Measured Laser Guide Star Aberrations after Implementation of the NGWFC on Keck II – KAON 479

Version: 0.0 Date: 9 April 2007

Richard Clare and Marcos van Dam

W. M Keck Observatory
California Association for Research in Astronomy
65-1120 Mamalahoa Highway
Kamuela, Hawaii 96743
808-885-7887

Optimal low-order wave-front measurements in LGS AO systems

Laser guide star (LGS) aberrations show up as the difference between the natural guide star (NGS) wavefront sensor (WFS) measurements on the low bandwidth WFS (LBWFS) and the time-averaged LGS WFS measurements. In March, the Next Generation Wavefront Controller (NGWFC) was implemented on Keck II. The purpose of this report is to compare the measured closed-loop LGS aberrations before and after the NGWFC was commissioned. Also, we compare this measured improvement in the LGS aberrations against the expected improvement predicted from the model of the LGS aberrations outlined in KAON 429.

The LGS aberrations are caused in part by the truncation of the asymmetric spots on the LGS WFS by the field stop and the extents of the detector pixels. This truncation introduces a bias in the centroid measurement. The LGS WFS for the Old Wavefront Controller (OWFC) consisted of a quad-cell detector with each pixel 2.1 arc sec square, and there is a circular field stop of radius 2.4 arc sec located at the focus of the telescope. The CCD-39, which is used in the NGWFC in 2x2 binning mode, consists of 3.0 arc sec square pixels, and a square field stop of 6.0 arc sec per side. So the NGWFC significantly increases the FOV of the LGS WFS detector.

In KAON 429, we modeled the LGS aberrations that we had measured on previous engineering nights. We used this model to predict the LGS aberrations for the NGWFC on Keck II, for a given typical sodium profile, shown in Figure 1, which was calculated as a least-squares fit of the sum of two Gaussians to an ACAM image. For this sodium profile, the modeled LGS aberrations for the OWFC and the NGWFC are plotted in Figure 1. Averaging over the pupil angle for this sodium profile and at zenith only, the modeled LGS aberrations for the NGWFC are 73% of the magnitude of those of the modeled OWFC.

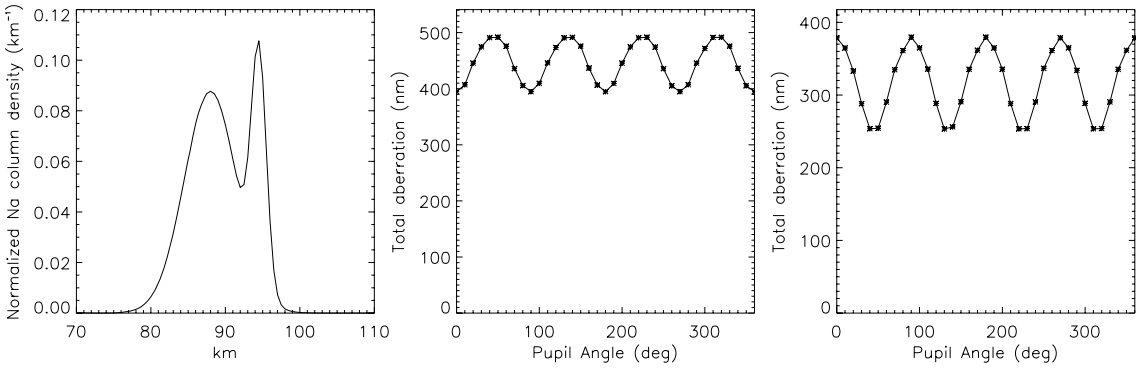

Figure 1 – Left: the sodium profile used for the modeling of the OWFC and NGWFC LGS aberrations. Center: the modeled LGS aberrations versus pupil angle at zenith for the OWFC. Right: the modeled LGS aberrations versus pupil angle at zenith for the NGWFC.

As detailed in KAON 429, the LGS aberrations were measured on engineering nights on the telescope by locking the tip/tilt loop on a bright NGS, and by locking the deformable mirror loop on the LGS and setting the LGS reference centroids to be all zeros. LBWFS images were then taken at regular intervals. It is also possible to monitor the LGS aberrations while astronomical observations are carried out in closed loop, i.e. the LGS WFS reference centroids (cog file) are updated so as to cancel the LGS aberrations. In closed loop, the LGS aberrations are calculated with a least-squares fit of the low order Zernike modes to the reference centroids for the LGS WFS (ie to the cog file (.cwf)).

We have collated data from 30 nights of LGS AO runs with the OWFC on Keck II from May, June and July 2006. This amounts to 17629 data points of LGS aberrations. This data was thresholded to points where the error on the .zc file, i.e. the residual uncorrected LGS aberration as seen on the LBWFS, is less than 150nm, which represents points where the reference centroids (i.e. the cog file) have sufficiently converged. Similarly, closed-loop LGS aberration data points were collected with the NGWFC in March and April 2007 from 12 nights. This yielded 5850 data points below the 150nm threshold of residual LGS aberration.

The LGS aberrations are a strong function of pupil angle and elevation. These collected data, for both the OWFC and NGWFC, are an average over all elevations and pupil angles. Since the data set is relatively large, there is no discernable bias between the two sets. Also, the two sets of data are recorded in different months (OWFC in May/June/July and NGWFC in March/April) and there is some variation in sodium return with season, but this is not thought to be a dominant effect.

The mean LGS aberration for these 30 nights with the OWFC is 423 nm, and for the NGWFC over the 12 nights is 329 nm, showing the expected improvement in performance with the larger field of view of the detector. The measured LGS aberrations with the NGWFC are 79 percent of the magnitude of the OWFC LGS aberrations on average. The corresponding modeled figure was 73%, showing a reasonable agreement between the measurements and the model given that the modeled aberration was for a single representative best-fit sodium profile and at zenith, and the measured aberrations over an ensemble of unknown profiles over the full operational range of zenith angles.