Optics for Instruments in Space & Solar Orbiter

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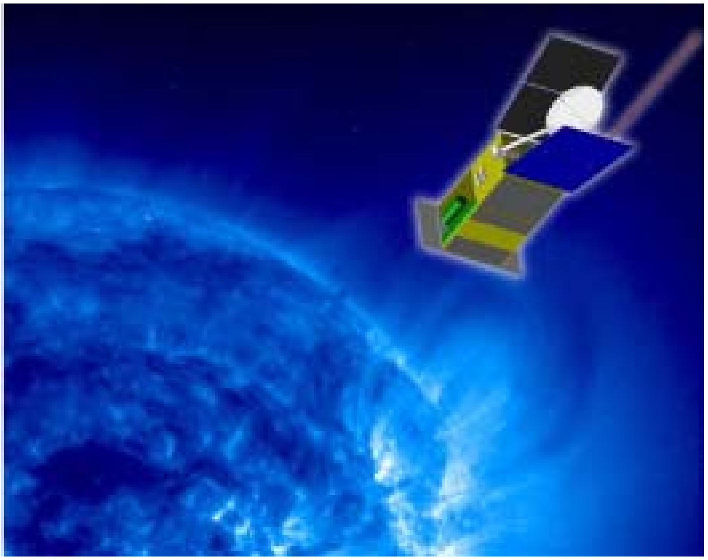
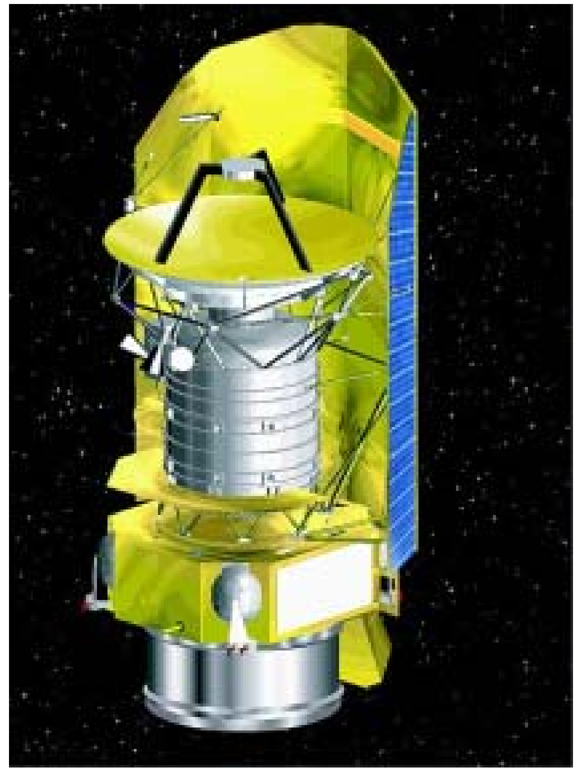


The Spacecraft

- Spacecraft
- Usually consist of two parts
  - Service Module
  - Payload module



- Herschel (vacuum vessel, primary and service module

Thermal Issues

- Space
  - Large temperature variation due to the spacecraft being subjected to:
    - Cold space (4 Kelvin)
    - The Sun

Cs0	AU	1/r2	W/m2	ratio
1367	0.21	22.7	30998	18.4
1367	0.9	1.2	1688	
1367	1.21	0.7	934	

    - Solar Orbiter Exposure to the Sun
  - Temperature variation of structures (not optics!)
    - Exposed to Sun: 100 Celsius
    - In the Earth's shadow: -180 Celsius
  - Thermal stability
    - Normally +/- 10 degrees
    - 1 micro-Kelvin (Gaia)

Mechanical Issues

- Structure
  - Is there to:
    - House - instruments, support equipment
    - Provide for secure launch environment
  - Provide for protection
    - Thermal
    - Radiation
    - Light (stray light)
  - Stability
    - Thermal
    - Optical
      - Optical benches (heavy)

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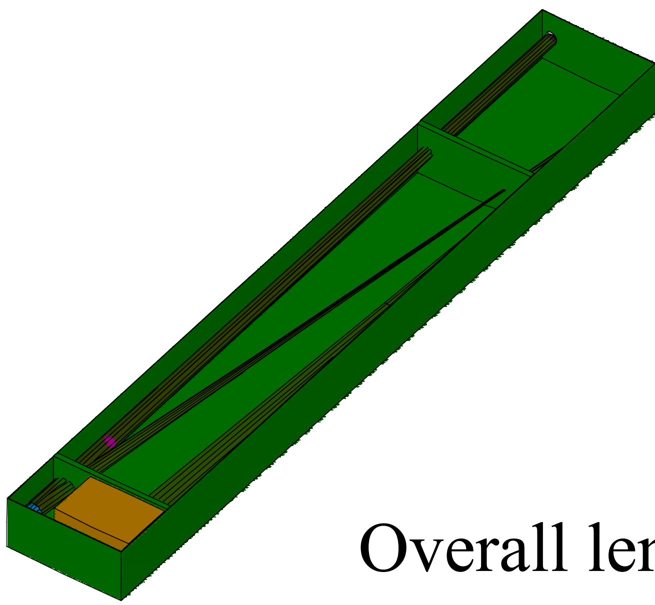
Material Issues

- Material often need to be able to:
  - Sustain radiation
  - Survive extreme temperatures
  - Strong
  - Lightweight
- Materials always need to be
  - Clean!
    - Low on out-gassing (optics!)
    - Don’t generate dust (optics!)

