MERTIS – the design of a highly integrated IR imaging spectrometer

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IfP

Background

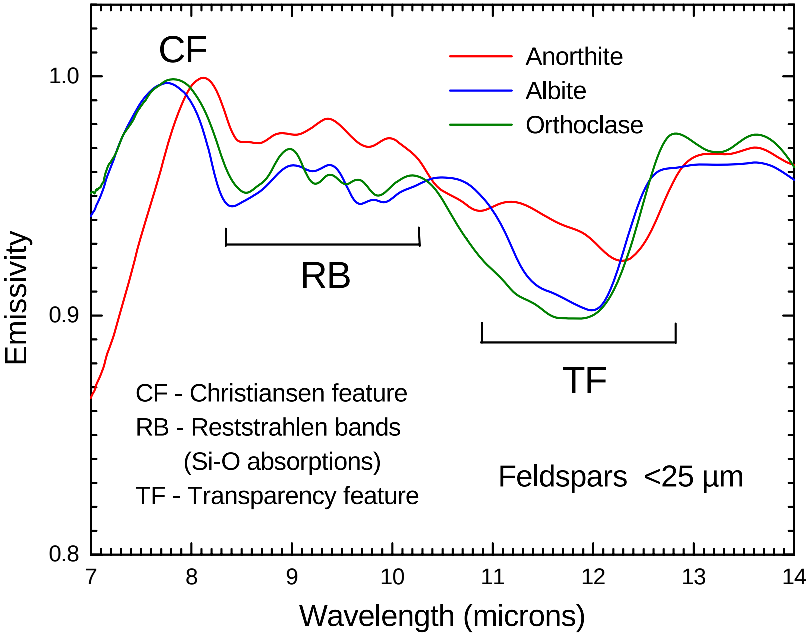
- Mercury has probably the oldest surface among the terrestrial planets with large daily temperature variations
- Investigation of the mineralogical composition and thermo-physical properties are motivating measurements of the spectral emittance and the radiometric behavior in the IR

Study of Mercury's surface composition
Identification of rock-forming minerals
Mapping of the surface mineralogy

Spectrometer objectives

Study of surface temperature and thermal inertia

Radiometer objective



Laboratory emittance spectra of fine-grained feldspar (ref. Wagner 2000)

Instrument Simulations

- Scientific performance assessment for initial instrument architecture
- Simulation of spectral signal and noise values depending on Mercury surface data and instrument parameters

Surface parameters
Temperature
Mineral emissivity

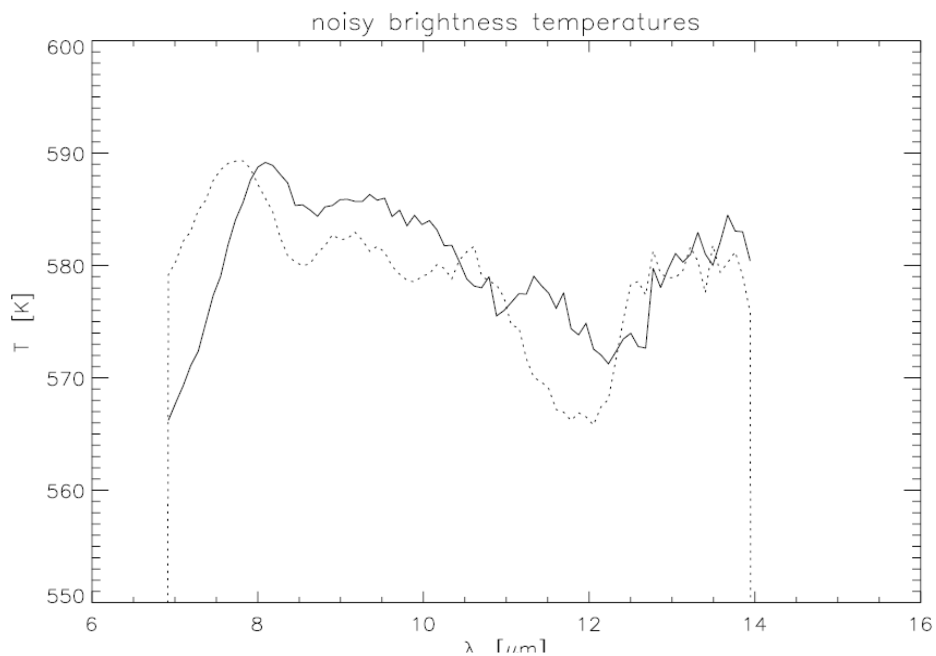
Performance Model (ref. Jahn/ Reulke 1995)

Instrument parameters
Intensity sampling distance
Spectral channel bandwidth
Dwell time, optics efficiency
F-number
Pixel size, macro-pixel

