AN027

The Effect of Plate Deformable Mirror Actuator Grid Misalignment on the Compensation of Kolmogorov Turbulence

Author: Justin Mansell
Revision: 4/18/11

Abstract

Plate-type deformable mirrors (DMs) are often used to compensate Kolmogorov-spectrum atmospheric turbulence. Recently, we have seen a trend toward strict requirements on the tolerance of the spacing of actuators making them into a more perfect grid. In this application note, we do a quick study of the effect of actuator grid misalignment on the ability of a DM to compensate Kolmogorov turbulence. Generally, we found that the compensation was tolerant of even a large distortion in the actuator grid.

Model Setup

In this study, we modeled a 5 x 5 actuator deformable mirror with 6-mm spacing between actuators using a 75-mm diameter clamped plate model. We generated a Gaussian distribution of actuator position error using the following Matlab code:

```
rrand = dact .* rrandFactor;
xact = xact + rrand.*randn(length(xact),1);
yact = yact +
rrand.*randn(length(yact),1);
```

where we varied `rrandFactor` to achieve a one-sigma Gaussian radius that was a fraction of the actuator spacing.

Influence functions were generated using the deformation of the clamped plate and summing those deformations such that there was no deformation at the actuator sites other than the active actuator. A 4x4 lens array in the Fried geometry was used for this model. Figure 1 illustrates the DM and Hartmann wavefront sensor geometry.

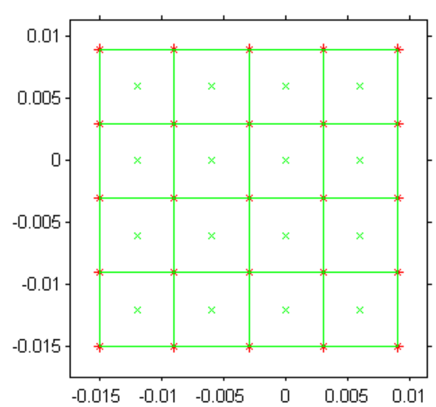

Figure 1 - Actuator positions (red stars) and lens array locations (green boxes with green "x"s at the center)

Figure 2 shows an example influence function when the actuator grid was perfectly aligned.

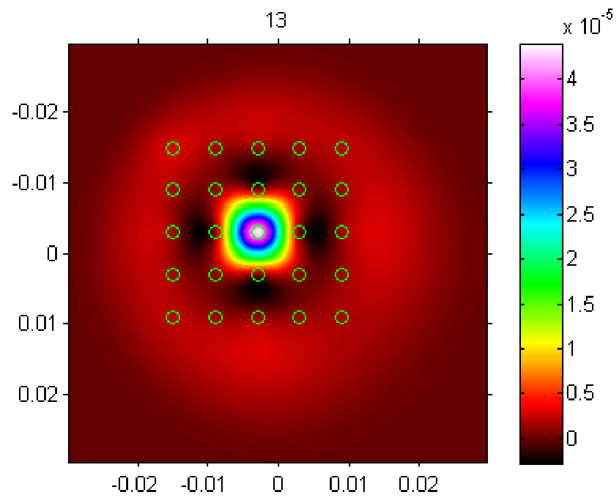

Figure 2 - Example DM Influence Function for Actuator #13

Once the DM influence functions were generated, they were measured on an idealized wavefront sensor that measured the slopes at each of the sub apertures by averaging the gradient (calculated using Matlab's gradient function) over the points in the sub-aperture. These vectors of slopes were then combined into a poke matrix and inverted using single value decomposition (SVD). SVD modes with less than 3% of the gain of the first mode were eliminated from the control matrix generation. Figure 3 shows the poke matrix, the SVD gains, and the control matrix for the ideal spacing.

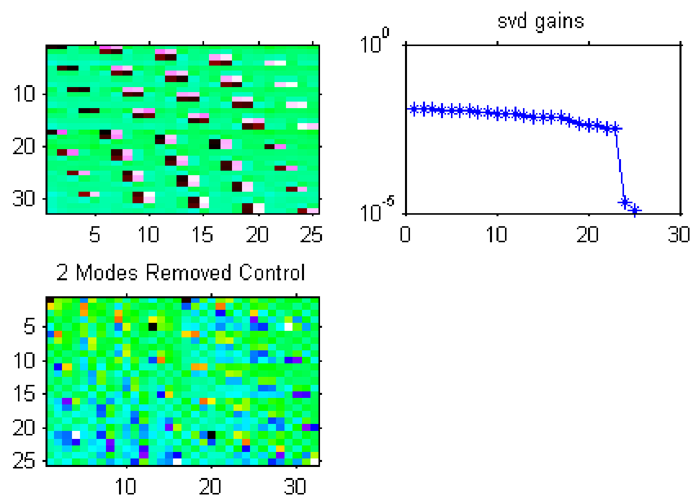

Figure 3 - Poke Matrix (Top Left), SVD Gains (Top Right) and Control Matrix with 2 SVD modes removed

Once a control matrix was generated, we tested the DM against a Fourier-generated Kolmogorov-spectrum turbulence profile from the KolmogorovTurbulenceScreen.m class from AOS with $D/r_0 = 5$ and D = 28 mm. No actuator throw limiting was used for this model. The turbulence was sampled on the idealized wavefront sensor. The slope vector was multiplied by the control matrix and the resulting commands were applied directly. No dynamic control model was used because we were studying a spatial compensation capability, not a temporal one. Figure 4 shows an example compensation.

