The Near-Infrared Coronagraphic Imager

Christ Ftaclas, Mark Chun and Mike Liu
Institute for Astronomy, University of Hawaii

Douglas Toomey
Mauna Kea Infrared

INTRODUCTION

The Near Infrared Coronagraphic Imager (NICI) is a facility instrument built for Gemini South by Mauna Kea Infrared, in Hilo Hawaii with an 85-element curvature AO system provided by the Institute for Astronomy (IfA). The PI is Doug Toomey (MKIR), the author is the Project Scientist, and Mark Chun (IfA) has been the lead on the AO system. The dual-channel concept for NICI derives from experience gained at NASA's IRTF with CoCo, where we found that frequent beam switching between target and reference stars and imaging in and out of Methane bands were effective in detecting faint cold objects. The plan for NICI is to use spectral discrimination to detect young gas giant planets by accumulating images in two different spectral channels at the same time.

INSTRUMENT DESIGN

NICI is fundamentally a coronagraphic camera and it has been optimized to attack the circumstellar imaging problem. The instrument has a built-in, dedicated, 85-channel, curvature adaptive optics system. The basic layout is in Figure 1.

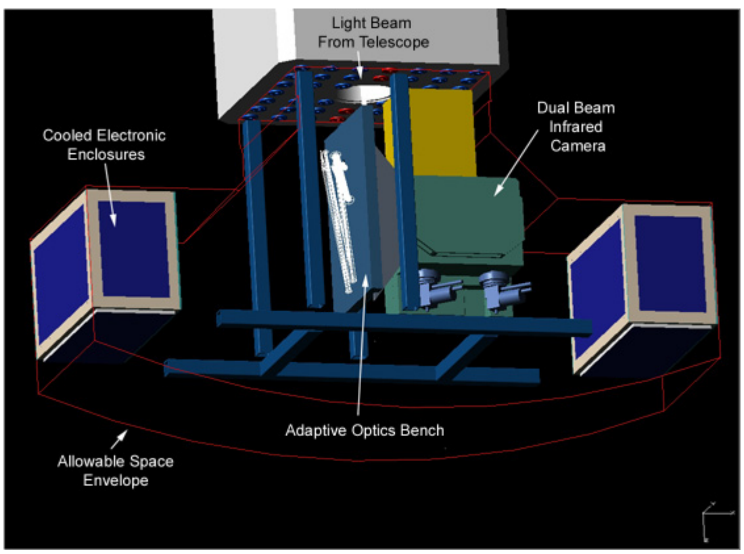

Figure 1: *NICI Instrument Layout. The telescope pupil is imaged on to the deformable mirror and then refocused. Prior to focus the beam is divided into science and wave front sensor light. The WFS light is sent through the optical bench to the WFS and the science light comes to focus on the warm occulting mask just ahead of the camera dewar window.*

Inside the dewar, the pupil is reimaged and a selection of Lyot stops is available. After the Lyot stop, the beam is divided between NICI's two channels. The design permits several options for doing this; at present only a 50-50 beam split has been implemented. The Lyot stop, beam splitting, and channel filter wheels are shown below. This resulted in detection capability plots like those shown in Figure 2.

Each channel is imaged onto an Aladdin 1KX1K array.

Features

In addition to its dedicated AO system and dual channel camera NICI includes several interesting features to either simplify design or enhance performance. These include:

a. A warm occulting mask. Experiments at the IRTF showed there was little penalty for doing this and it allow easy inclusion of user or specialty masks.
b. Halftone, semi-transparent apodized occulting masks. These masks have a central landing with neutral density ~3 to permit seeing the occulted star for alignment purposes.

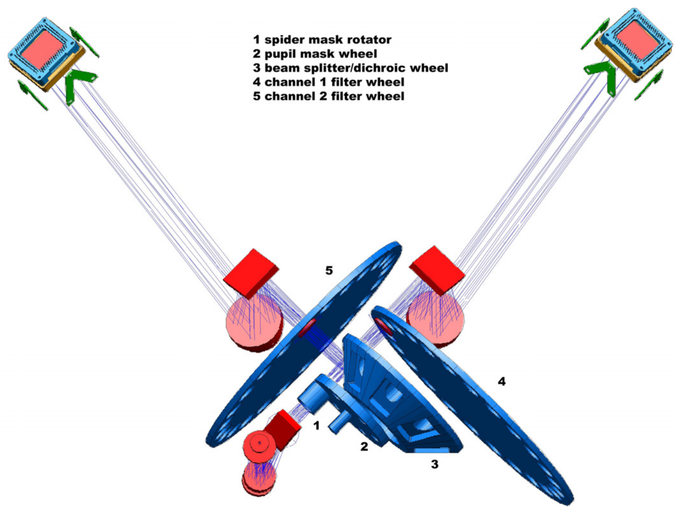

***Figure 2:** The NICI Pupil Mask/Beam Division Assemblies. Options are available for a variety of pupil masks, beam splitting strategies and individual channel filters.*

c. A rotating spider mask. This mask is permanently in place and also includes a baseline inner Lyot stop.
d. An apodized pupil mask. This is used without an occulting mask to get low halo images in crowded fields.
e. Multiple channel filters. Each channel has a 25 position filter wheel which at present have IR band pass filters as well as 1% and 4% narrow band spectral differencing filters.
f. Detector mapping masks. Pinhole masks at the first focus permit imaging identical spot patterns onto both detectors to allow accurate mapping of the detectors onto one another.

