A Calibration Source for SAFARI on-ground Calibration

- Design and design supporting tests -

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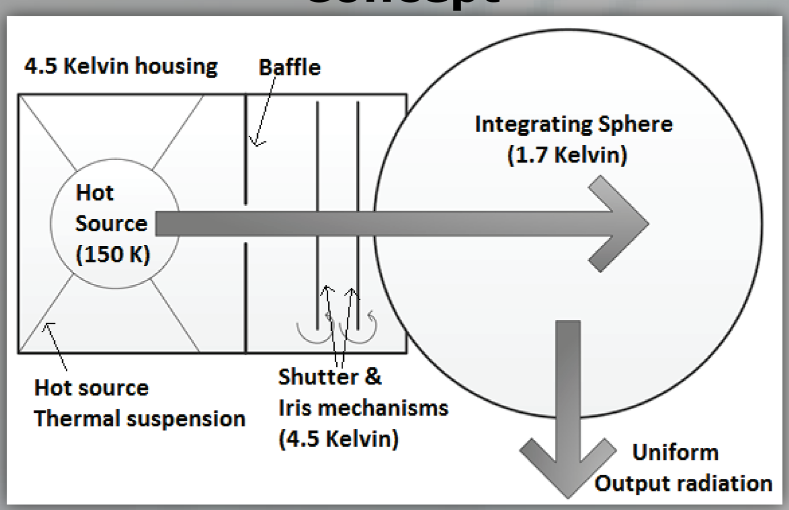
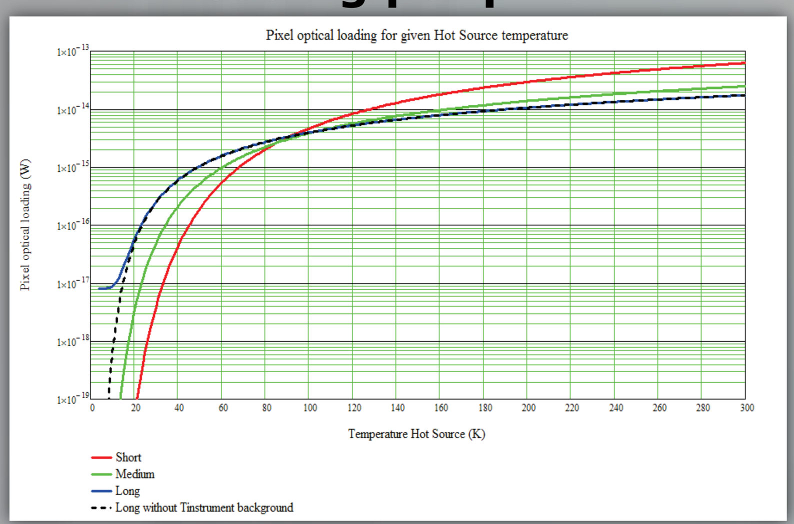
Introduction - In a European consortium led by SRON Netherlands Institute for Space Research, the SpicA Far-infraRed Instrument (SAFARI) is being developed. SAFARI is an imaging Fourier Transform Spectrometer working in the 34 – 210 μm wavelength range with a Nyquist sampled instantaneous field of view of 2′ x 2′. It has a selectable spectral resolution R of between 3 and 2000. It is to fly on the joint JAXA-ESA SPICA mission (SPace Infrared telescope for Cosmology and Astrophysics) which features a telescope that is actively cooled to ~5 K. SAFARI will therefor be sky-background limited with the individual pixels having a goal NEP of $\sim 2*10^{-19}$ $W/Hz^{1/2}$ and a saturation power of $\sim 10*10^{-15}$ W.

The on-ground verification and calibration program will be performed in-house at SRON. For this a test facility is under development. To perform absolute calibration of the instrument a calibration source is needed that covers the full dynamic range of the individual detectors from atto-watts to femto-watts per pixel in the SAFARI bands with accurate knowledge of both the power level and its spectral distribution. The design of the calibration source is now past the conceptual stage and the actual hardware is being made and tested. Below is an overview of the current status of the project and results of the tests so far.