Noise
Photon
Detector

Simulated surface brightness temperatures

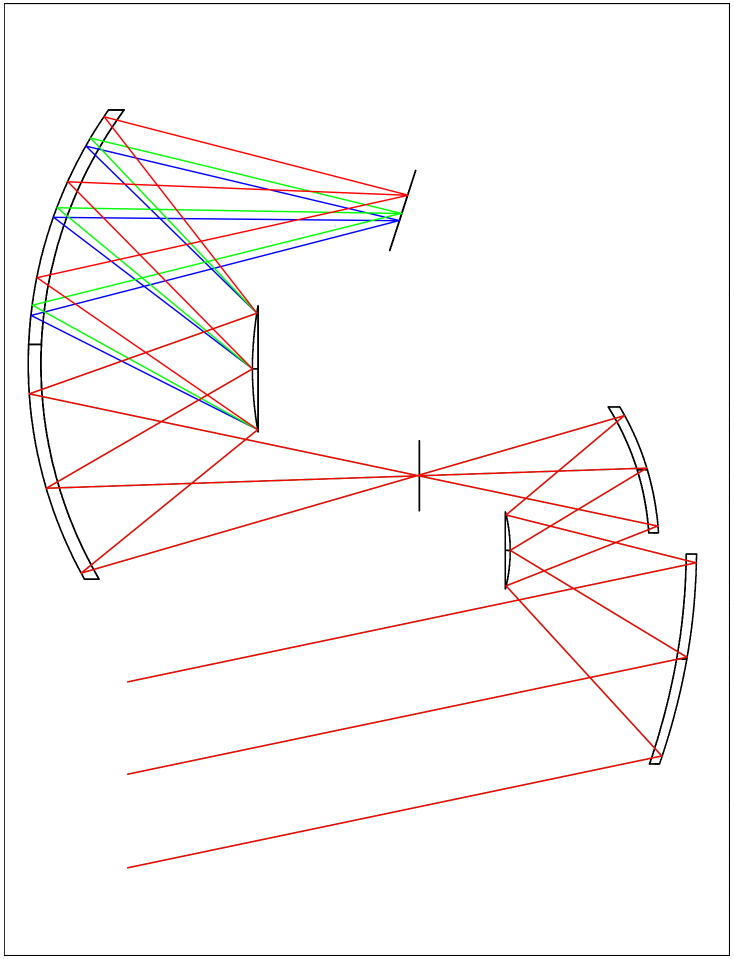
Probability for correct spectral feature detection



as initial, 2x pixel size

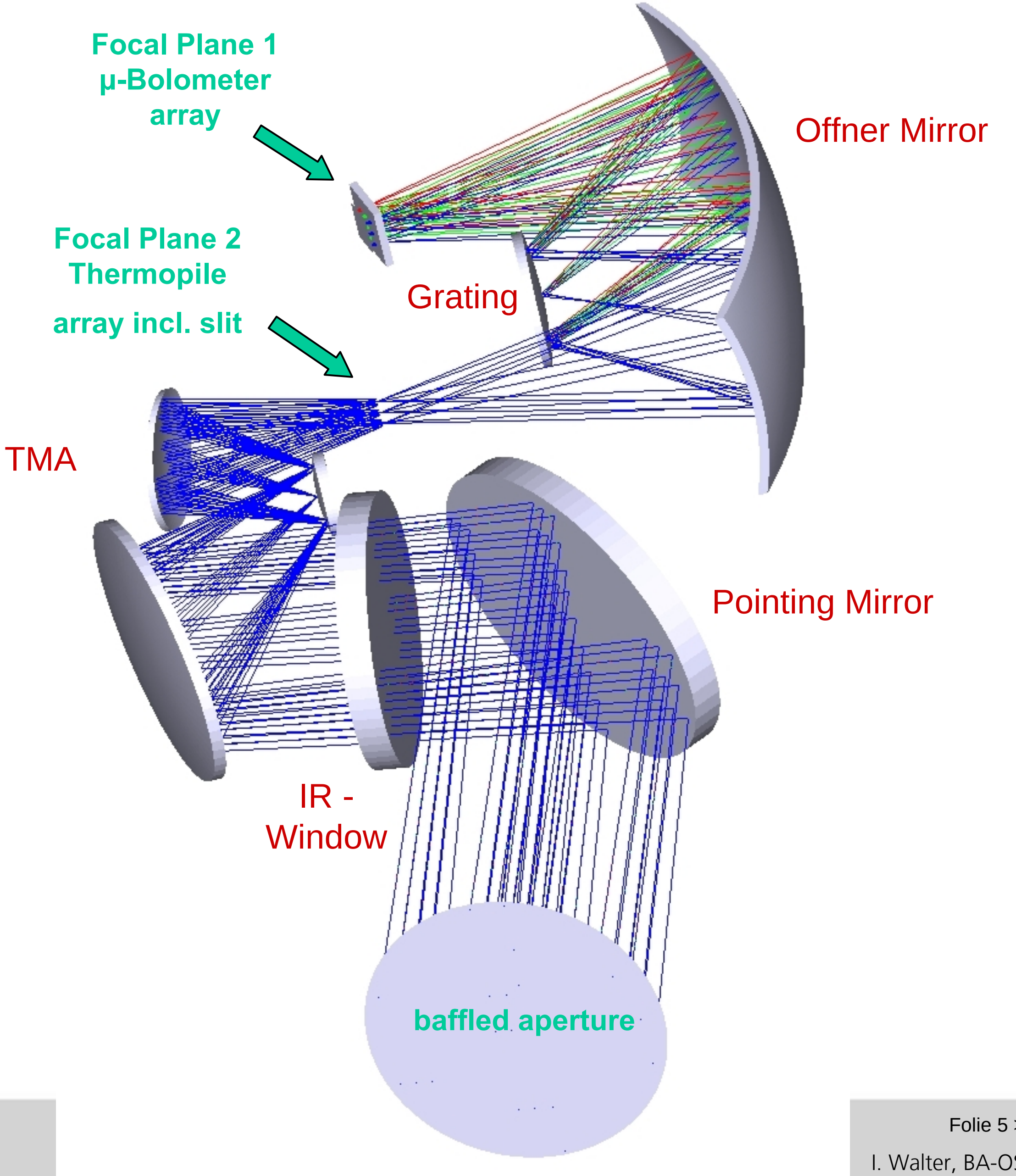
Instrument Concept

- **MERTIS – MER**cury **T**hermal **I**nfrared **S**pectrometer
- IR-imaging spectrometer based on the push-broom principle (80 channels @ 90 nm)
- Application of un-cooled micro-bolometer array providing spectral separation and spatial resolution according to its 2- dimensional shape
- Operation concept principle is characterized by intermediate scanning of the planet surface and 3 different calibration targets – free space and on-board black body sources
- In - field separated micro-radiometer based on thermopile line arrays

