Optical & IR Instrumentation for Modern Telescopes

Spartan Infrared Camera

High Resolution Imaging for the SOAR Telescope

www.pa.msu.edu/~loh/SpartanIRCamera

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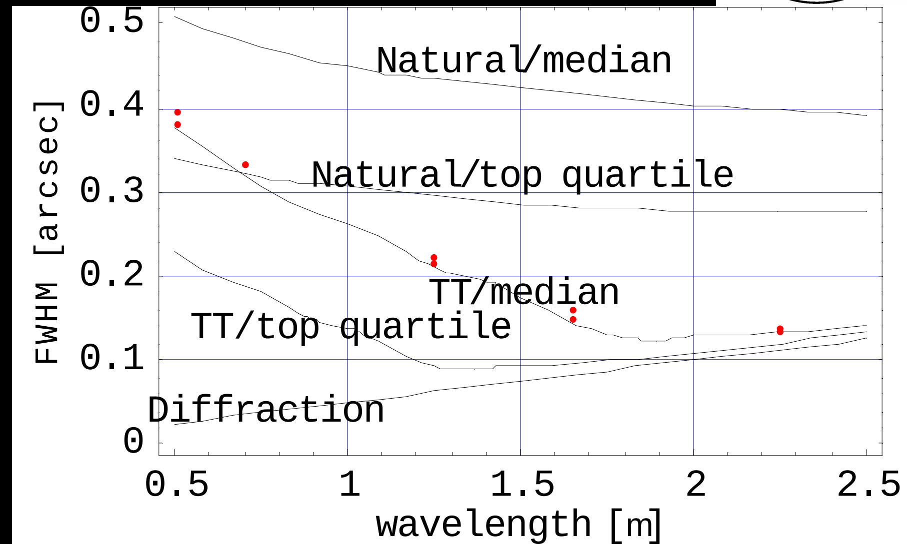
- Observing with tip-tilt correction for atmospheric turbulence
  - –High angular resolution: 0.2 arcsec
  - –Imaging at the diffraction limit @ H & K
- Instrument Design
  - –Aluminum mirrors
  - –Symmetry $\Rightarrow$ stiffness
  - –Alignment of optics with metrology
  - –Novel thermal reflector

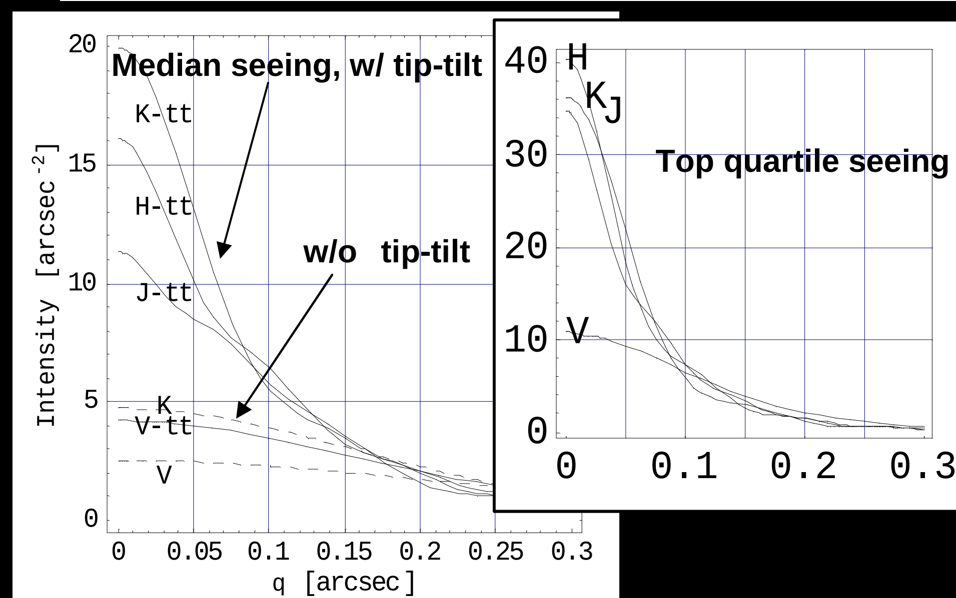
Science Objective: High Resolution Imaging

