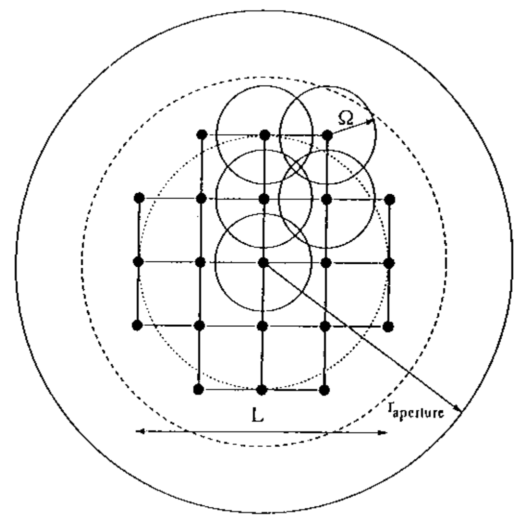
New approaches for modeling with deformable mirrors



Arrangement of a typical 21-element DM. The Gaussian radius of the influence function is Ω, and three different aperture radii are shown for the expansion of the Zernike polynomials.

New applications for adaptive-optics technology are being found that use simple deformable mirrors (DMs). Performance models are needed that are appropriate for DMs that are relatively small in terms of aperture size and number of actuators. At the University of Central Florida/CREOL, we have developed approaches for two key issues in the modeling of small DMs: edge effects in transfer-function models and Zernike polynomial models.

The spatial-frequency transfer function of a DM describes its wavefront-correction capability. Edge effects are usually ignored in transfer-function models for large DMs, but for smaller DMs, these are more important. Because of the edge, the influence functions for the individual actuators can no longer be represented at shift invariant. Using matrix techniques, we obtain an approximate transfer function of the DM, including edge effects. This allows an extension of transfer-function-based analysis to the case of small DMs.

Zernike polynomials can be used in DM performance models by expressing the actuator influence functions as a finite summation of Zernikes. This is particularly appropriate for DMs with small numbers of actuators, because fewer polynomial terms are required for a given degree of accuracy than would be required for a large DM. However, the choice of the radius of the aperture over which the Zernikes are defined affects the accuracy of the expansion. Minimizing the variance of the wavefront error allows us to choose an optimum aperture size for a Zernike analysis of any specific DM configuration.

We are also pursuing experimental verification of these and other models using a 21-element DM provided by United Technologies Optical System, West Palm Beach, Florida. An interferometric sensor has already been configured, with a CCD-based wavefront sampler under development.

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Air Force widens field of view

continued from page 1

90 percent of the total turbulence strength and one at 9 km with 10 percent of the total turbulence strength. In performing these computations it is assumed that the telescope is a 0.9m square aperture with a diagonal field of view of ~ 92 μrad ≈ 19 arcsec. The WFS model consists of a grid of 36 square subapertures, with the subaperture dimensions matched to the Fried seeing cell size r_0. An array of four guide stars at an altitude of 90km is used to sense the wave front phase contributions of the two turbulent layers.

The results for this specific case show that this 2-DM MCAO system achieves an rms residual phase error of $< \lambda/8$ over its entire FOV. By way of comparison, an adaptive optics system with a single DM and single guide star imaging through the same atmosphere achieves a residual phase error of $< \lambda/10$ over a diagonal FOV of ~5 μrad ≈1 arcsec and $< \lambda/8$ over a diagonal FOV of ~30 μrad ≈6 arcsec.

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