NSTX

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Status of two-color IR on NSTX

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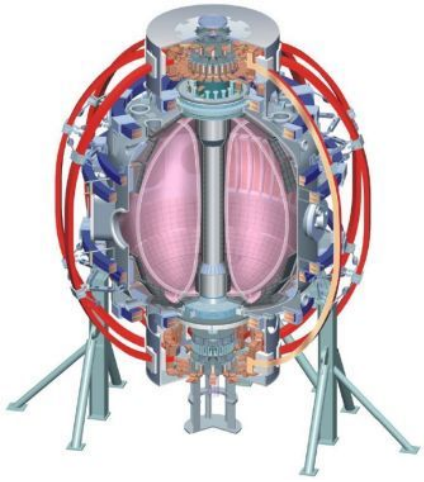
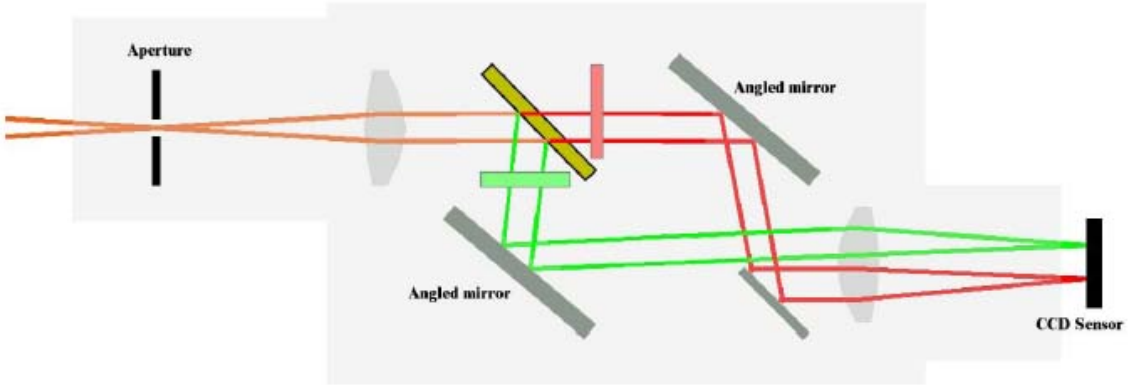
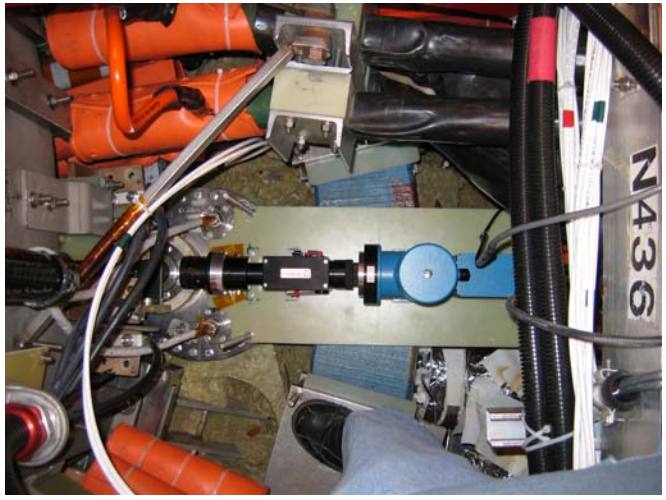
April 14, 2010



Introduction: A two-color infrared imaging adaptor for the fast IR camera on NSTX

