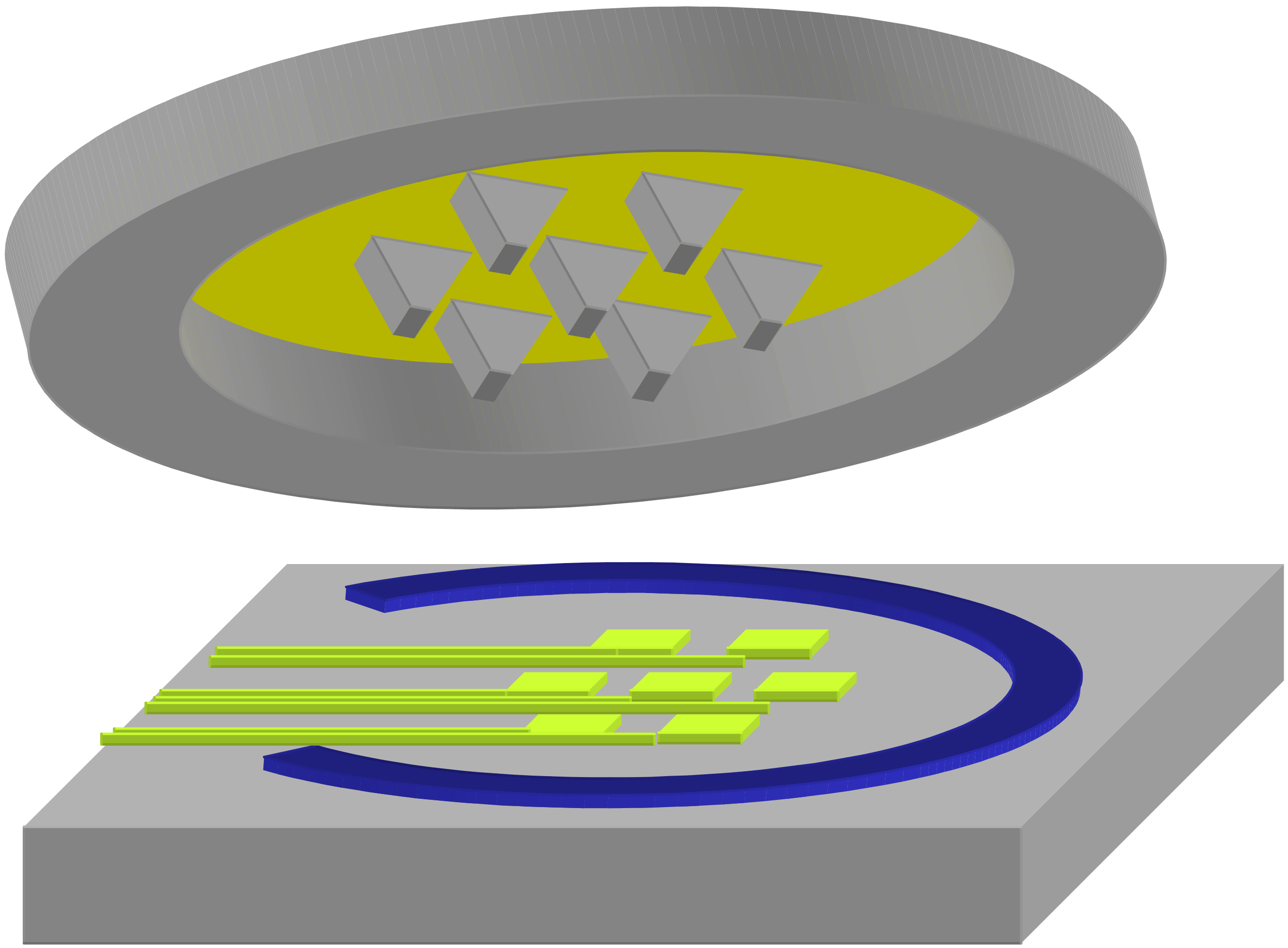
3D View of Mirror Architecture



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