Concept



Loading per pixel



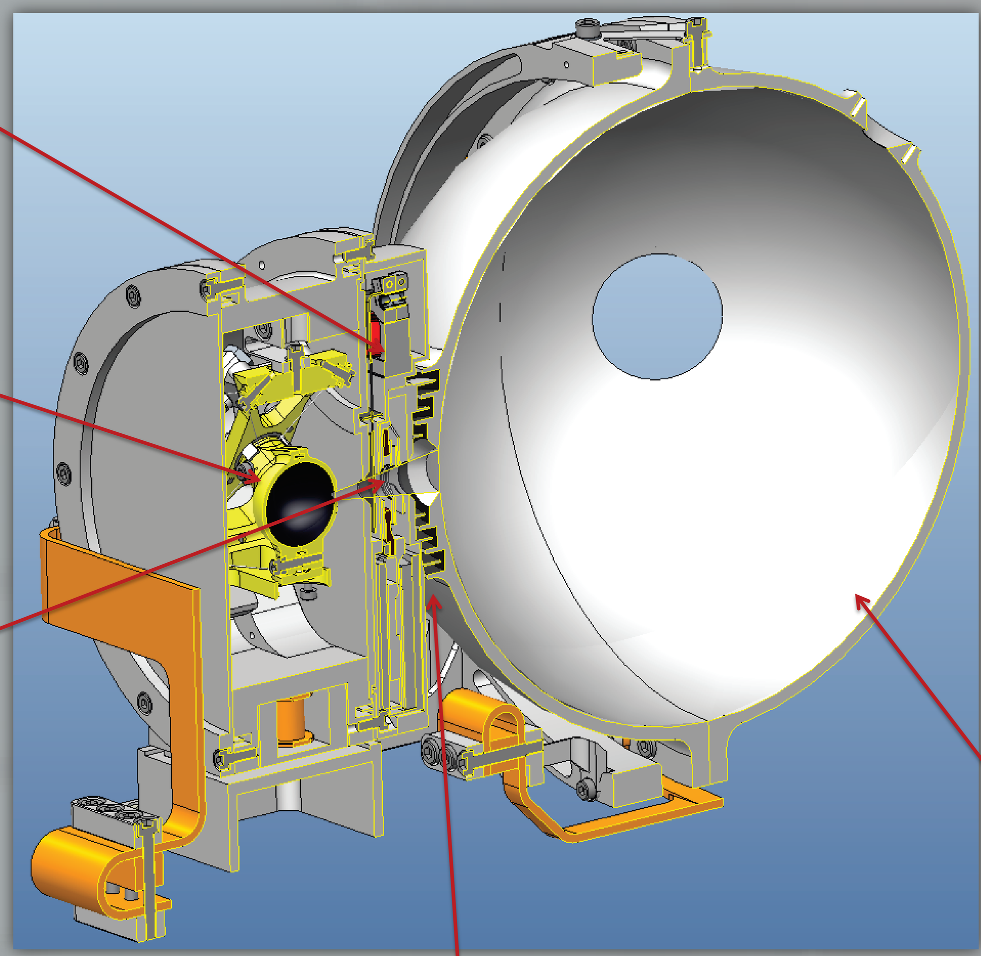
Design

The **Shutter** can close the aperture to allow other measurements during cool-down and warm-up of the hot-source.

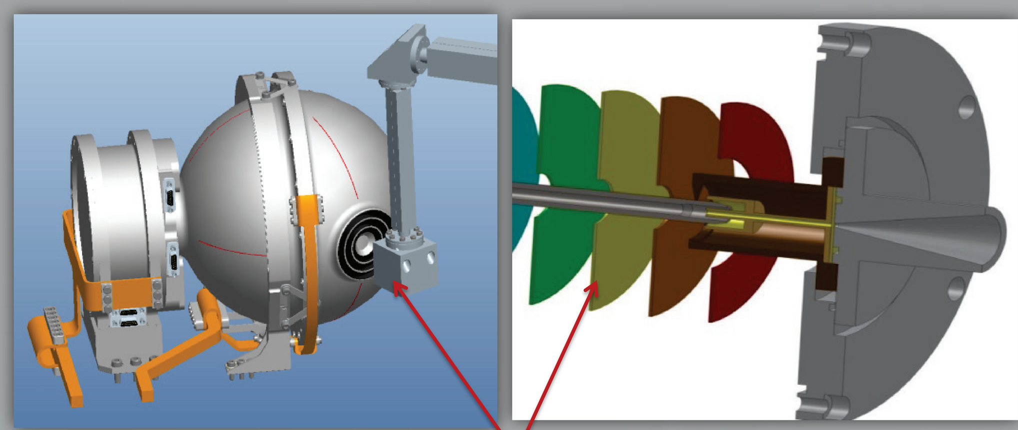
The **Hot Source** is a black body cavity that provides the desired radiation. It can be heated to 150 Kelvin.