The NICI optical system was designed and specified with two simple goals: that the planet image would have the highest possible Strehl, and that even for the best possible atmospheric conditions, the final focal plane would always be turbulence dominated. Meeting these goals required constraining both the magnitude and distribution of optical surface errors. We feel we have succeeded in meeting these goals as evidenced by the static image quality data shown in Figure 3.

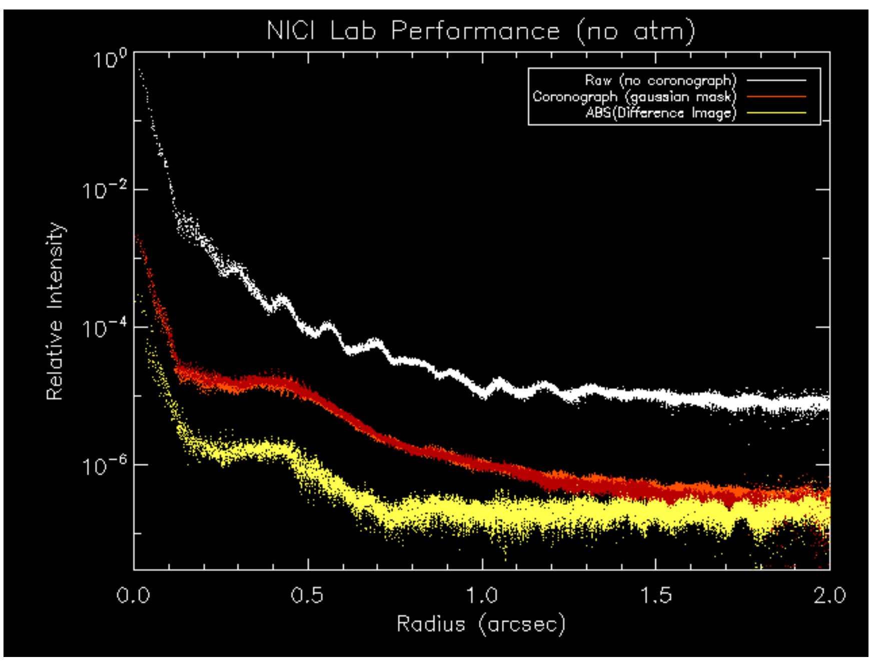

***Figure 3:** NICI Static Image Quality. The plots above show the no coronagraph image profile, the post coronagraph image profile for each channel (red and orange traces) and finally the profile of the difference image. All images were taken with the Lyot stop in place and occulting mask was moved in and out of the camera. The difference images were clearly noise dominated and longer exposures will be required to get firm limits on the frame differencing limits.*

OBSERVATIONAL OUTLOOK.

Gemini has decided to use NICI initially in a campaign mode. To prepare for this campaign NICI performance was modeled by coupling planetary and brown dwarf spectra with AO and coronagraph simulations. This resulted in detection capability plots like those shown in Figure 4. They show that NICI imaging performance clearly compliments radial velocity detections. NICI has gone through acceptance testing and is currently en route to Gemini South. It will be commissioned in early 2007 and the planet detection campaign should begin later in the year.

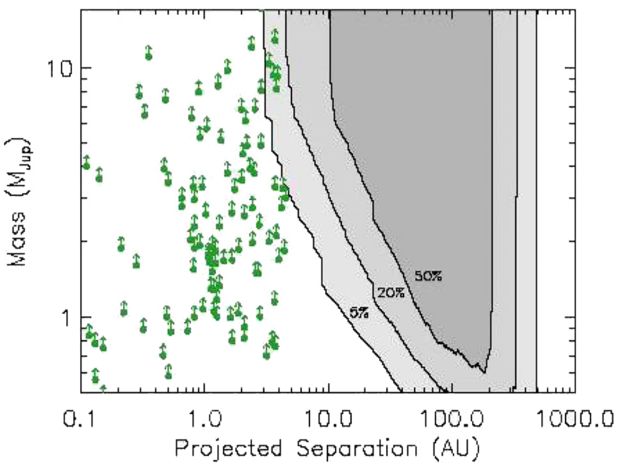

Figure 4: *NICI Planet Detection Performance (from M. Liu et al., 2005)—Sensitivity for our NICI survey compared with RV searches. The shaded areas of 5, 20, and 50% show the {mass, separation} regime imaged for our targets, i.e.,* ***at ≈10–30 AU projected separations, 20% of our sample will be surveyed to ≈1 M_{Jup} and most stars to 3 M_{Jup}.*** *RV planets around old Sun-like stars are shown as open circles with arrows. The inner edge of NICI detectability is due to its focal plane mask. (The detection floor at 0.5 M_{Jup} represents the low-mass limit of the theoretical models available for these calculations.)*

D.W. Toomey, C. Ftaclas, R.H. Brown, D. Trilling, *Proc. SPIE* Vol. **3354**, p. 782-790, IR Astron. Instrum., Albert M. Fowler; Ed.(1998)