



Thermal balance test of Solar Orbiter EUI instrument Structural and Thermal Model with 13 Solar constants

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Outline



- **What we do at CSL?**
- **Solar Orbiter**
- **EUI**
- **Test setup presentation**
- **Test results**
- **Test correlation**
- **Conclusions**



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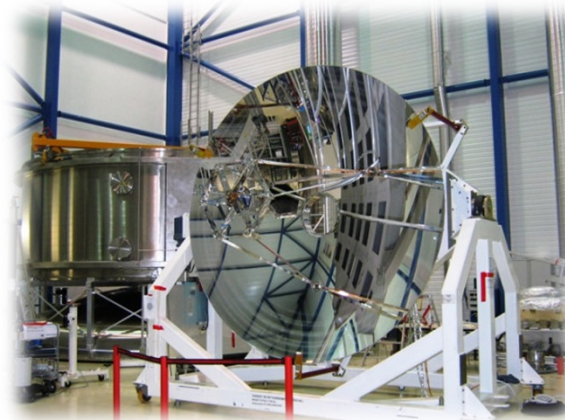
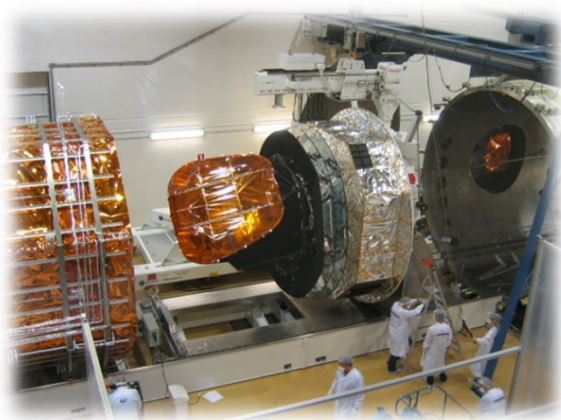
Space Center in Liège, Belgium



University of Liège Research Center (since 1959)

Test facility for ESA:

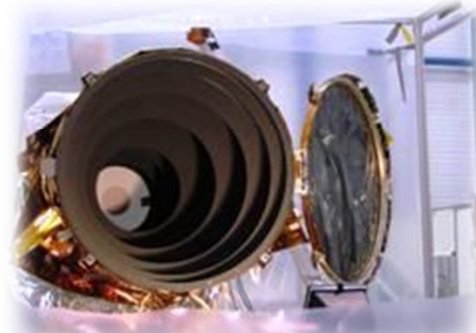
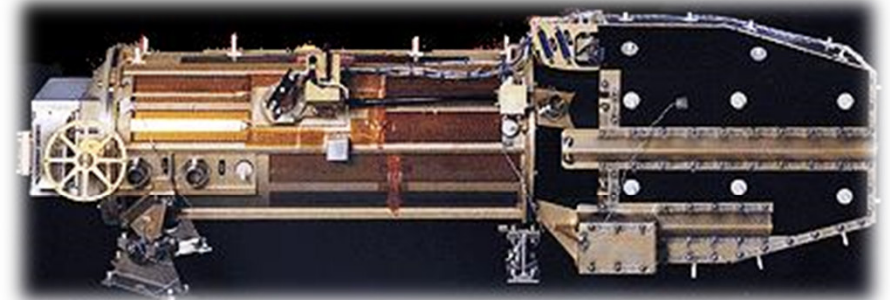
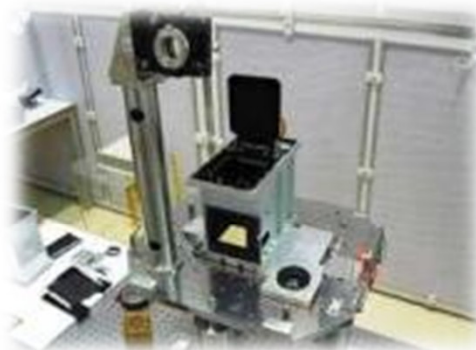
- Class 10000 & class 100 cleanrooms
- 5 Vacuum chambers with optical bench (1.5 to 6.5m Ø)
- 2 shakers in cleanroom (also cryo-vib)
- Planck S/C, Herschel mirror, GAIA (PLM), XMM telescope,...



Space instruments developed at CSL



EIT (SOHO), OM (XMM), FUV/SI (IMAGE), Sun baffle (CoRoT), HI (STEREO), PACS grating & DEC/MEC (Herschel), MIRI (JWST), UVS SMA (JUNO), SWAP & LYRA (PROBA-2), **EUI (Solar Orbiter)**, ASPCIIS (PROBA-3),...

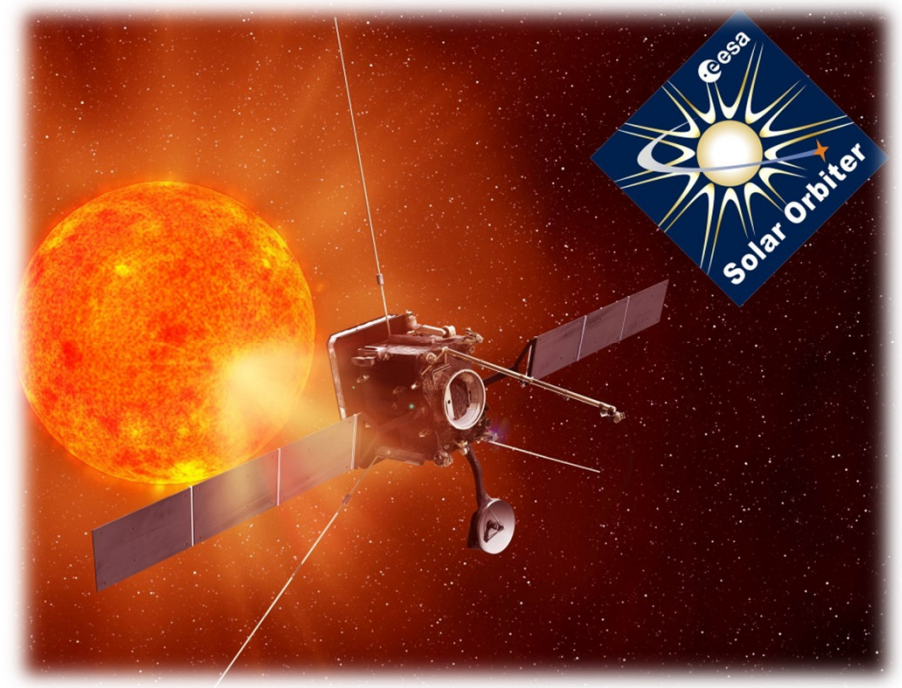


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Solar Orbiter key figures



- **ESA M-Class mission**
- **S/C currently in CDR**
- **Oct-2018 launch**
- **0.28AU perihelion (17.5kW/m²), 1.47AU aphelion**
- **6 remote sensing instruments**
- **4 in-situ instruments**
- **~1800kg S/C (~190kg payload)**
- **~1kW**
- **400mm thick heat shield**

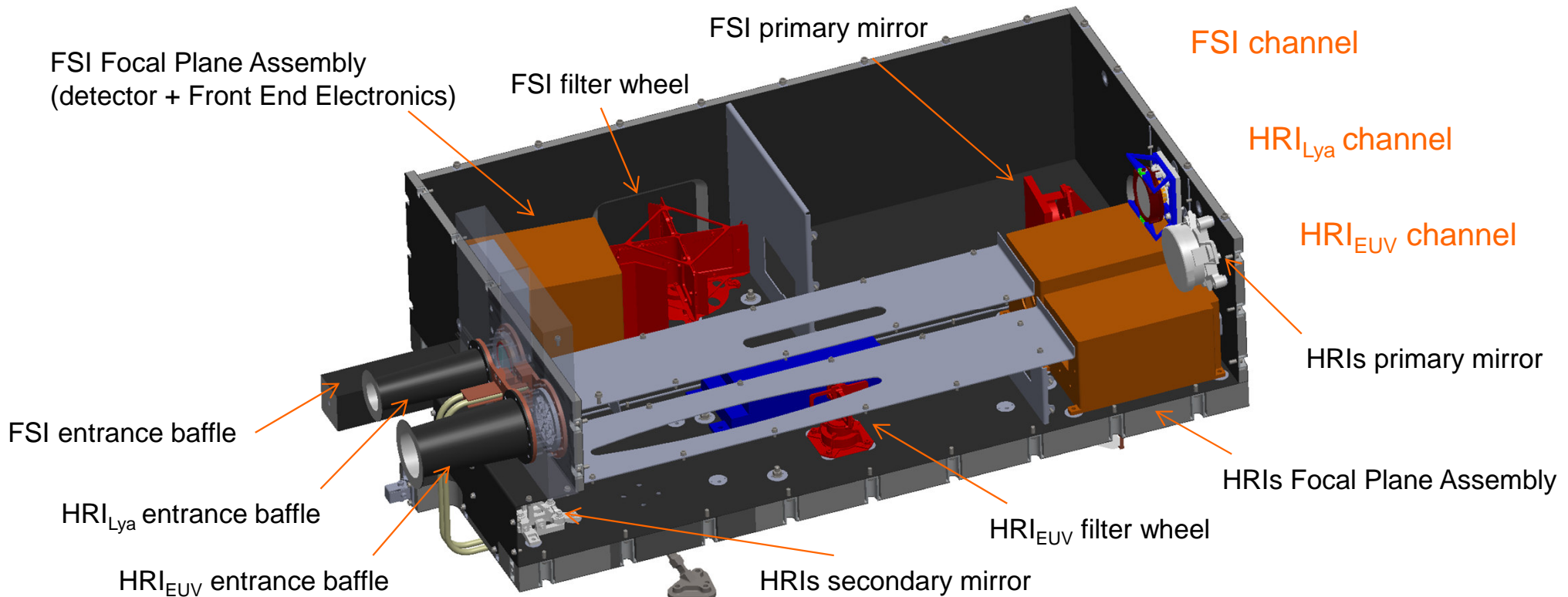


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The Extreme-Ultraviolet Imager