- Prediction for tip-tilt correction of atmospheric turbulence
  - @ 500nm, r_0=20cm (median seeing) & 30cm (top 25%)
- Observing with tip-tilt
  - Point-spread function has spike of diffraction width & broad wings
  - Spike has substantial amount of light in H & K bands.
    - » **Strehl≡(amplitude in diffraction core)/ideal**

Band	Strehl Top 25%	Strehl Median
K	0.50	0.28
H	0.30	0.12
J	0.15	0.05

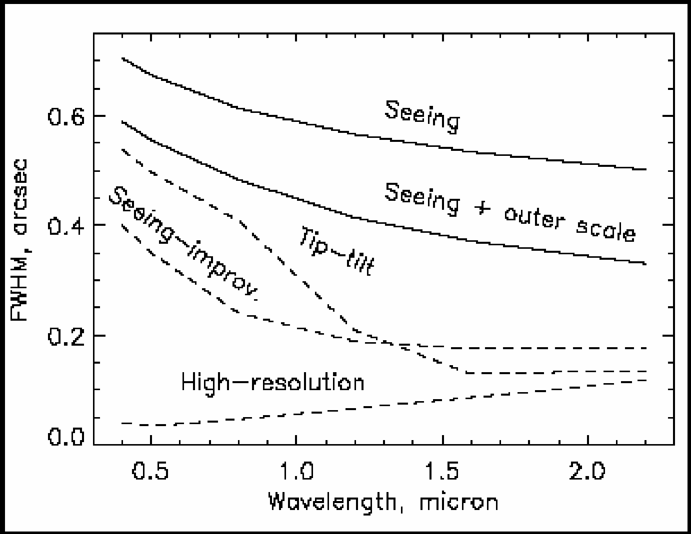
  - For optimal estimate of flux of point sources, tip-tilt gets 0.4 mag deeper or takes ½ observing time.
- For 1hr exposure, mJ=24.6, mH=23.1, mK=23.2.
  - 5σ; aperture for max S/N; median seeing; 10C; ε=0.1; MKO filters.

