Laboratory Performance Report for NIIS

Michael Pierce (University of Wyoming)

This document summarizes the laboratory performance of the Near-Infrared, Imaging Spectrograph (NIIS) developed by Michael Pierce (University of Wyoming). NIIS is planned as a visiting instrument at the APO 3.5-m telescope at Apache Point, NM. NIIS has undergone extensive testing at the University of Wyoming over the past 6 months and a summary of that testing is presented here. Additional information and photos are available on the NIIS webpage: http://www.physics.uwyo.edu/~mpierce/IRCAM.

History of NIIS

Funding for the instrument was obtained through the NSF Major Research Instrumentation program with additional support from the State of Wyoming and NASA Goddard. Although the instrument was originally intended as a camera for the Wyoming Infrared Observatory's 2.3-m telescope it soon became clear that the scientific potential of this instrument would be more fully realized if it were on a larger telescope at a better site. As a result, NIIS is now planned as a visiting instrument at APO with the goal of first light commissioning in the spring of 2012.

Optical and Mechanical Design of NIIS

The optical design of NIIS was developed by Charles Harmer (NOAO) and is based on his design of the FLAMINGOES imaging spectrograph at Gemini. The primary difference being that NIIS is designed with a faster camera for a wider field of view. NIIS is designed for wide-field, near-infrared imaging surveys and is based on a 2048x2048 Hawaii-2 array. It includes a complement of Y, J, H, and K' filters for broadband imaging. On APO the image scale will be 0.39 arcsec/pixel with a field of field-of-view of 13.3 arcmin on a side. As a result, NIIS will complement existing APO instrumentation, e.g., NIC-FPS, and provide a wide-field, near-infrared survey capability for APO.

The optical configuration consists of three modules: a 2-element corrector, a 4-element collimator, and an 8-element camera. This design allows for reimaging the principle image plane at a scale, which will maximize the field of view with the Hawaii-2 array and still provide reasonable sampling of the point-spread function in typical seeing at APO. The design also features a collimated beam within which grisms could be placed to enable multi-object spectroscopy. Limited funds precluded the purchase of grism for NIIS and so any spectroscopic capability will require a future upgrade. The 7-slot filter wheel allows for filters up to 100mm in diameter within the collimated beam of 79mm. The Hawaii-2 detector has a dark current of 0.1 e-/sec. at LN2 temperature and is operated with a Leach, 32-output controller resulting in a read-noise of 16 e-, or 24 e- with CDS operation. The 32-outputs allow a minimum exposure time of 0.65 sec. and a read-out time of 1.3 sec. The filter wheel and focus stepper motors are controlled via a graphical user interface programmed in Labview. The interface also monitors the 10 internal temperature sensors and the internal heating control loops to maintain the detector temperature at 80.0 +- 0.02 ^{o}K.

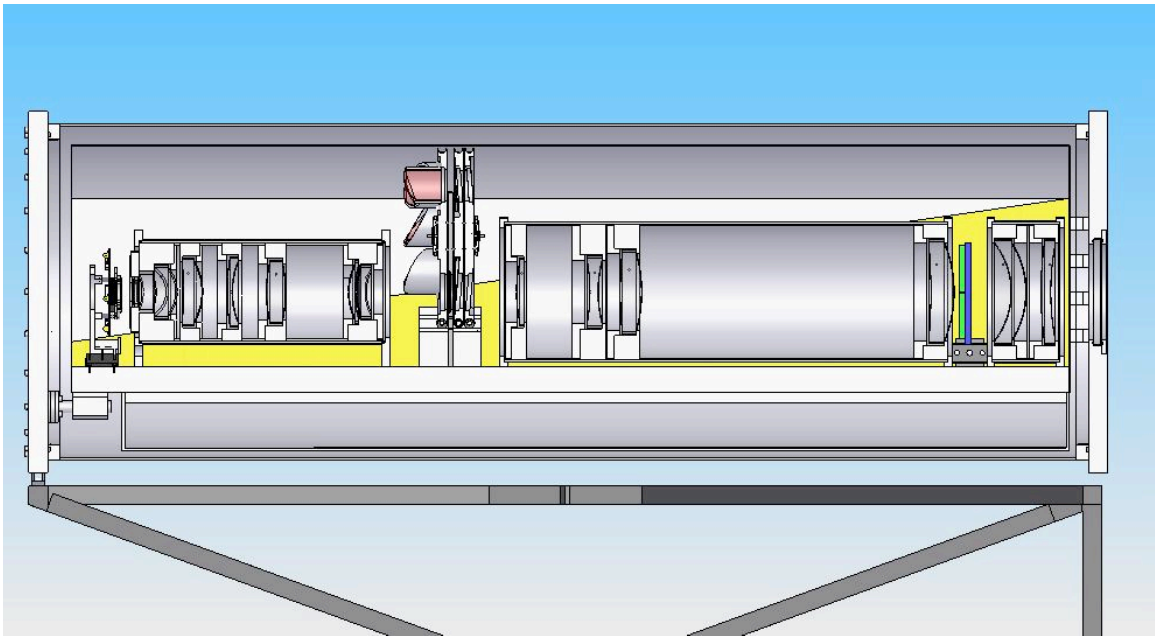

Figure 1: Cut-away view of NIIS showing (from right to left) the dewar window, the two-element corrector, the collimator assembly, the filter and grism wheels, the camera assembly, and the focal plane array. The optical bench is supported at both ends to minimize flexure and a hemispherical LN2 tank can be seen underneath the optical bench. Not shown is the internal support bracing and the thermal shielding (MLI) blanket.

