

# **SDN 1015 NICI Alignment Plan**

**Mauna Kea Infrared**  
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# 1 Introduction

NICI is designed to position the optical elements within tolerances by precision referenced optical mounts. That is to say that each optical element is manufactured and mounted in such a way as to place the element surface where it is supposed to be. This method has been used in numerous previous instruments with good success. All optical mounts are pinned to the structure and optical elements are mounted on hard points referenced to the front surface. Mechanical interfaces are minimized between referenced elements to keep required part accuracies low.

NICI is a relatively forgiving instrument in terms of optical alignment. The front end is  $f\#/16$ , the tail end of the infrared camera is  $f\#38$  and the WFS is  $f\#/60$ . The slow beams result in more compliant positioning tolerances. Additionally most of the powered elements are spherical mirrors in which small decenters can be corrected with tilt adjustment. The parabolas in the IR camera will be diamond turned with precision pinned bases and they interface to the same structure with only one interface. The parabolas in the relay are quite long focal length and are less important since any aberrations induced in the relay will be sensed by the WFS and corrected.

While NICI is a relatively easy instrument to align, alignment checks are still required particularly between major subassemblies where tilt errors will be difficult to achieve with mechanical positioning. The approach, described below, will be to assume that the centering tolerance is met and use alignment methods to verify centering of the central ray at each optical element. Then image quality will be evaluated in the WFS and the IR camera data.

## 2 Alignment Methods

NICI has, built in, three very powerful alignment tools. The first is the fiber calibration source. This is a fiber mounted at the center of the cass focus that can be illuminated with a laser diode. This produces an expanding beam that will fill the first parabola in the AO Relay and produced a focused image of the fiber at each focus in the instrument. By using two bare multiplexers in the IR camera this spot can be imaged on the IR arrays. This will be used to verify centering on the WFS and the IR camera and to verify focal position in both as well.

The second alignment tool is the center segment of the lenslette array. This is an unused segment of the lenslette but it has a fiber and can be “reverse” illuminated sending a collimated beam along the center of the optical path.

The third built-in alignment tool is the pupil imager in the IR camera. This can be used to verify alignment of the pupil stop in the IR camera, the DM and the telescope secondary are all centered.

Two other methods will be used to verify alignment. One is a laser alignment where the laser will be sent in through the mounting surface of the instrument and auto-collimated with the mounting surface. This will be used to verify that the instrument is pointed directly at the telescope secondary. The second method is to use a collimating telescope to look through the optical path. By focusing at different depths within the instrument vignetting and flaws in the baffling can be checked.

### **3 Alignment tolerances**

The Optical Performance document found that when a 1/10 mm(0.004 inches) decenter and tilt caused by a 50 micron (0.002 inches) wedge would result in a Strehl ratio at the science focal plane of 99%. The analysis also showed that there are no particularly sensitive elements since almost all elements are optically near the pupil.

Achieving the decenter tolerance of 0.1 mm is not particularly difficult to achieve. A pinned base will have a tolerance of about 0.0005 inches and the mounting pads about the same. This leaves 0.002 inches for error in optical manufacturing. This would be very difficult to achieve for an absolute manufacturing tolerance but the optic can be measured to this tolerance. The approach is to have the optics measured to this accuracy and adjust the mounting where required to match the as-built optics.

Achieving the tilt tolerance is a bit more difficult for some elements. The tilt tolerance can be met for most elements but it is not expected that it will be met for all elements. The elements that are expected to need adjust for tilt are the warm dichroic, the folds through the optical bench, These are expected to need adjustment because they are the feed optics that link subassemblies. All of the optics are mounted on three fixed pads that reference the optical surface in tilt and each mount is referenced to the mounting structure through three precision pads two of which have dowel pins. Tilts can be adjusted by shims under the pads or by adjusting the fixed pad heights by machining. This method results in a robust optical system that maintains alignment.

### **4 Alignment Equipment**

The following equipment or hardware will be needed for the alignment process:

- ~5mW red laser
- Brass shim stock ( 0.001, 0.002, 0.005 inches)
- Collimating telescope
- Flat mirror 2 inch round
- Two fiber lasers
- Fiber illuminator with flex fiber head
- Assorted ND filters
- Digital calipers
- 50/50 visible beamsplitter 2 inch diam.

Alignment jigs:

Focal plane defining plate (AO Bench)

Plate 6"x3" with 1 inch hole in center and flat and parallel to 0.001"

Hole plate for focal plane mask wheel (0.2 inch hole)

Pin hole plate for focal plane mask wheel(0.032 inch hole)

Pin hole plate for fiber calibration slide (0.2 inch hole)

Hole plate for the pupil wheel (0.2 inch hole)

Fake detector package with center target(0.02 inch cross 0.2x0.2)

Blank off filters with .010 inch dimple in center

50/50 beam splitter for dichroic wheel

lenses 6 inch focal length and 1 inch diameter

dummy detector mount plate with 1 inch hole

dummy window with target offset for cold structure shift

## **5 Alignment Procedure**

The IR Camera and the AO Bench will be aligned independently first and then bolted together for final alignment checks.