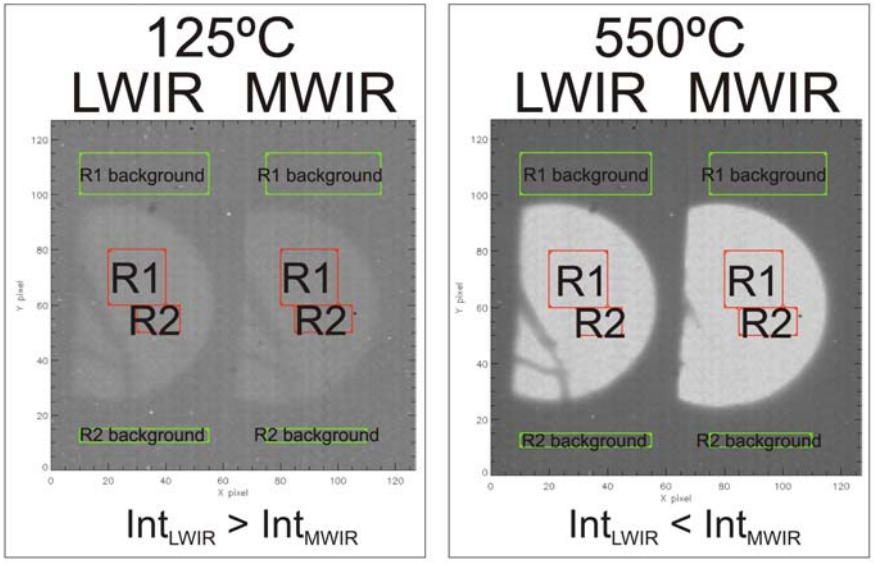
- Use of the LLD in NSTX will make assumptions of high surface emissivity (applicable to graphite) inaccurate
  - Complications include: Surface coating changes in real time during plasma shots, emissivity changes due to H-absorption in Li, reflections from Li surface, deposition of Li on C surfaces, erosion/transport of Li and C
- Two-color camera measures temperature based on the ratio of integrated IR emission in two IR bands, not single band intensity
- Image split into medium wavelength (4-6 μm) and long-wavelength IR (7-10 μm) using a dichroic beamsplitter, filtered with bandpass filters, projected side-by-side into the ORNL fast IR camera (1.6 kHz 128x128 pixel full frame)



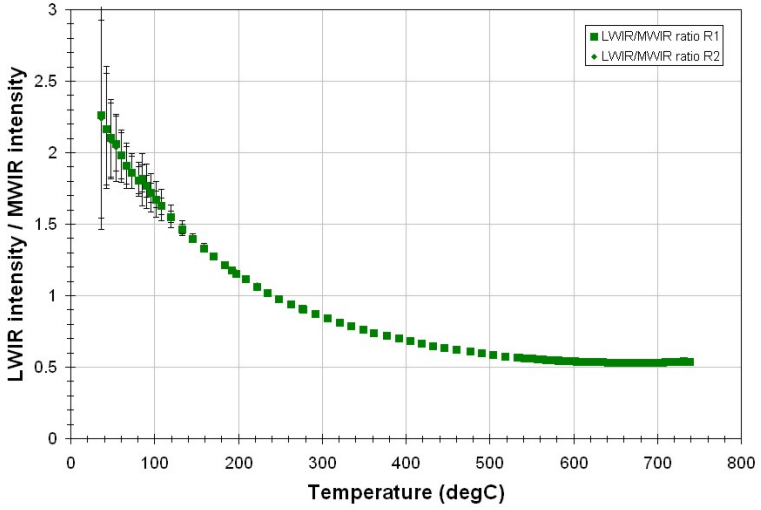


Demonstrated application of two-color IR with extensive *ex-situ* calibration

- Calibration accomplished using a 25-750˚C blackbody source
  - Useful, low error LWIR/MWIR ratio from ~100-600˚C
- Additional i*n-situ* calibration during heating of LLD plates from 0-320˚C
  - Shows extended useful range due to losses in MWIR channel
  - Analysis ongoing due to analysis of LLD thermocouple data