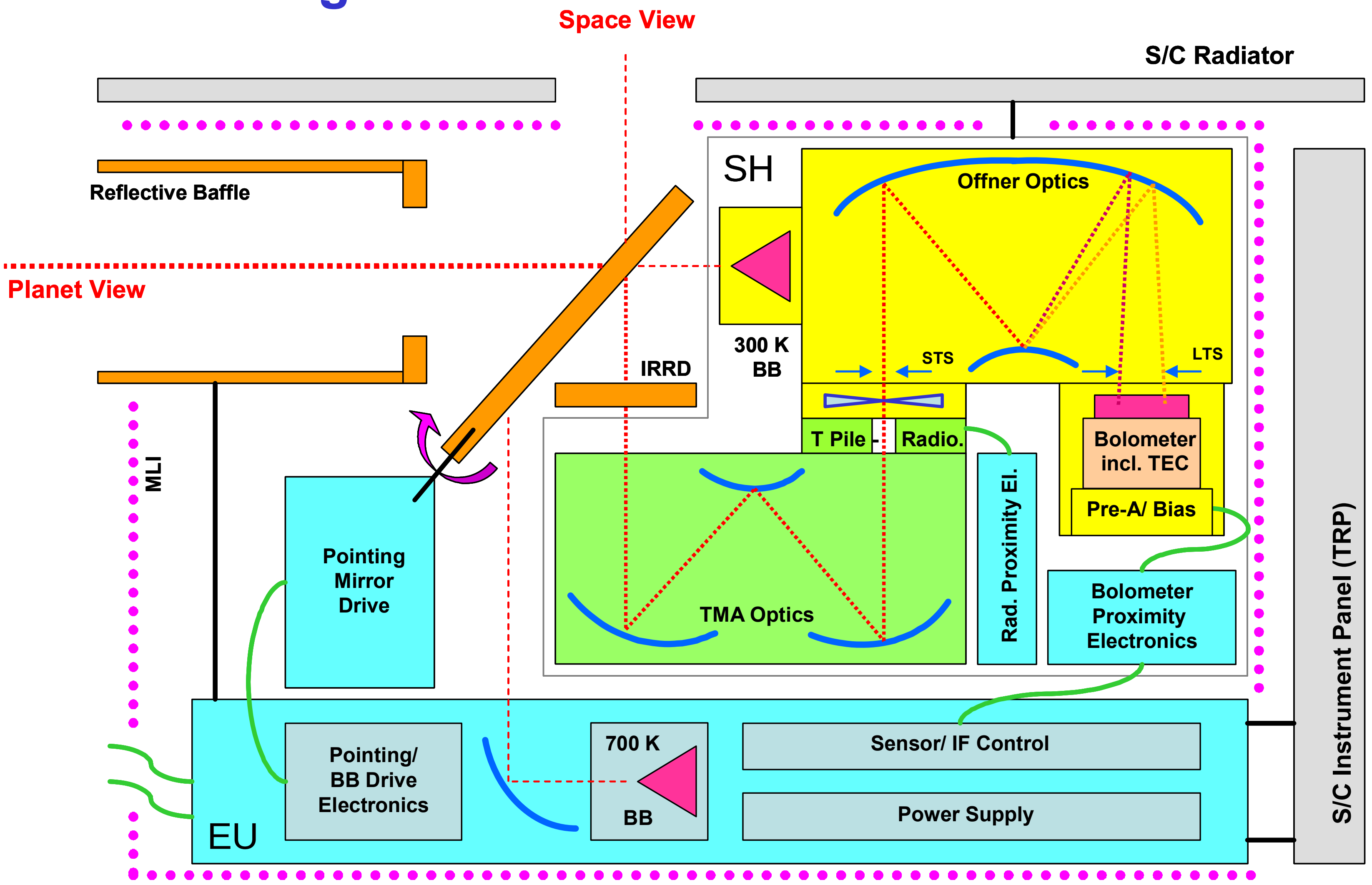


Optics

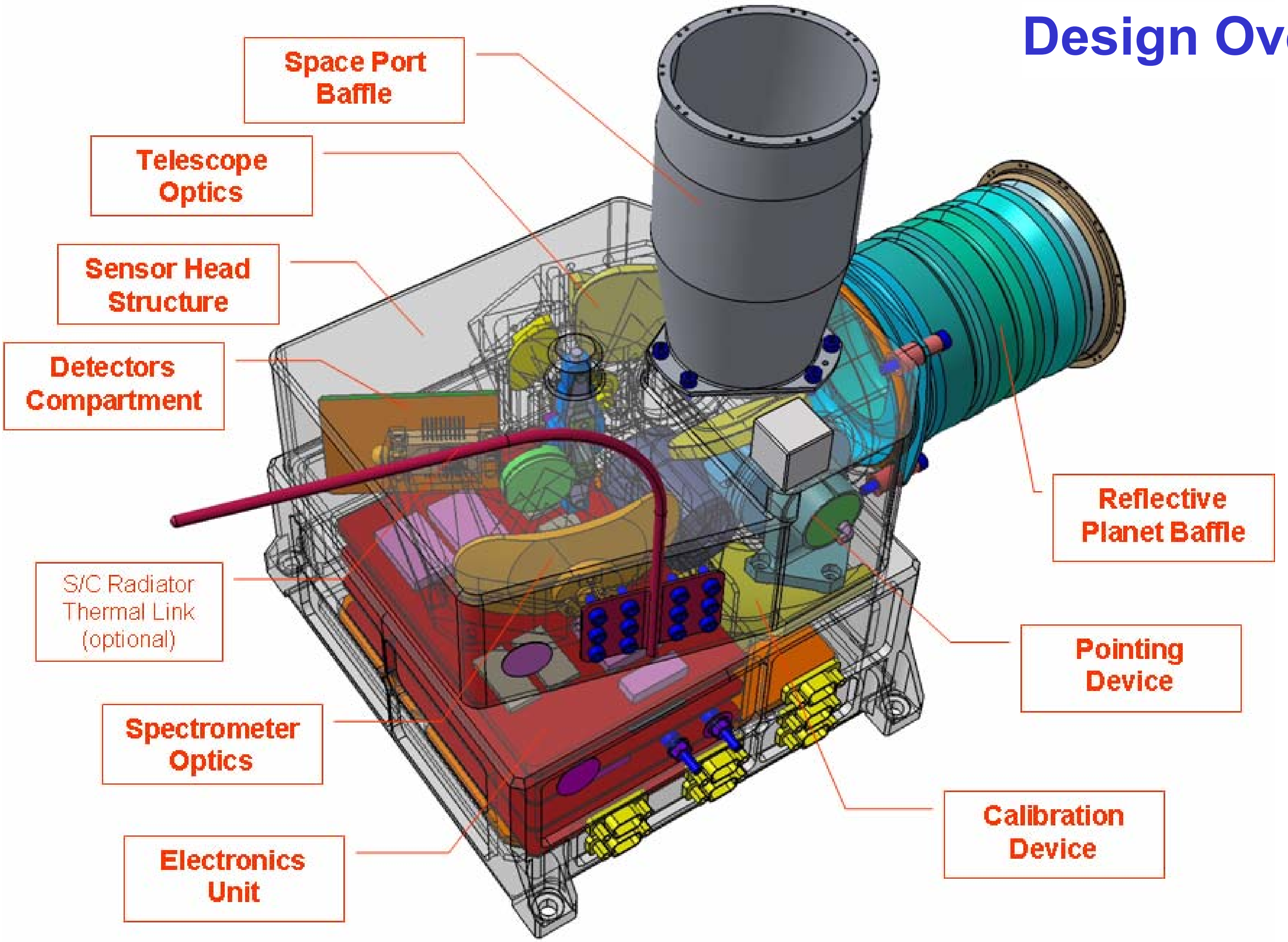
- All - reflective optics design for high efficiency
  (0.95 mirrors * 0.57 grating)
- Off - axis TMA behind a IR- entrance window
  (F# 2 / 50, 7- 40 µm transparence)
- Offner spectrometer including convex grating
  (blaze structure 90 x 5 µm, angle 3.7°)
- Innovative integrated dual focal plane concept
- Pointing mirror to target orientation
  (FOV 4° x 1° each)



