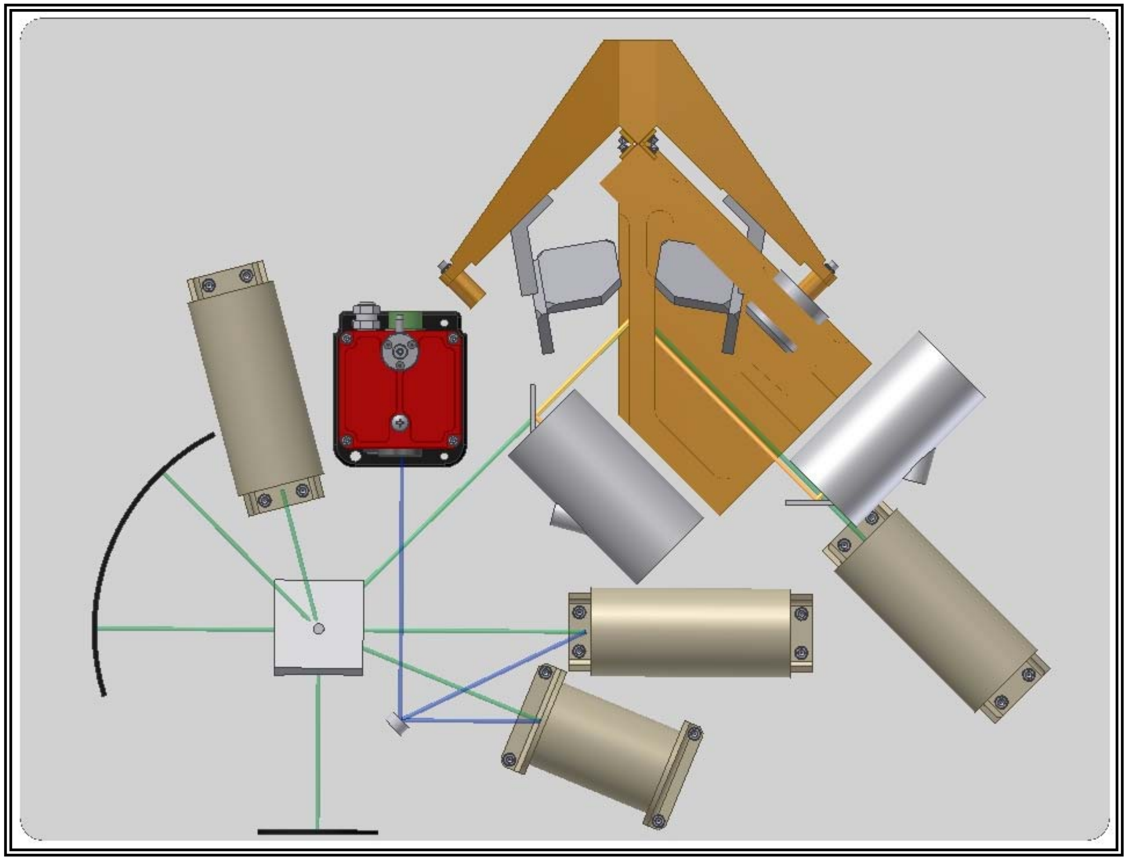


Quantum Cascade Laser Based Reflectometry for On-Orbit Blackbody Emissivity Measurements for CLARREO

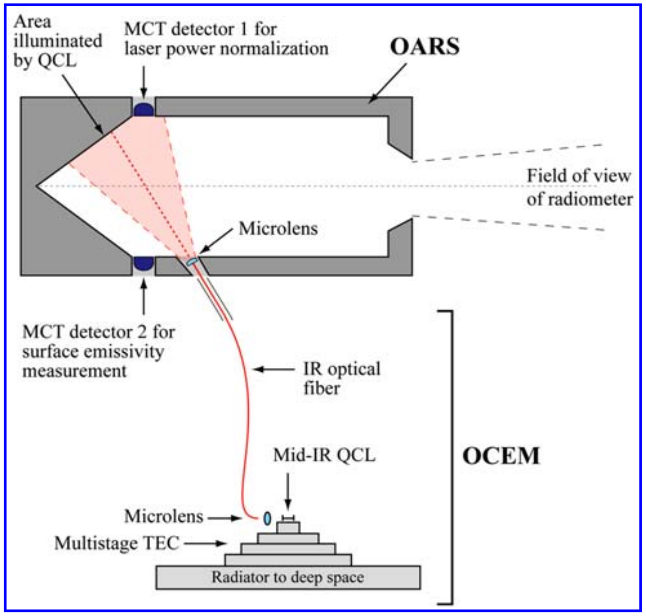
john dykema, mark witinski, jonathan gero,
james anderson

calcon 2009

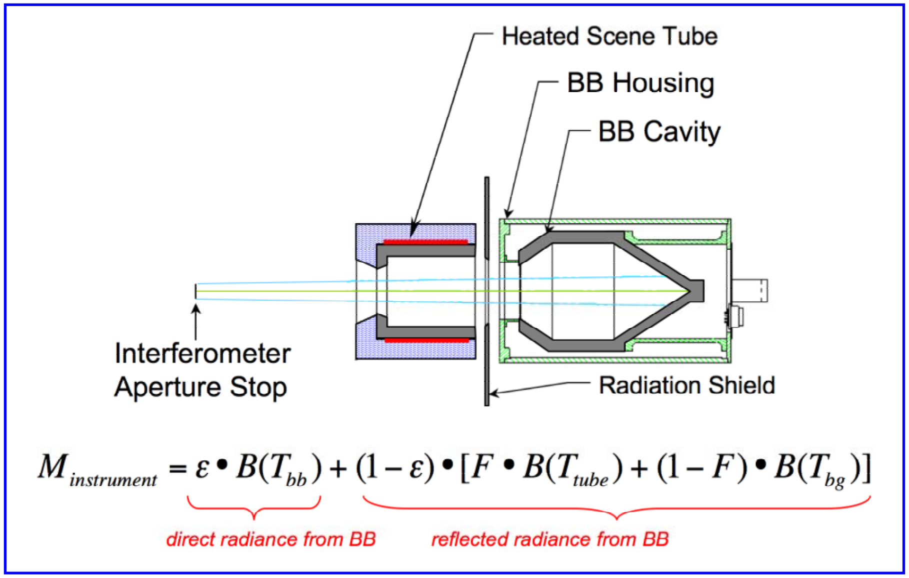
On Orbit Cavity Emissivity Module (OCEM)

Two versions are being developed:

- » one using a quantum cascade laser source (Harvard), and
- » one based on a heated halo source (Wisconsin).