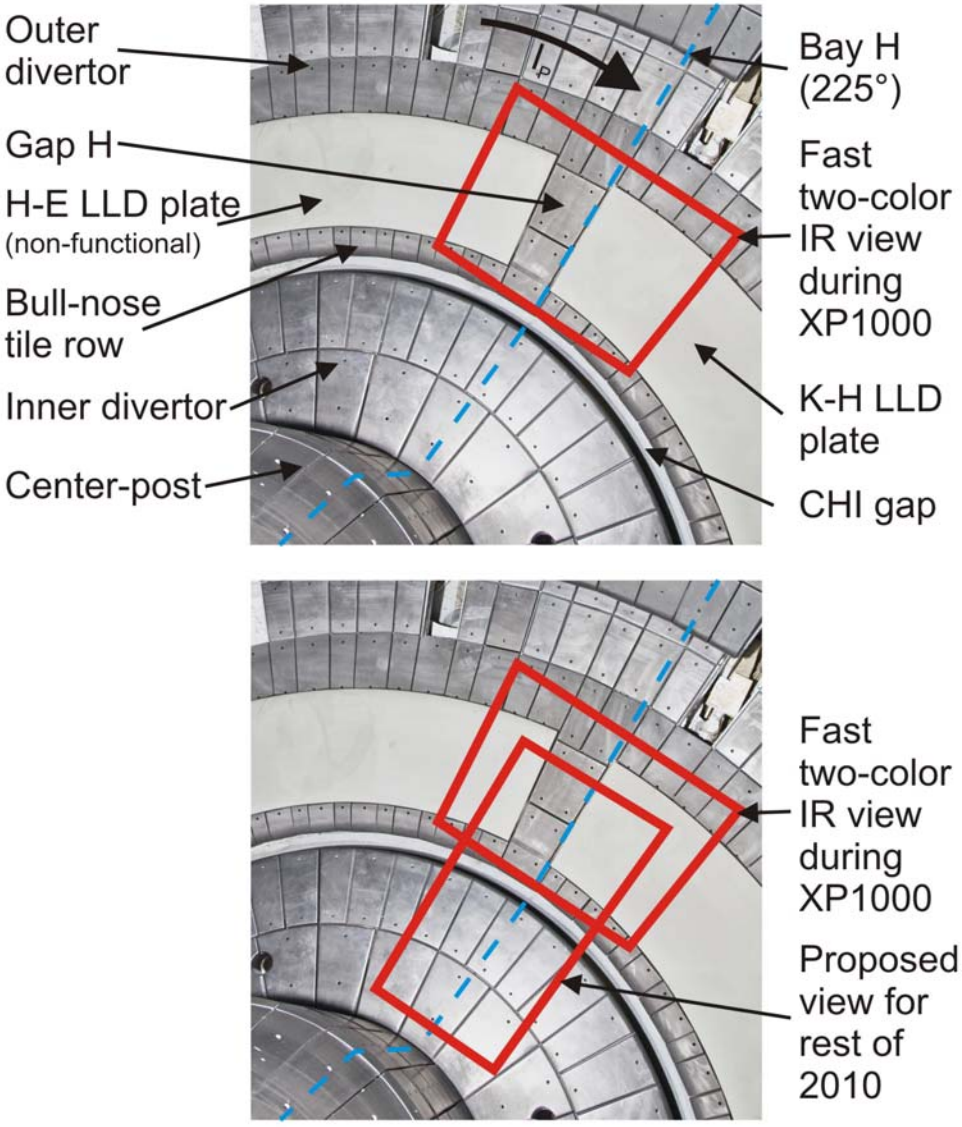


SBFP 2-color intensity ratio calibration, blackbody source, 22 us integration time