Block diagram



Design Overview

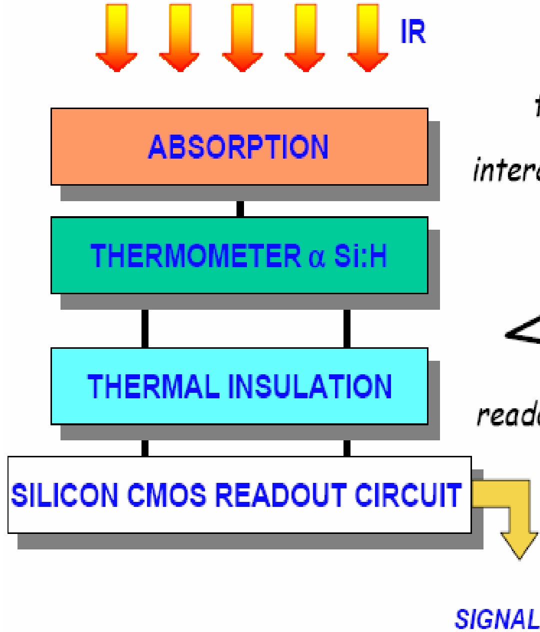


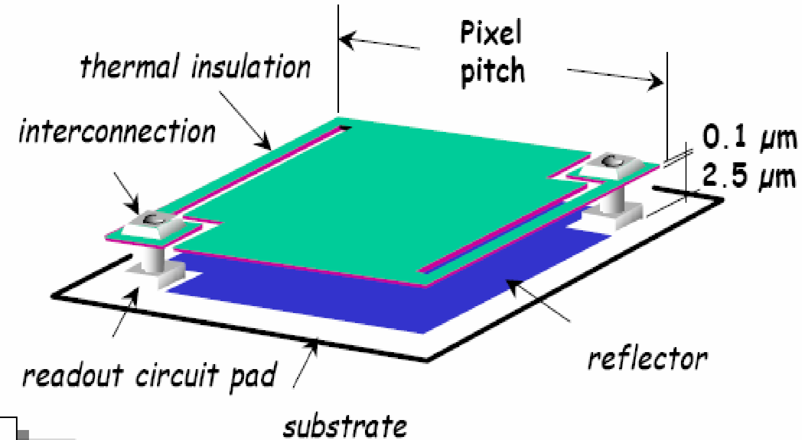
Main Parameters

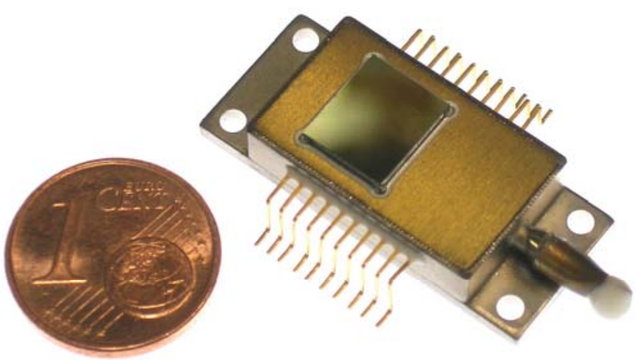
Parameter	Unit	Spectrometer	Radiometer (µRAD)
Focal length	F	50 mm	
F – number	F#	2.0	
Optical efficiency	ηopt	0.54	
Microbolometer array detector • illuminated pixels µRAD thermopile line array	pixels	160 x 120 @ 35 µm 100 spatial 80 spectral 2 x 15 @ 250 µm	
Spectral channel width	$\lambda\delta$	90 nm / pixel	
Spectral resolution	$\lambda/\lambda\delta$	78 – 156	
Spectral range	λ	7 – 14 µm	7 – 40 µm
Detectivity	D*	0.95 10^9 cm $Hz^{1/2}$ W^{-1}	7 10^8 cm $Hz^{1/2}$ W^{-1}
Instantaneous field of view	IFOV	0.7 mrad	5 mrad
Ground sample distance • Periherm 400 km • Apoherm 1500 km	GSD	280 - 1400 m (M = 1- 5) 1050 m	2000 m 7500 m
Dwell time • Periherm 400 km Apoherm 1500 km	τ	109 ms 784 ms	775 ms 5597 ms
Field of view	FOV	4° ACT, 0° ALT	4° ACT, 1° ALT
Swath width		28 km	
Instrument overall dimensions + ext. Baffle		140 x 160 x 120 mm³ 93 x ø54 & 92 x ø68 mm³	
Instrument total mass incl. 20% margin		2.85 kg	

Detector Spectrometer

- Resistive semi-conductor micro-bolometer
  (Array 120 x 160 pixels @ 35 µm pitch)
- Thermally controlled MEMS Device
  (TEC at 10 mK stability)
- Established technology to be space-qualified for BepiColombo