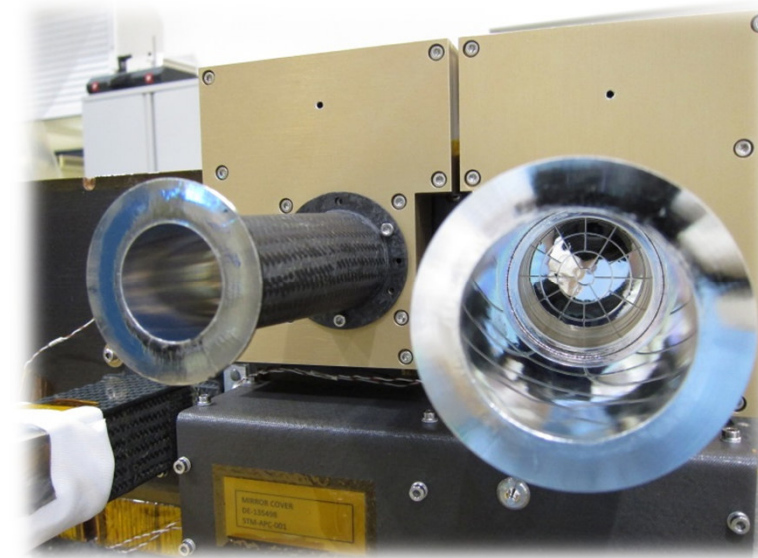
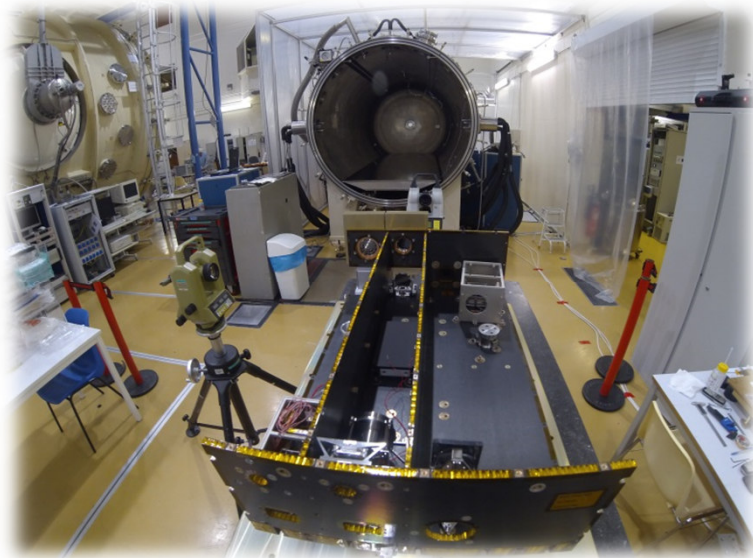
- Remote sensing instrument with 3 channels
- 2 High Resolution Imagers (100km resol.)
 - $\text{HRI}_{\text{Ly}\alpha}$ at Lyman- α line (1216Å)
 - HRI_{EUV} at 174Å
- 1 dual-band Full Sun Imager at 174Å and 304Å (900km resol.)



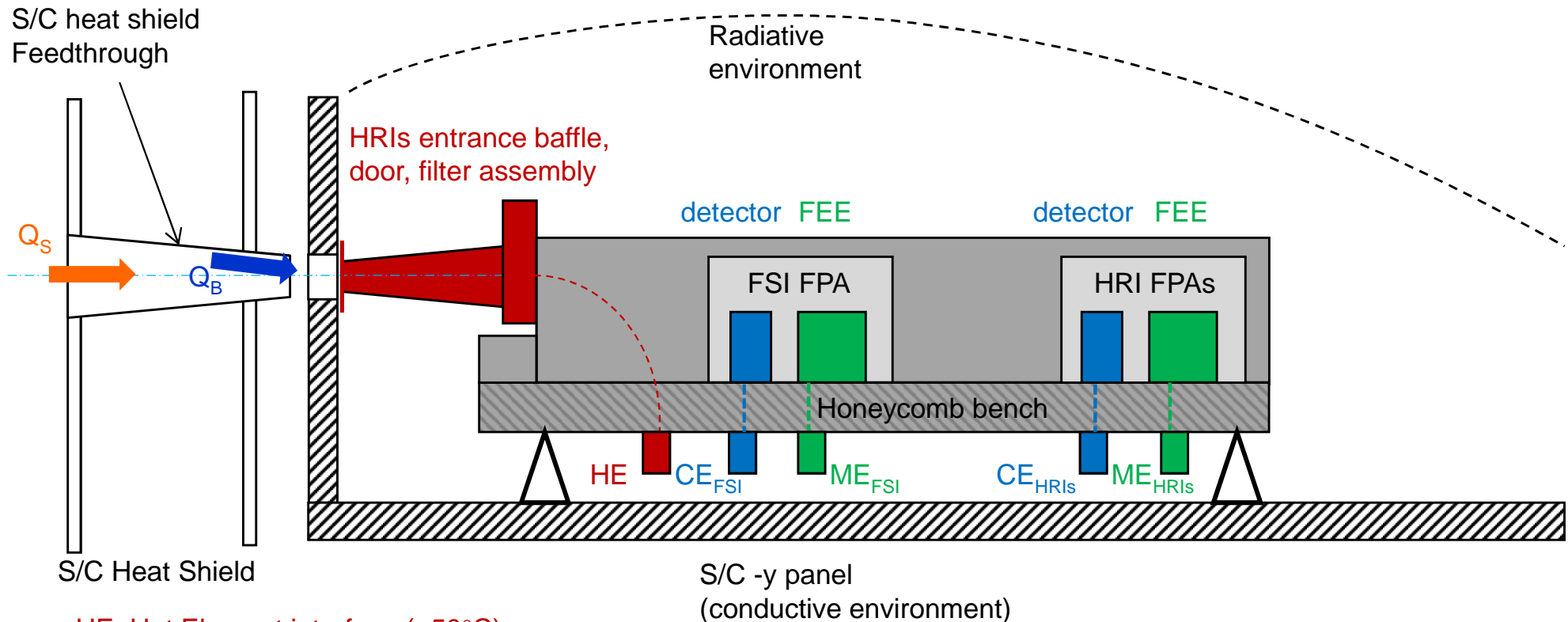
EUI in a nutshell



- 860 x 450 x 360 mm, ~15kg, 28W
- CFRP-Alu honeycomb-CFRP sandwich structure
- Ultrathin HRI_{EUV} & FSI entrance filters (150nm thick Al.)
- MgF_2 coated $\text{HRI}_{\text{Ly}\alpha}$ entrance filter
- Al. coated CFRP entrance baffles
- Heat-pipes to cool down entrance filters, baffles and doors
- -40°C cooled detectors (Al. Nitride package)



S/C thermal interfaces



HE: Hot Element interface (+50°C)

CE: Cold Element Interface (-50°C)

ME: Medium Element Interface (+20°C)

Q_B : IR load from S/C heat shield feedthroughs at ~300°C

Q_S : Solar heat flux (17.5kW/m² at 0.28AU)