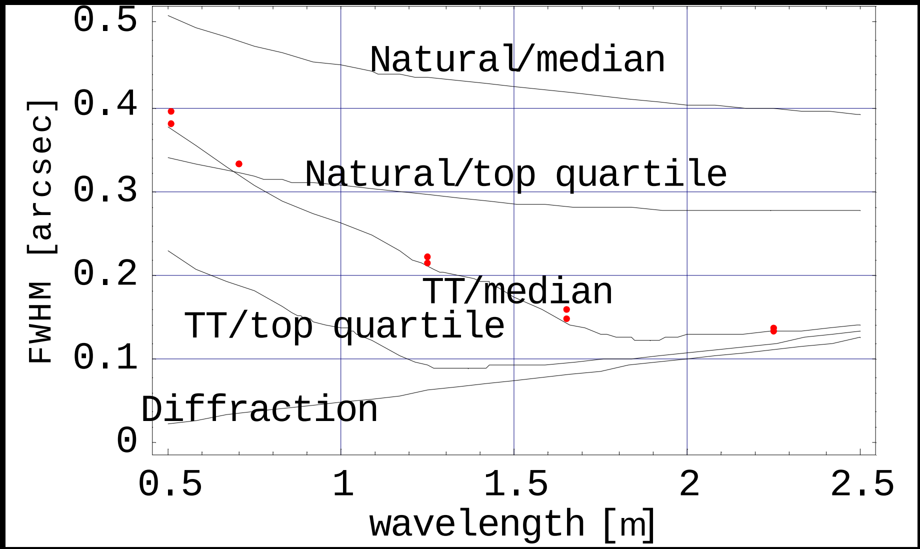




Turbulence with finite scale

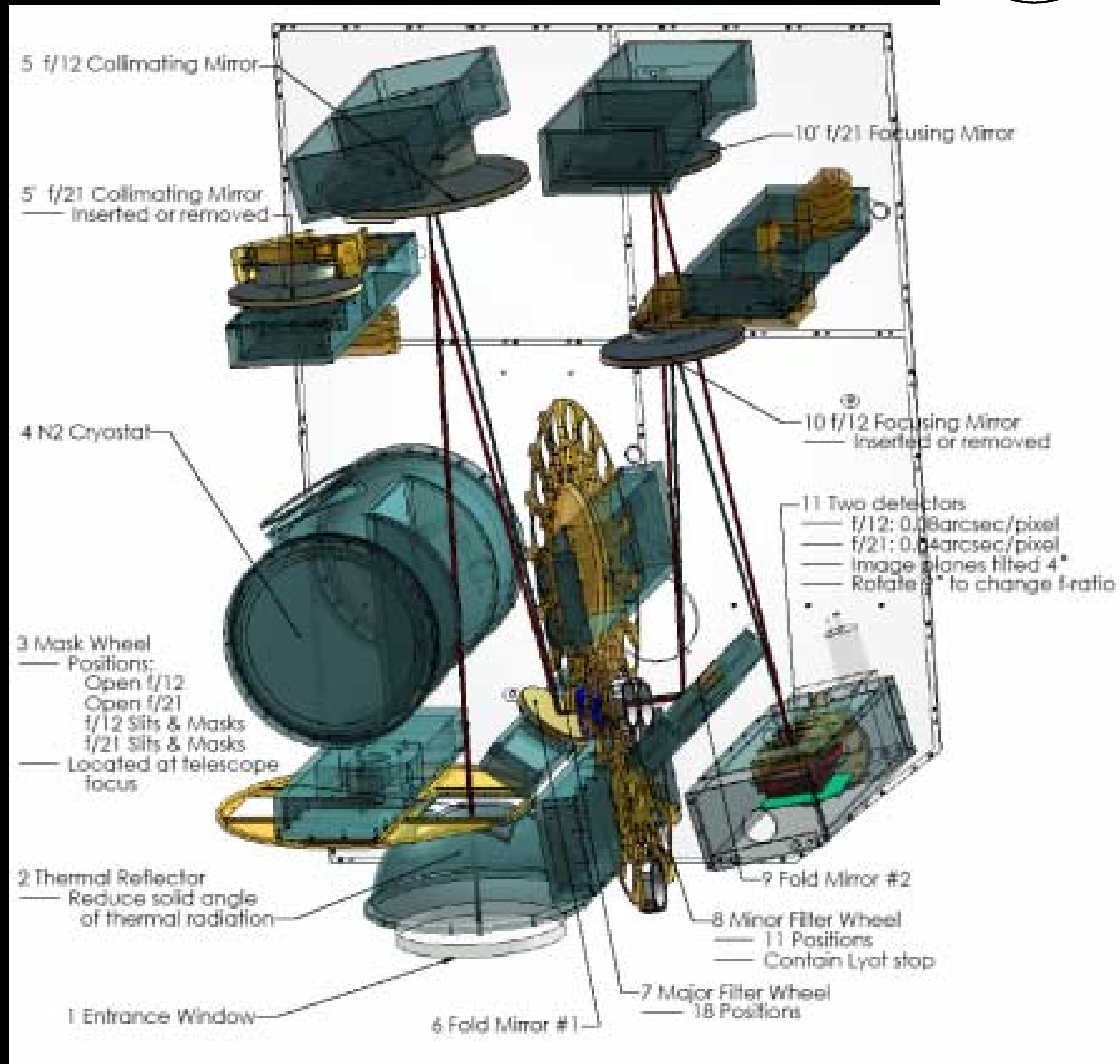
- Model with turbulence cut off at 25m (Tokovinin 2003, “SOAR AO CoDR, Appendix A.”)
  - r0=15cm & 25cm. (Same seeing; reduced image motion)
- Substantial improvement with tip-tilt