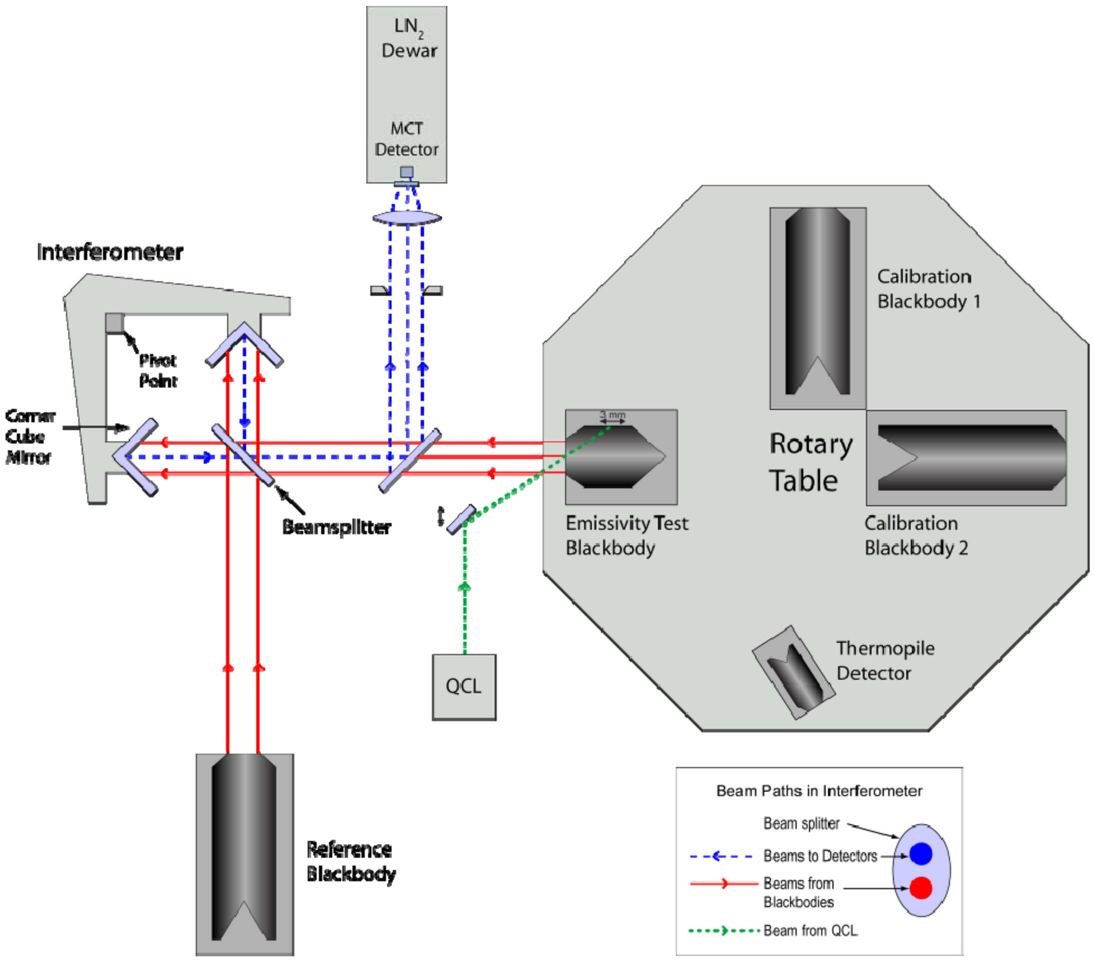


Harvard QCL Approach



UW Heated Halo Approach

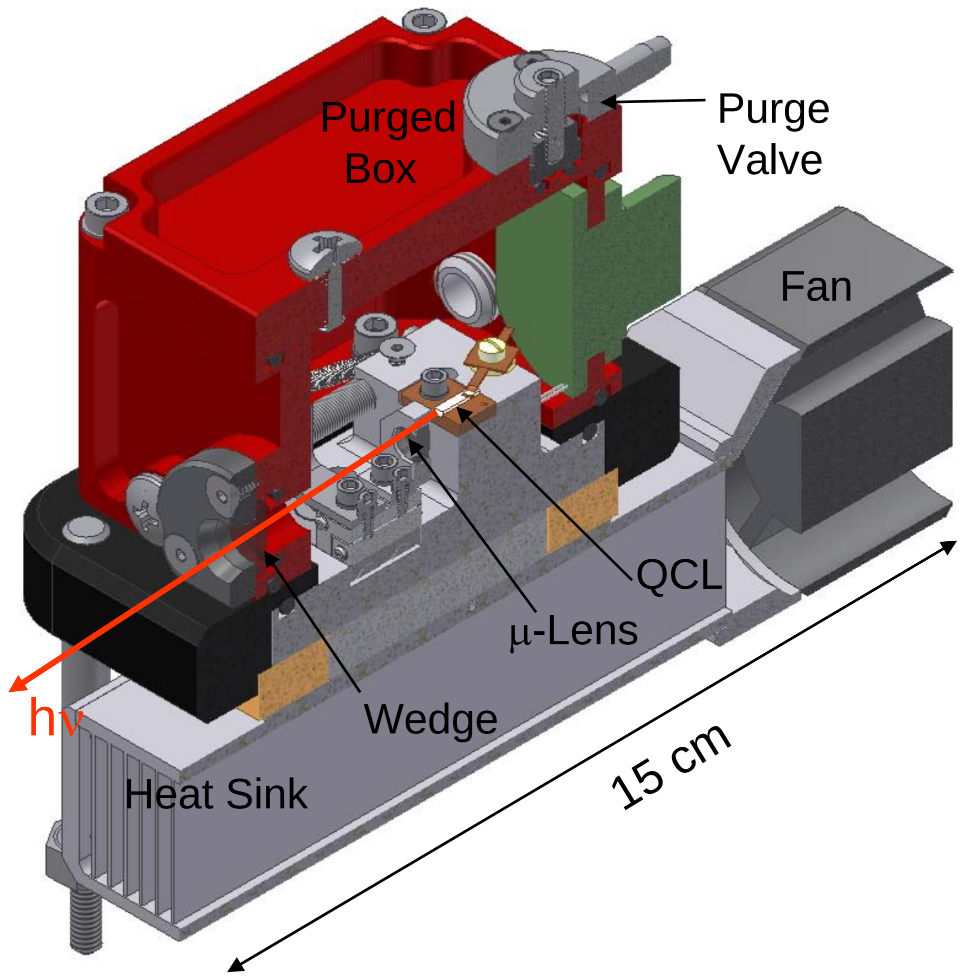
Cavity Emissivity and Spectral Response Using Single Cavity/QCL System



