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HIRMES – High Resolution Mid-infrarEd Spectrometer for SOFIA

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Abstract

HIRMES is a third generation SOFIA instrument designed to cover the gap in the middle infrared region with a broad range of spectra resolution from very low (300-600) to high resolving power of 10^5 . With its high resolving power modes (R from 50,000 to 100,000), HIRMES will provide unique access to HD in protoplanetary disks, and allows velocity resolved spectroscopy of water at temperatures characteristic of the snow line. HIRMES measures the velocities of orbiting gas in [OI] 63 μ m line, one of the strongest fine structure lines, a tracer of spatial structure that is not available from direct imaging. HIRMES uses its grating mode (R ~ 600) to determine the mass of water ice in the system and to explore the crystalline mass fraction of the ice, providing information about its thermal evolution. HIRMES observations of the distribution of water ice, water vapor (including heavy isotopologues), and oxygen in planet-forming disks will illuminate the fossil record of these components in our own Solar System, as preserved in comets and asteroids. HIRMES is a direct photon detecting spectrometer, thus it achieves the sensitivity necessary to be in the discovery space which is fundamentally inaccessible to heterodyne receiver instruments. Hundreds of protoplanetary disks in associations within 500 parsecs of our Solar System, including well over 100 in the three nearest Young Stellar Object (YSO) associations 140-160 pc away, are within HIRMES grasp.