The **Iris** controls power and creates transients so time varying signals can also be verified.

A **Bolometer** integrated in the wall of the integrating sphere is used for monitoring the optical output power level.



A **Thermal Break** separates the 1.7K integrating sphere from the 4.5K environment.



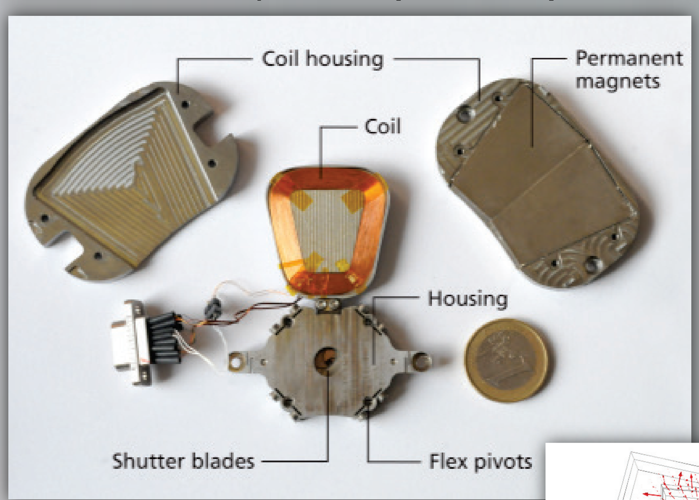
A **Light Pipe** injects signal from external sources (Line source, FTS) to do absolute frequency calibration of the instrument.

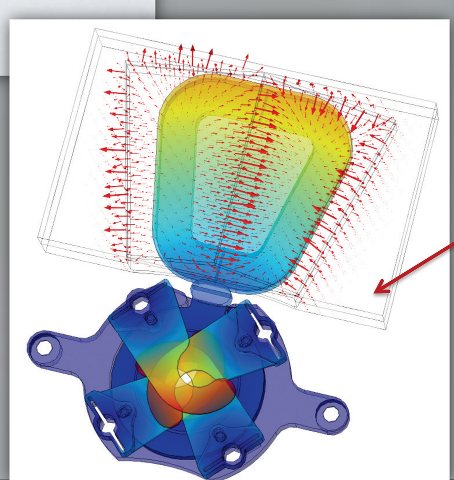
The **Integrating Sphere** redistributes the incoming radiation and provides a uniform 'flat-field' output. It is cooled 1.7 Kelvin to present negligible background to the instrument.

Cryo-mechanisms

Iris aperture design

4 aluminium blades rotating on flex-pivots.
Rotating ring made from Vespel-SP3.
Driven by Arc-type Voice Coil actuator
Low dissipation (< 2mW).

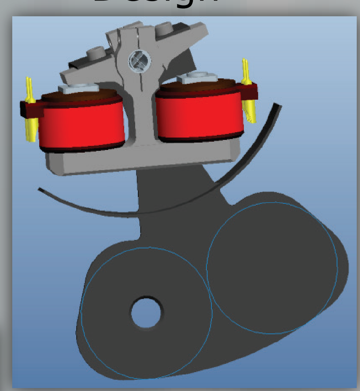




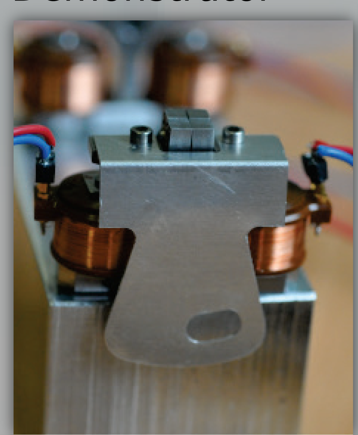
Bi-stable shutter design

Bi-stable shutter from heritage.
Uses 2 coils (4000 windings) and a flex-pivot.
Option to be used as chopper at the resonance frequency.
Light-tight shutter blade design.