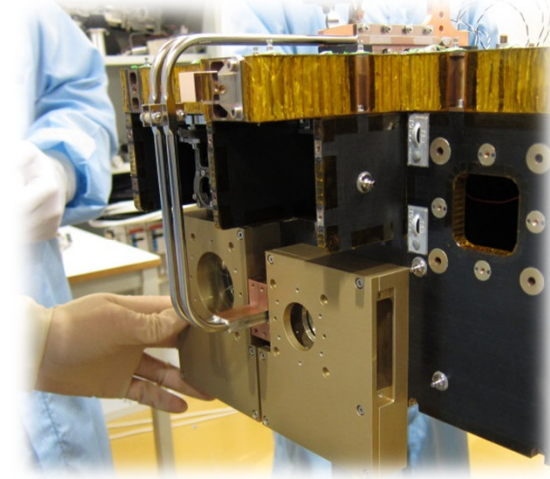
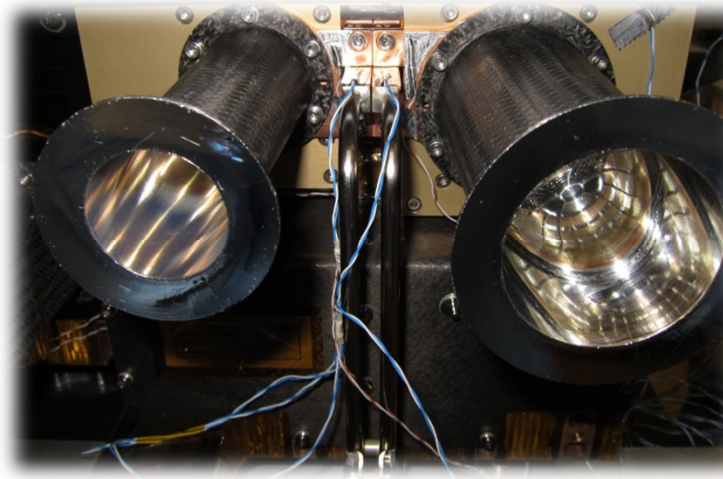
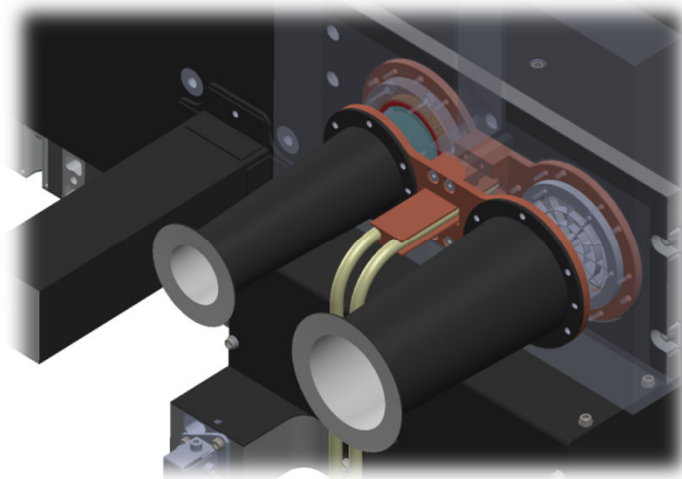
T_R : S/C cavity radiative environment (+50°C)

T_{SRP} : S/C conductive environment (+50°C)

HRIs heat pipes



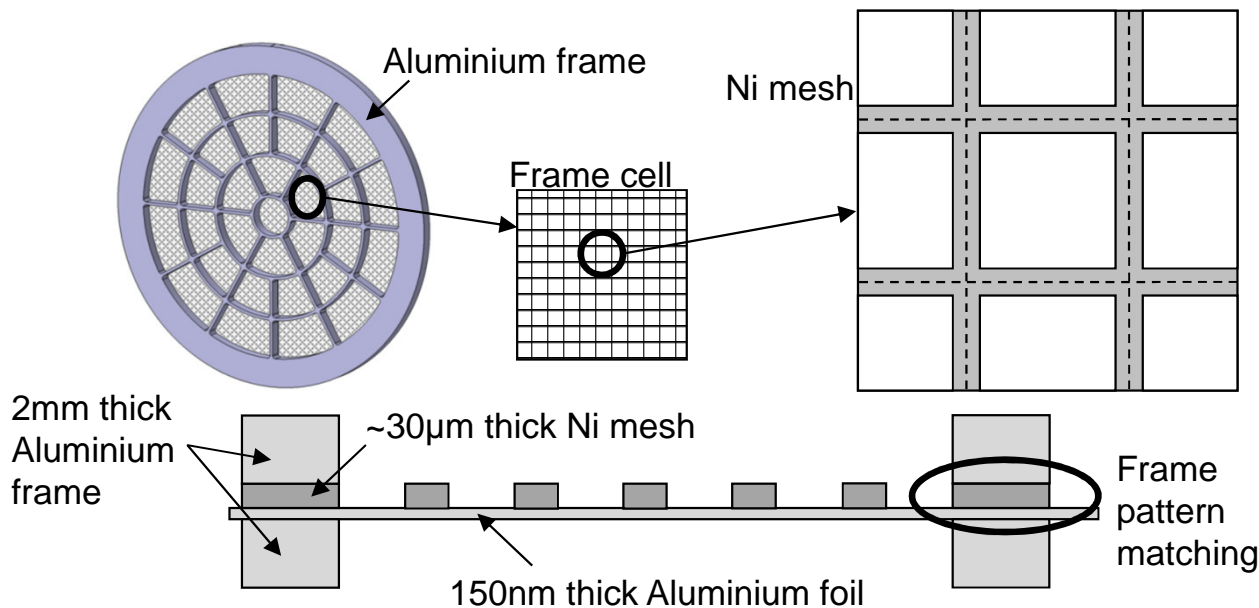
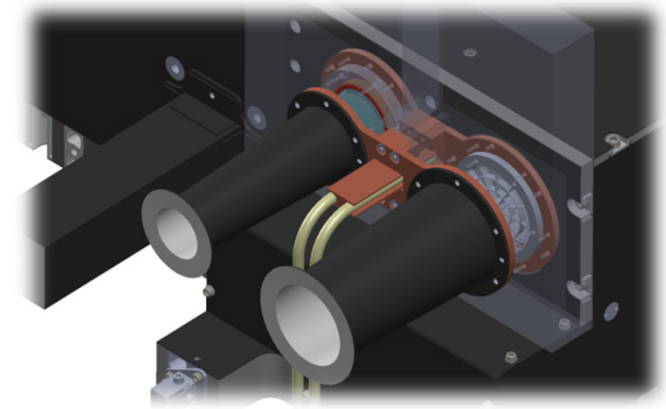
- **Conducts heat from HRIs filters, baffles & doors to HE**
- **Two redundant heat-pipes**
- **Al-NH₃ heat pipes with H-shaped copper brazed interfaces**
- **Copper goggles connecting doors, baffles, filters to HP**
- **Instrument orientation in TB test (also at S/C level)**



Ultrathin HRI_{EUV} entrance filter



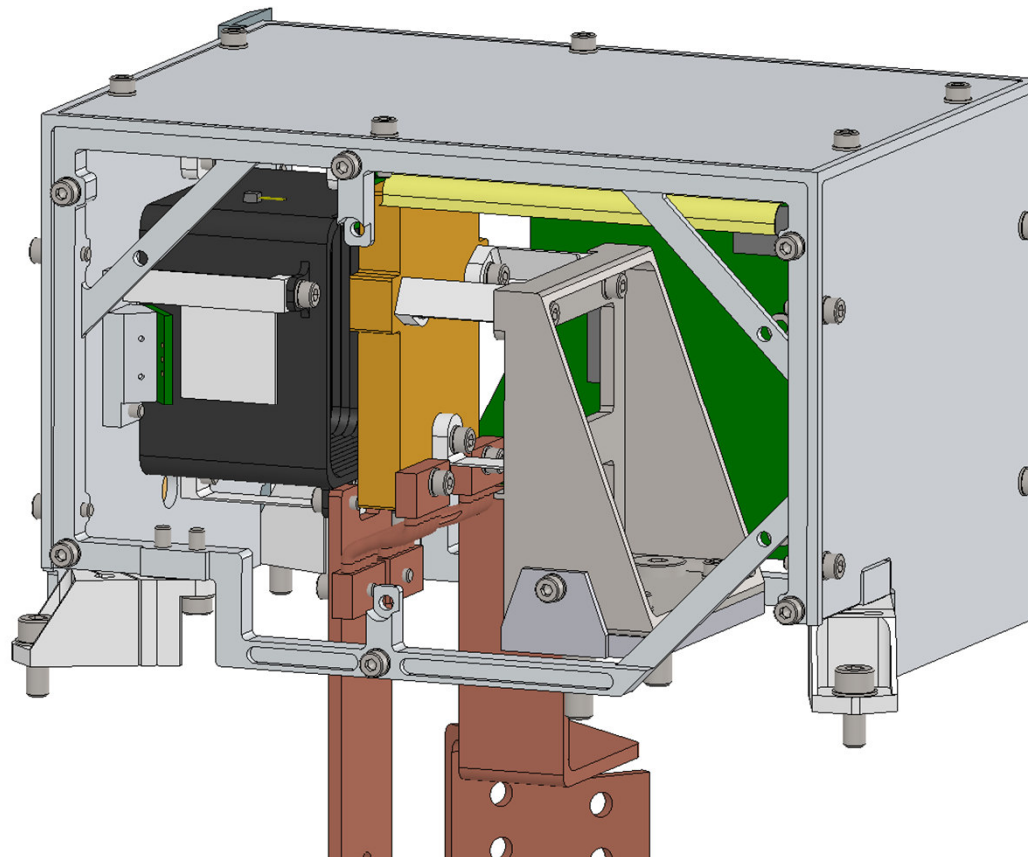
- 10⁸ rejection of visible part of Solar spectrum
- Twice reinforced for structural & thermal
 - Local Nickel mesh grown onto Al foil
 - Clamped between Al. frames