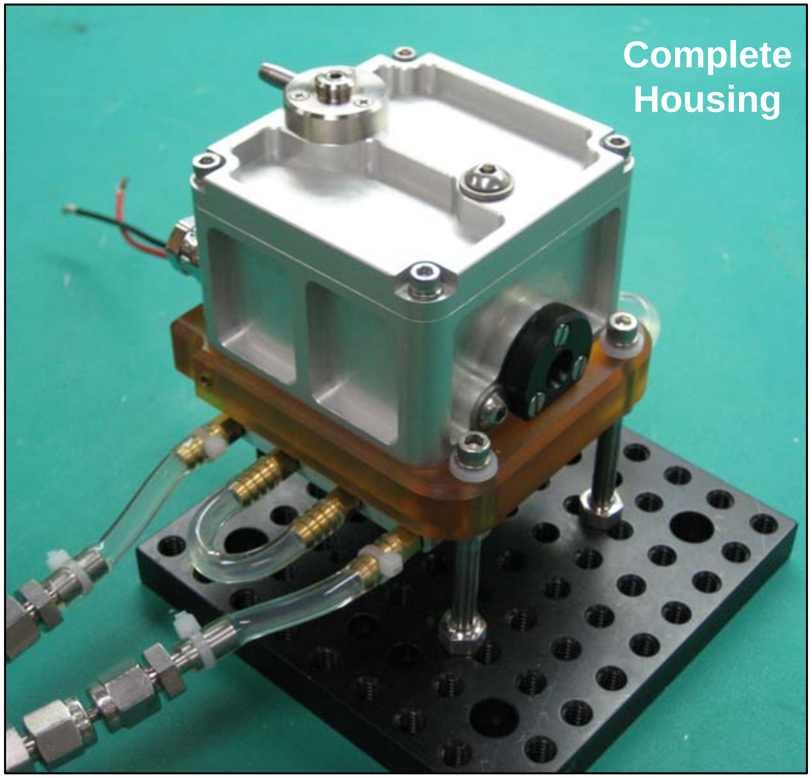
TE Cooled QCL Housing

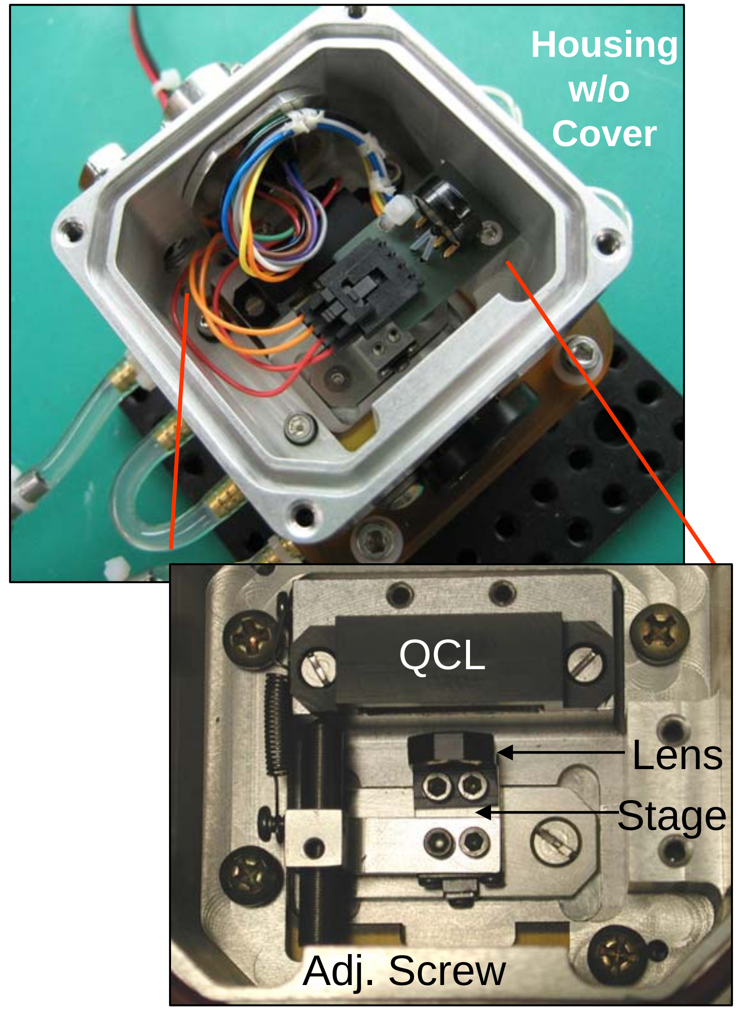
- Translatable AR Asphere
- 2 Stage TE Cooler (min. Temp. = -20°C, *cw*) with Air-Cooled Heat Sink
- Wedged, AR Exit Window