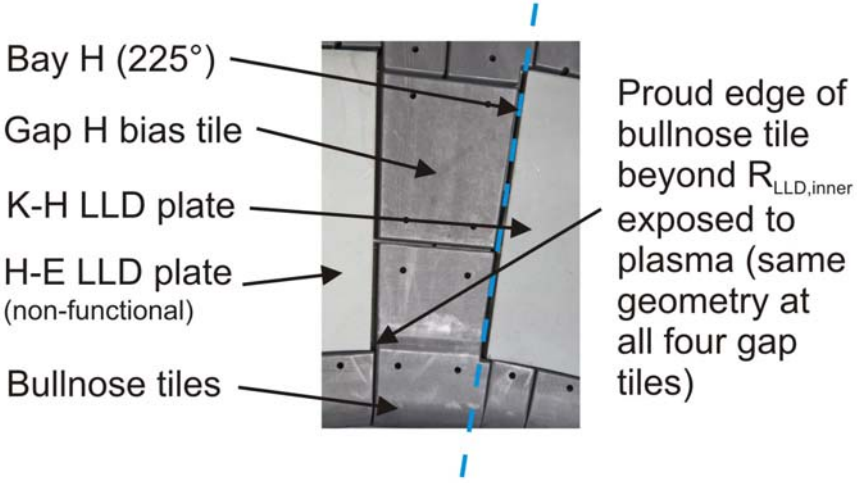
Application of fast two-color IR so far

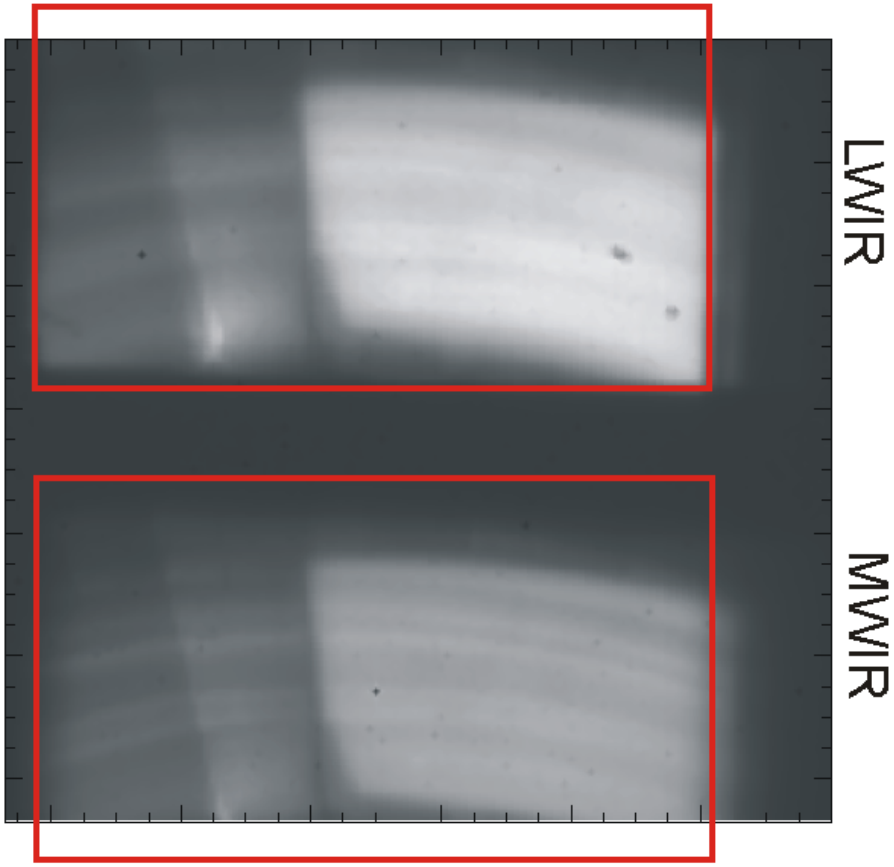
- Maximum 64x128 pixels on IR detector per channel (i.e., color), 0.6-1.6 kHz frame rate
- In practice, limited to ~55-60 x 115-120 pixels to
- Initial view of the floor oriented toroidally
  - Re-orientation of optical adaptor will take place over maintenance week
- Data captured in ~350 shots so far, stored to MDSplus
  - Initial inspection of ~15% of stored shots
  - Initial data look promising for detailed analysis



Sample data from April 7, 2010

- Clear view of OSP on hot and cold LLD plates, heat flux on gap tile
- Higher intensity on LWIR channel indicates temperature <400°C
- Significant heating of exposed edge on gap bullnose tile
- Figures demonstrate some of the challenges in overlapping two channels to acquire ratio