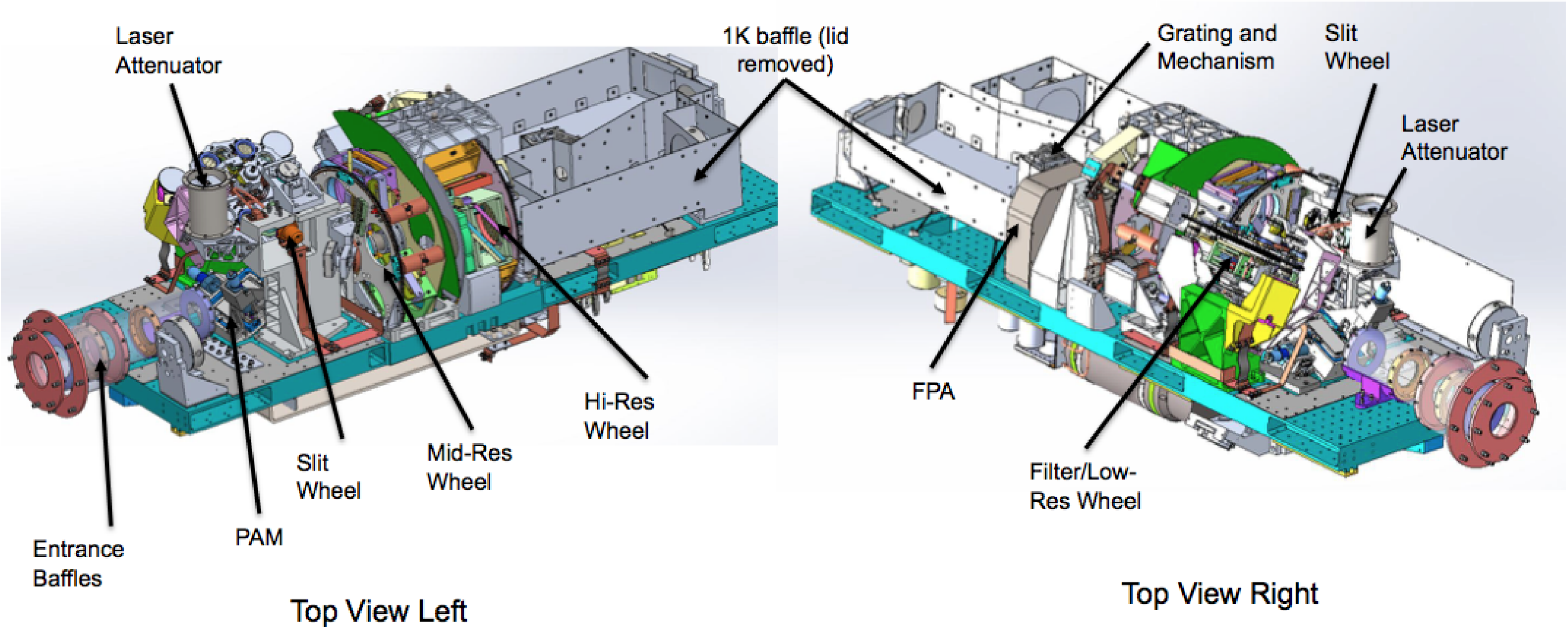
HIRMES instrumentation

HIRMES is a direct detection spectrometer covering the spectral range from 25 to 122 μ m. There are four spectroscopic modes to HIRMES:

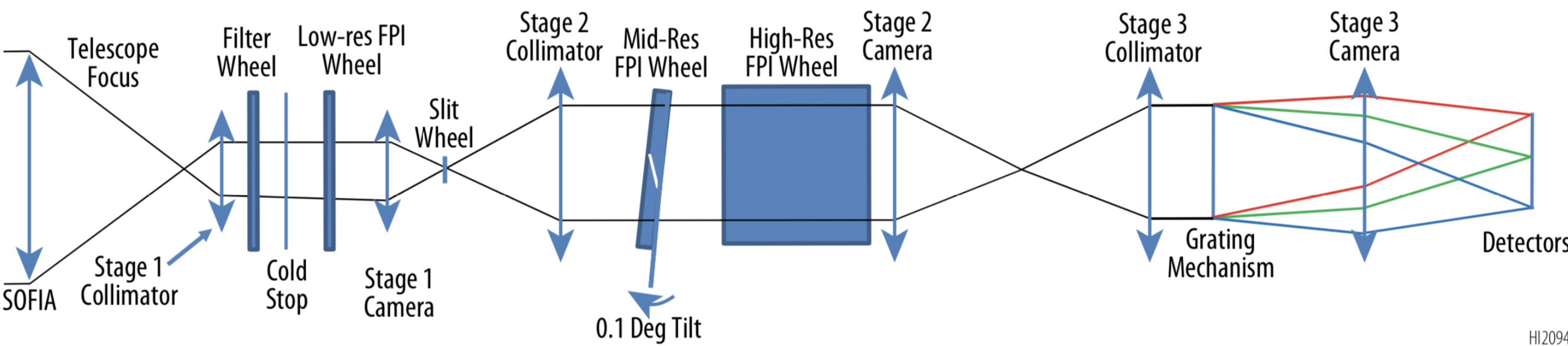
- High-res mode: R ~ 100,000
- Mid-res mode: R ~ 12,000
- Low-res mode: R ~ 300-600
- Imaging spectroscopy mode: R ~ 2000

The modes are optimized to deliver the maximum sensitivity achievable with SOFIA. HIRMES uses:

- Background limited bolometers (TES)
- Combination of Fabry-Perot Interferometers and gratings for both low and high res spectroscopy.