Detector & Focal Plane Assembly



- **3k x 3k Active Pixel Sensor (developed for EUI)**
- **Aluminum nitride package (T° uniformity + CTE matching)**
- **3 Ti blades support (0.4mm thick for thermal decoupling)**

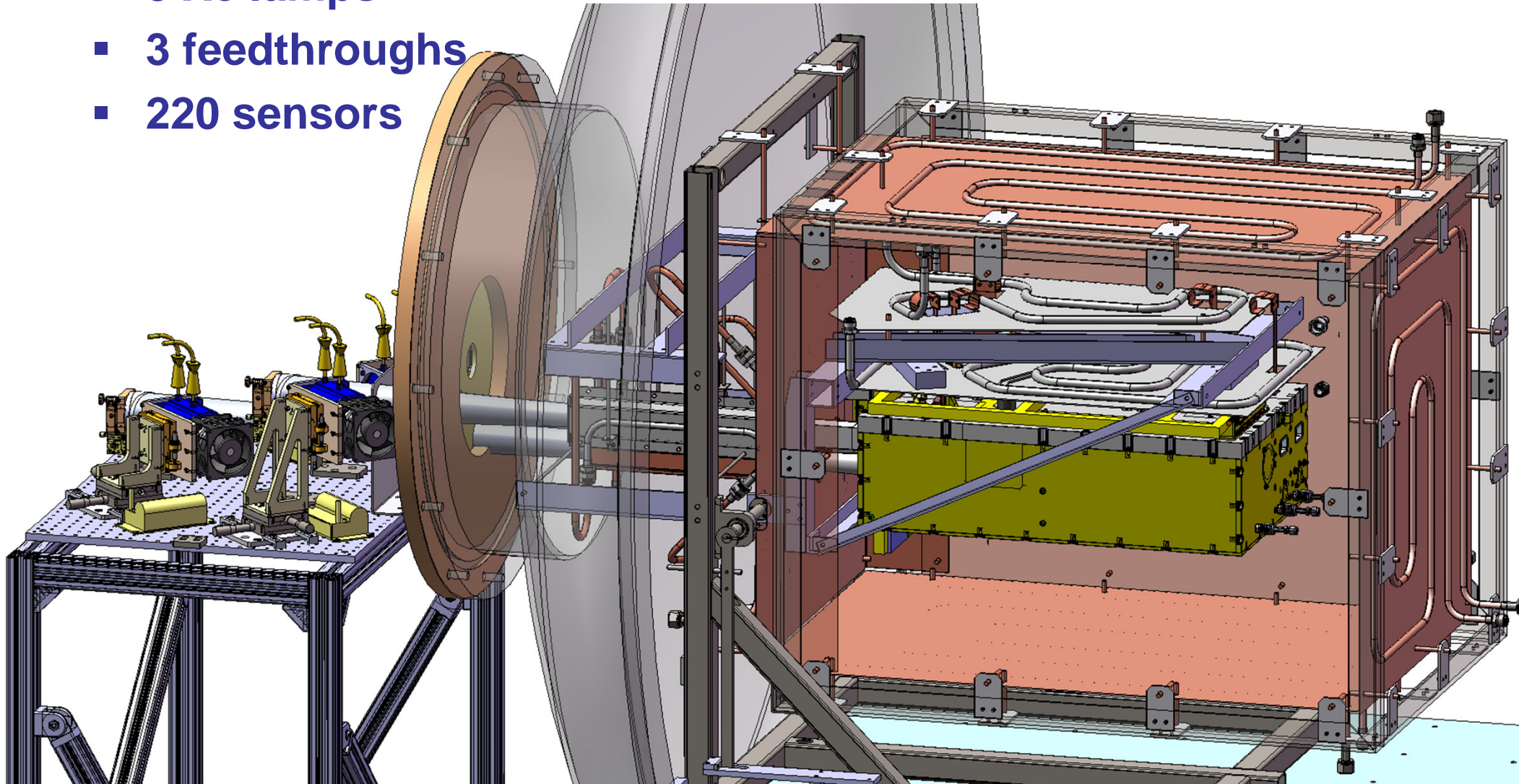


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Thermal balance test setup overview



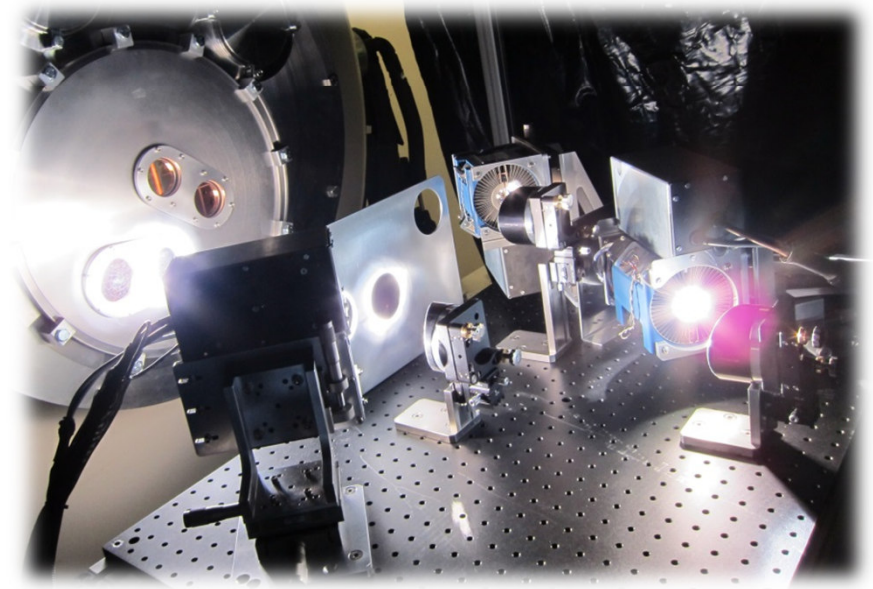
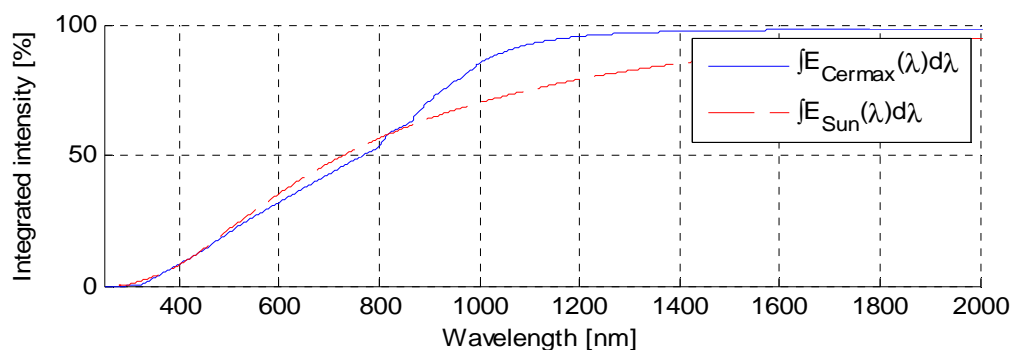
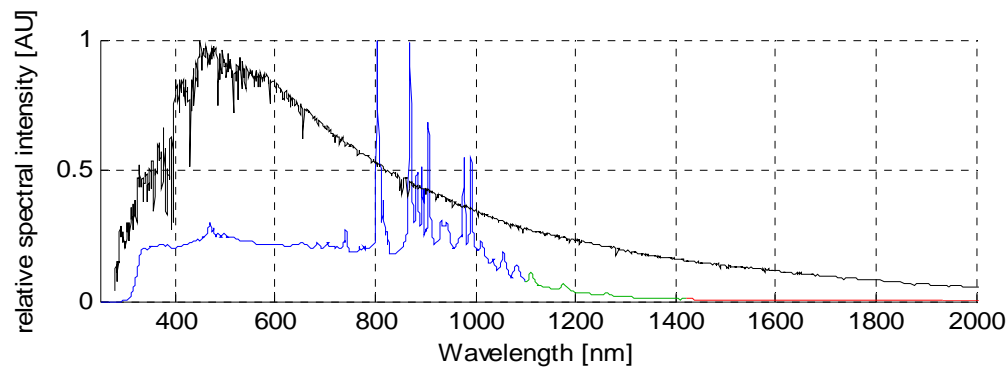
- Instrument STM upside-down
- 3 Xe lamps
- 3 feedthroughs
- 220 sensors