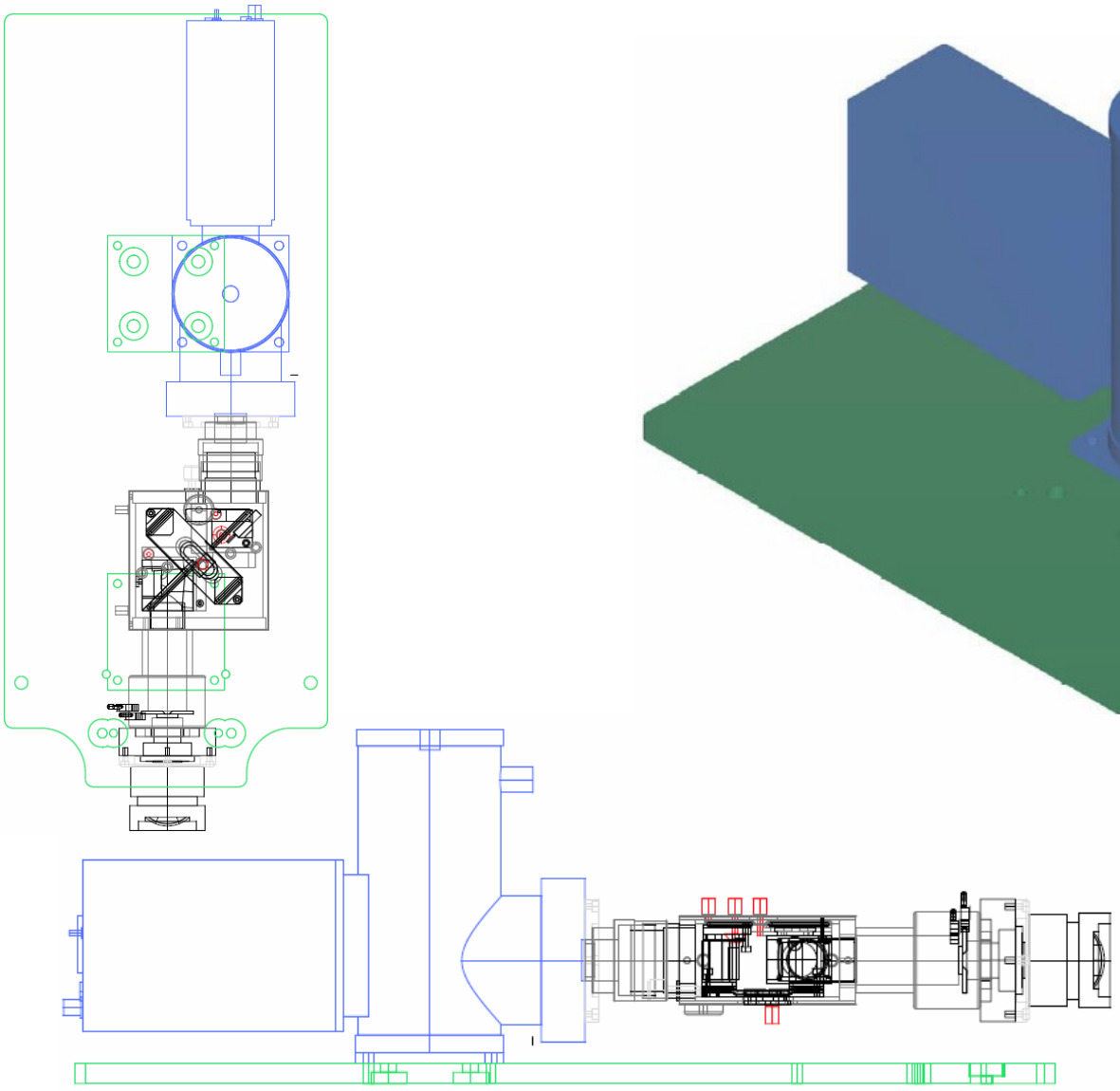


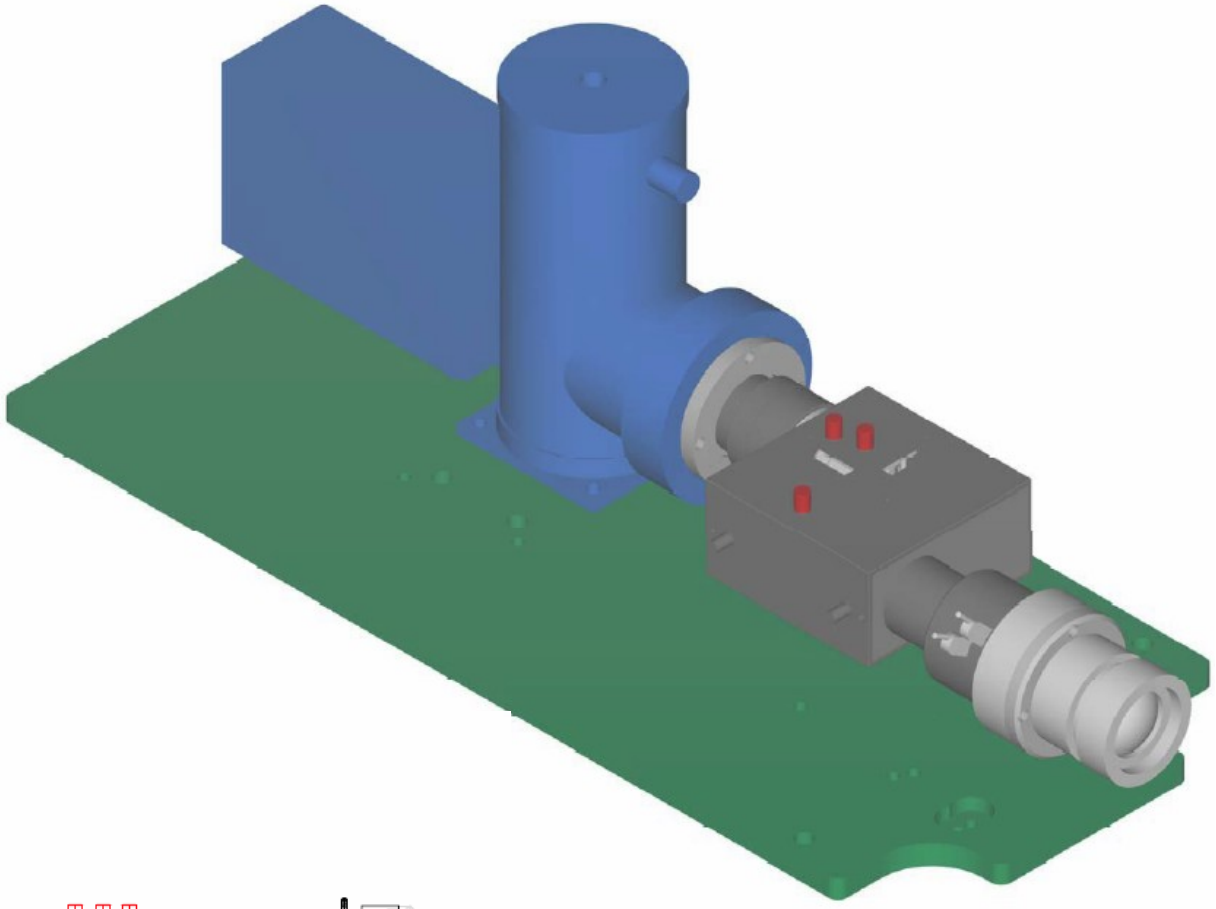
Future plans/hopes/dreams for two-color IR on NSTX

- Secure mount to prevent jitter/vibration in one or both channels
- Mini IR source to allow alignment/focus of system at Bay H port
  - PCMCIA CameraLink card, W-filament and LED IR sources
- EMF interference a continuing problem
  - Camera electronics located <6” from PF2 coil
  - Leads to lost frames, variable frame rate,
    - Makes calculation of heat flux very difficult
  - Incorporates combination of high magnetic saturation and high initial permeability mumetal shielding (~10-20 lbs total)
  - Shield box would be mounted from the umbrella structure
- Alternative: Optical relay
  - Extremely challenging for broadband IR (4-10 um) due to chromatic aberrations
  - Investigating use of diffractive optic elements in 2-color adaptor
- Stepper-motor control of Bay H mirror orientation
  - Very difficult to properly aim without *in-situ* IR source (heatable tile in 2011)
- Moveable in-vessel pulsed IR source, or fiber for window calibration
  - UHV rotary feedthrough bakeable to 350 (Lesker)
  - In-vessel source would require electrical feedthrough
  - IR optical fiber limited to ~300˚C before devitrification