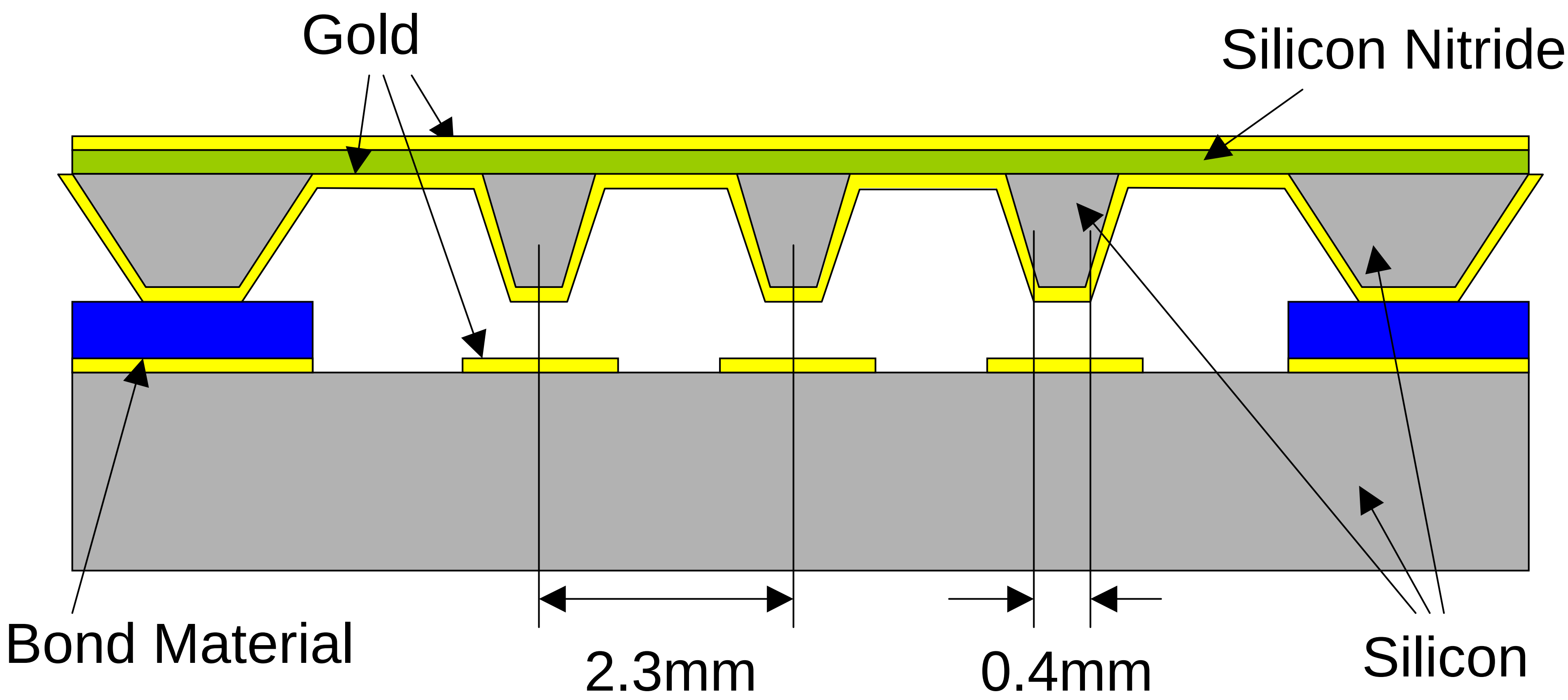
Cross-Section of Mirror Architecture