- Acquired Alpes QC laser at 1260 cm^{-1}



TE Cooled QCL Housing

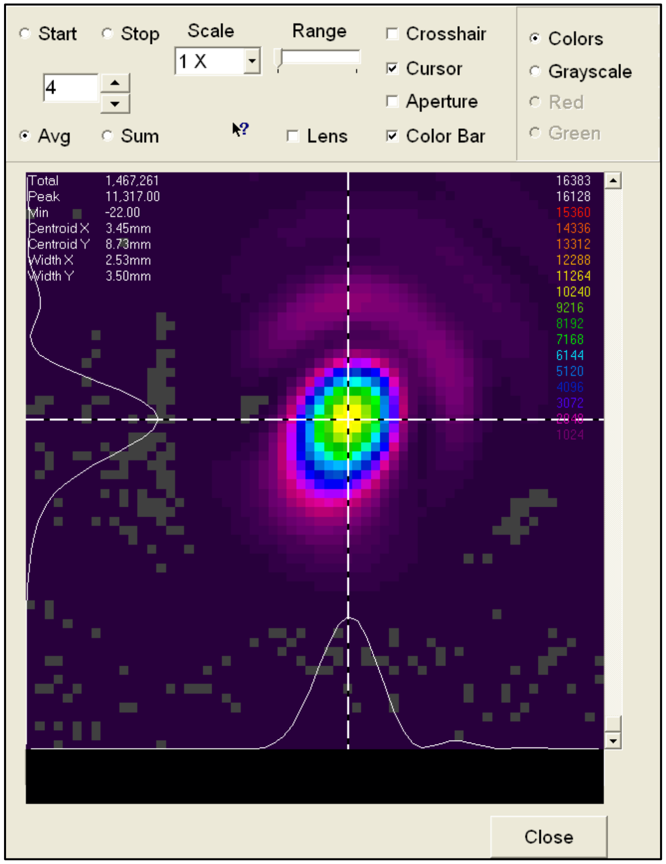




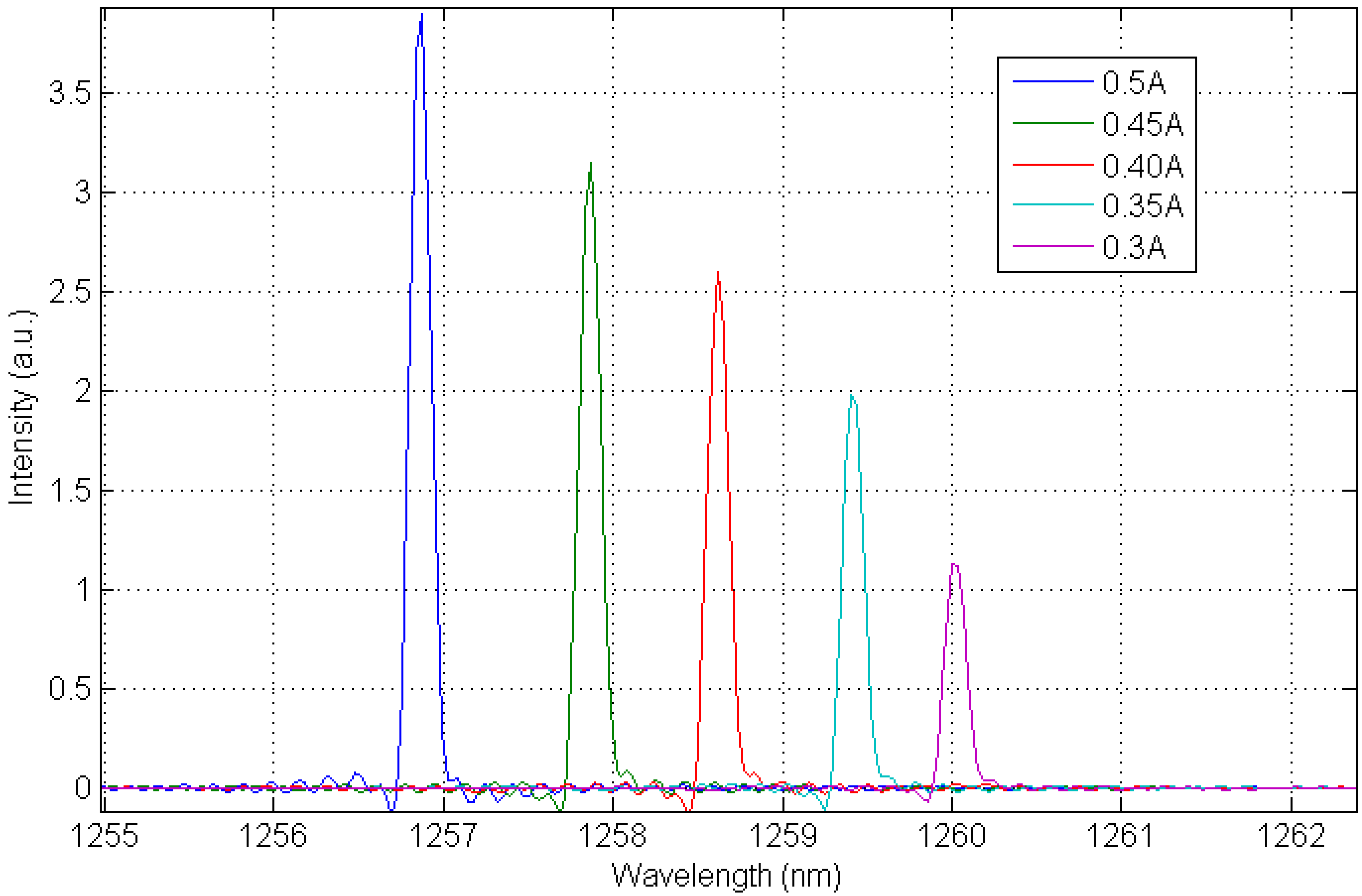
QCL Beam Profiling with IR Camera

Spiricon
Pyrocam III

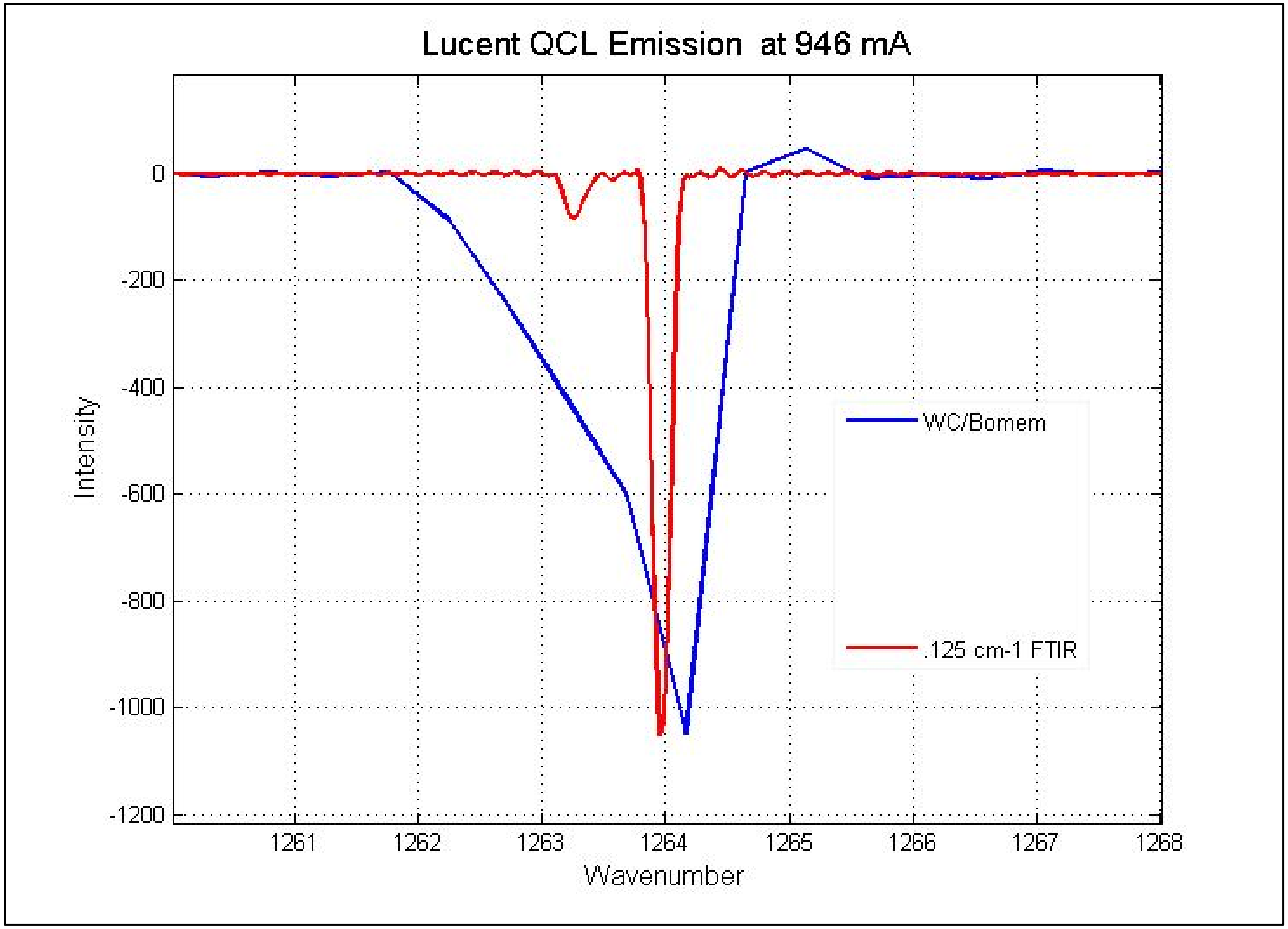
- 124 x124 Pyro Array (Uncooled)
- P > 1 mW
- Real Time Beam Adjustments
- Software for characterizing beam properties



