The (new) Mid-Infrared Spectrometer and Imager (MIRSI) for the NASA Infrared Telescope Facility

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Abstract

The Mid-Infrared Spectrometer and Imager (MIRSI) was developed at Boston University (Deutsch et al. 2003) and has been in use since 2002 on the Infrared Telescope Facility (IRTF), making observations of asteroids, planets, and comets in the 2 – 25 μm wavelength range (Kassis et al. 2008), as well as observations for non-solar system science programs. Recently the instrument has been unavailable due to electronics issues and the high cost of supplying liquid helium on Maunakea.

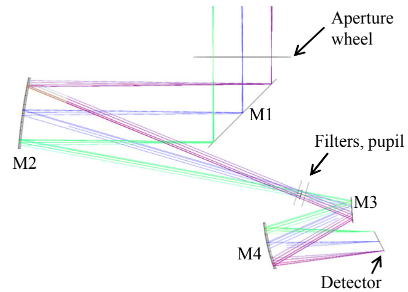
We have begun a project to upgrade MIRSI to a cryocooler-based system with new array readout electronics and a dichroic and optical camera to simultaneously image the science field for image acquisition and optical photometry. **The mechanical cryocooler will enable MIRSI to be continuously mounted on the IRTF along with the other facility instruments, making it available at any time for multi-wavelength imaging and spectral observations**. We will propose to use the refurbished MIRSI to measure the 10 μm flux from Near Earth Objects (NEOs) and determine their diameters and albedos through the use of a thermal model. We plan to observe up to 750 NEOs, most of whose diameters will be under 300 meters, over the course of a three year survey. Here we present an overview of the MIRSI upgrade and give the current status.

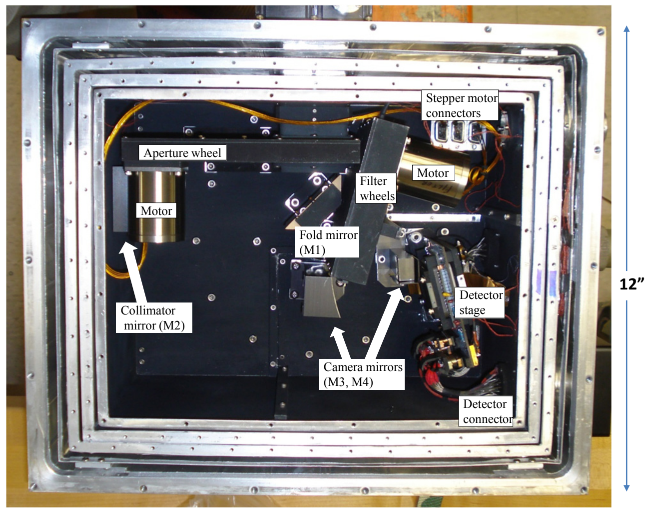
MIRSI Instrument

MIRSI was designed to observe at the IRTF at high spatial resolution with background-limited sensitivity. The system can acquire images and low-resolution grism spectra within the 8–14 and 17–26 μm atmospheric windows. MIRSI has been operated as a collaborative PI/facility instrument at the IRTF since 2002.

The optical layout and inner dewar are shown in the figures to the right. The all-reflective design using diamond-turned aluminum mirrors allows the system to be aligned at optical wavelengths at room temperature, and provides high throughput and excellent optical quality over the full wavelength range. The telescope beam enters through a KRS-5 window at the top of the figure to the right. The telescope focus is at the wheel positioned near the entrance, where apertures or slits can be selected. A fold mirror (M1) directs the light into the collimating mirror (M2) and then through the filters and pupil stop. The filter wheels and pupil stop are enclosed in a box that, along with other baffles, prevents stray light from falling onto the camera mirrors M3 and M4 that reimage the focal plane onto the detector. The use of cryogenic stepper motors eliminates the need for mechanical feedthroughs and ensures a reliable system which minimizes light leaks. MIRSI uses a Si:As blocked impurity band (BIB) detector array (320×240 pixels) developed by Raytheon (Goleta, CA; see Estrada et al. 1998). The array is connected to a CMOS readout integrated circuit through indium bump bonds and mounted to a leadless chip carrier. MIRSI is configured to read out the detector in 16-channel mode.

Figures: At right is a ray-tracing of the optical path through the MIRSI dewar. Below is a photo of the inner part of the dewar in the same orientation. The view is looking down on the cold plate where the components are mounted, which will be looking up in the new nominal orientation on the IRTF. Several light shields have been removed to expose the mirrors and array mount in this photo.





MIRSI Upgrade

Conversion to cryocooler-based system

MIRSI has operated successfully at the IRTF for over 10 years, but in the past few years the cost and availability of LHe on Maunakea has made operating MIRSI prohibitively expensive and operationally difficult. The upgrade concept relies on the relatively simple design of the MIRSI dewar, where all of the critical components of the system are attached to the optical mounting plate, and contained within the rectangular box shown in the figure to the left. This can be easily separated from the cylindrical section containing the cryogen reservoirs and attached to a new upper section. The new upper section will be much smaller and contain just the cryocooler cold head and a mounting plate that will be supported by low thermal conductivity connections to the outer dewar shell. All of the optics, filters, motors, and detector array will use their existing mounts and electrical connections to the outside of the dewar. Cryocooler vibration is a concern, but current systems have lower vibration levels than before, and with careful isolation, systems of this type have been demonstrated to have sufficiently low vibration so as to not degrade image quality. The cryostat upgrade will be performed by Infrared Laboratories of Tucson, who built the original MIRSI dewar.