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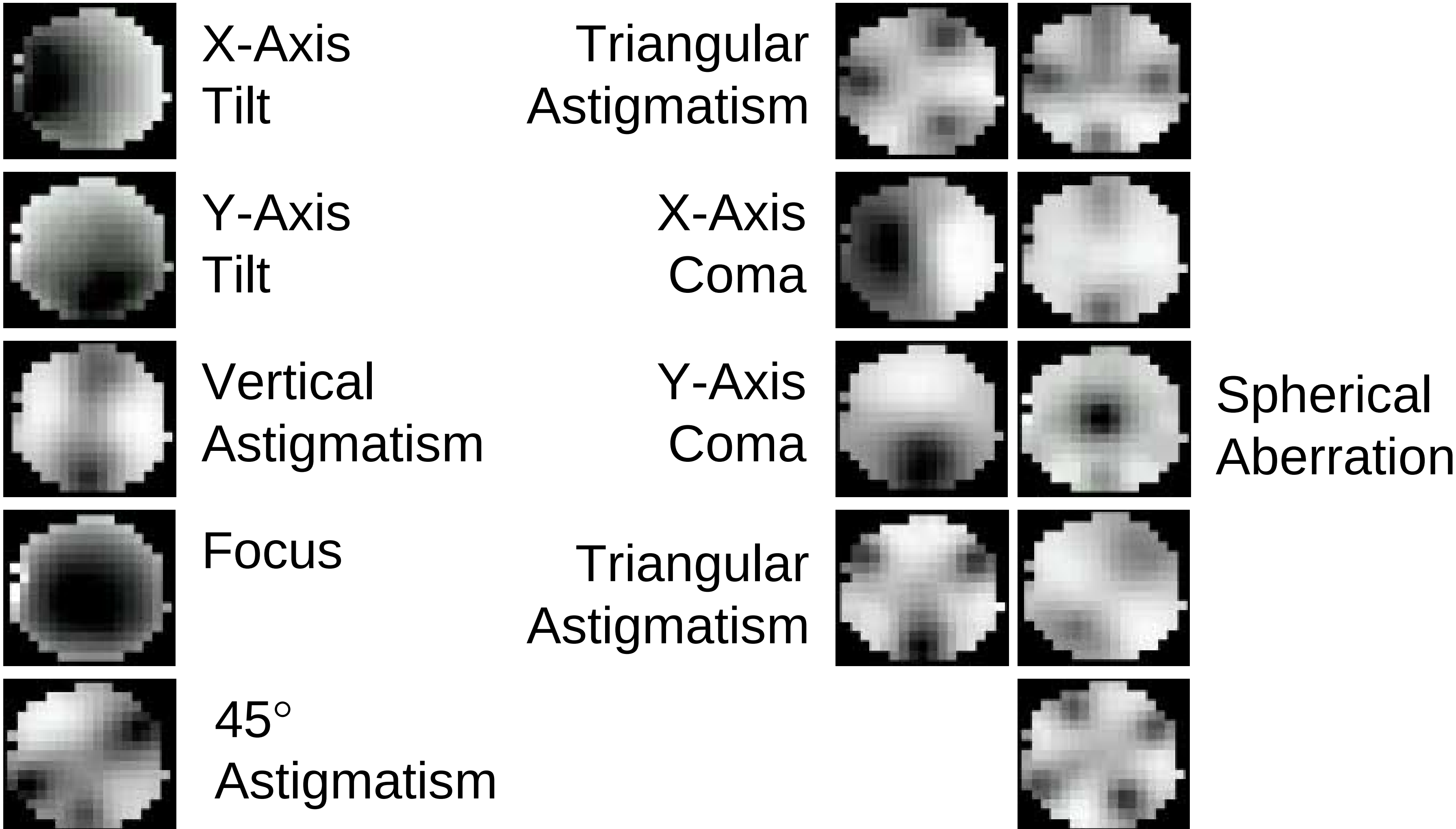
Stanford DM Photograph

Stanford's Silicon DM Characteristics

- 19 actuators with 2.3mm spacing in a 1.6cm aperture
- **Low Static Aberrations** (~λ/2 PV in astigmatism)
- **Good Power Handling** (42nm rms surface distortion from 4.5W of cw 1064nm laser light)
- **Versatile** (10μm throw in center actuator)
- **Low Power** (200V to actuate, but almost no current)
- **Fast** (>500Hz mechanical resonance frequency)
- **Low-cost fabrication**
- **Robust** (Electrostatic snap-down does not damage the mirror and is fully recoverable)