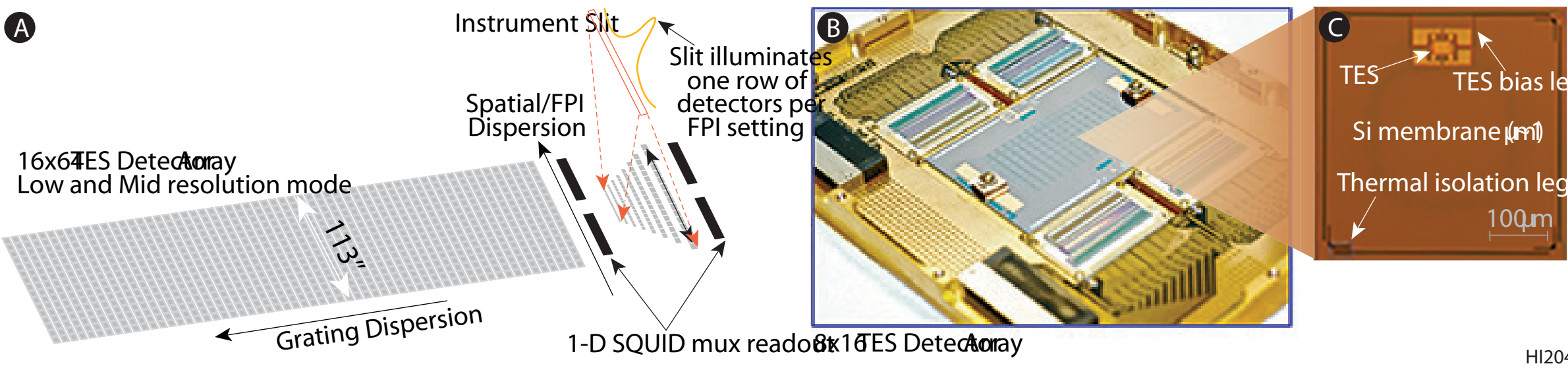


Optical layout



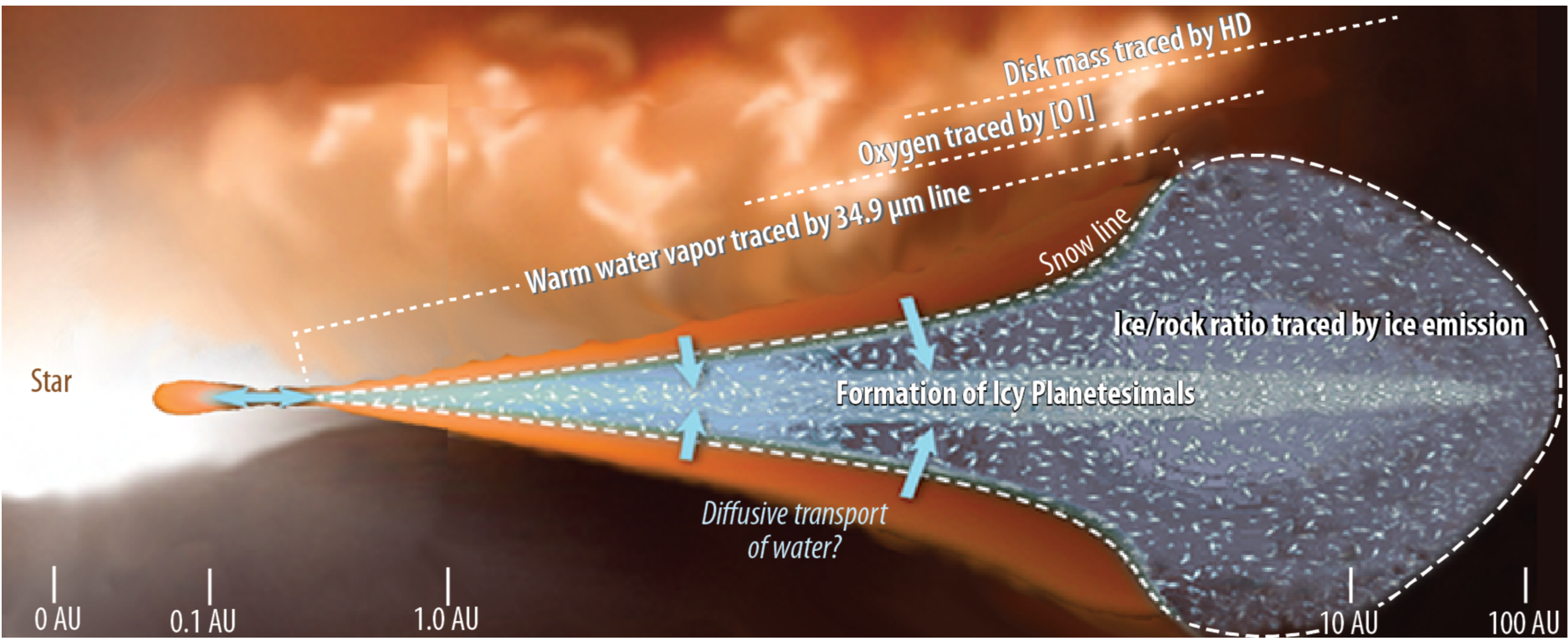
In the HIRMES optical layout, the beam passes through a thermal blocking filter that reflects ambient temperature radiation and transmits longer wavelengths to the Stage 1 collimator. It then travels through the 12-position filter wheel, three-position low-res FPI wheel, a four-position slit wheel, then through the Stage 2 collimator, followed by the four-position mid-res FPI wheel into the four-position high-res FPI wheel. It continues through the Stage 3 collimator into the four-position grating wheel, and then onto the two detector arrays. High-res FPIs deliver the required instrument resolving power of 50,000- 100,000, and the mid-res FPIs, gratings, and filters serve as order sorters. For the grating mode, high- and mid-res FPIs are removed from the beam. Baffles and separated stages serve to mitigate stray light.