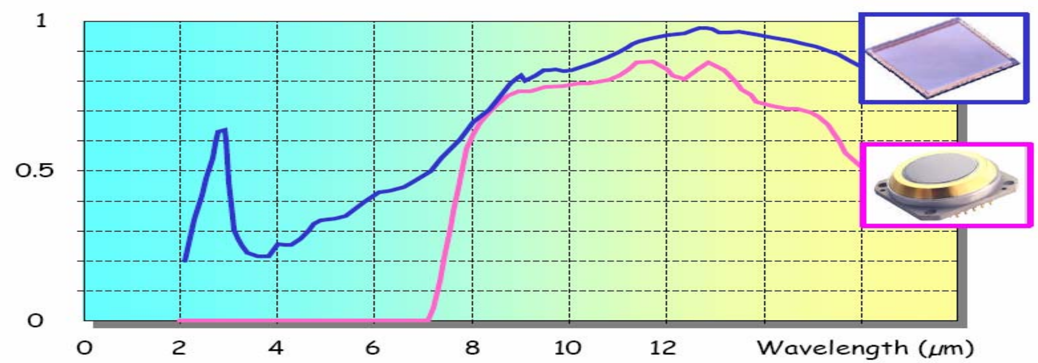






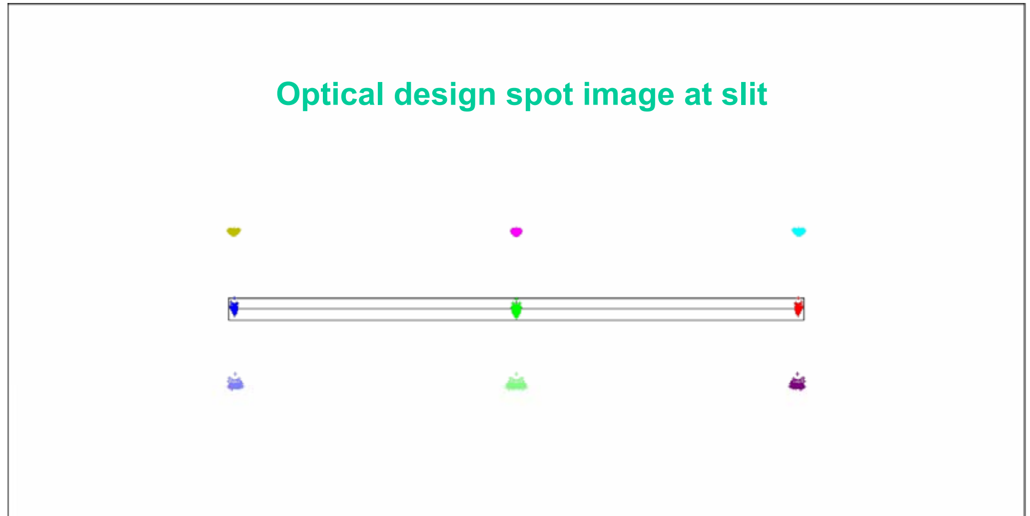
COTS detector for bread-boarding

ULIS

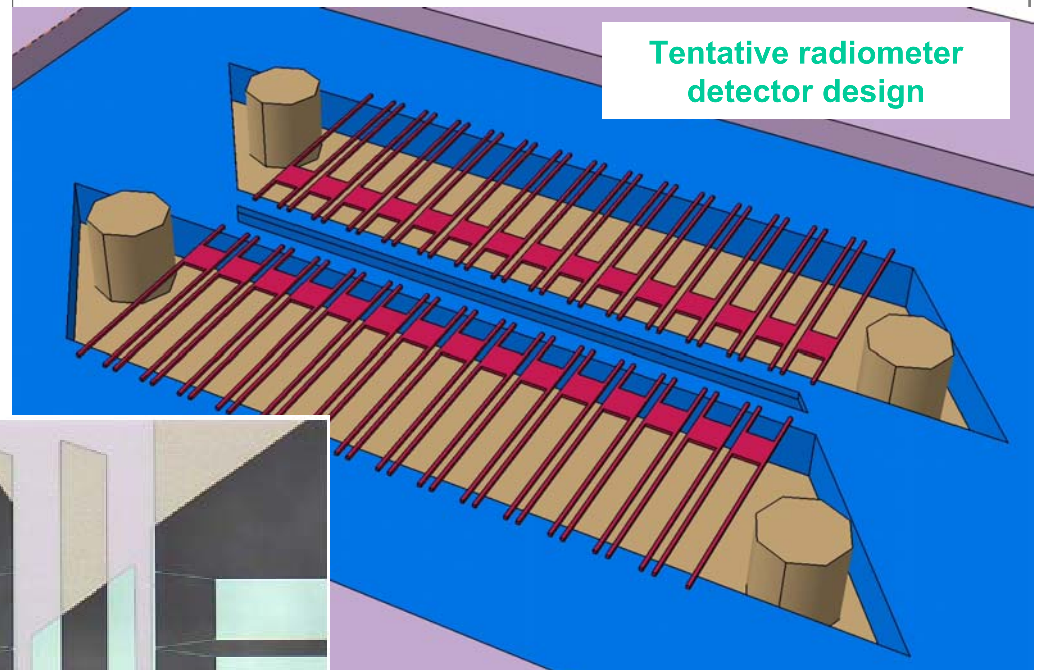


Detector Radiometer

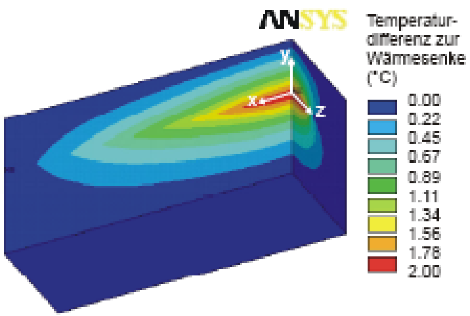
- Thin film IR thermopile with thermoelectric high-effective material
  (2 line arrays 2 x 15 pixels @ 250 µm pitch)
- Spaced in-parallel from the optical axis
  (0,5 mm from slit centre)
- Technology study and performance simulations ongoing

