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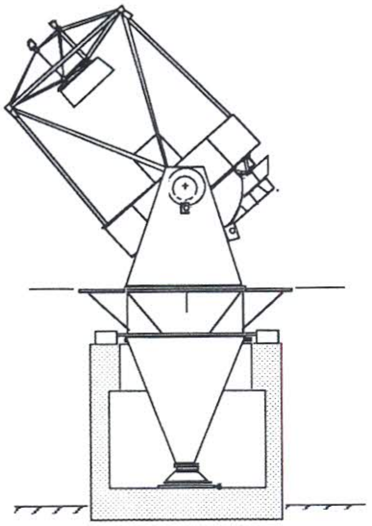

3.5 Meter Telescope

Active Optics System for a 3.5-Meter Structured Mirror

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WODC 02-14-01

Presented at SPIE

Active optics system for a 3.5-meter structured mirror

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ABSTRACT

An active optics system for a 3.5-meter f/1.75 borosilicate honeycomb mirror has been designed and built. The system hardware and software are described, and preliminary test results are presented that demonstrate the structured mirror responds well to the active optics control. Plans for extensive further testing are described. The results of the testing will guide a redesign of the system, before installation of the second-generation system in the WIYN Telescope, to be built on Kitt Peak in Arizona.

1. INTRODUCTION

At six o'clock in the morning of Saint Patrick's day, 1989, a truck started slowly rolling north on Cherry Street in Tucson, under the orange glow of low-pressure sodium street lights. On the bed of the truck was a large shipping container, and inside was a 3.5-meter mirror blank that had been cast the previous December at the Steward Observatory Mirror Laboratory under the University of Arizona football stadium. When the truck arrived at the National Optical Astronomy Observatories headquarters building after a trip of less than a kilometer, the NOAO 3.5-meter Mirror Project began in earnest.

This project has been described in a previous paper.[1] Its principal goal is to develop technology to make possible the construction of high-resolution telescopes of the 8-meter class using structured borosilicate glass mirrors. After completion of the project, the finished 3.5-meter mirror will be installed in the WIYN Telescope on Kitt Peak.[2]

We are presently involved in the second phase of the project, an extensive series of tests to evaluate the performance of the mirror and its associated hardware. One part of this test program is evaluation of the active optics system that was developed for this mirror.

The advantages of active optics for astronomical telescopes have been well described by other authors.[3,4] Our goals for this project are to develop a system that will: 1) allow a relaxation of the polishing tolerances for low-spatial-frequency aberrations, 2) correct figure errors in the telescope caused by performance variations in the support or thermal control systems, 3) allow partial compensation of figure errors in other optical elements. In contrast to some other active optics systems, we are not attempting to actively counter wind loading on the mirror. The distributed defining feature of the axial support design will react wind loads passively without producing large mirror distortions.

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††Operated by the Association of Universities for Research in Astronomy, Inc. under cooperative agreement with the National Science Foundation.

2. THEORETICAL BACKGROUND

The 3.5-meter active system is similar to an experimental system built previously at NOAO for a 1.8-meter borosilicate honeycomb mirror.[5] However, the current system is different in some respects both in hardware and in its approach to the active control. In setting up the previous system, finite-element analyses were used to calculate the response of the mirror to unit force loads. The influence function from each unit load was fit to a Zernike polynomial, and the coefficients of 36 low order terms were calculated. These sets of coefficients were combined into an influence matrix. This matrix was used to precalculate the force sets, or vectors, required to produce a set of orthogonal displacement modes, in this case individual terms from the Zernike polynomial, using a least-squares fit to calculate the forces required to produce each mode. These force vectors were combined into a matrix that was the pseudo-inverse of the influence matrix.

To correct a measured mirror distortion, the distorted surface was described in terms of Zernike coefficients, and this vector of coefficients was multiplied by the pseudo-inverse matrix to yield a set of forces. This set was the summation of the force sets required to correct the individual Zernike terms in the distorted mirror surface.

On the 3.5-meter mirror a slightly different approach is being applied. As in the previous system, finite-element analyses were performed to calculate the surface distortion of the 3.5-meter WIYN primary mirror subjected to unit forces at the actuator locations. The SAP IV program was used. The finite-element model is a symmetric half-mirror model with 14 element groups and three levels of nodal points (a total of 994 nodes). This model is illustrated in Figure 1. Constant strain plate bending elements were used for the mirror blank and linear translation boundary elements were employed to monitor the reactions at three hard points. These hard points were used for the analysis only, and do not physically exist. Their influence was eliminated by superimposing individual load cases in the correct proportions when creating the influence matrix, so that in each combined case the summation of force at each hard point was zero.

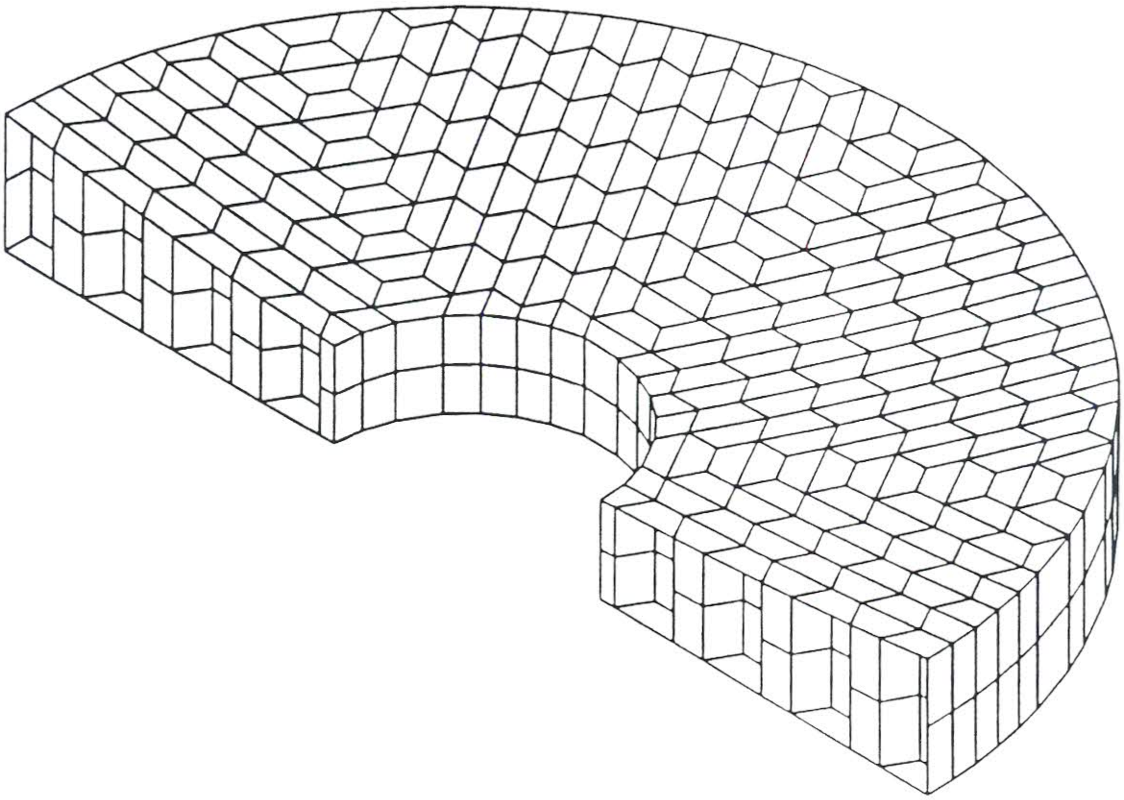

Figure 1. The half-mirror finite-element model.