Illumination setup



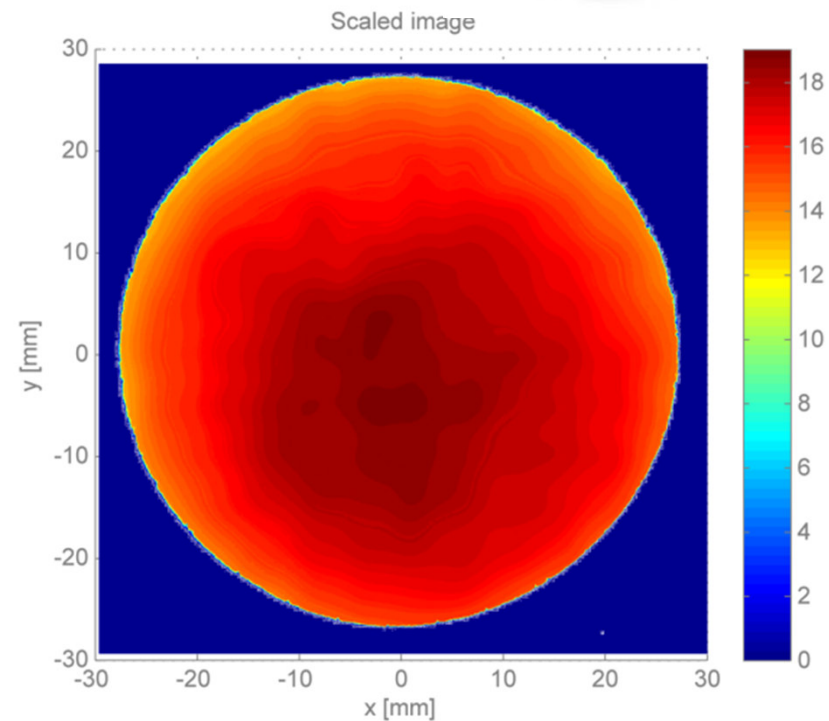
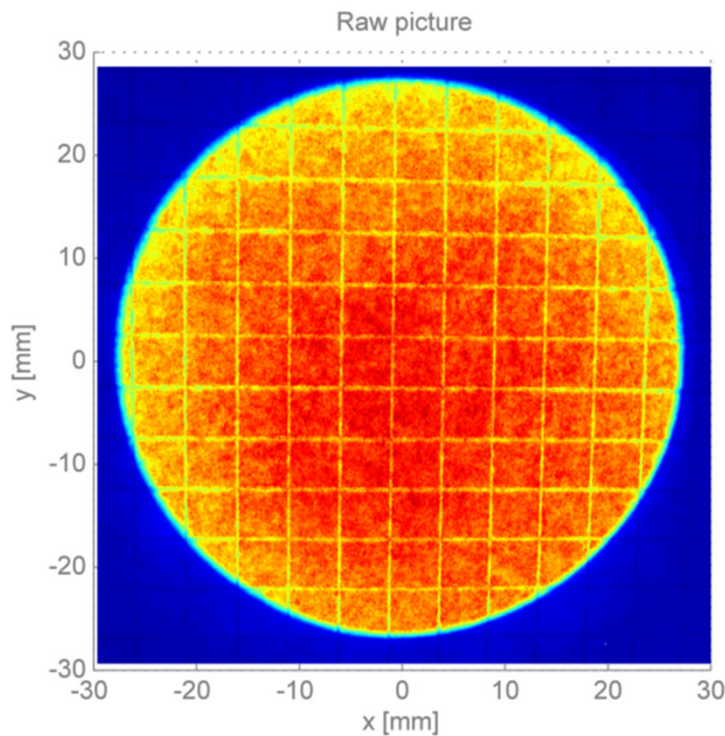
- 3 elliptical Cermax Xe arc-lamp + parabolic folding mirror
- Lamp spectrum + mirror spectral reflectivity
- Instrument coating absorptance adjusted



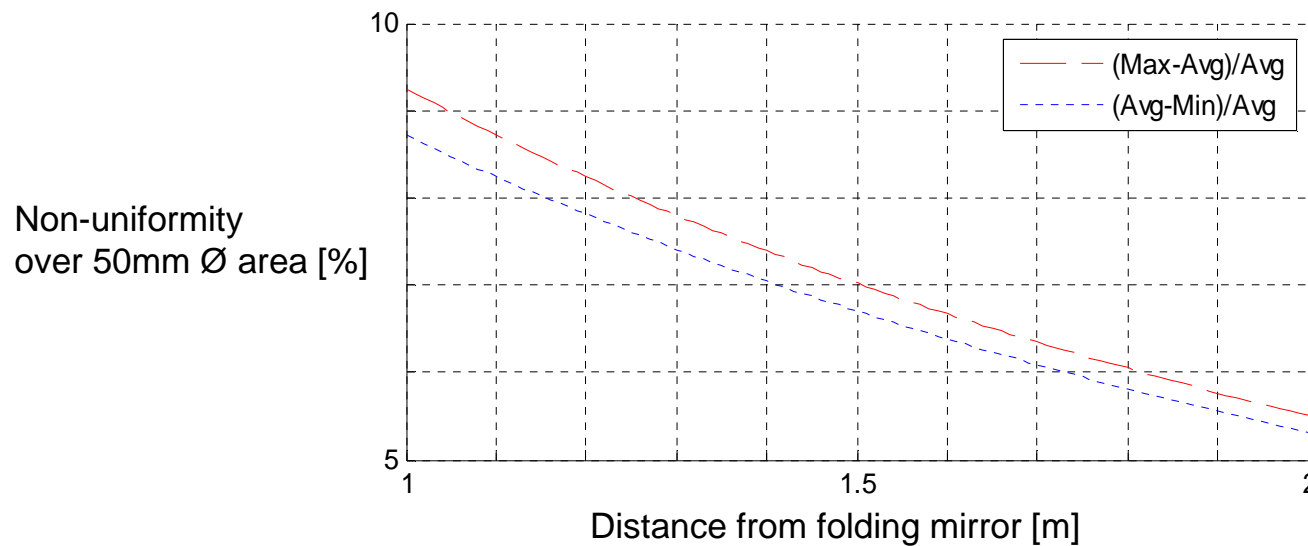
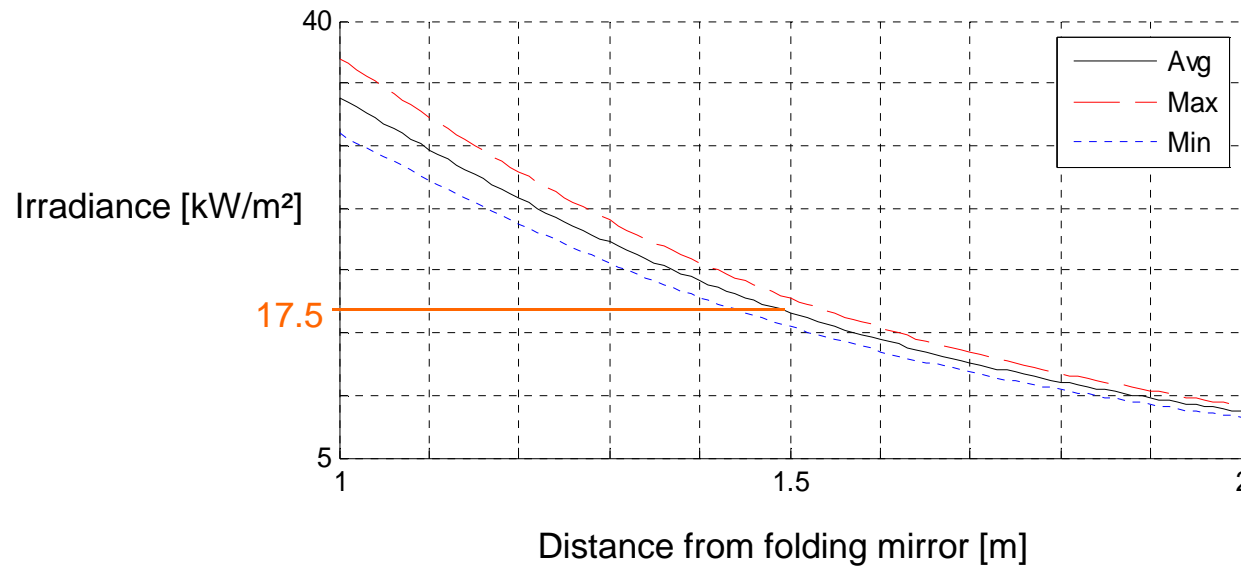
Illumination setup calibration