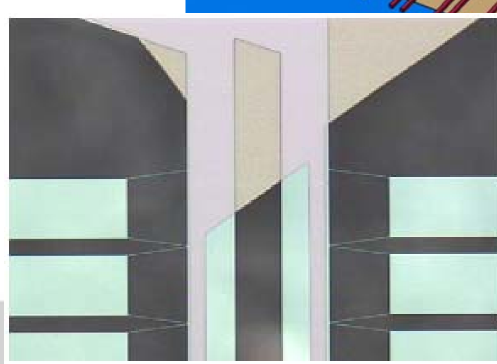


Optical design spot image at slit



Tentative radiometer detector design

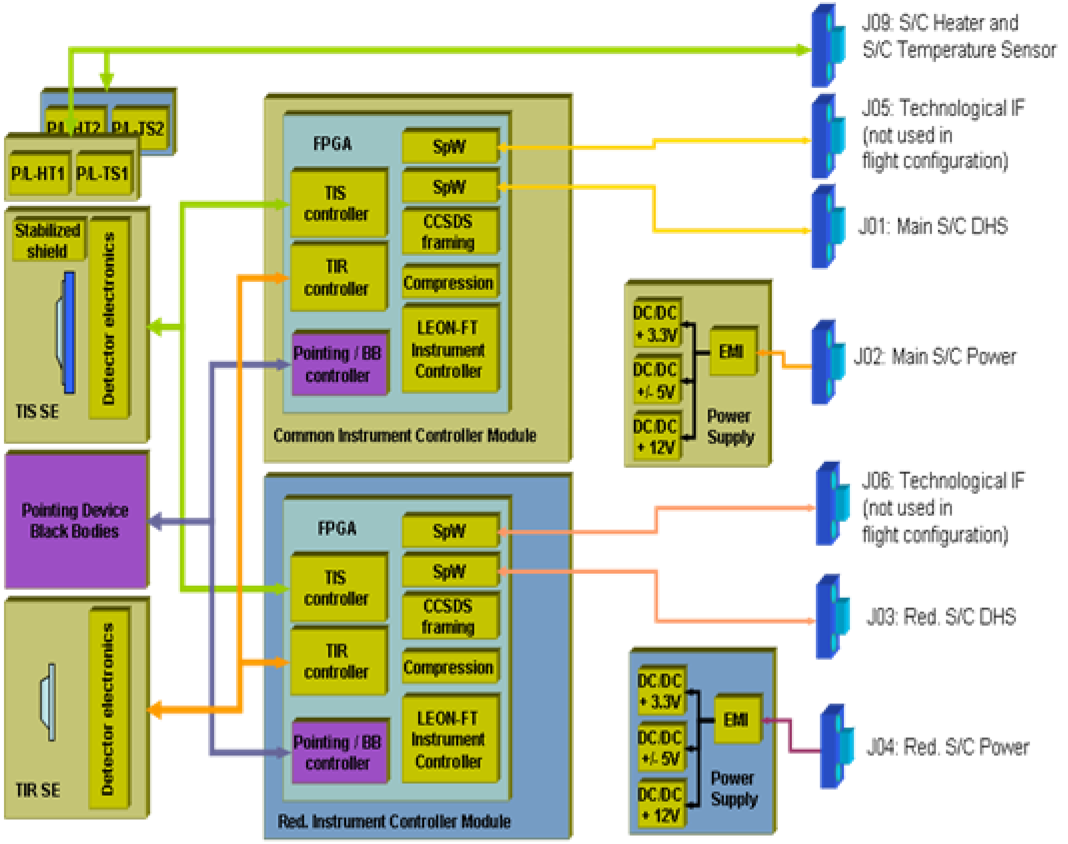




FEM simulation and experimental Si-wafer for tests

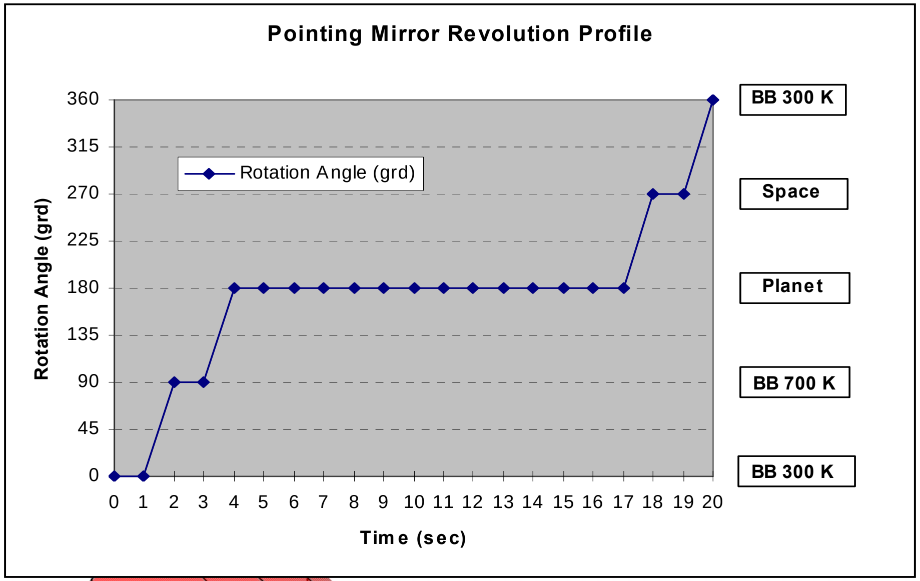
Electronics Architecture

- Modular concept based on FPGA technology
- Cold redundancy of main electronics parts
- Tasks
  - Independent control of the MERTIS sub-systems
  - Acquisition and processing of science data
  - Providing of internal voltages and interfacing the +28V S/C power bus
  - TMC management and interfacing to the S/C DHU
  - Control of the pointing mirror black bodies and optional shutters