Detectors



Two focal plane TES detector arrays:

A: A high-resolution ($\lambda/\Delta\lambda = 100,000$) 8x16 pixel array with pixel area optimized for each optical wavelength, with $NEP \leq 3 \times 10^{-18}$ W/ $\sqrt{Hz}$ and a low-resolution ($\lambda/\Delta\lambda = 2,000 - 12,000$) 16x64 pixel array with identical pixels optimized over a broadband, with $NEP \leq 2 \times 10^{-17}$ W/ $\sqrt{Hz}$. B: TES detector package with 8x16 high res array (e.g., for GISMO, as shown). C: Micrograph of a single TES bolometric detector pixel used in HIRMES' 64x16 pixel array.

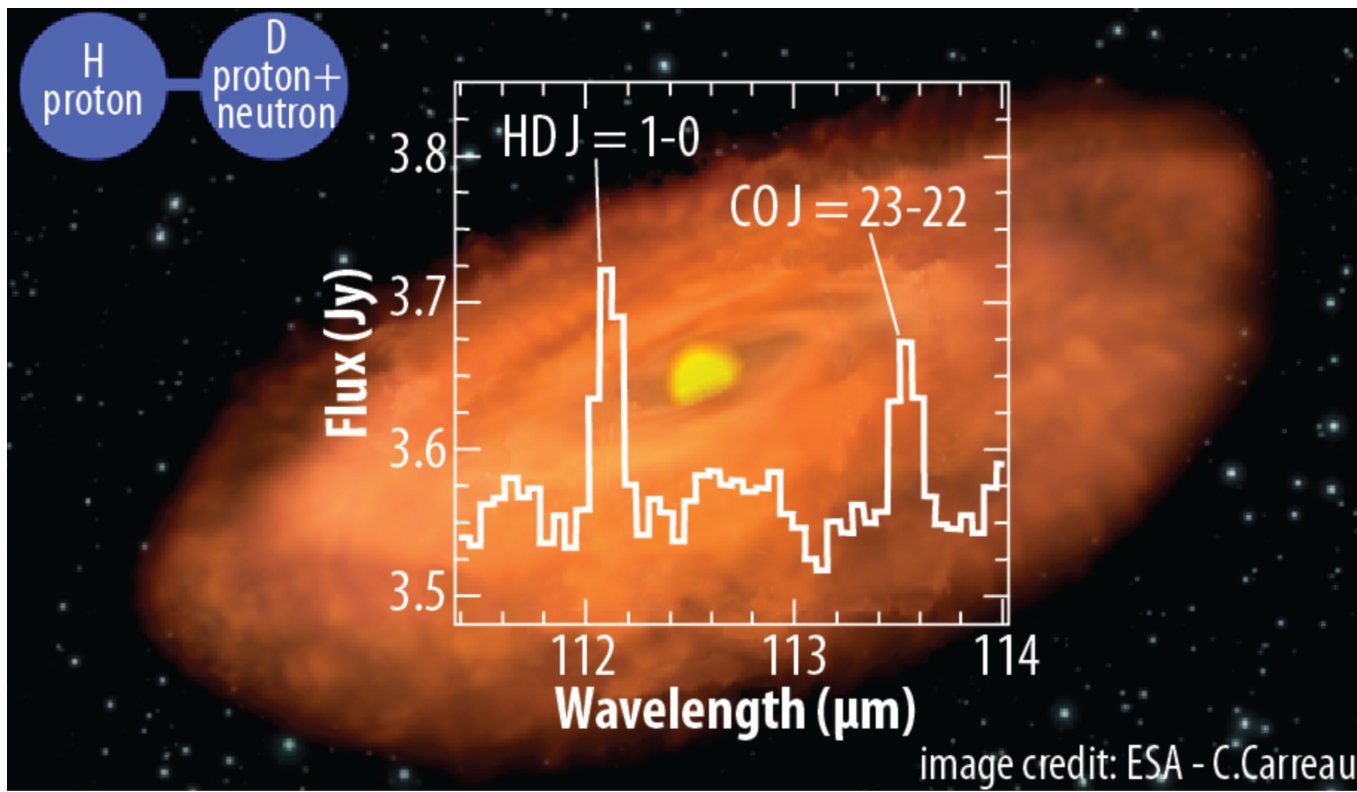
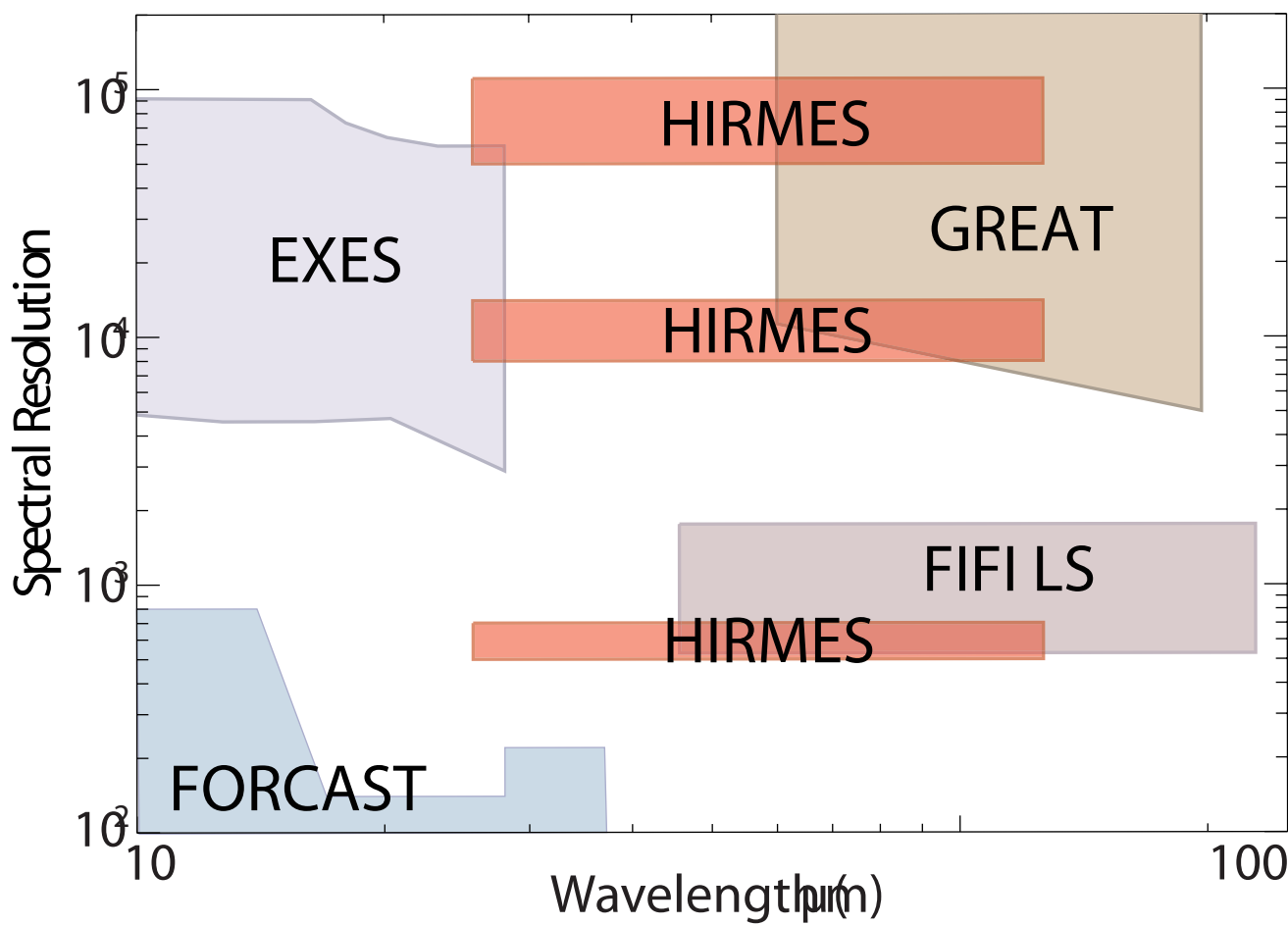