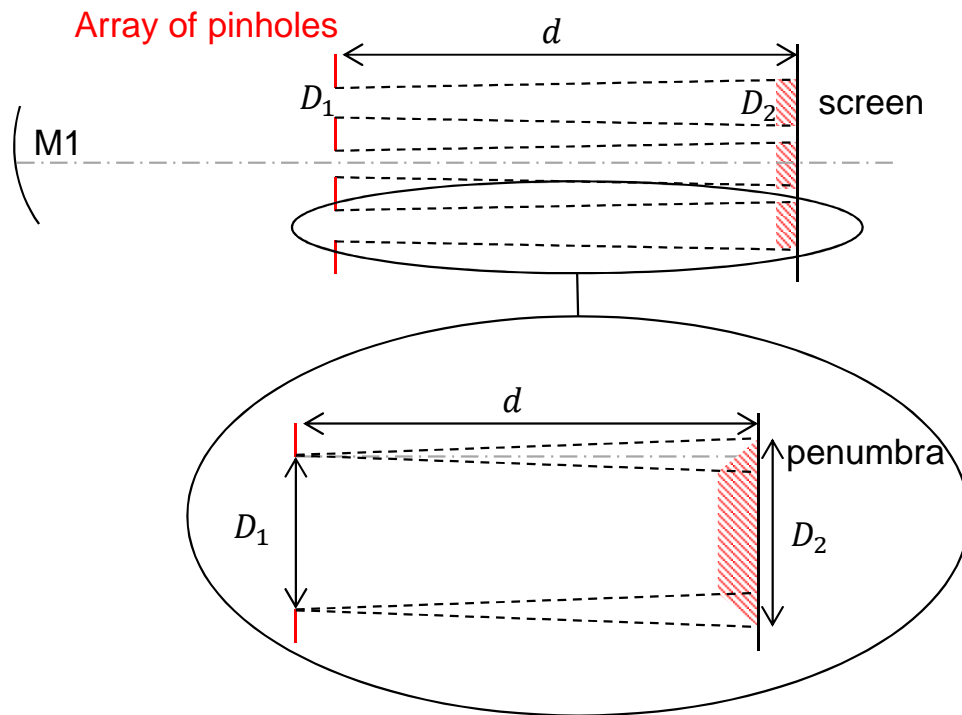
- Profile measured with picture & photodiode mapping
- Intensity measured with pyranometer



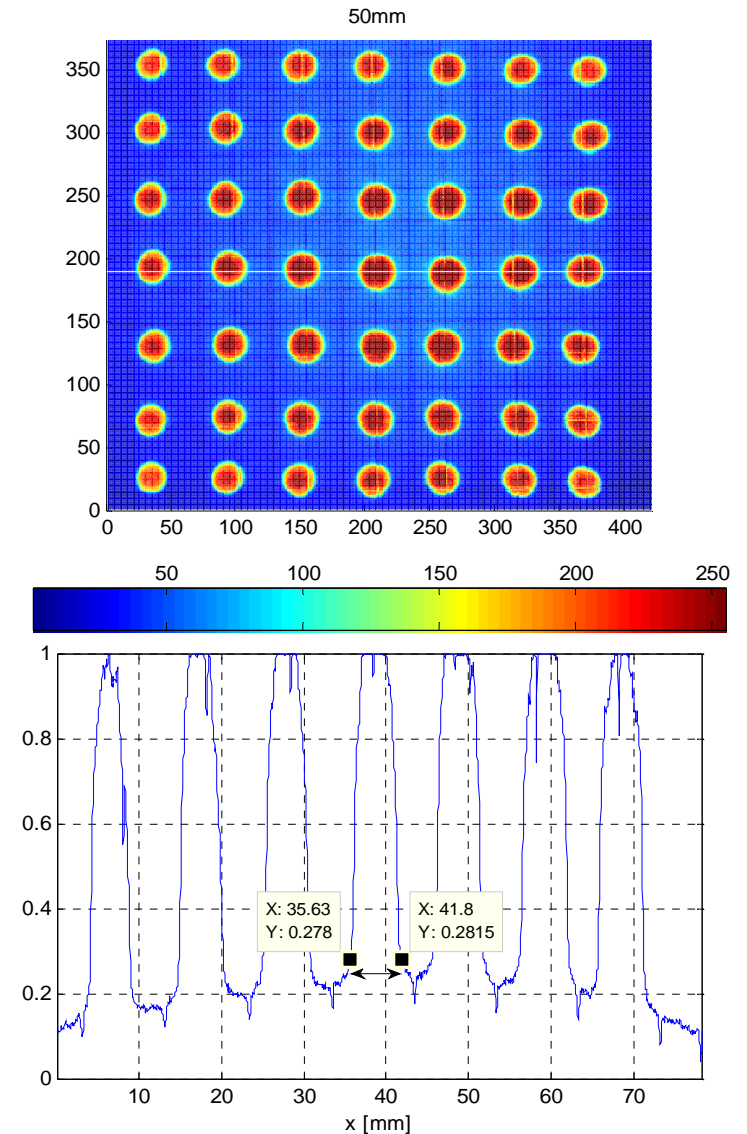
17.5kW/m² @ 1.5m



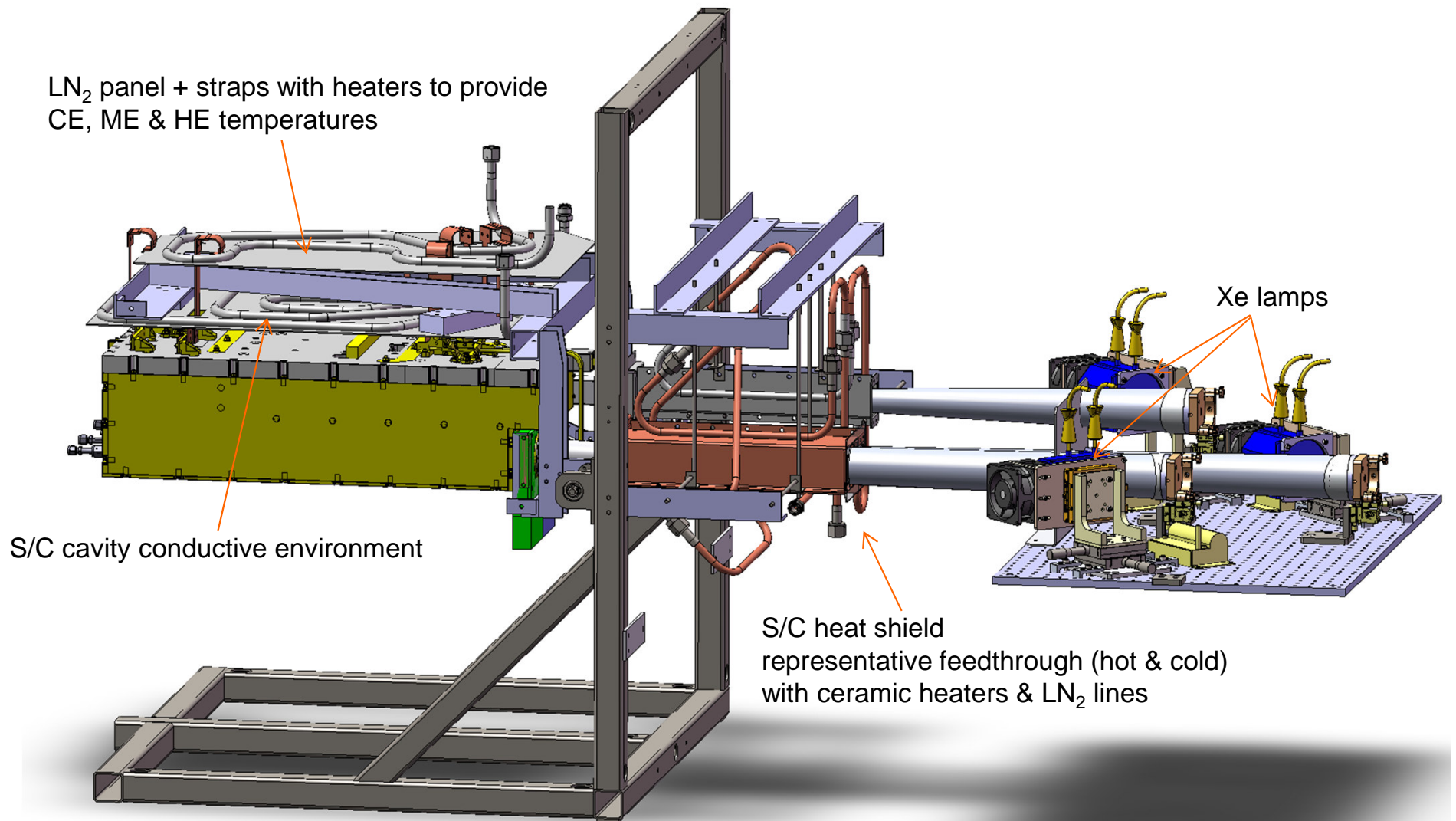
Divergence from pinhole spot size



$$\delta = \text{atan} \left(\frac{\Delta D}{2d} \right) = \text{atan} \left(\frac{D_2 - D_1}{2d} \right) = 1.4^{+0.3}_{-0.3} \text{deg}$$