  - Providing of HK and status information
  - Control of the detector
  - Temperature stabilization of the detector
  - Detector signal conditioning

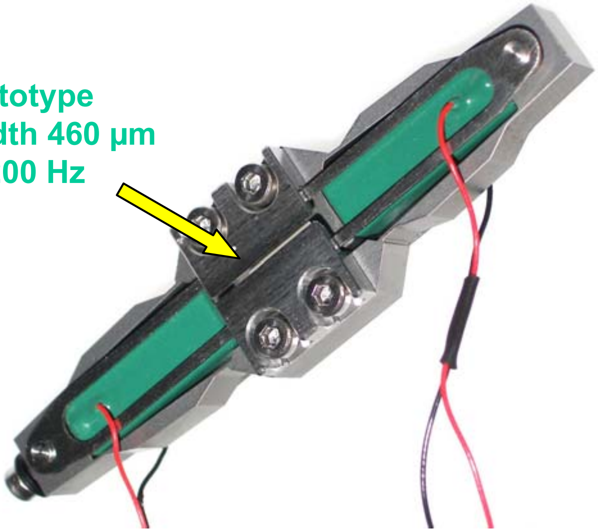


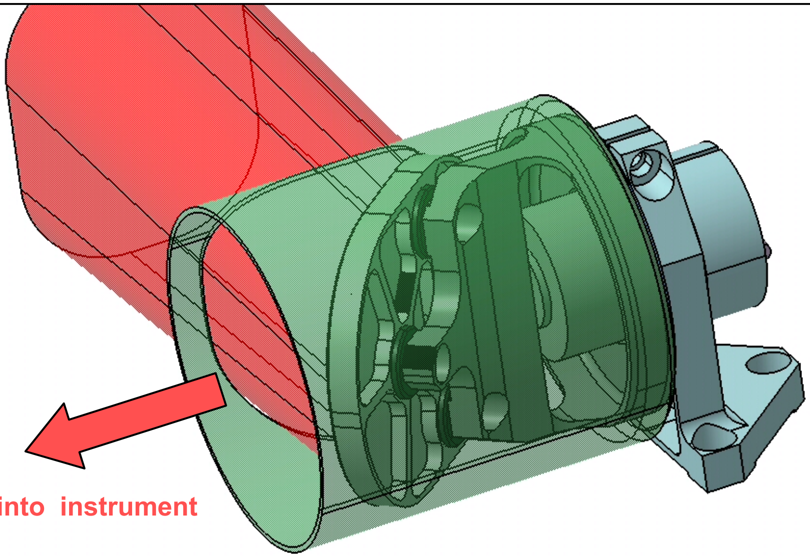
Development - Actuators

- In-flight calibration purposes
- Pointing Unit for target selection
  - Planet (65 % duty cycle min.)
  - Deep space
  - 300 K black body
  - 700 K black body
- Short Term Shutter for instrument temperature reference
  - Operated every dwell time (~10 Hz)



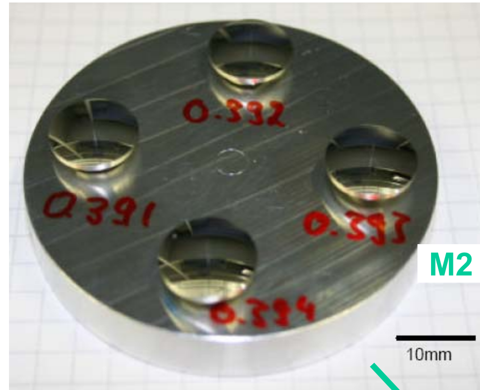
STS prototype
• Slit width 460 µm
• F_{res} ~ 200 Hz

