Keck Adaptive Optics Note 1538

HAKA Nighttime Operations

A. Bouchez, E. Marin, C. Guthery, M. Cissé

V0.2; 2026 June 19

1 Introduction

This document describes observing procedures for the HAKA upgrade to Keck II AO. It is a living document, updated as we refine the system performance and operations software functionality.

2 Starting Software Tools

The order in which these software tools are started is not critical.

On k2aoserver-new:2

- Start most GUIs from the background menu
  - NGS-AO Control > Start All NGS-AO Software or
  - LGS-AO Control > Start All LGS-AO Software
- Start PyAO GUIs from the background menu
  - K2 AO Tools > PyAO > Start Control Main
  - K2 AO Tools > PyAO > Start Quicklook
  - K2 AO Tools > PyAO > Start Status Monitor

On k2aoserver-new:3

- Start reconstructor GUI and process (not yet part of Start All … Software)
  - From the background menu open a k2obsao@k2aoserver-new terminal
  - IDL > reconproc
  - From the background menu open a k2obsao@k2aoserver-new terminal
  - IDL > recongui
- Start power spectral density (PSD) analysis tools (requires TRS)
  - From the background menu open a k2obsao@k2aoserver-new terminal
  - cd /home/k2obsao/mvandam/PYTHON
  - ipython
  - ipython > run analyze_dtt (NGS TT PSD)
  - ipython > run analyze_dm (DM PSD both NGS and LGS)
  - ipython > run analyze_strap (LGS TT PSD)
    - Will not run until relevant loop is closed
- Start DM seeing Estimator (optional, useful, requires TRS)
  - From the background menu open a k2obsao@k2aoserver-new terminal
  - cd /home/k2obsao/mvandam/ESTIMATESEEING
  - ipython
  - ipython > run atmogui
  - Leave all default parameters and click START

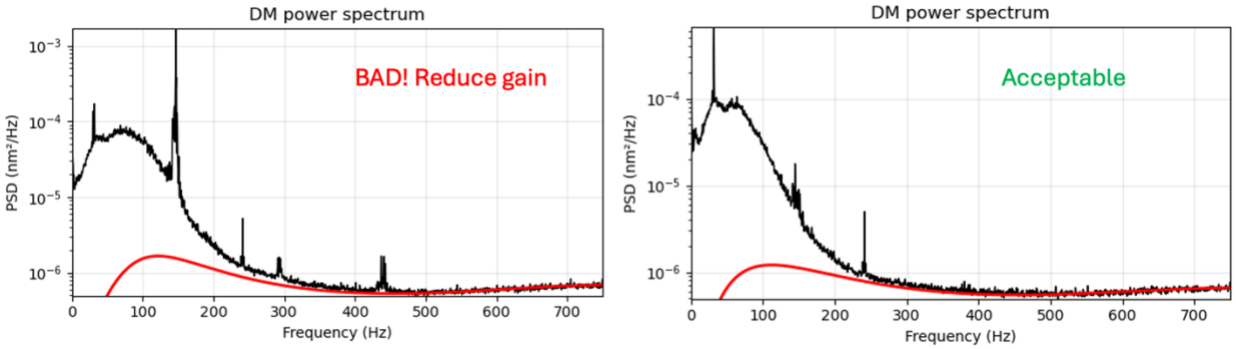
3 NGSAO Observing Procedure

- Run AO start-of-night script
    - Maori > Menu > Scripts > Night-time Setup
        - Select NGS-AO mode; set right 2 displays for sound output
- While slewing to target:
    - Setup Bench
        - Check that AOAcq shows correct target name, magnitude
        - Set desired pointing origin (eg. NIRC2)
        - Verify that Mode = NGSAO is selected
        - AOAcq > Setup Bench
        - **If changing modes** (eg. from LGSAO to NGSAO, or at start of night), **set the mode again** using PyAO Control Main (mode: NGS_57x57 > SET button)
- Setup NIRC2 (generally observer responsibility)
    - Set rotator mode, filter, pupil mask, subarray size, integration time, etc.
- Acquire NGS
    - AOAcq > Acquire Star
- Verify that reconstructor is running (first target only)
    - Recongui settings:
        - Smoothing parameter = 10 in NGS, active subaps = 60
        - Mode = Auto
    - Reconproc will calculate and load a new reconstructor whenever the DTT or UTT loop is closed and the pupil angle or AO rotator angle has changed ≥2 degrees.