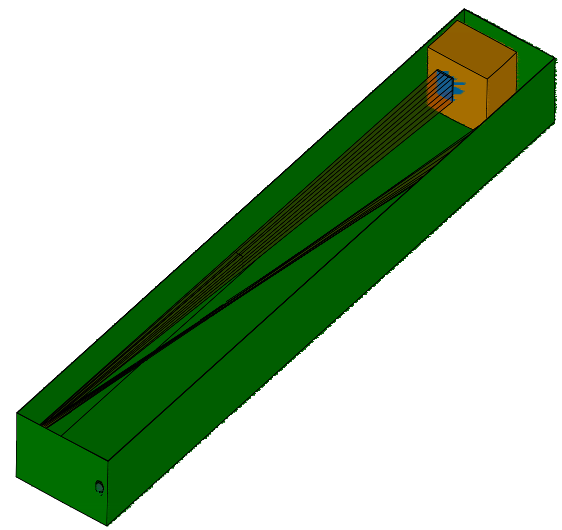
Optics

- Outgassing
  - Optical components have shiny surfaces that radiate heat better than absorb it
    - In general optical components are the coldest in their environment
    - Any dust and molecular contamination will settle mostly on optical components
  - Some wavelengths require extremely clean instruments (EUV)
    - XMM-OM
    - UVOT
    - Solar-B and Solar-Orbiter
- Alignment
  - In the order of 1 to 10 micron is pretty normal (1 micron or better for EUV)
  - It does go down to nano-meter stability and alignment (Gaia)
  - The thermal expansion of materials itself is causing problems
    - typical distance between optical components is 500 - 1500 mm
    - typical temperature swing is in the order of +/- 5 degree
    - typical low thermal expansion material has CTE of 0.5 - 2 ppm/K
      - misalignment variation 2.5 to 30 mircon

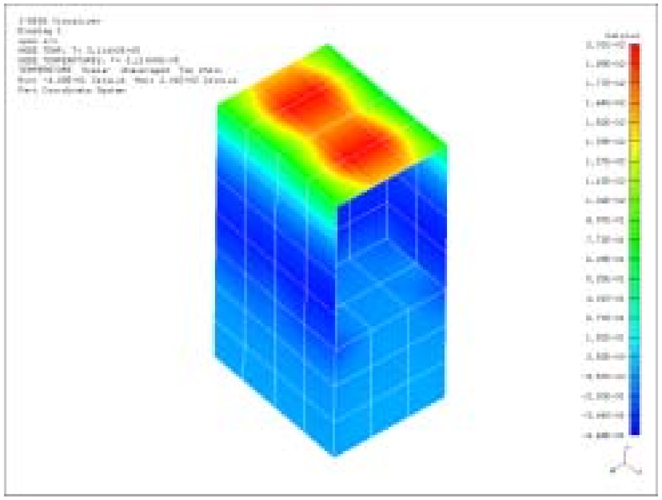
Solar-Orbiter (Solo)
General layout of the HRI and FSI



Overall length 1.5 m



Thermal Design - Solo



- General observation on thermal design
  - Spacecraft thermal environment is very severe
    - Large fluctuation in solar (heat) flux (factor of 18 in final orbit...)
    - No doubt the part of the spacecraft facing the sun will be very hot
      - Initial calculations indicate a maximum heat shield temperature of 400-600 Celcius
      - Thermal environment of the payload bay varies between
        - » looking at cold space 4-5 K
        - » Looking in the direction of the heat shield 200 Celcius
    - This will induce large thermal gradients around the telescopes

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Thermal Design - Solo

- Telescope
  - Telescope temperature depends strongly on the interface with the spacecraft
    - Assuming the thermal coupling is minimised with regard to conduction
    - Assuming half the telescope surface is seeing (part) of dark space
  - Telescope temperatures in the range of 0-100 °C are likely to be reached
  - During the orbit away from the sun the telescope will cool down considerably if no special measures are taken
- Detector
  - Operating temperature 20 °C (TBC)
  - Using passive cooling this may be possible to reach in case the telescope external temperature is 100 °C
    - We very likely need a cold finger to an external radiator
    - We also may need a heat pipe to dump the heat to that radiator
- With a telescope temperature of 100 °C we are looking at a heatflux of about 100-200 W radiated inside the telescope, this is a significant amount

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Mechanical Design - Solo

- Mass budget for this mission is very tight (range 5-10 kg for main structure)
- Structure needs to be stiff to isolate the instrument from main S/C resonances
- The sensitivity of the alignment due to temperature fluctuations needs to be minimal
  - We need a material which has a high effective stiffness and a low CTE
- CFRP is the best material to meet these requirements
  - Design of lightweight CFRP structures has drawbacks (needs to be acknowledged)
  - Continuous loss of moist, CFRP keeps shrinking....

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Mechanical Design Solo

- Due to a temperature variation of +100 °C
  - 1500 mm of CFRP will expand 50-75 micro meter (Al would have expanded 3.5 mm)
  - This raises concerns with regard to S/C design....
- The suspension of the cluster of three telescopes needs to be:
  - actively controlled following the current requirements
  - kinematic (to minimise overall deformation of the telescopes due to S/C interface)
- The materials used need to be ultra clean at high temperatures
  - Low in outgassings

Conclusion

- This presentation gave a brief (coarse) overview of things to be considered when designing instruments for use in space
  - Thermal environment can be challenging
  - Mass critical
  - Cleanliness
  - At critical wavelengths (EUV) adaptive optics are needed

- It needs to be said that:
  - The space community is very conservative
    - reliability
    - heritage
- Adaptive optic adds to the complexity of the instrument and introduces a single point failure possibility
  - Adaptive optics are likely only applied when conventional techniques can't meet the requirements
  - Time constant for adaptive optics in space is long...... varying between 1.5 h to 30 days