HIRMES will address fundamental questions on how planetary systems form and evolve

- How do planetary systems form?
- What is the origin and role of water in this process? What is the mass distribution of stellar debris disks?
- Do the constituent materials of our solar system have a common origin?
- HIRMES capability to measure the distribution of water vapor and ice in stellar debris disks is unique wrt any other facility and will substantially enhance the science return of JWST and ALMA wrt planet formation.

What are the processes through which protoplanetary disks evolve into nascent planetary systems?

HIRMES on SOFIA

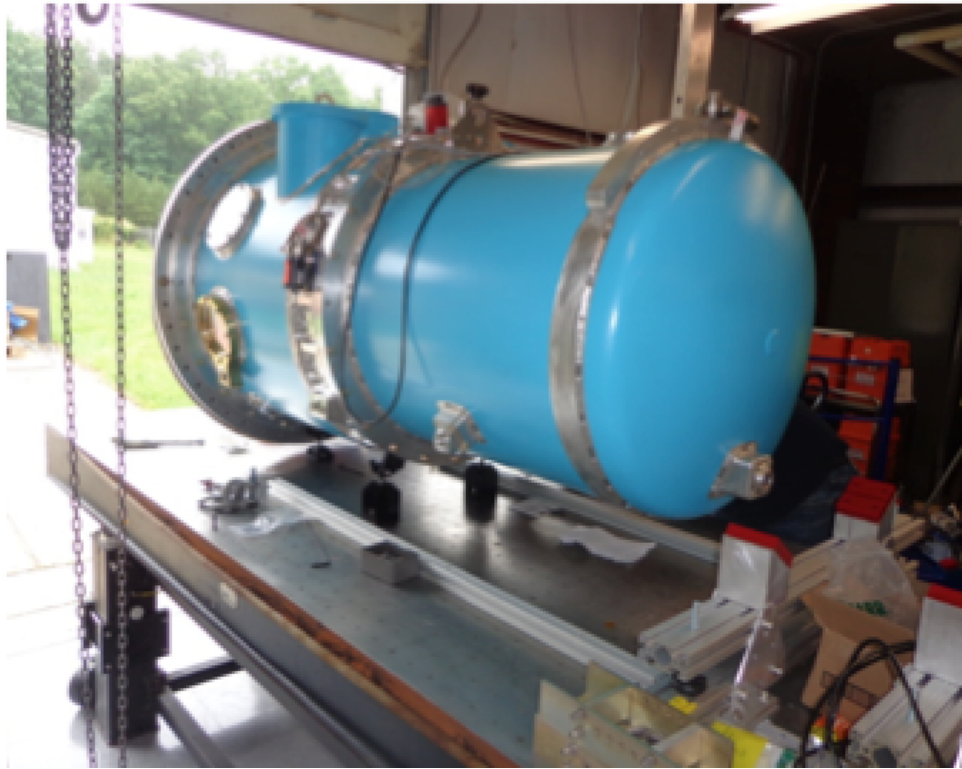


Herschel PACS detected HD in TW Hya without spectrally resolving the line. HIRMES measures the spectrum of sources with sufficient resolving power to map the kinematic structure of the protoplanetary disk.