Modes

- J, H, & K spectral bands 1-2.4µ
- Rockwell HgCdTe 2048x2048 detectors
  - Two initially
  - Four in a year (B Barbuy & S Viegas)
- Modes
  - Wide-field imaging at f/12
  - Diffraction-limited imaging at f/21
  - Grism spectroscopy; resolution 200. (Descoped)
  - Coronagraphic mask
- Filters
  - J, H, K
  - Others can be added. Need $.

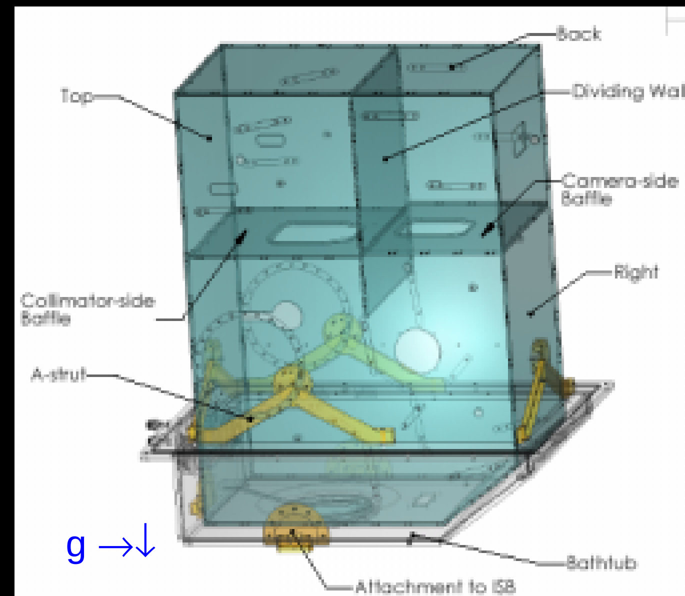


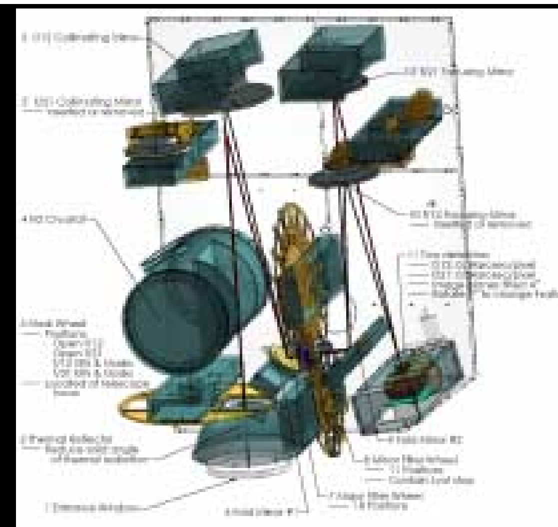
Aluminum Mirrors

- Advantages for aluminum
  - Mirror can be installed by metrology of mirror pads.
    - » **Mirror fabricated, polished, & tested while bolted to master jig.**
    - » **Mirror surface & mounting pads located by interferometry**
  - Focus is athermal, since mirror & COB are both aluminum
    - » **Install & test at 300K; run at 77K.**
- Details
  - Surface accuracy 50nm (PV) $\Rightarrow$ Strehl of 4 mirrors is 0.991 @1200nm.
  - Axsys Technologies, Rochester Hills, MI
  - Computer-generated hologram
    - » **Makes reflected wave from off-axis asphere into a sphere**
    - » **Creates alignment for master jig & interferometer**
  - Diamond-turned surface; nickel coated; polished; Ag with SiO2 coating. 99% reflectivity.