Current Status and Performance of NIIS

NIIS is now complete and has been undergoing extensive testing at the University of Wyoming. The camera has been test fit to its instrument support/handling cart and is currently undergoing internal flexure tests. The optical mounts for the lenses have been shown to maintain their optical alignment from room temperature to 77 ^{o}K over several cool-down cycles. The output from a 100 um fiber is projected into the dewar at the principle focus and is reimaged onto the detector. The fiber is slightly resolved with a measured FWHM of 2.2 pixels over the full field of NIIS corresponding to 0.86 arcsec on APO. The focal plane appears flat to the precision that can be measured in the laboratory.

The Hawaii-2 detector has a single CDS noise of 23 e-, comparable to the original specifications of 18 e- read noise. At present this is the only readout mode implemented but Fowler sampling and a “sample up the ramp” is planned. These readout modes offer the promise of significantly reducing the read noise. The detector is operated with a gain of 1.15 e-/ADU such that the 16-bit A/D converted saturates at 65534 ADU before the array response goes non-linear. The response has been measured to be linear over the full A/D range to better than 0.5%. Higher gain readout is possible but currently not implemented. An exposure time correction of 0.65 sec. is necessary and sets the minimum exposure time for the detector. That is, a requested exposure of 0.0 sec. is actually 0.65 sec. The figures below show a CDS-subtracted image (not flat-fielded) of the optical fiber used in the testing of NIIS and the azimuthally averaged profile of the fiber.

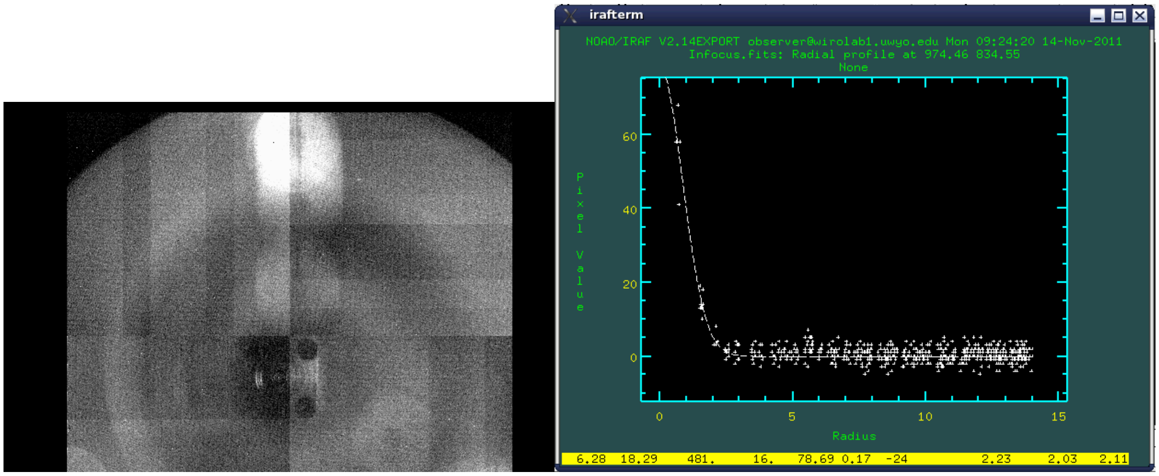

Figure 2: On the left is a low-level stretch of an image of an optical fiber and its mount (near center) taken with NIIS. Although the lower portion of the image is cropped the image shows most of the NIIS detector. The four quadrants of the array are visible as are the 32 outputs stripes. The image also shows an out of focus reflection of the fiber (top center). On the right is an azimuthally averaged radial profile of the fiber pixels. The FWHM of 2.1 pixels is shown at lower right.

The vignetting in the corners at the top of the array has been traced to an error in the positioning of the detector focusing stage, which has subsequently been corrected. The cosmetics of the array are also quite good with only a small number of bad and hot pixels. These will be characterized via bad pixel masks.

The instrument control software of NIIS is fully functional. However, modifications are planned to provide additional read out modes for the detector and a more robust error checking and faster initialization of the filter wheel and focusing mechanisms. Additional planned software upgrades include adding Labview calls to execute PYTHON scripts which will allow robust communication of the user interface with the telescope TCS. This will allow TCS information to be included in the NIIS FITS headers.

Summary

The laboratory performance of NIIS has been characterized and documented. The results are summarized here and on the instrument web pages. NIIS has been cooled down several times and the optics have remained in alignment and produce excellent images over the full field of view. The detector performs close to the original specifications. NIIS is currently undergoing internal flexure tests and some software upgrades and appears ready for commissioning at APO.

Summary of NIIS and Laboratory Performance

Detector: Hawaii-2 HgCdTe Array
Number of Rows: 2048
Number of Columns: 2048
Pixel Pitch: 18 microns
Plate Scale: 0.39 arc-seconds/pixel
Gain: 1.15 e-/ADU
Single CDS Read Noise: 23 e-
Dark Current: 0.1 e-/sec
A/D: 16 bit
Linearity: Linear to 65534 ADU within 0.5%
Full Well: approx..200K e- (MMIRS data)
Minimum exposure: 0.65 seconds, 1.3 seconds for CDS mode
Quantum Efficiency: 70% at J (1.2 μm), 80% at H 1.6 μm) and K (2.2 μm)
Effective focal ratio: f/3.7
Field of View: 13.3 arc-minutes
Optics FWHM: 100μm fiber (0.58 arcsec at APO) projects to 2.1 pixels FWHM