4 Performance Optimization (NGSAO or LGSAO)

- Check WFS settings
    - Average WFS counts per subap should be 200 (faint stars) to 5000 (bright stars).
    - Framerate should be as high as possible (≤ 1500 Hz) while maintaining sufficient WFS counts. The goal is to balance measurement and latency error. The default settings will be appropriate if the sky is clear, but you may need to modify frame rate or EM gain in cloudy conditions or if the star magnitude is incorrect.
    - The OCAM2K camera will enter safe mode if counts in 50 pixels exceed 8000 in 3 consecutive frames. If OCAM is in safe mode (WFS intensity display colored orange), either reduce the EM gain (for bright stars) or increase the frame rate and reset the EM gain (for faint stars). Take a new WFS background off-target and continue. Multi-colored WFS intensity display indicates you are near the safe mode threshold.
- Optimize control loop gains
    - The PSD tools enable the operator to monitor system performance and set optimal control loop gains. The AO system will not work well unless you do this! After acquisition, run analyze_dtt and analyze_dm. Each will display a plot of the residual wavefront error power spectrum and will give a recommended gain for that control loop.

- If the recommended gain differs from the current gain by > 0.05 and there are no strong resonances (see below), then follow the recommendation and update the control loop gain in the MAORI > AO Control tab.
- The HAKA DM face sheet has strong mechanical resonances at 140-200 Hz at the locations of the 3 missing actuators. We are still developing control approaches to deal with this. For now, if you see strong resonances in the DM power spectrum (narrow peaks more than 10x above the curve), then reduce the DM gain. The PSD on the left is bad – reduce the gain. The PSD on the right is acceptable despite the small resonances.



- Run Fast & Furious
  - Fast & Furious takes 3-10 min to run depending on star magnitude and will likely improve K Strehl by 5-10%. The correction is a function of pupil angle, so in PA mode the correction will rapidly go stale. In Vertical Angle mode the correction will last >1 hr, with some benefit provided all night.
  - F&F is now integrated into the PyAO Main Control GUI, on the "Fast and Furious" tab. Instructions on when and how to run F&F are provided here: FandF_Operation.docx
  - If F&F was run and you would like to re-use the centroid offset (cog) file on the next target, run the following IDL command:
    - IDL > loadcog, 'FandF_260530-054750.cog' (replace with last F&F cog name)
- Measure Strehl ratio
  - Measuring the Strehl ratio of an unsaturated star is the best measure of end-to-end AO performance.
    - From the background menu, NIRC2 Menu > Start Strehl Tool
    - Autofind = ON, Auto update image = ON
  - The expected K Strehl versus star magnitude in median conditions (0.6 arcsec DIMM seeing) is shown here: link

5 LGSAO Observing Procedure

- Run AO start-of-night script
  - Maori > Menu > Scripts > Night-time Setup
    - Select LGS-AO mode; set right 2 displays for sound output
    - If starting with NGS checkout, select beamsplitter
- Run laser start-of-night script (runs very fast, provides no feedback)
- NGS Checkout (see NGSAO Observing, above)
  - Slew to R=10 engineering star that will stay below EL=80 for ≥30 min