Symmetrical Design

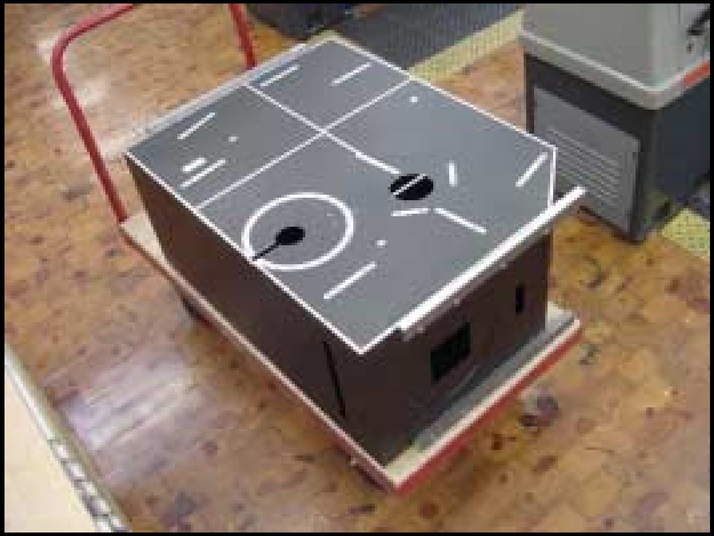
- Boresight requirement: Detector & tip-tilt sensor maintain alignment as Nasmyth port turns
  - 0.04” in sky
  - 5µrad for mirrors inside instrument
- Symmetry eliminates torques
- Cryo-optical box (COB) has two plates & optics are mounted on posts centered between plates
  - Gravity is parallel to plates of COB
  - No torque parallel to plates