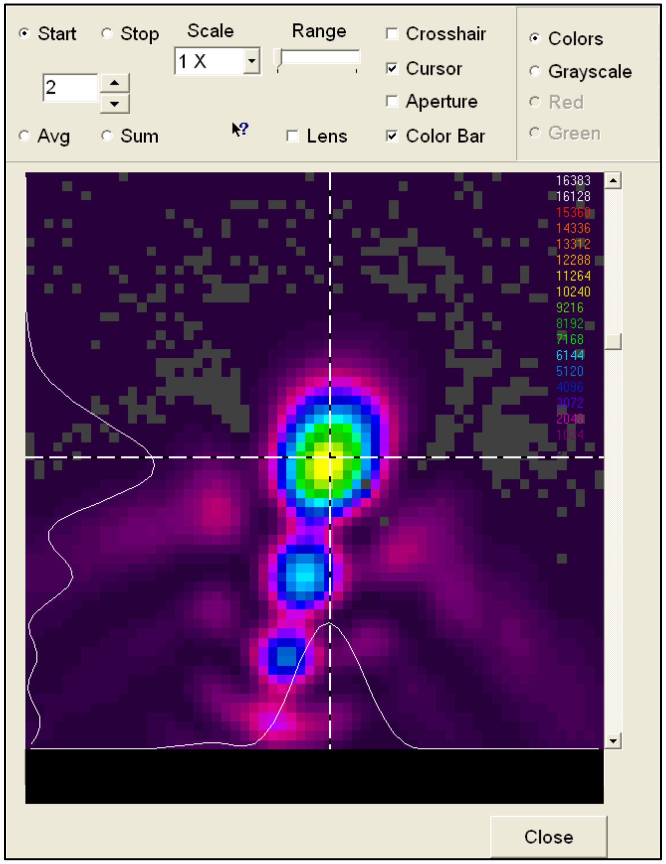
QCL Spectral Characterization at 0.125 cm^{-1} Resolution (ensure single mode performance)