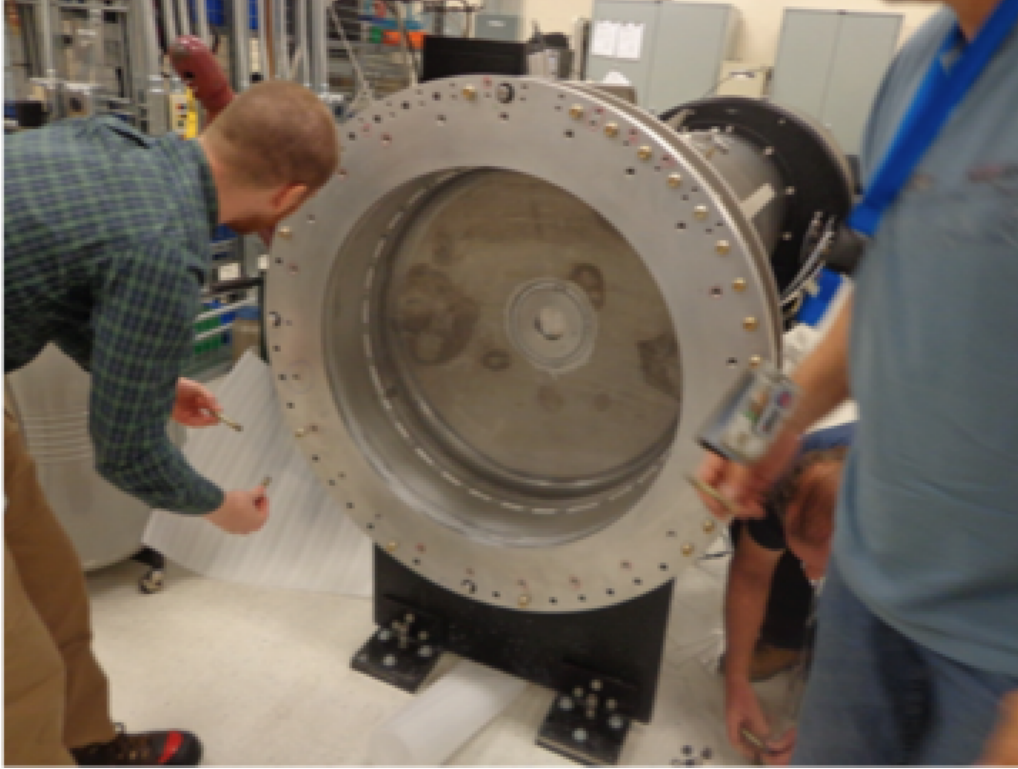
Instrument integration and assembly



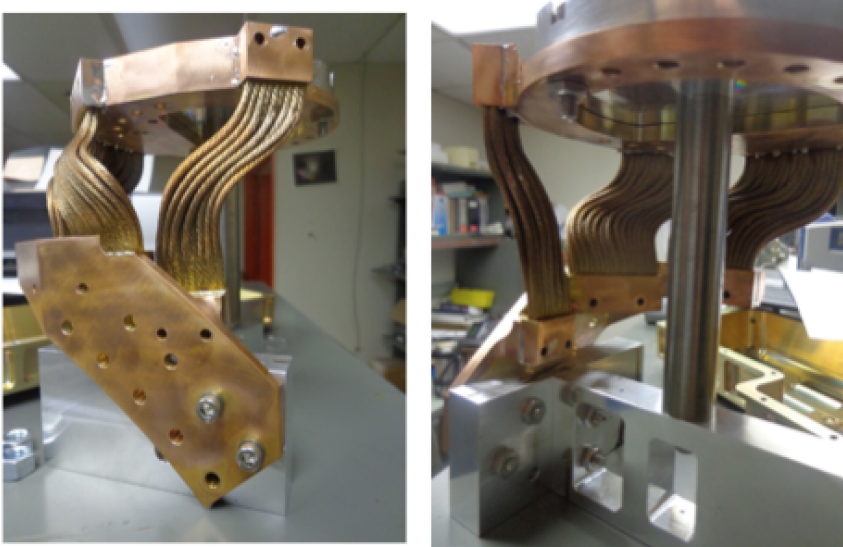
Optical bench assembly received and verified for performance from SDL: includes fixed optics, PAM (pupil adjustment mirror) and grating mechanisms