Stanford DM in Zernike Terms



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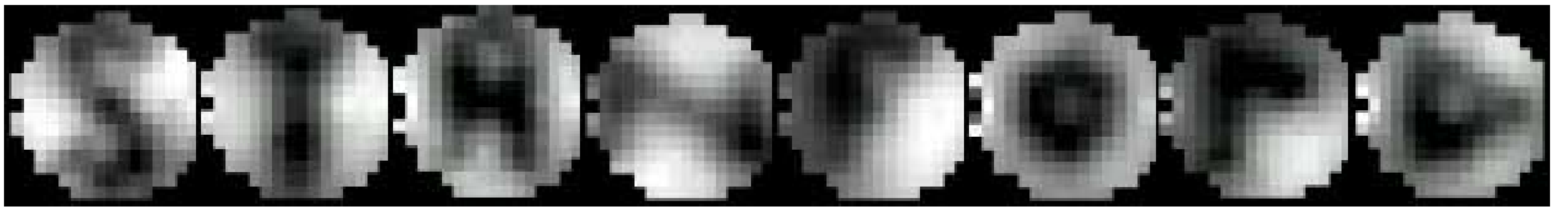
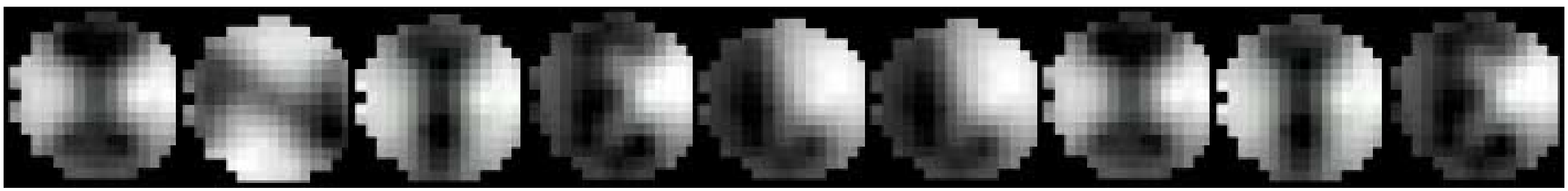
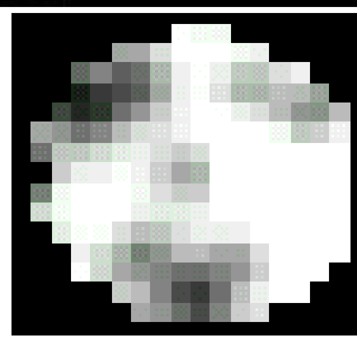
“Optical Communications” via Spatial Phase