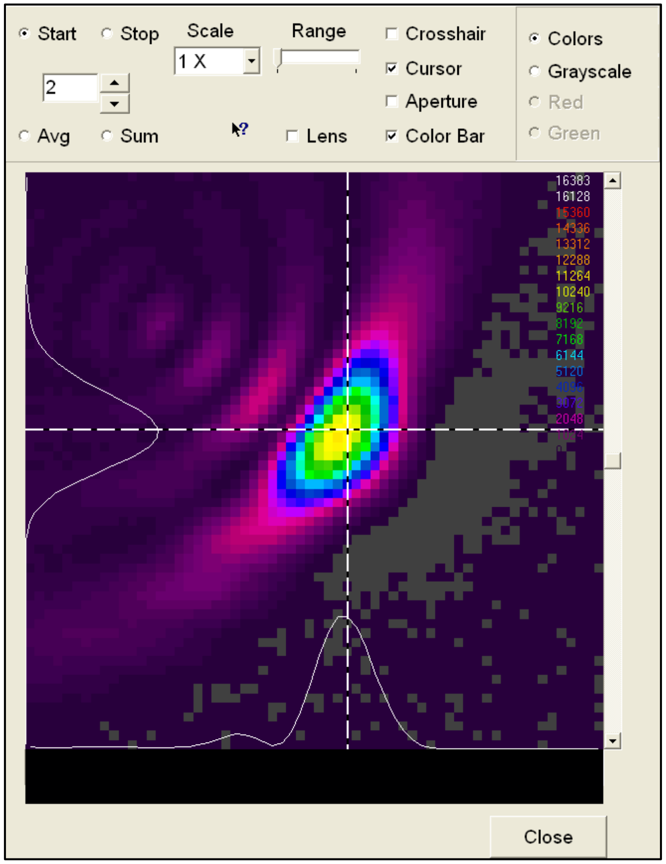


QC Spectral Characterization

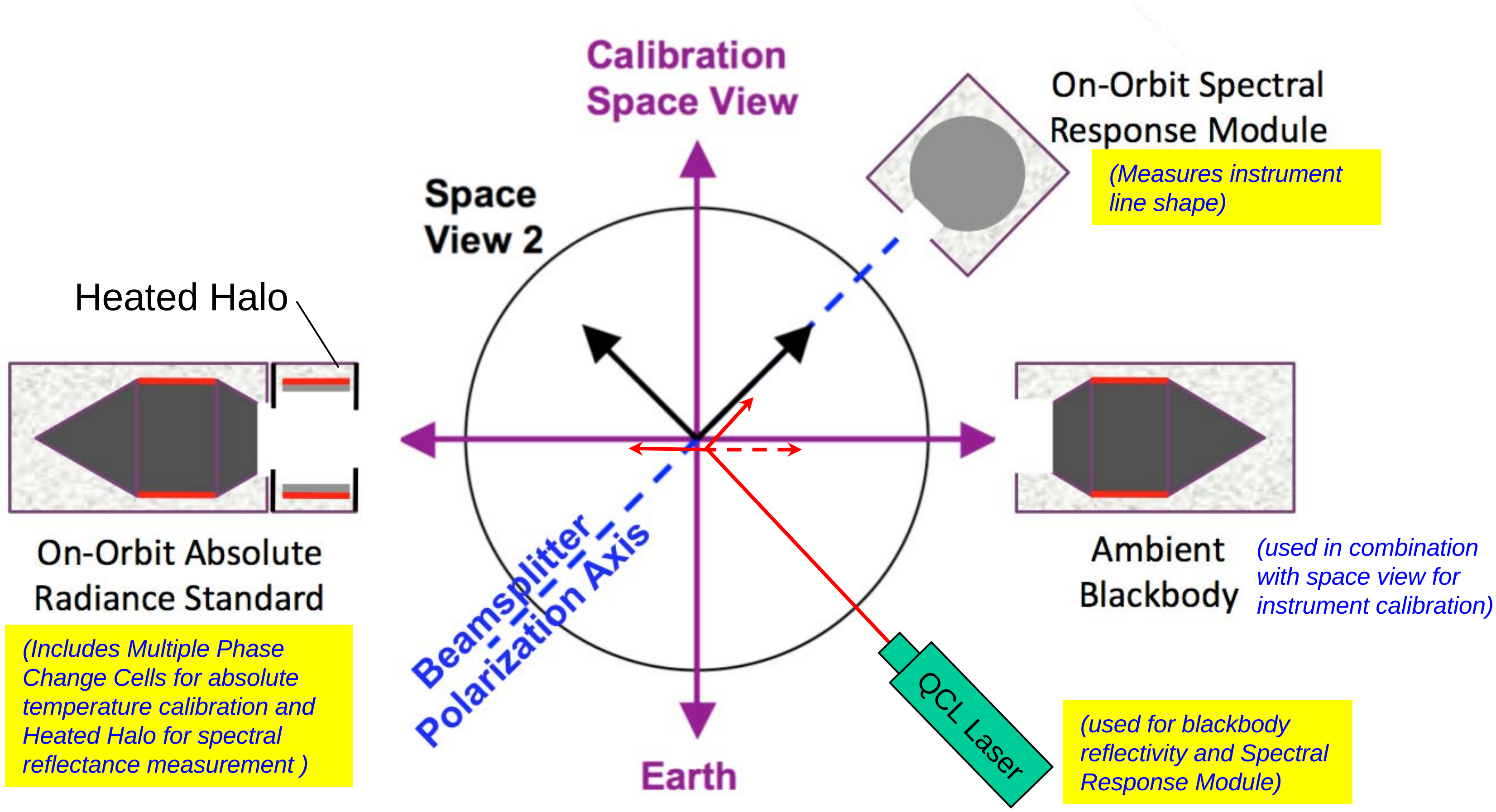


QC Beam Profiling (Alpes Laser)





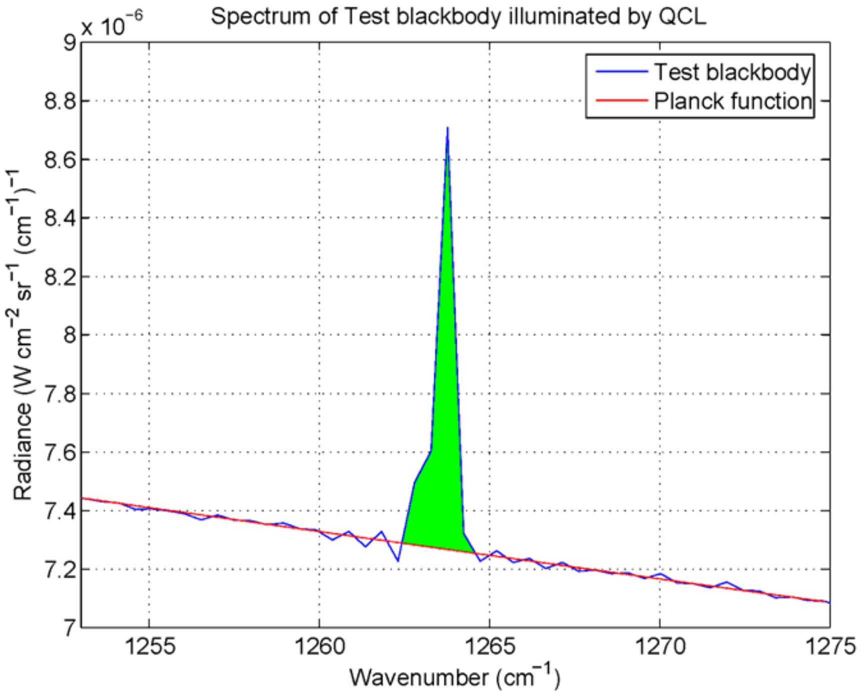
On-orbit Emissivity Testing

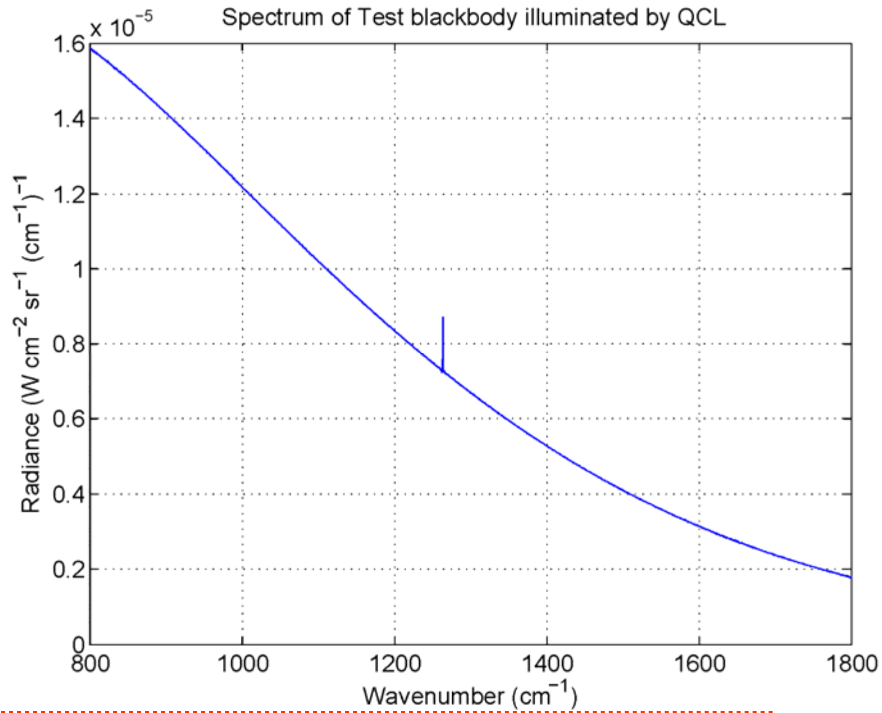


Viewing configuration providing immunity to polarization effects.

Proof-of-concept study for laser reflectometer

- Verified reflectance signal is accurately quantifiable with spectrometer.