    - Set AOAcq NGSAO mode, PO=NIRC2
    - AOAcq > Setup Bench
    - AOAcq > Acquire Star
    - Optimize control loop gains
    - Take an unsaturated NIRC2 image in BrG filter and measure Strehl. It should be 0.4-0.7 depending on seeing conditions.
- LGS Checkout towards R=10 star (https://www2.keck.hawaii.edu/inst/ao/nirc2_cls_checkout_new.html)
    - Set AOAcq LGSAO mode, PO=Opt Axis
    - AOAcq > Setup Bench
    - Acamtool > Cal Setup
        - Will prompt to note secondary position and refocus to Na layer.
    - Propagate laser
    - Center on WFS using Geevum (steer Rayleigh scatter *towards* pupil center)
    - Focus LGS (disable focus compensation, adjust lxsf to minimize FWHM, "Set Base Focus", re-enable focus compensation)
    - Click "Update FWHM", "Fine" alignment (closes UTT and offload loops), and "Done" (sets reference pointing offset)
- LGSAO performance check on R=10 star
    - Set AOAcq LGSAO mode, PO=NIRC2
    - AOAcq > Setup Bench
    - AOAcq > Acquire Star
    - Optimize control loops (see above)
    - Takerun e (filt BrG, tint=0.2, coadd=10) and measure Strehl
- While slewing to each LGSAO target:
    - Setup Bench
        - Check that AOAcq shows correct target name, magnitude
        - Set desired pointing origin (eg. NIRC2)
        - Verify that Mode = LGSAO is selected
        - AOAcq > Setup Bench
            - Keep an eye on STRAP status in Maori > WFC. If faulted, try to STDBY and INIT.
        - **If changing modes** (eg. from NGSAO to LGSAO), **set the mode again** using PyAO Control Main (mode: LGS_57x57 > SET button)
- Setup NIRC2 (generally observer responsibility)
    - Set rotator mode, filter, pupil mask, subarray size, integration time, etc.
- Acquire star, offset to target if required
    - AOAcq > Acquire Star
    - AOAcq > Offset to target
- Verify that reconstructor is running (first target only)
    - Recongui settings:
        - Smoothing parameter = 60 in LGS, active subaps = 60
        - Mode = Auto

    - Reconproc will calculate and load a new reconstructor whenever the DTT or UTT loop is closed and the pupil angle or AO rotator angle has changed ≥2 degrees.

6 End of night

- Run AO end-of-night script
    - Maori > Menu > Scripts > End of night
- If laser was used, run laser end-of-night script
- From the background menu, run "Stop Most NGSAO [or LGSAO] Software"

7 Trouble-Shooting Guide

Notes from past nights of troubleshooting poor performance

- **DM loop unstable:** Reduce DM loop gain. On bright stars, it often needs to be reduced to < 0.25. Faint stars can benefit from DM gain up to 0.5
- **WFS Intensity too low:** If the average intensity is below 400 or the maximum is below 1000, increase the EM gain or framerate
- **If the DM is misbehaving along pupil edges:** This could be due to the reconstructor being stale and not matching the current pupil illumination. To check this, click WFS Intensity Display "Recon. Mask is OFF" to overlay the mask used by the current reconstructor on the WFS intensity. With the mask applied, you should still be able to see all of the pupil (minus some spots over the spiders/segment edges). If the mask cuts off the illuminated pupil, open the DM loop and trigger a new reconstructor with the recongui, then reclose the DM loop.
- **Trouble closing UTT and DM loops in LGS-AO mode:**
    1. It is possible that the reconstructor was computed while the wavefront sensor illumination was uneven (eg. if the UTT loop was unstable). Open the UTT and DM loops, center the LGS on the WFS using Geevum, and TRIGGER a new reconstructor with the Recon GUI. Wait for it to load (all green lights on the PyAO Status GUI). Then close the UTT and DM loops.
    2. Another possible cause for the UTT and DM loops not being stable is if there is excessive focus on the WFS because the FCS is not conjugated to the sodium layer. Open the UTT and DM loops, then type the following in a k2aoserver-new terminal:
        - cd abouchez/keckAOIDL/src/
        - IDL
        - IDL> focus_fcs()

       This will update the Na altitude estimate based on the open-measurement of the WFS, moving the FCS to the best possible starting position. Then close UTT and DM loops.