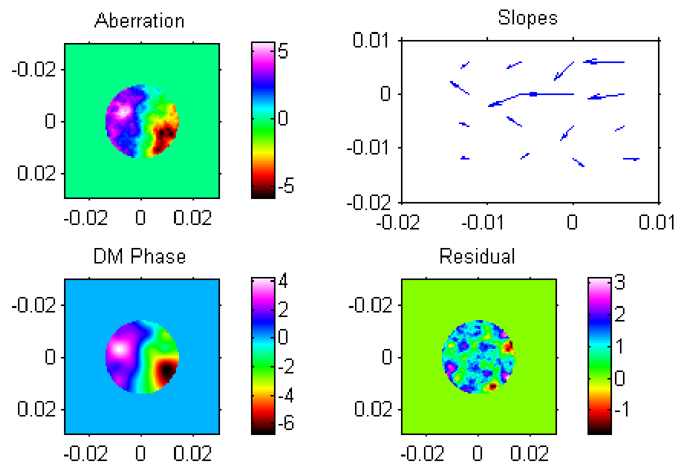

Figure 4 - Example of a compensation with an aberration (top left), its slopes as measured on an idealized Hartmann sensor (top right), the best DM phase compensation (bottom left), and the wavefront residual (bottom right)

We performed compensation for 100 randomly generated turbulence phase screens and recorded the RMS turbulence wavefront distortion and the RMS wavefront error after compensation. Figure 5 shows example results for perfect actuator alignment.

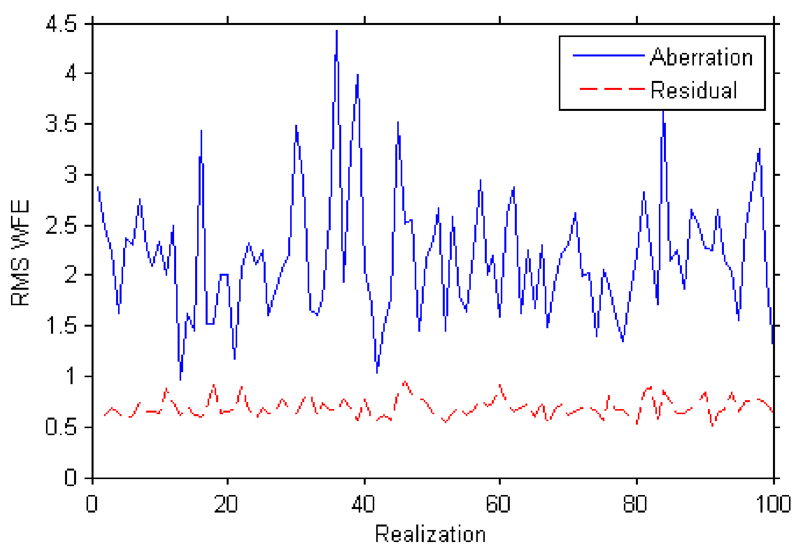

Figure 5 - Example results for perfect actuator alignment

We then varied the amplitude of the random actuator offsets and again compensated the same 100 Kolmogorov-spectrum phase screens to determine the effect of the misalignment on the compensation capability. Figure 6 shows an example grid and influence function when the one-sigma position noise was set to 5% of the actuator spacing. In this first study, we generated a new control matrix for each distorted-actuator-grid DM.

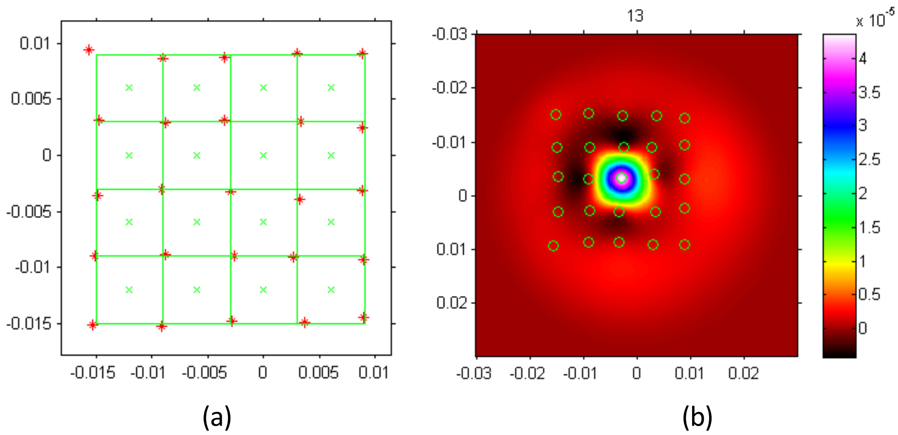

Figure 6 - Example actuator grid (a) with the one-sigma Gaussian position noise at 5% of the actuator spacing and the corresponding influence function of the center actuator (b)