> ➢ Prototype experimental duration : 30 minute integration for reflectometer

Robust estimate of laser power is critical

- Evaluated uncertainty budget (from P. J. Gero *et al.*, in press, *J.TECH.*, 2009)

Component	Value	Unit
Test blackbody		
Length	91.4	mm
Aperture diameter	38.1	mm
Aperture area	11.4	cm^2
Aperture solid angle	2π	sr
Measured surface reflectivity at 1264 cm^{-1}	0.031	
Modeled cavity reflectivity at 1264 cm^{-1}	4.5×10^{-4}	
Incident laser power		
Mean	3.84×10^{-2}	W
Mean random uncertainty	1.7×10^{-4}	W
Systematic uncertainty	3.8×10^{-3}	W
Reflected laser power		
Mean	3.54×10^{-5}	W
Spectral noise random uncertainty	6.0×10^{-7}	W
Spectral scale random uncertainty	3.4×10^{-6}	W
Positional dependence	-3.6×10^{-6}	W mm^{-1}
Laser reflectivity		
Mean	9.22×10^{-4}	
Mean random uncertainty	8.9×10^{-5}	
Positional dependence	-9.5×10^{-5}	mm^{-1}

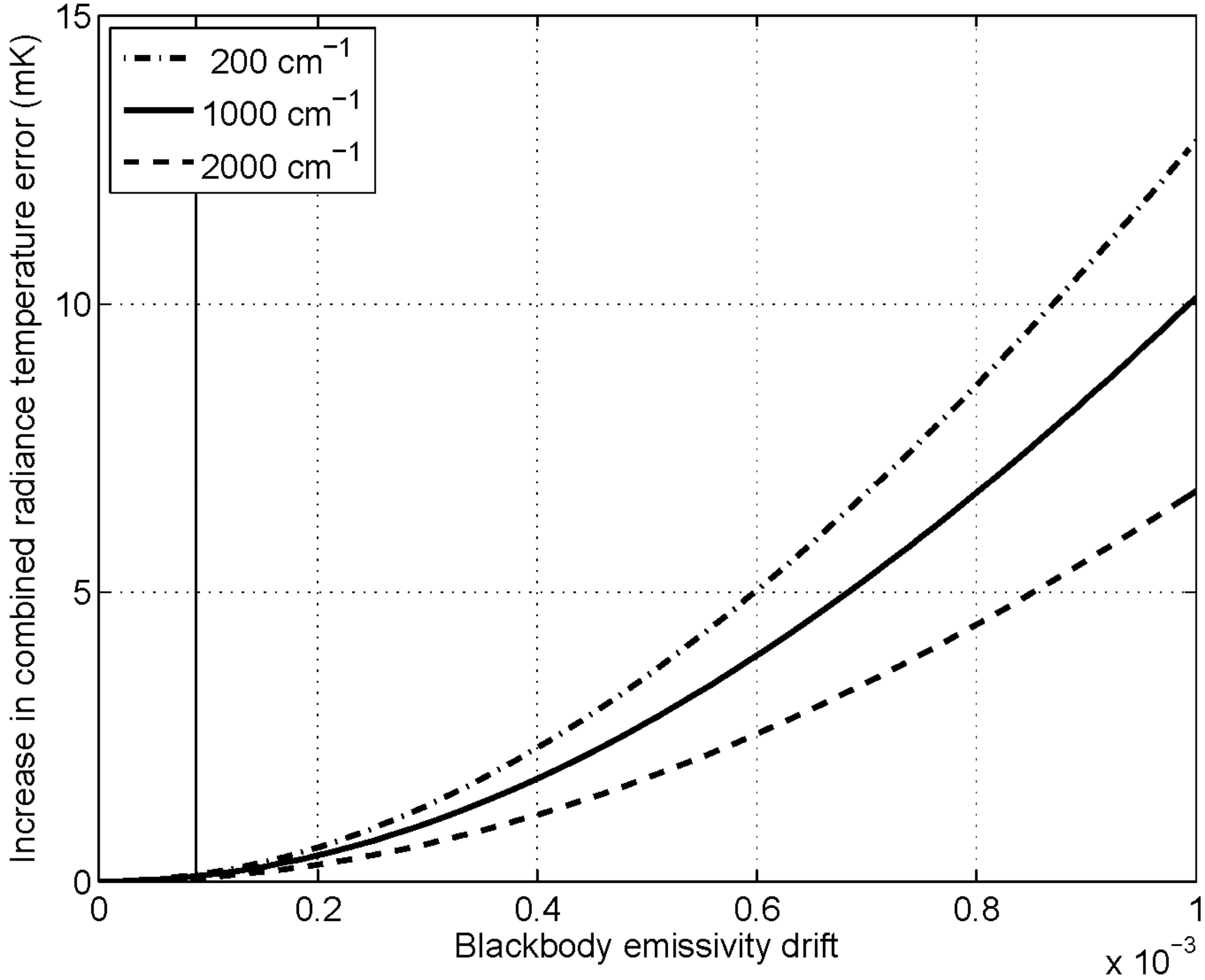
Uncertainty in laser power

Noise in spectrum

Blackbody emissivit
y

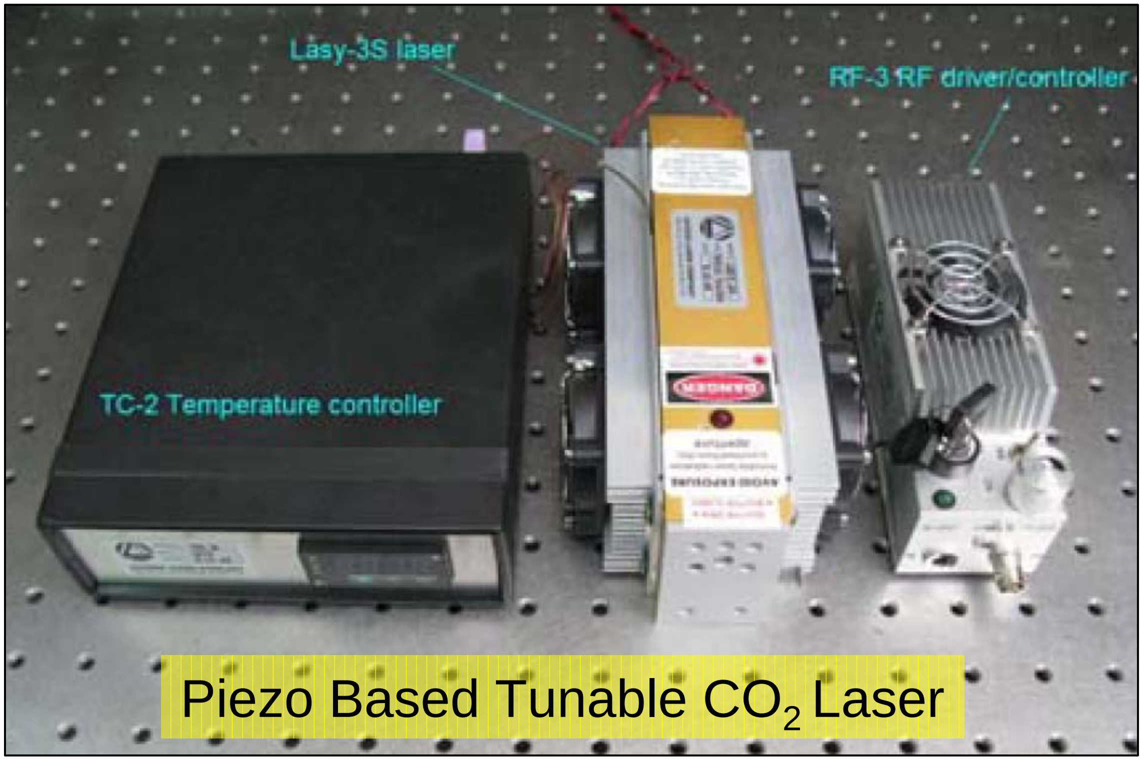
Laser reflectometer puts strong constraints on emissivity