Electronics and Mechanism Upgrades

The MIRSI detector readout electronics will be replaced by a system based on the same array controller and readout electronics used by other IRTF instruments. This will solve the intermittent electronics issues present in the current system, and make it easier to maintain and repair when problems develop on the summit. The cryogenic stepper motor drivers will also be replaced, including using Hall effect sensors instead of microswitches for improved reliability of wheel position sensing and accurate filter selection.

Optical camera

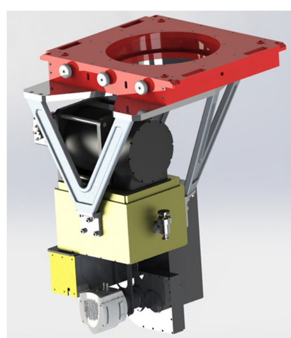
MIRSI will be paired with a copy of the MORIS camera (MORIS2), a fast readout optical camera used on the SpeX instrument at the IRTF. MORIS2 will enhance MIRSI's capabilities by allowing the observer to place objects accurately on the field, and guide on the science target. This is especially important for spectroscopy since guiding errors result in the object moving off the slit, and often multiple reacquisition and/or offsets from nearby sources are necessary. With the guide camera mounted to the same instrument, guiding errors due to different flexure of the science instrument and guide camera are minimized. In addition, the MORIS2 camera will allow observers to perform simultaneous optical/IR photometry. This will be achieved by using a cold dichroic mirror mounted in the MIRSI dewar, which will reflect the IR beam into the mid-IR system and transmit optical light out of the dewar and into the MORIS2 system.

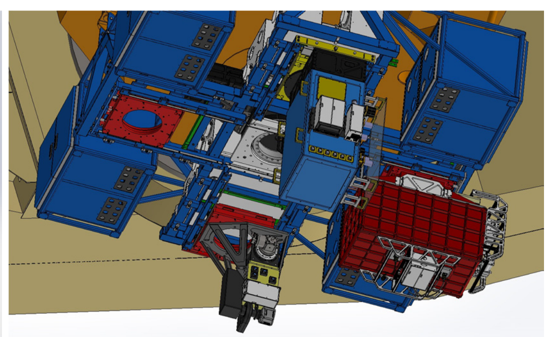
Project Status

A preliminary design review of the upgrade concept and design was held at IR Labs in October 2015. We will soon finalize the design and begin the dewar conversion work, which should take roughly six months to complete.

MIRSI Sensitivity

Wavelength (μm)	Bandwidth (%)	Diffraction limit at IRTF FWHM (arcsec)	Point-source sensitivity (1 σ 1 min.) (mJy)	Diffuse-source sensitivity (1 σ, 1 min.) (mJy arcsec^{-2})
4.9	21	0.34	16.4	24.9
7.7	9.0	0.53	47.2	45.5
8.7	8.9	0.60	14.7	12.6
9.8	9.4	0.67	47.0	35.6
10.6	46	0.73	4.11	2.9
11.6	9.9	0.80	22.0	14.1
12.7	9.6	0.87	25.6	15.0
20.6	37	1.42	235.7	84.9
24.4	7.9	1.68	212.6	64.6
CVF - 10.2	5	0.72	53.8	40.6





The above figures show the model of the upgraded MIRSI. The left figure shows MIRSI attached to the IRTF Multiple Instrument Mount (MIM) truck (red). The large gold box is the existing MIRSI optical section, and the black cylinder above it houses the cryocooler cold head. The smaller gold box below the optical box is the array electronics, and the black and silver parts beneath MIRSI is the MORIS2 optical camera. The figure above right shows MIRSI mounted on the MIM at the IRTF with the other facility instruments.

MIRSI web page:
www.cfa.harvard.edu/mirsi

References:

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Estrada, A. D., et al. 1998, in *Infrared Astronomical Instrumentation*, Proc. SPIE, 3354, 99

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This work is partially funded by the NASA Solar System Observations/NEOO program.

Importance to Solar System Science

In the past few years, other mid-IR instruments have been decommissioned, including ones on the Keck and Gemini telescopes. The *Spitzer Space Telescope* no longer operates at wavelengths beyond 5 μm. Currently there are few options available for observations in the 8-20 μm range from the northern hemisphere. The SOFIA FORCAST instrument has capabilities similar to MIRSI, but due to the smaller telescope and operating environment on the plane, FORCAST has poorer resolution (~2″5 FWHM at 10 μm, compared to 0″8 for MIRSI) and lower point source sensitivity at 8-13 μm compared to MIRSI. SOFIA will have fewer hours to devote to planetary science, and has many limitations in scheduling and conducting observations compared to the IRTF.

In addition to the NEO science we have proposed, there are many other solar system science applications for MIRSI. For example, MIRSI has been used over the past 10 years to investigate the temperature, composition and aerosol structure of Jupiter's Great Red Spot, make measurements of the properties of the nuclei of comets and their ejecta, estimate the size and surface properties of asteroids, observe the stratospheric vortex on Saturn, study the minerology of the surface of Mercury, and observe the effects of collisions of objects with Jupiter (see the MIRSI web page for details). MIRSI observations have also been used to support several solar system missions, including EPOXI, Rosetta, Cassini, and the Hayabusa rendezvous mission. The upgrade will enhance MIRSI's usefulness by allowing it to be used on a much more frequent basis and on short notice for targets of opportunity.

Division for Planetary Sciences Meeting, Washington, DC ♦ 8-13 November 2015 ♦ Poster 312.21