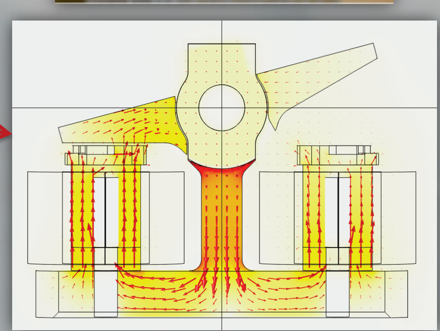
Design



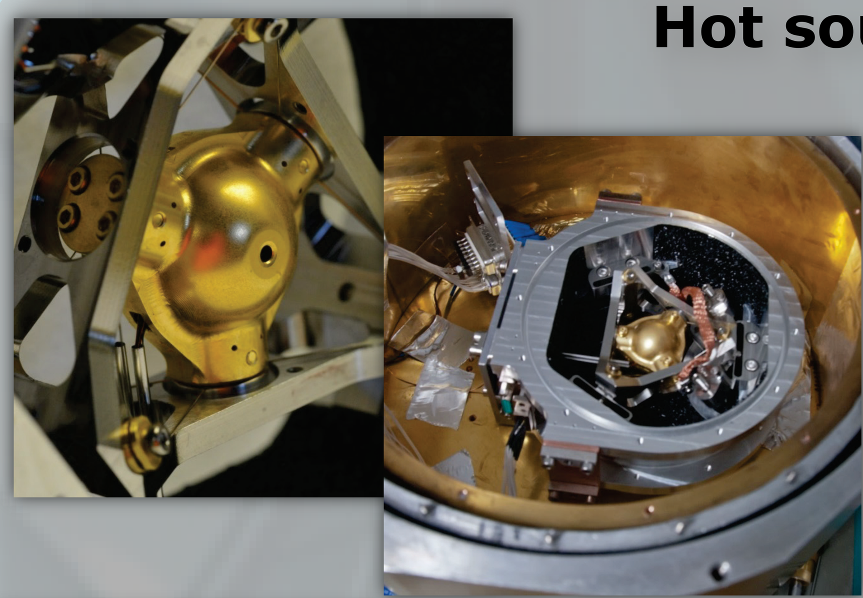
Demonstrator



Optimised using COMSOL

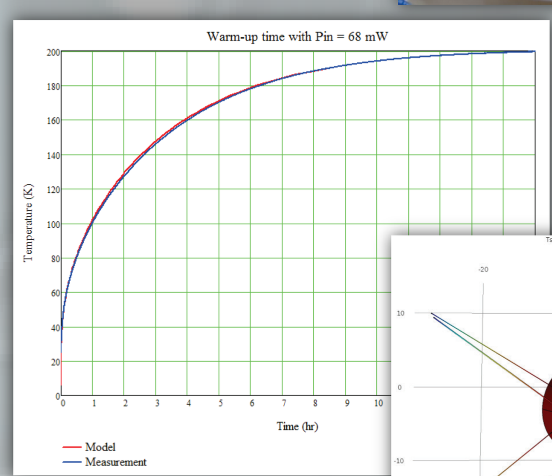


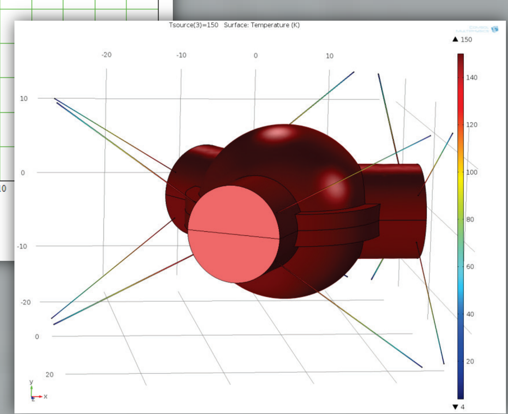
Hot source



Thermal balance testing
The hot source is currently undergoing thermal balance testing. Thermal behaviour is accurately described by our model.

Issues:
- Gold plating has a higher then expected emissivity of ~0.08.
- The support frame of the hot source is warming up under radiation load.