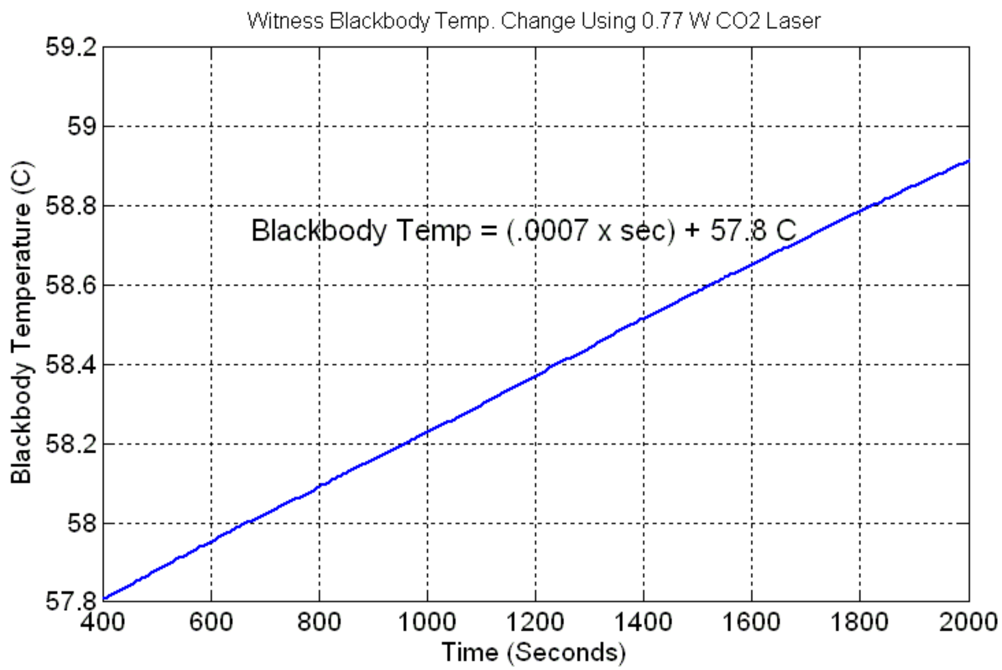
contribution to total uncertainty



- Impact on system level uncertainty due to uncertainty in ambient calibration blackbody emissivity as found by laser reflectometry

Tunable CO_2 Laser as Second Mid-IR Source





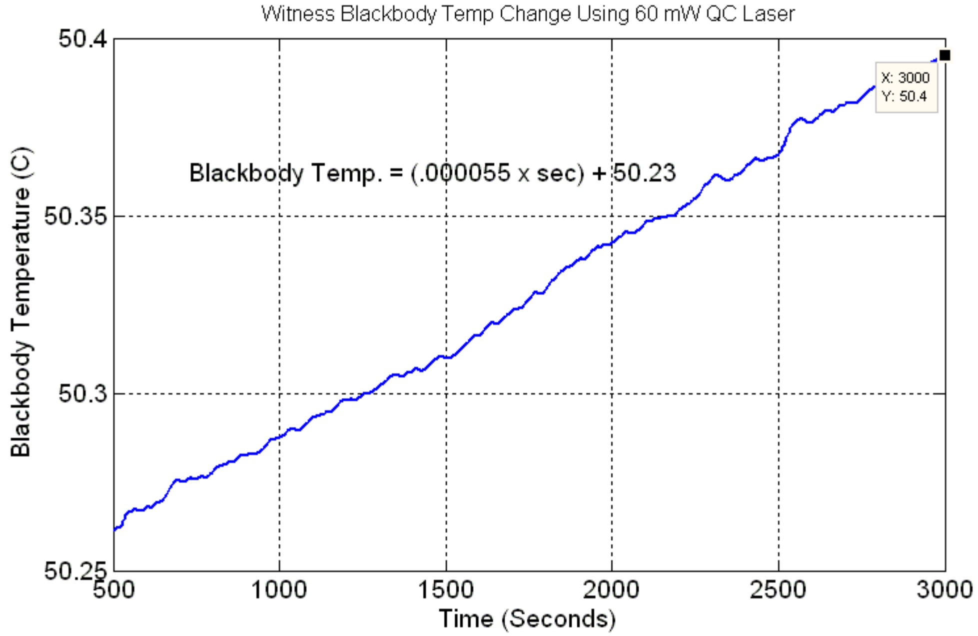
$$(1)\quad C\left(\frac{dT}{dt}\right)^{Cavity} = \varepsilon P^{QC} \Longrightarrow \quad C = 1241g \times .900\frac{J}{g}$$

$$\varepsilon = .9999925$$

$$(2)\quad \int_{\Delta\upsilon} d\Omega\, dA\, I_\upsilon\, d\upsilon = \varepsilon B_\upsilon T^{Cavity} + (1-\varepsilon)P^{QC} \qquad P^{QC} = 0.77W$$

$$\Rightarrow Strategy: Measure\ I_v\ and\ \frac{dT}{dt} \qquad \left(\frac{dT}{dt}\right)^{Cavity} = \frac{\varepsilon P^{QC}}{C} = 6.87\times10^{-4}\,\frac{K}{\sec}$$

$$Evaluate\ P^{QC} and\ \varepsilon\ On-Orbit$$



$$(1)\quad C\left(\frac{dT}{dt}\right)^{Cavity} = \varepsilon P^{QC} \Longrightarrow C = 1241g \times .900\frac{J}{g}$$

$$\varepsilon = .9999925$$

$$(2)\quad \int_{\Delta\upsilon} d\Omega\, dA\, I_{\upsilon}\, d\upsilon = \varepsilon B_{\upsilon} T^{Cavity} + (1-\varepsilon)P^{QC} \qquad P^{QC} = 0.058W$$

$$\Rightarrow Strategy: Measure\ I_{v}\ and\ \frac{dT}{dt} \qquad \left(\frac{dT}{dt}\right)^{Cavity} = \frac{\varepsilon P^{QC}}{C} = 5.58\times 10^{-5}\,\frac{K}{\sec}$$

$$Evaluate\ P^{QC} and\ \varepsilon\ \ On-Orbit$$

Future Work

- Monte Carlo modeling to confirm relationship between directional-hemispheric and hemispheric-directional emissivity
- Spectral ILS calibration
- Calibration demonstration with CLARREO breadboard
- Round robin experiments