STANFOrD



INTELLITE





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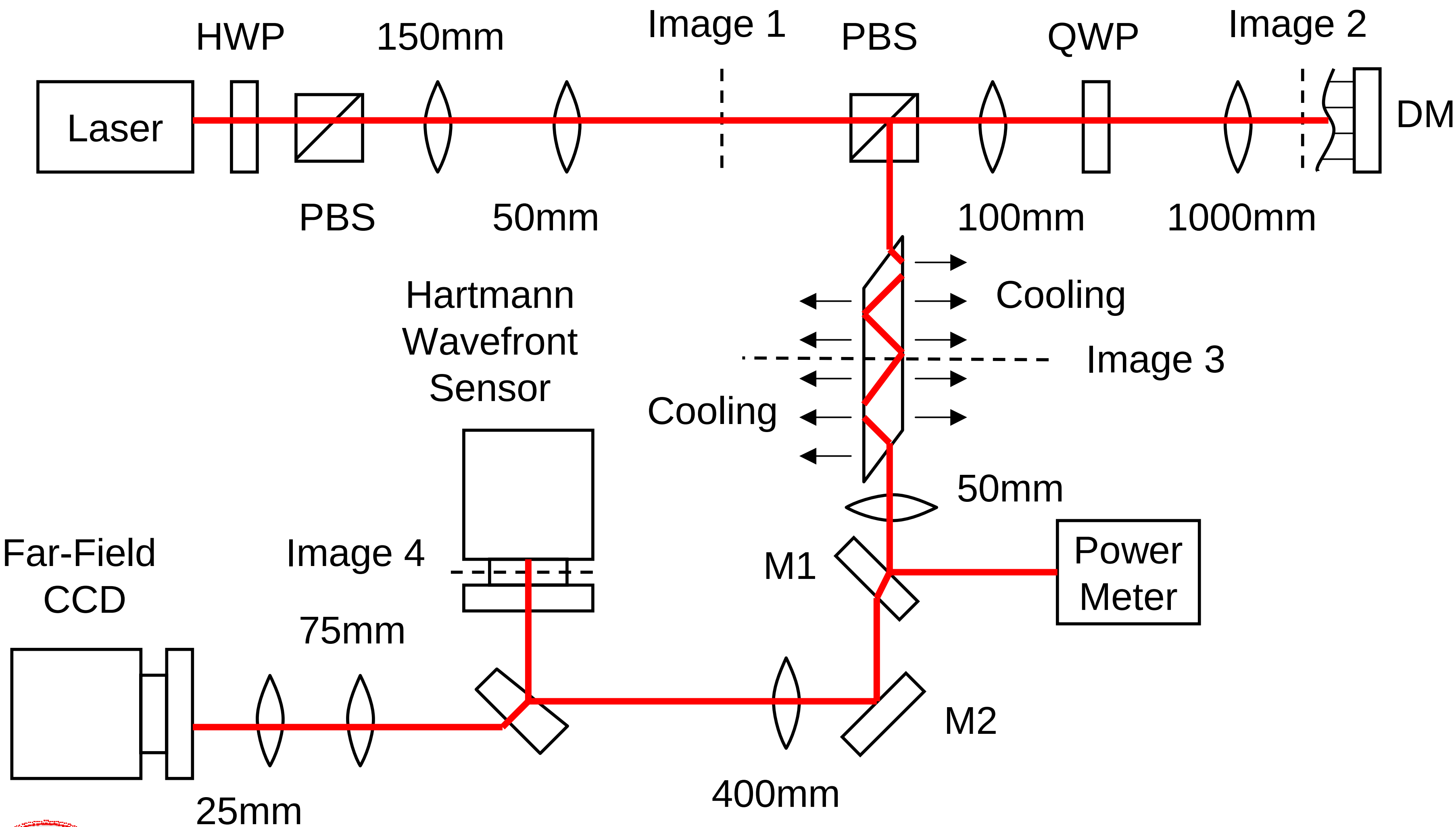
MOPA Experimental Setup



