Simulated Phase Error Corrections for Segmented Primary Mirrors

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The residual aberrations of the 10-meter Keck Telescopes after correction by an adaptive optics (AO) system are determined via simulation. The ability of the AO deformable mirror to fix various spatial frequency errors under static conditions is simulated by applying a phase filter to a high-spatial frequency phase map of the measured Keck segmented primary mirror phase errors. Four types of errors were studied: the initial tip/tilt and piston alignment of the segments, segment aberrations, and misalignment by the segment control system. The simulation shows improvements on all four types of segment errors. As a result, the peak sensitivity of the image is improved. These simulation results will enhance the understanding of the current Keck AO system performance. Also, they will be useful in the design of the next generation AO systems.

Introduction

By Simulating the performance of the adaptive optics system to correct phase errors, the correction for different causes of primary mirror errors can be analyzed aside from the correction for atmospheric turbulence.

Static Phase Map for Keck 10 Meter Segmented Primary Mirror

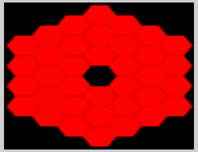


Figure 1
Segmented Primary Mirror
(1024 by 1024 pixel array)

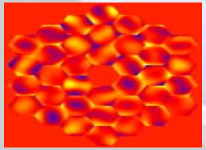
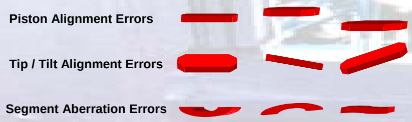


Figure 2
Segmented Primary Mirror
With Phase Errors

The Four Types of Mirror Segment Errors



Active Control System (ACS) Errors are the tracking of the combined above errors

The change in color of the segments in Figure 2, with respect to the background color, varies with the phase errors

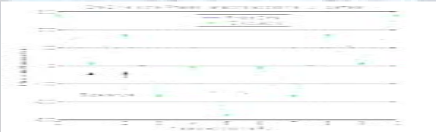


Figure 3

Phase error data across the mirror in figure 3 showing the subaperture spacing can correct for low spatial frequency errors but not high spatial frequencies errors

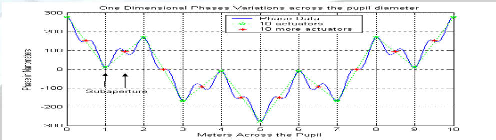


Figure 4

As the actuators across the mirror are increased (figure 4) the subaperture spacing gets smaller allowing correction for higher spatial frequencies errors

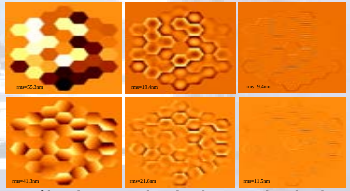
Error Correction Method

- Create Phase map based on the Keck Primary segmented mirror Phase errors
- Write C++ program to simulate phase error correction based on Arroyo Class Library[3]
  - I. Read phase map into diffractive wavefront file
  - II. Apply Fast Fourier transform on complex array values
  - III. Apply Highpass filter for given number of subapetures
  - IV. Apply Inverse Fast Fourier transform
  - V. Save filtered phases into diffractive wavefront file
  - VI. Compute rms error from phase data
  - VII. Propagate diffractive wavefront to far field and save to image file

Results

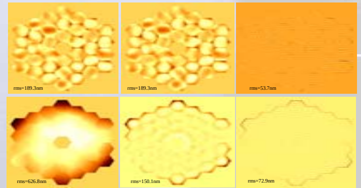
Unfiltered and Filtered Phase maps with Phase errors

Piston phase error filtering; Tip/Tilt phase error filtering



Unfiltered phase maps | Filtered with 16 subapertures | Filtered with 64 subapertures

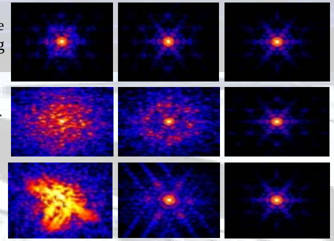
Aberration phase error filtering; Active Control System phase error filtering



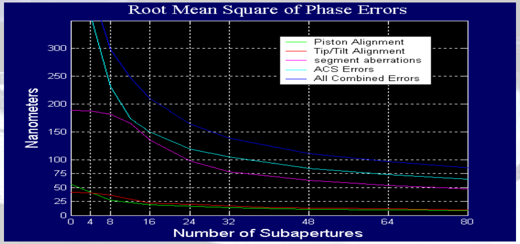
Unfiltered phase maps | Filtered with 16 subapertures | Filtered with 64 subapertures

Point Spread function (far field propagation) of Unfiltered and Filtered Images

Tip/Tilt phase error filtering; Aberration phase error filtering; Active Control phase error filtering



Unfiltered images | Filtered with 16 subapertures | Filtered with 64 subapertures



ACS errors are the most dominant but decrease rapidly for an increase in subapetures, while segment aberration errors are relatively more persistent. The tip/tilt and piston errors appear to be negligible from the plot

Conclusion

- Accomplished a method for calculating residual wavefront error after AO correction
- Alignment errors are not a major source of error
- ACS and segment aberrations a dominant source of error
- The use of an ideal filter causes ringing which slightly overestimates the rms phase errors

References

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Acknowledgments

Mitchell Troy, Principal Investigator, Jet Propulsion Laboratory; Matthew Britton, Research Advisor, California Institute of Technology

Lisa Hunter,Human Resource Director, Center for Adaptive Optics; Malika Moutawakkil , Education Coordinator, Center for Adaptive Optics

National Science Technology Center for Adaptive Optics AST-987683