THE CURRENT AND POTENTIAL FUTURE CAPABILITIES OF IRTF

Current capabilities

The IRTF is a 3-m infrared-optimized (1-25 μm) equatorial yoke-mounted telescope sited at 4,150 meters (13,600 feet) on the summit of Maunakea, Hawaii. Facility instruments are mounted at the Cassegrain focus of an f/37 secondary mirror. For optimum sensitivity at wavelengths > 5 μm the secondary mirror is capable of chopping and nodding. The 0.3-m diameter Cassegrain hole in the parabolic primary mirror limits the field of view to about ten-arc minutes diameter and the off-axis telescope guiders further limit the useable field to a few arc minutes. Median seeing at IRTF is about 0.7 arc seconds FWHM at 2.2 μm.

Instruments are stowed on a four-position multiple instrument mount (MIM) surrounding Cassegrain focus and can be moved in and out of the on-axis position in about 20 minutes by onsite telescope operators. The north, east and west stow positions are used for facility instruments; while the south stow position is reserved for visitor instruments. IRTF can accommodate roughly one-meter cube instrument envelopes and maximum instrument weights of 500 kg. Electronics are housed in cooled cabinets attached to the mirror cell just above the MIM.

The current suite of facility instruments consists of:

1. SpeX, first-light 2000, upgraded 2014
   - 0.7-5.3 μm XD medium-resolution spectrograph (*R*=2500-500)
   - 0.7-2.5 μm high-throughput prism mode (*R*=250-50)
   - 1-5 μm slit viewer/guider and imager (60″x60″ FOV), 14 filters
2. MORIS (built in collaboration with MIT), first light 2011
   - High speed CCD camera (60″x60″ FOV) fed from SpeX for simultaneous optical-IR observations, 10 filters
   - Optical guider for SpeX
3. iSHELL, first-light 2016
   - 1.06-5.3 μm XD high-resolution spectrograph (*R*=75,000-15,000)
   - 1-5 μm slit viewer/guider and imager (42″ diameter FOV), 8 filters
4. MIRSI (long-term loan from Boston University), first-light 2002, upgraded 2018
   - 5-20 μm camera (85″x64″ FOV), 12 filters
   - 8-15 μm CVF (*R*~50)
   - 8-20 μm GRISMS (*R*=100-200)
5. MOC, first light scheduled 2018
   - High speed CCD camera (60″x60″ FOV) fed from MIRSI for simultaneous optical-MIR observations, 8 filters
   - Optical guider for MIRSI

Current visitor instruments include the mid-infrared spectrographs TEXES (*R*=100,000-2500), BASS (*R*~100) and HIPWAC ($R \sim 10^6$), which are available to all users by collaboration with the instrument teams.

With the ability to do quick instrument changes the IRTF schedules multiple observing programs per night with observing blocks as short as 30 minutes possible. Daytime observing can also be scheduled when needed for comet and planet apparitions. The investigators themselves have the option of observing at the telescope or remotely. About ninety percent of observing time is now done remotely. Suitable programs can be conducted in service mode but queue observing is not offered.

Potential future capabilities

The goal of the IRTF workshop is to understand the future needs of IRTF users and identify science drivers for improved and new IRTF capabilities. The following is an outline of potential future capabilities resulting from in-house IRTF discussions and can serve as the starting point for the workshop. These are focused on upgrades to the existing 3-m telescope and new instrumentation.

Facility

In the best seeing conditions image quality is limited by the primary report mirror support, which consists of 16 axial support pads and a mercury ring radial support. The ideal solution would be to replace the primary mirror with a lightweight mirror and active support structure. Replacing the primary with a much smoother mirror would significantly benefit a potential high-order AO system. A lightweight mirror would also improve thermal control and improve the seeing. Costs for a new primary mirror and support system would be about $10-15m. Facility downtime for these changes could be an issue.

A simpler 'mirror bender' system to improve image quality has already been designed. It consists of eight levers attached to edge of the primary mirror to correct the bending forces on the mirror due to the imperfect mercury ring support. The system is driven by a relatively simple and slow (corrections < 1 Hz) low-order off-axis AO system mounted in the telescope guider. The low-order AO system alone would correct the slow focus changes of the telescope that are probably the biggest source of wavefront error. Both the mirror bender and low-order AO can be funded from telescope operations.

Focus control with the low-order AO system would probably be of the biggest benefit for the seeing-matched slits in SpeX and iSHELL, for example. Undoubtedly the best way to improve the point-source sensitivity of the spectrographs is by feeding them with an AO system and the best way to do this is with an adaptive secondary mirror. Using an adaptive secondary removes the need to reimage the telescope pupil, which reduces throughput and increases emissivity. A conservative estimate is for an improvement in Strehl ratio by a factor of ten for a sensitivity gain of over two magnitudes for source brightness-limited targets. Large adaptive secondary mirrors produced commercially have been deployed with success on LBT and VLT and so an adaptive mirror for the IRTF's much smaller secondary should now be feasible (cost including AO+tilt-tilt system $5m).

Instruments

Science drivers for new need instruments need to be discussed in detail. Potential new instruments include but are not limited to:

1. R~100 high-throughput spectrograph optimized for small solar system bodies, transients, time domain follow-up
   - Three channels: 0.4-0.8 μm, 0.8-2.4 μm, 2.7-4μm (hydrated minerals)
   - 5″x 5″ IFU to remove slit losses
   - Very stable, no mechanisms

2. Optimized imager for general science, planetary atmospheres, faint object colors
   - ~2′ x 2′ FOV
   - CCD channel, fixed filters
   - 0.8-5 μm channel, fixed filters, CVF (R~100), polarimetry
   - Seeing-limited and high spatial resolution (AO) modes

3. Multi-channel (>6) imager primarily for time domain follow-up, transients, simultaneous small body colors
   - ~2′ x 2′ FOV
   - 0.4-2.5 μm (channel band-passes TBD)
   - Imaging and long-slit spectroscopy modes (*R* TBD) in each channel

4. MIRSI further upgrade, NEO albedos, planetary atmospheres, general MIR science
   - State-of the-art MIR array if available (current detector two decades old)
   - Rebuilt camera head

All instruments would benefit from AO.

Operations

Modifications to the MIM could allow instruments to remain in the fixed stow positions and be fed with a pick-off mirror mounted at Cassegrain focus. This would require changes in the instrument fore-optics but it would have significant operational advantages. Manual instrument changes would no longer be required and an instrument could be 'changed' instantly by rotating the pick-off mirror. With fixed instrument positions the telescope could be perfectly balanced, improving pointing and tracking, which currently present problems, particularly for efficient daytime observing.

This would open up the possibility of fully remote operation of IRTF and rapid response but also requires upgrading other facility systems to reduce reliance on on-site personnel. Estimated cost is about $5-10m. Queue mode observing would become possible but its utility is controversial with many observers.