### **5.1 IR Camera Alignment**

The key element of concern in the camera is the dichroic. The parabolas and the fold flats are tightly referenced to the same structure. The dichroic however is mounted in a mechanism and has more interfaces. The goals of the alignment will be:

Check that center ray traces centered to both detectors

Verify focus position for both detectors

Verify Lyot stop is centered on the beam

Verify filter wheels are centered on the beams

Verify pupil imager produces a centered image on array

Check for vignetting and glints

Start with all optics mounted in the cold structure and the cold structure mounted in the vacuum jacket. The fake detector packages mounted in place of the detectors, the fake filters in the filter wheels, fake pupil mask in pupil wheel.

Set up the collimating telescope so that it is centered on the center on the target on the window that is offset to account for the warm position of the camera optical path. Verify that the telescope is normal to the mounting surface of the vacuum jacket. Verify that the crosshair hits the center of each of the following:

Focal plane mask

OAP 1

Fold 1

Spider mask

Pupil mask  
Dichroic  
Filter  
Fold 2  
OAP 2  
Pupil lens  
Detector

### **MUX Test**

With both muxes installed and the pinhole in the focal plane mask image the pinhole in both channels to determine the position in each array and to check the focus position.

## **5.2 AO Bench Alignment**

The AO Bench can be aligned independent of the cryostat although it must be checked after integration with the cryostat since the interface may distort the bench. The off-axis parabolas will be marked by the manufacturer indicating the direction to the vertex and this will be referenced to a mark in the mount so clocking of the OAPs will not be required.

The AO system uses spherical mirrors for all powered optics excluding the lenslette array. Small decenters will appear as tilts that cause the beam to be decentered on the next element. Alignment of this type of design involves shimming the mirror mounts to keep the central ray centered through each optic.

By illuminating the fiber on the central segment on the lenslette array we will create a beam along the center optical axis. We can follow that through all the way back to the fiber calibration source at the top of the relay carefully checking the centering on each optic. If the beam is decentered on an optic the previous element is tilted. Tilts will be on the order of 0.001-0.004 inches although experience shows that most elements will not need adjustment. The steering mirror must be energized and at zero,zero position to do this alignment.

Then illuminate two segments in the outer ring of the lenslette at twelve o'clock and three o'clock. Using a target in front of the DM verify rotation of the lenslette with respect to the DM. This rotation alignment will be fine tuned by looking at the interaction matrix but must be close enough to get sensible data.

Switching to the single mode fiber in the fiber calibration source, which is located at the cass focus position, light can be run back in the opposite direction. Light from this source is diverging and fills the first relay OAP which produces a beam that focuses at the focal planes allowing focus to be checked at the membrane mirror, focal plane mask and detector. Using the single fiber in the fiber calibration slide illuminate the system. The tip/tilt pzs behind the DM must be energized and at zero position. Adjust the DM tilt to get the focused image on the membrane mirror. Verify that the image is in the center of the focal plane entering the WFS.

### **5.3 Image Checks During Integration**

Once the system is integrated and the multiplexers are working two straightforward checks can be made to verify end to end performance. The first test involves imaging a pin hole or fiber from the cass focus position onto the two IR multiplexers set up to image visible light. The second check is to analyze the wavefront error as measured by the instrument WFS by averaging the measured curvature over time.

#### **5.3.1 Imaging Test**

One of the important first tests after the optics and multiplexors have been installed is to image a spot from the front of the instrument to the back of the instrument. A pinhole of about 100 microns in diameter will be placed at the CASS focus position, in the fiber source calibration slide. This pinhole will be rear illuminated. With the DM tip/tilt pzts in the zero position this spot should be imaged in focus on both arrays in positions that are within ~10 pixels apart. As part of this test a hard-edge mask should be imaged to verify that the focal plane mask position is in focus as well. It should be verified that the DM does not have significant global curvature which would shift the focus. If so it should be replaced with a flat mirror.

#### **5.3.2 WFS Test**

Once the system is integrated and the AO system is working it can be used to give image quality information about it self. By energizing the AO system locked onto the fiber calibration source the measured curvature can be averaged to yield a static curvature. Excess static curvature can indicate a problem in the relay or in the WFS. Imaging the image at the tail end of the relay can show if the problem is caused by the relay. Problems in the relay will be sensed by the WFS can corrected but will reduce the DM stroke available for atmospheric correction and is therefore of concern. Aberrations in the WFS will be sensed and corrected resulting in an equal an opposite aberration seen at the science detector. Aberrations in the WFS can be measured by putting an illuminated pinhole at the WFS first focus and viewing the averaged curvature signal.