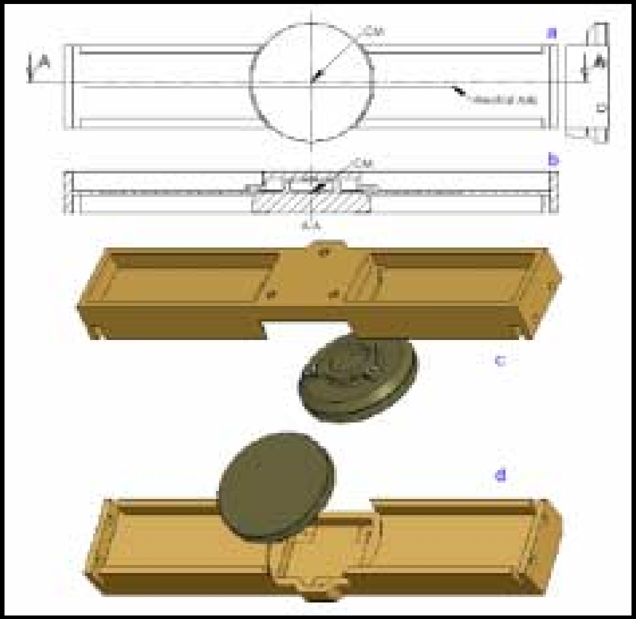
Machining the Cryo-optical Box

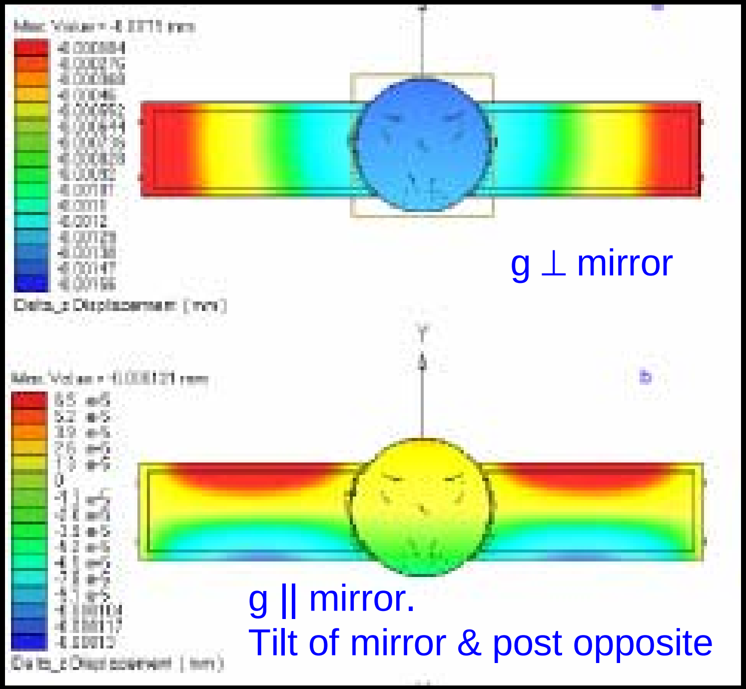





Post for Fold Mirror

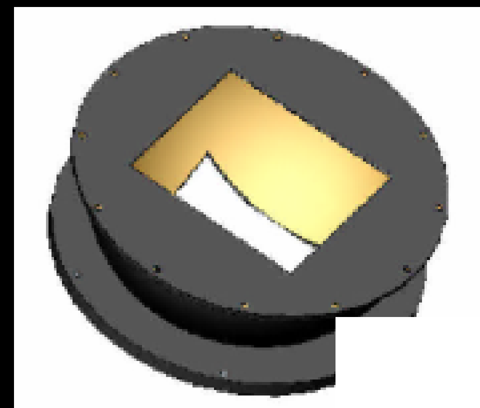
- Posts designed to eliminate torque parallel to mirror surface
  - Put CM on neutral axis

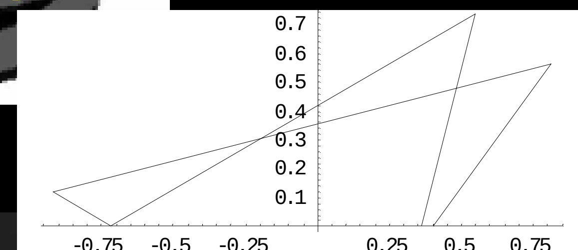




Thermal Reflector

- Thermal radiation in the 120x120mm opening is 4.7W. Thermal load is 4.1 W for all else.
- Thermal reflector is a plane & hemisphere. Cases:
  - Hemisphere reflects radiation back directly
  - Hemisphere & plane make a corner reflector to reflect radiation back
  - Radiation enters entrance aperture
  - Radiation is absorbed in thermal reflector
- Fabrication
  - Hemisphere is polished Al
  - Plane covered with aluminized mylar
- Thermal reflector reduces load by 0.34.
- Total heat load of 1000x700x400mm cryogenic box is designed to be 6W. (3L/day of N2)
  - Currently, we measure 14W. Conduction because of H_2?