Thermal IF setup

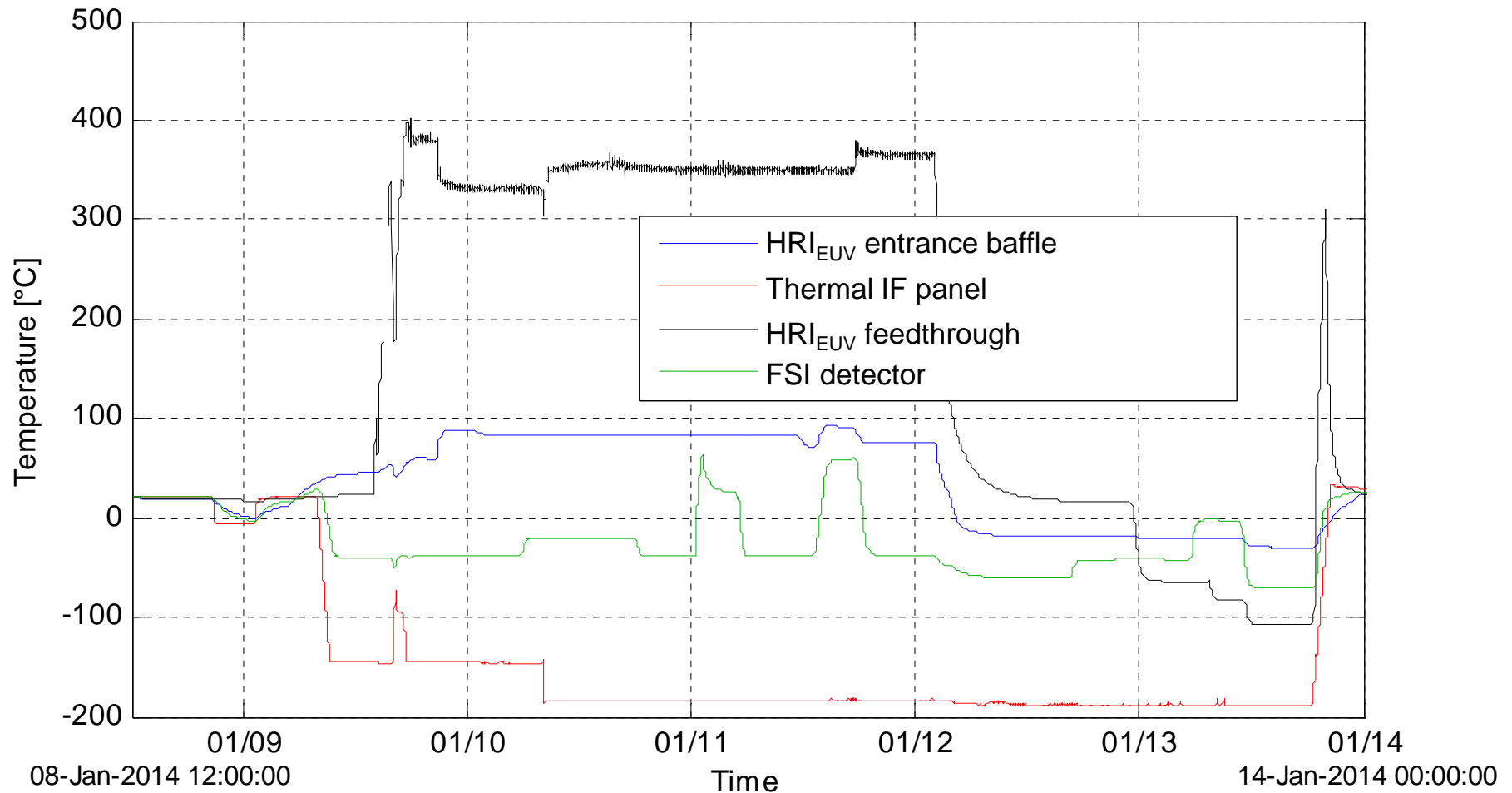


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Test sequence & results overview



close vacuum chamber and pumping	Start hot case - 1 Fuse broke up - 1 S/C Heater lost	Switch to LN2 on radiator and wait stabilization	- Hot NOP case - 3SC case - Start cold OP case	Back to ambient P and T
Thermal shroud PID tuning	Switch ON lamps to 17.5kW/m ²	- ≠ OP cases - Rotation of the instrument: Heat pipe stall	- ≠ OP cases - Start cold NOP case	

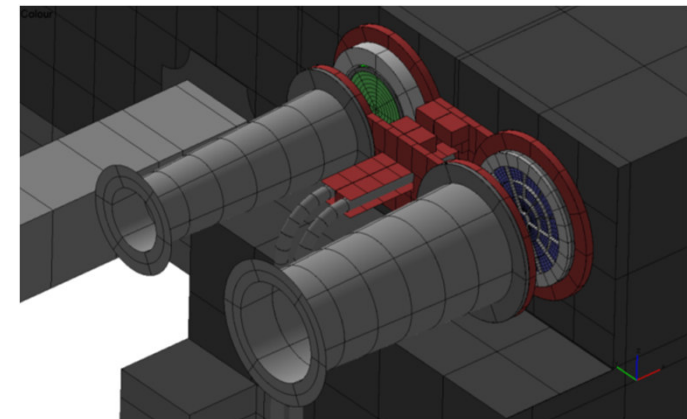
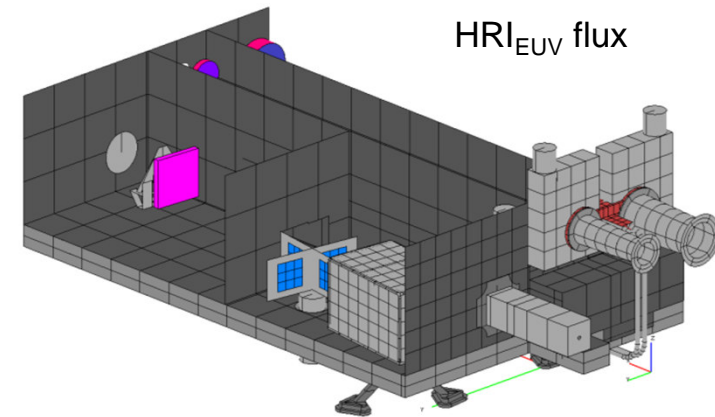
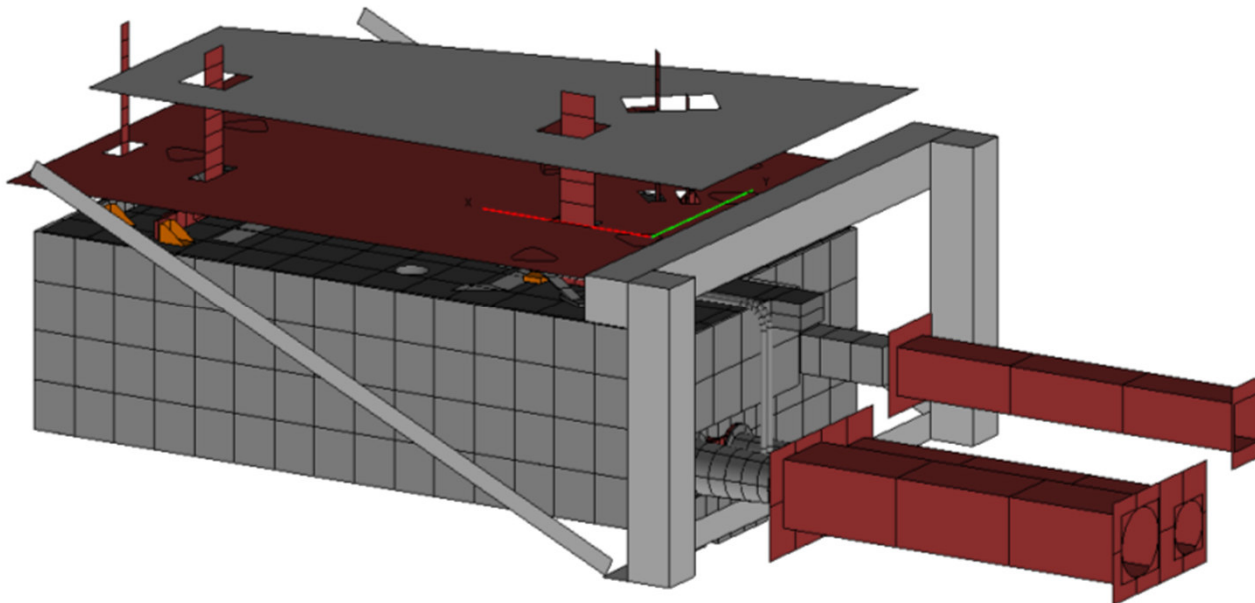
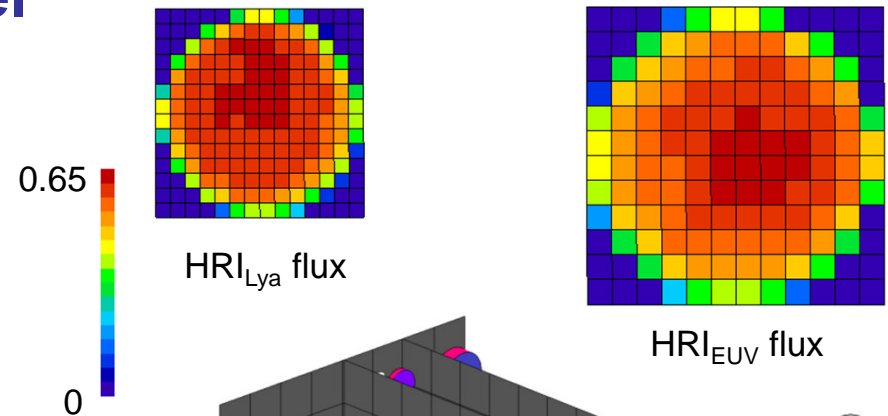
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Thermal model description