Figure 7 shows the average reduction ratio and the standard deviation of the reduction ratio for the 100 Kolmogorov turbulence screens as we increased the actuator position grid distortion on the DM. For up to 20% actuator spacing one-sigma (1.2 mm), the reduction in the compensation capability was negligible.

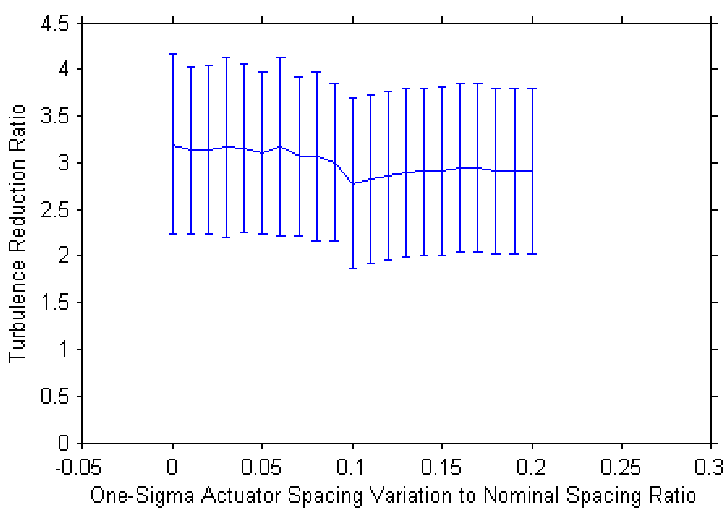

Figure 7 - DM Compensation capability as a function of the one-sigma actuator position noise when generating a new control matrix for each DM

Many people use control matrices generated numerically instead of those generated from the measured data when doing adaptive optics control in order to minimize the noise in the control matrix. To simulate how this procedure might further degrade AO system performance with a distorted actuator grid, we repeated the study above and used the control matrix generated for the perfect actuator alignment. Figure 8 shows the results of this study. There was a clearer reduction in the system performance, but it was very slow and almost negligible.

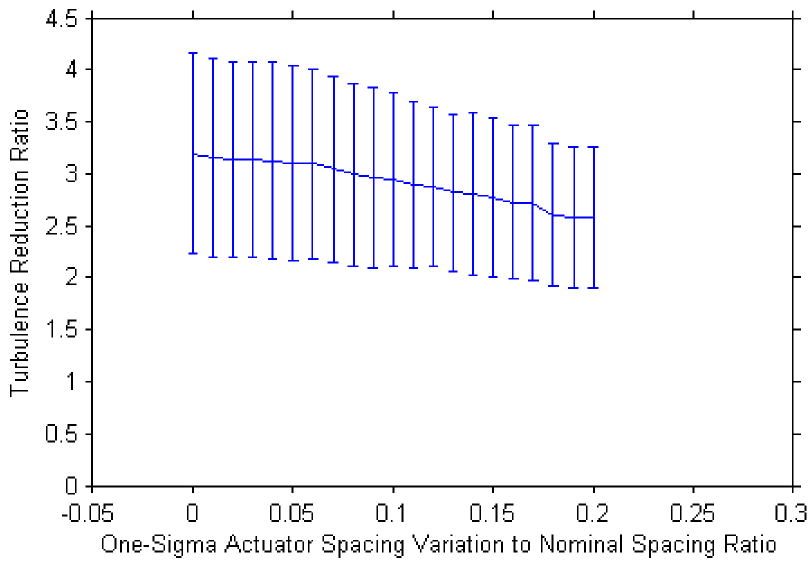

Figure 8 - RMS wavefront error reduction as a function of actuator grid distortion amplitude when using the control matrix generated when there was no grid distortion

Conclusions

In this application note, we showed that the ability of a DM to compensate Kolmogorov spectrum turbulence was not affected dramatically by distortion in the actuator grid. There are some aspects to actuator grid distortion that we would like to consider further in the future. As actuators in a DM become closer together, their throw is reduced because of the stress in the faceplate and the bonds. In the future, we would like to consider how this throw reduction might affect the aberration compensation performance. We would also like to study compensation of aberrations other than Kolmogorov spectrum turbulence.