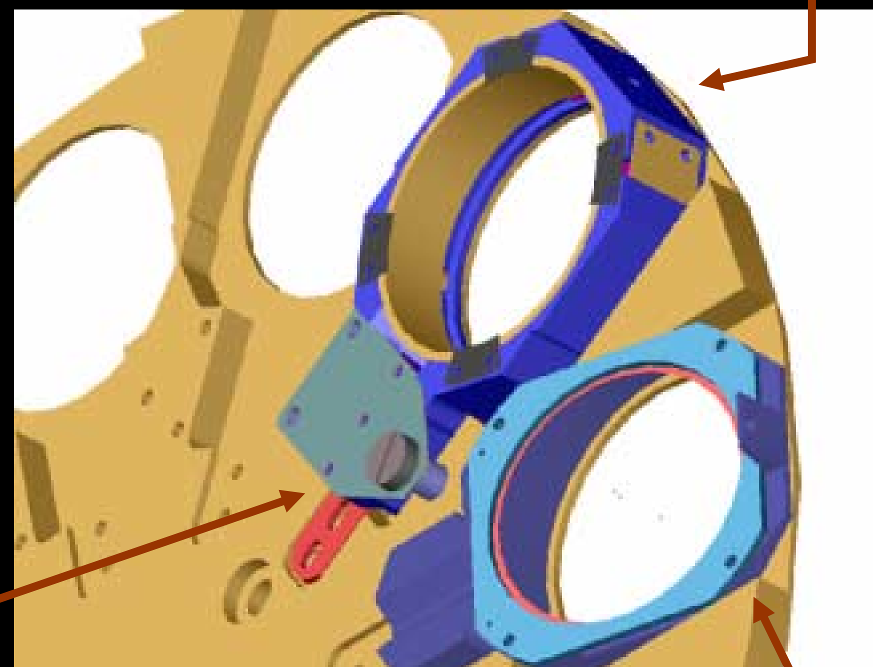




First Cold Test w/o Optics

Filter wheels

- Designed by René Laporte
- Filters can be inserted through port in vacuum enclosure.
  - Warm-up required. Disassembly of optics not required
- Positions
  - 18 on filter wheel #1
  - 11 on wheel #2

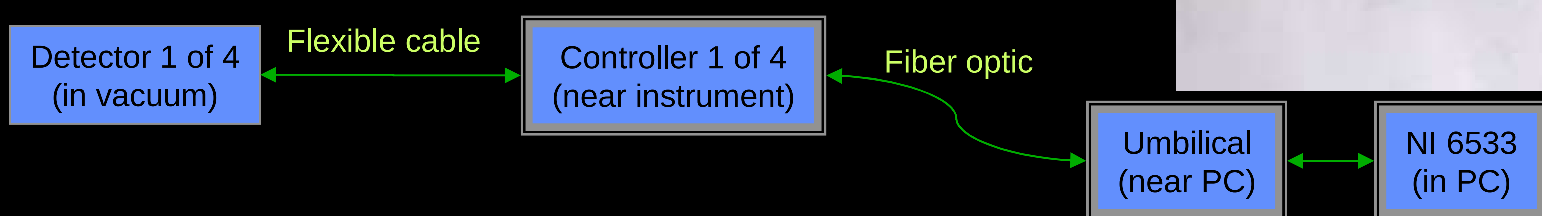


Alignment with Metrology

- Problems with optical alignment
  - Many degrees of freedom: Two off-axis aspherical mirrors, two fold mirrors
  - Adjustments have thermal problems
- Align with metrology
  - Require 0.1 mm & 0.15 mrad precision.
  - Coordinate-measuring machine has 6µm accuracy over 1000x700x400mm volume
  - Mirrors fabricated with accurately placed pads.
  - Shim is between cryo-optical box (COB) & post for optic. Shim allows x-y motion, machined for z. Shim pinned to COB.

Electronics

- Use NI I/O card, which has LabView driver
- Four custom cards
  - Umbilical board for serializing/deserializing. One for 4 detectors
  - Controller board to control & read detector. One 3U (160x100-mm) board per detector. 1.5 Watts
  - Detector board for thermal isolation
  - Flexible cable between controller & detector. Potted to vacuum bulkhead. Thermal isolation. Microstrip ⇒ very clean signal path.



The Team

- Members & responsibilities
  - J Biel (technician), electronics
  - J Chen (gs) & N Verhanovits (gs), software
  - E Samet & Hanold (ug), testing, metrology
  - B Lien (gs), testing
  - D Circle, D Keesaer (MC Molds), R Laporte (INPE), & O Loh (JHU), mechanical
  - M Davis (gs, now at SWRI), optics
  - MSU Phys-Ast shop & McMolds, mechanical fabrication
  - E Loh, PI