HiCIAO: High Contrast Instrument for the Subaru Next Generation Adaptive Optics

Motohide Tamura and Ryuji Suzuki
National Astronomical Observatory of Japan

Klaus Hodapp, HiCIAO Team
University of Hawaii

ABSTRACT

HiCIAO is a new high-contrast instrument for the Subaru telescope. HiCIAO will be used in conjunction with the new adaptive optics system (188 actuators and/or its laser guide star - AO188/LGSAO188) at the Subaru infrared Nasmyth platform. It is designed as a flexible camera comprising several modules that can be configured into different modes of operation. The main modules are the AO module with its future extreme AO capability, the warm coronagraph module, and the cold infrared camera module. HiCIAO can combine coronagraphic techniques with either polarization or spectral simultaneous differential imaging modes. The basic concept of such differential imaging is to split up the image into two or more images, and then use either different planes of polarization or different spectral filter band-passes to produce a signal that distinguishes faint objects near a bright central object from scattered halo or residual speckles.

In order for the Subaru telescope to be at the forefront of the ground-based high contrast science, we are currently developing a higher contrast instrument for the Subaru telescope. We call it HiCIAO (‘Hi’gh ‘C’ontrast ‘I’nstrument for the Subaru Next Generation ‘A’daptive ‘O’ptics). The HiCIAO camera is designed as a flexible camera that can be configured into different modes of operation in an optical bench environment at the Subaru telescope Nasmyth focus. HiCIAO will be the first instrument which can combine coronagraph with either simultaneous polarization or spectral differential imaging modes (PDI or SDI modes) with minimizing efforts for un-common path errors. The basic concept of such differential imaging is to split up the image into two or more images, and then use either different planes of polarization, or different spectral filter bandpasses, or both, to produce a signal that distinguishes objects near a star (dust clouds, planets, etc.) from scattered light artifacts (residual speckles).

HiCIAO consists of several modules; some of them can be easily upgraded. Those modules are as follows (from upstream):

- The Subaru Nasmyth 188-actuator AO system now under development, and its second MEM-based deformable mirror system to be added in near-future. The combination of these will eventually work as an extreme adaptive optics system.
- The coronagraph module in the room temperature environment. This will start from the classical Lyot coronagraph, but can be upgraded to more advanced coronagraphs in near-future.
- The high contrast optics module in the room temperature environment. This optics enables either polarization or spectral simultaneous differential imaging. Simple direct imaging with a high throughput is also supported.
- The infrared camera module in the cold environment. This is equipped with the state-of-the-art detector (2048 × 2048-pixel HgCdTe array - HAWAII-2RG) and its new array-controller (ASIC - “Sidecar”).

The instrument is under the assembling phase in Hilo, Hawaii and its first light at the telescope is expected in the spring of 2007.

As mentioned before, we plan HiCIAO to be upgraded in the future. We are considering using a second stage MEMS deformable mirror (a 1024 actuators MEMS DM from Boston Micromachine Company) which is

currently under test for another experiment at the Subaru telescope. This mirror, combined with advanced readout possibilities of the HAWAII-2RG ASICS controller, is expected to provide a solution for focal plane wavefront sensing (e.g., Guyon 2005). More advanced coronagraph solutions may also be considered for a future upgrade, especially to increase the throughput (since very high Strehl ratios are required to reach the coronagraph contrast capabilities).

Table 1: *HiCIAO overallspecifications.*

Platform	Subaru Nasmyth focus (IR-side)
Combined adaptive optics	188-elements curvature sensing AO With natural guide star (2007-) With laser guide star (2008-)
Wavelength coverage	zJHKs bands (optimized at H)
Detector	2048 × 2048 HgCdTe (Rockwell HAWAII-2RG #29)
Detector controller	ASIC (Rockwell "sidecar")
Pixel scale	0.01 arcsec/pixel (proper PSF sampling at J)
Spatial resolution	0.03 arcsec (J) , 0.04 arcsec (H), 0.055 arcsec (Ks) FWHM
Sensitivity	24.3 mag (J), 24.2 mag (H), 23.8 mag (Ks), ~23.3 mag (CH_4) (5σ, 1hr)
Contrast goal	10^4 at 0.1 arcsec, $10^{5.5}$ at 1 arcsec (with DI model + coronagraph)
DI mode	Direct Imaging 20 arcsec × 20 arcsec FOV, general purpose imaging High throughput (only 5 lenses), with or without coronagraph
PDI mode	Polarimetric (o-ray and e-ray) dual imaging with YLF Wollaston prism 20 arcsec × 10 arcsec FOV, polarized target imaging
SDI mode	Spectral simultaneous differential imaging with double Wollaston prism 6 arcsec × 6 arcsec FOV, highest contrast imaging
PI mode	Pupil imaging for optical alignment check in real-time
Filters	11 common filters (zJHKs and narrow band filters) 4 sets of differential filters (methane, [FeII], and others)
Coronagraph Occulting masks Lyot stops	Starting with the classical Lyot coronagraph. More sophisticated coronagraph will be implemented later. 3 sizes with real-time remote choice. Stop with spider/center-hole blocks & rotation compensation.

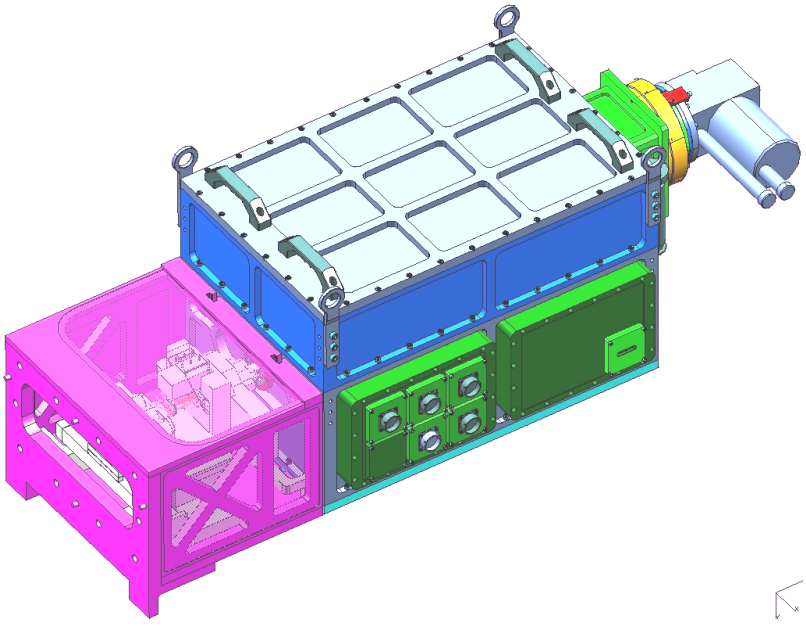

Figure1: *Mechanical design of HiCIAO. which is composed of warm foreoptics including coronagraph optics and cold IR camera including differential filters.*