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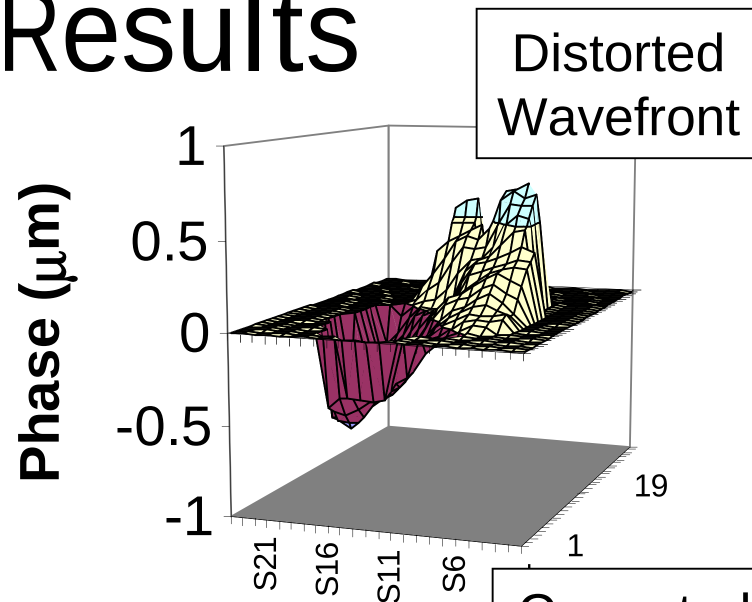
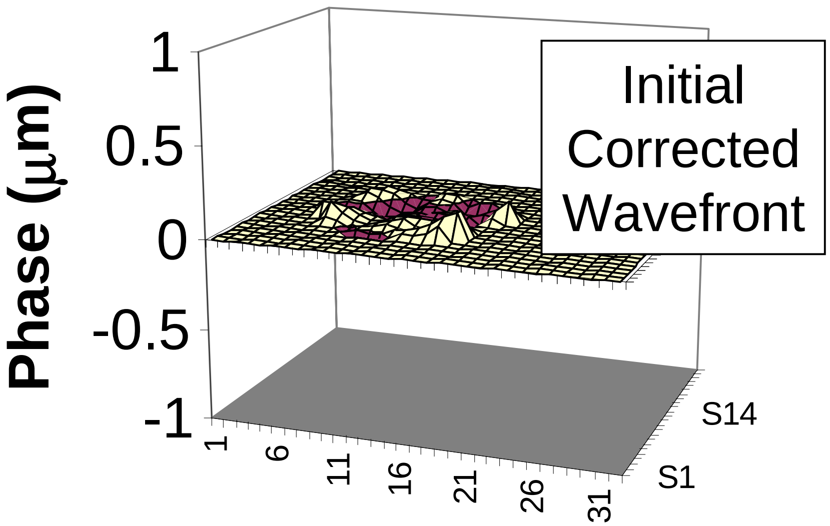
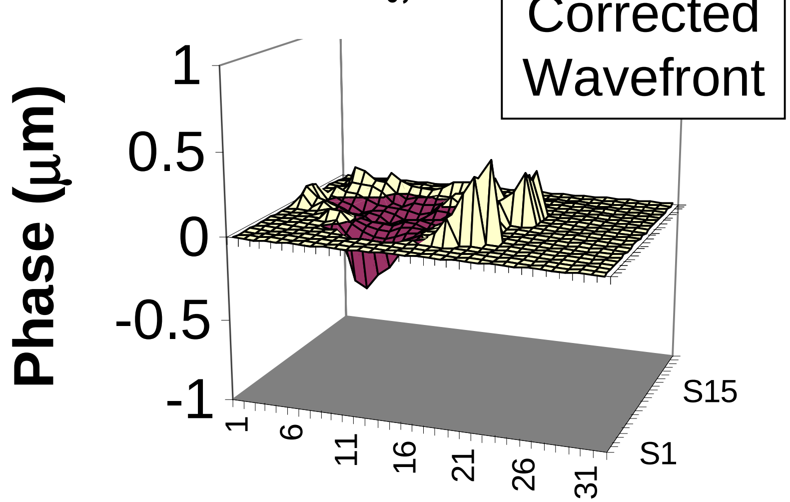
Experimental Results

- Started 92% in TEM_{00} mode.
- AO increased to 95%.
- Pumping reduced to 31%
- AO increased to 89%