Backup slides

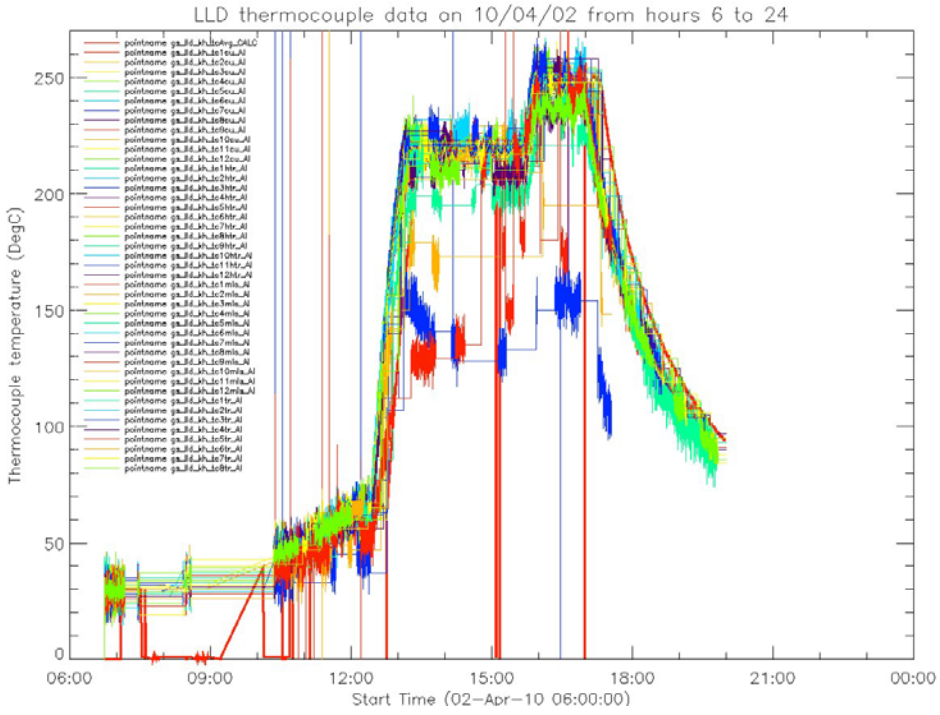
3D CAD model of two-color IR camera and adapter

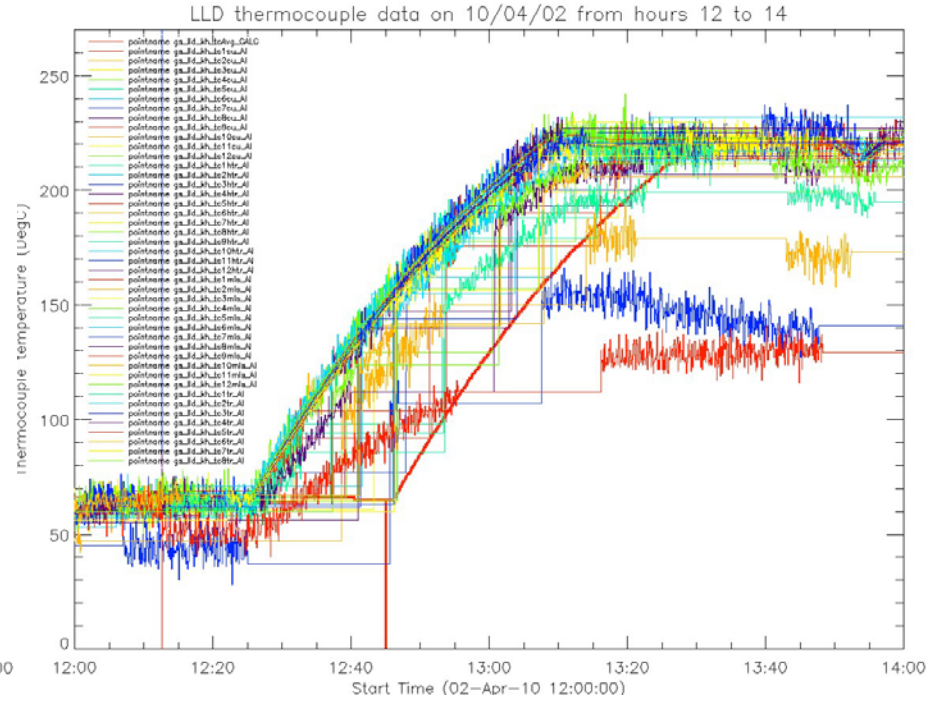




LLD thermocouple data used for IR calibration

- 44 TC channels from each plate trail average LLD TC signal by ~20 minutes on April 2 - 7





ORNL IR system currently on NSTX

- Two slow (30 Hz) IR cameras
  - Indigo Omega, 30 Hz, 160x128 pixel uncooled microbolometer FPA, 3.4 x 3.7 x 4.8 cm
  - 7-13 μm, 12-bit, 0-700°C range, ZnSe window
  - First camera: 15° FOV of lower divertor, ~0.7 cm/pixel resolution
  - Second camera: 15° FOV of upper divertor, ~0.6 cm/pixel resolution
- One fast (1.6-7.0 kHz) IR camera
  - Santa Barbara Focalplane (Lockheed Martin) ImagIR 128x128 pixel HgCdTe FPA
  - 2-10 μm, 14-bit, LN-cooled
  - Bay H, 12.5° FOV of lower divertor