- Semi-transparent screen to model lamp flux non-uniformity
- Actual divergence
- Actual absorption
- 5219 nodes

Solar transmissivity



Thermal model correlation

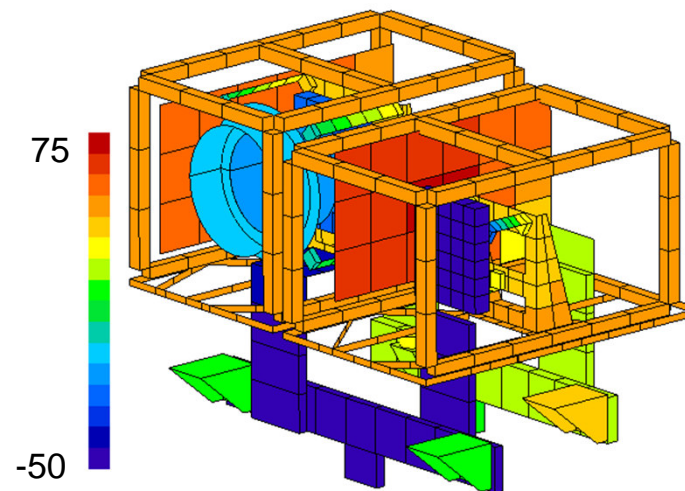
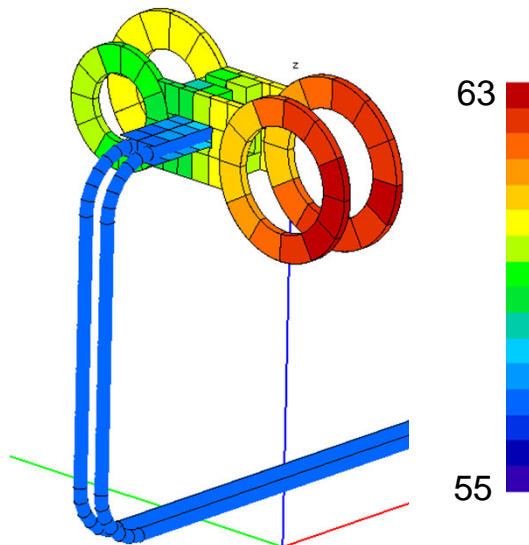
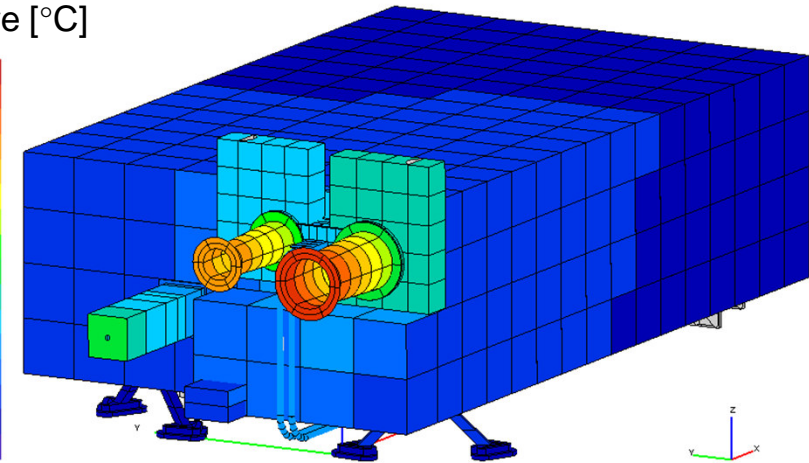


- RMS error (93 sensors): 1.2K (4.8K before correlation)
- Error max: 2.8K
- Hot OP case results:

Temperature [°C]

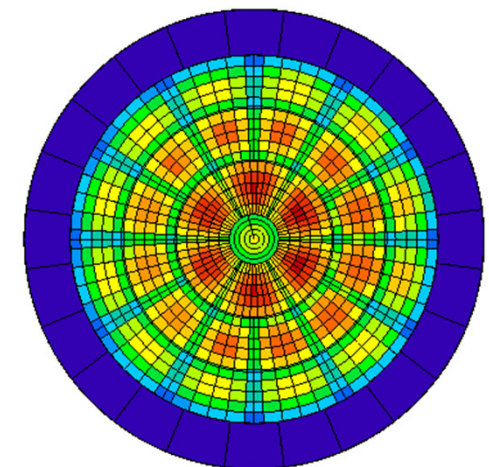
88

45



200

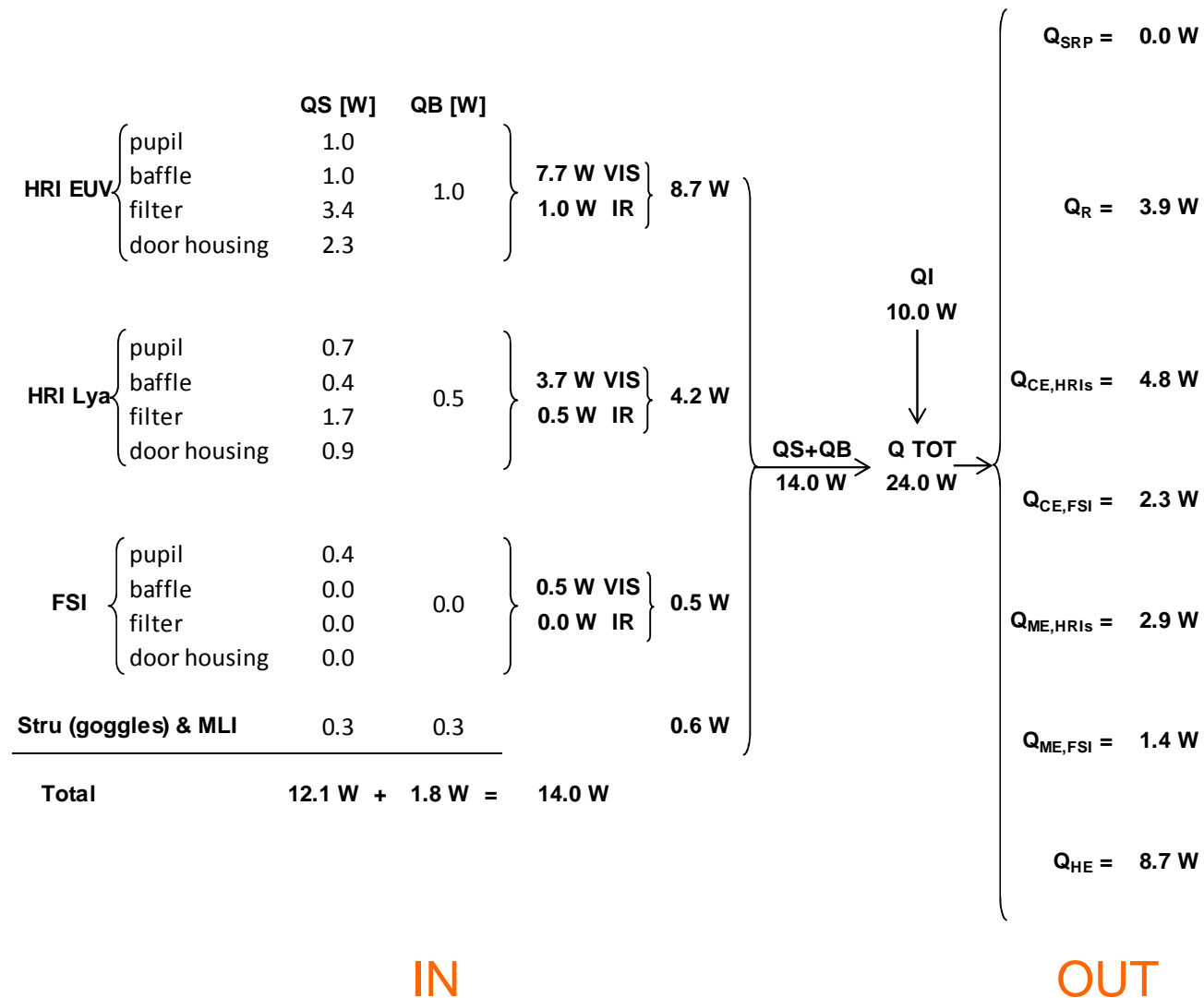
60



Test heat balance



- 14.0W environment input, 10W dissipation





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Conclusions



- **Model correlated**
- **Ultrathin filters survived**
- **Hot & cold thermo-elastic measurement performed & correlated**
- **Lessons learned for QM and FM thermal tests**
- **Further unit dedicated test:**
 - **Focal plane assemblies QM**
 - **Doors QM**



Thank you for your attention...

any question?

Contact



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