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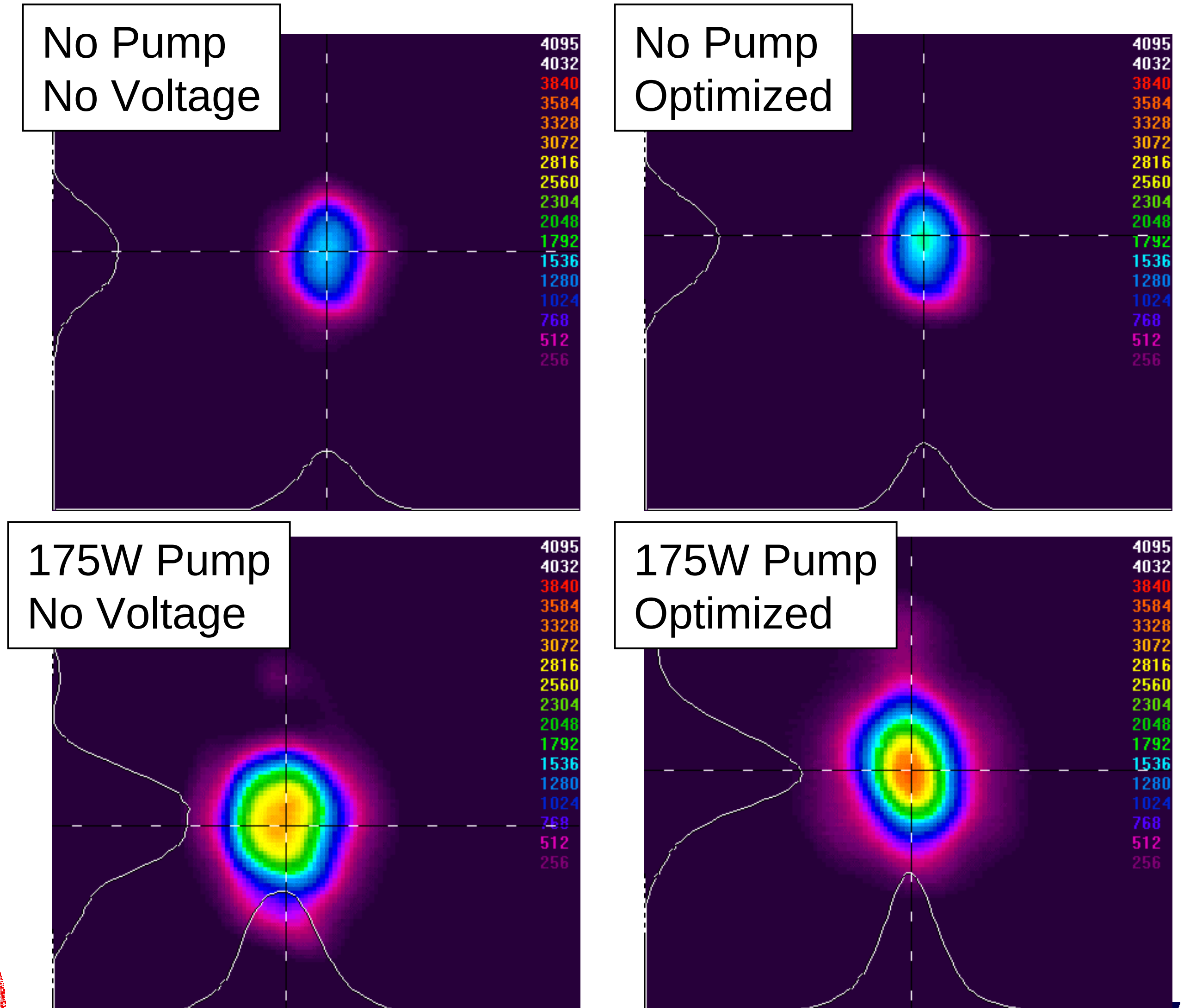
MOPA AO Far-Fields



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Conclusions

- Introduced new type of silicon deformable mirror designed for high power laser operation.
- Demonstrated active compensation of slab amplifier distortions.
- Increased TEM_{00} mode power coupling from 31% to 89%.
- Thanks to the NSF for funding this work.

Future Work

- Low Absorption Coatings
- Three-Level Architecture
  - Piston Bias Condition
  - Larger Area & Higher Resonance Frequency
  - Lower Crosstalk
- Low Cost System Integration
  - Cheap Wavefront Sensor
  - Cheap Control Computer