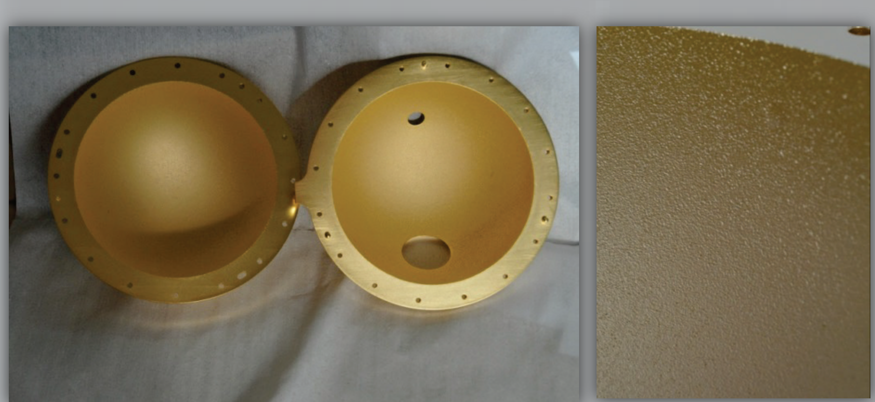


Performance verification
Next step will be the verification of the hot source output. Two routes are under investigation:
- measure output using a calibrated bolometer.
- use a large thermally isolated absorber and measure the thermal balance temperatures.

Fabrication

Sandblasting
Sandblasting creates a Lambertian scattering surface. Process parameters: F12 SiC grains at P= 6 bar.

Issues:
- Fractured SiC pollutes the surface
- Deep crevasses are formed which might lead to absorption.

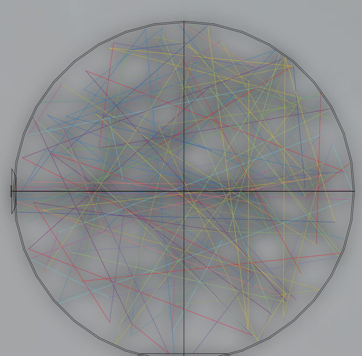


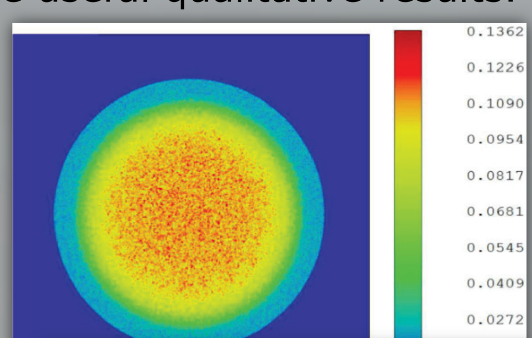
Gold-plating
A standard gold-plating process was used to obtain the required high reflectivity.

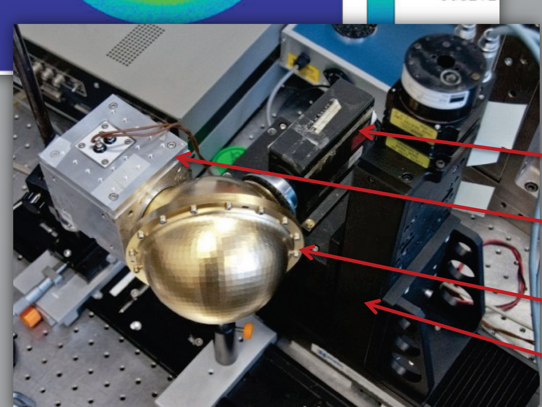
Issues:
- Higher than expected emissivity, ε=0.08.
- Gold smoothed out all the deep structures, roughness too low.

Integrating Sphere

ZEMAX Model
Zemax ray-tracing is used to model the behaviour of an integrating sphere. It was difficult to model the exact behaviour of a rough scattering surface from its physical surface parameters only.
Modelling does give useful qualitative results.







Measurements
The integrating sphere performance can be measured at room temperature:
Input: Hot filament (700 K), spectrum centred at 45 μm.
Output: Golay-detector on X-Y stage, output is noisy due to low signal levels.

Transmission is low for:
- Sandblasted aluminium.
- Gold-plated rough aluminium.

Roughness is OK for 30-60 μm wavelengths, to be proven for 210 μm wavelength (using adequate filters).