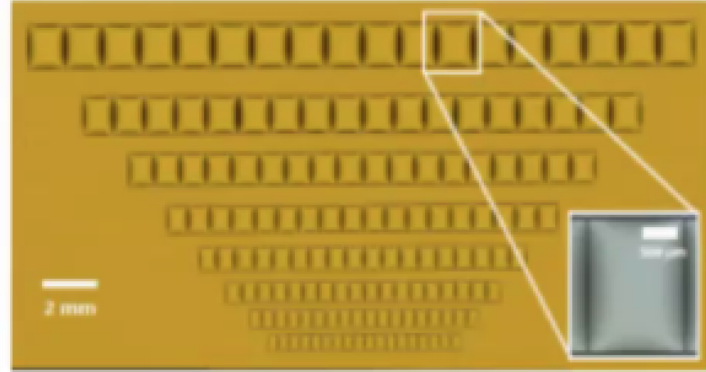
HIRMES Cryostat on 3 point mount to Newport Bench ready for disassembly.



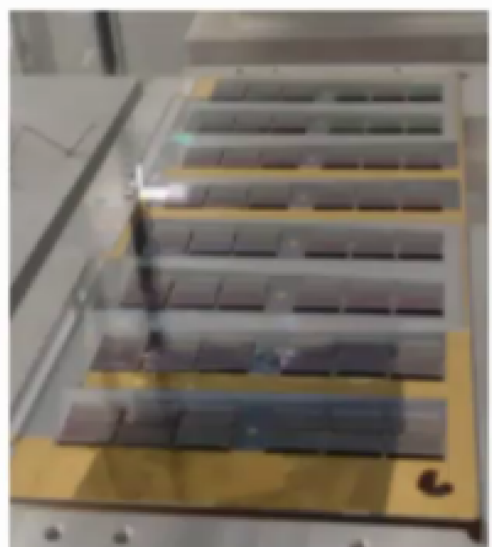
HIRMES dome fitcheck at AFRC to Telescope Assembly Simulator



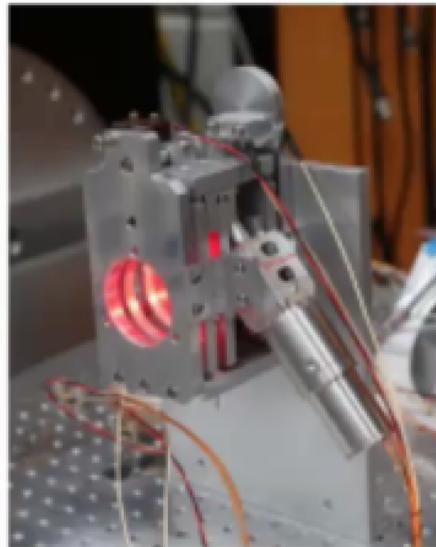
Cryocooler thermal straps in fab



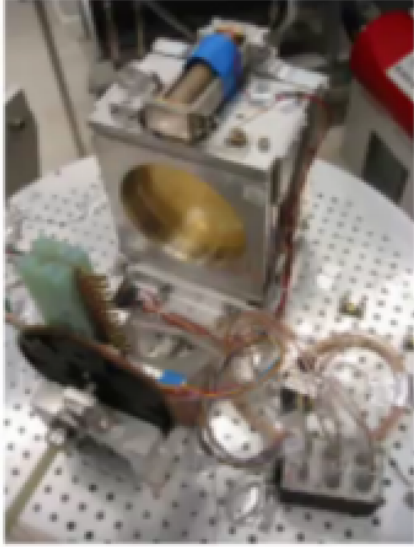
Hi-Res Detector Fabrication SU-8 "Rail" process



Low-Res Detector Package



Low-Res Imaging FPI



Mid-Res Imaging FPI