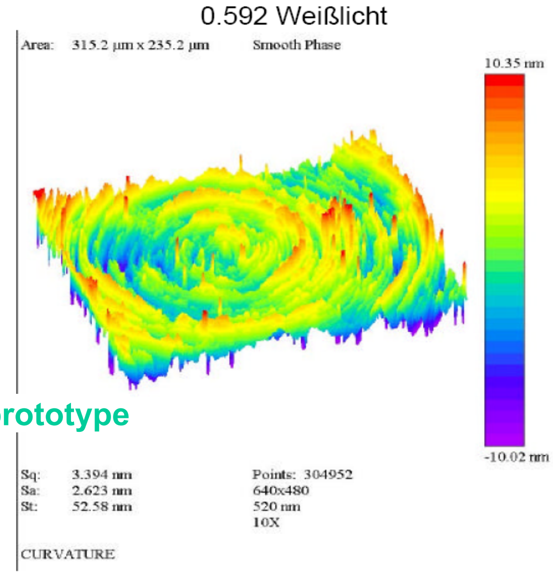




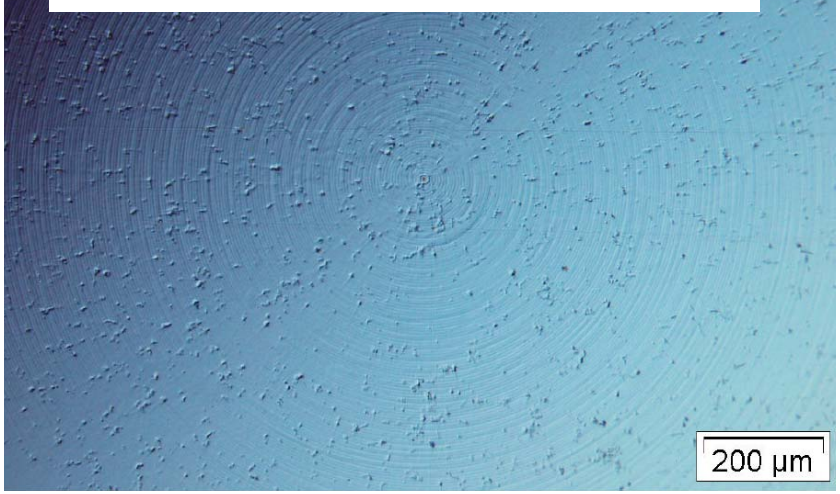
Development – Optics Technology

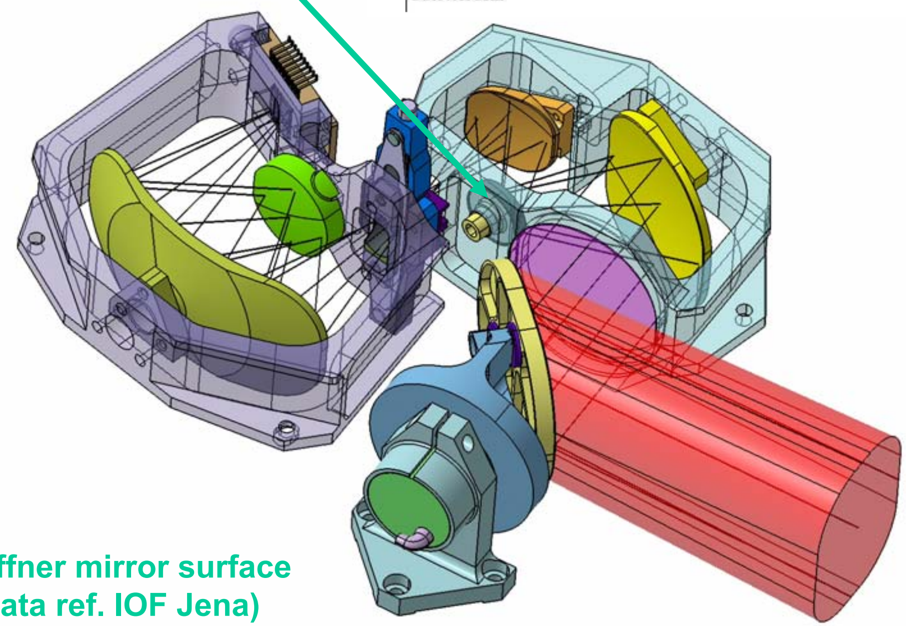
- o Early identification of flight optics technology
  - Single point diamond turning
  - All aluminium + gold coating
  - Element parameters and efficiency measurements (grating)
- o Verification of Phase A Sensor Head design
  - TMA Unit performance
  - Spectrometer Unit performance
  - Optics structure design





M2 prototype

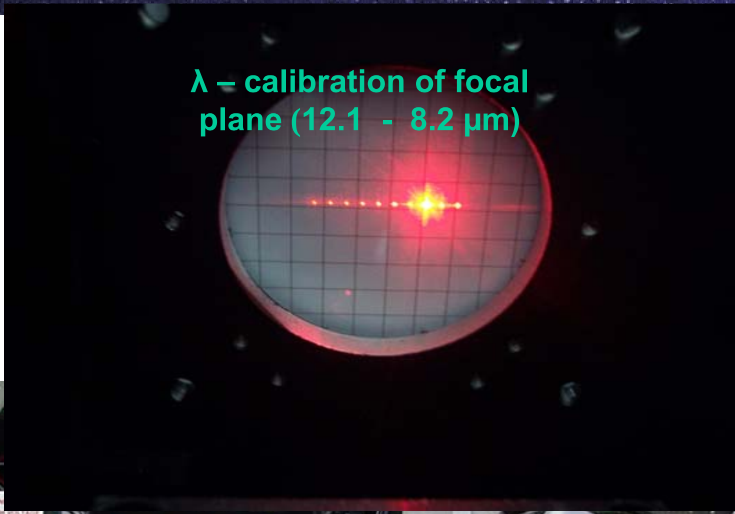


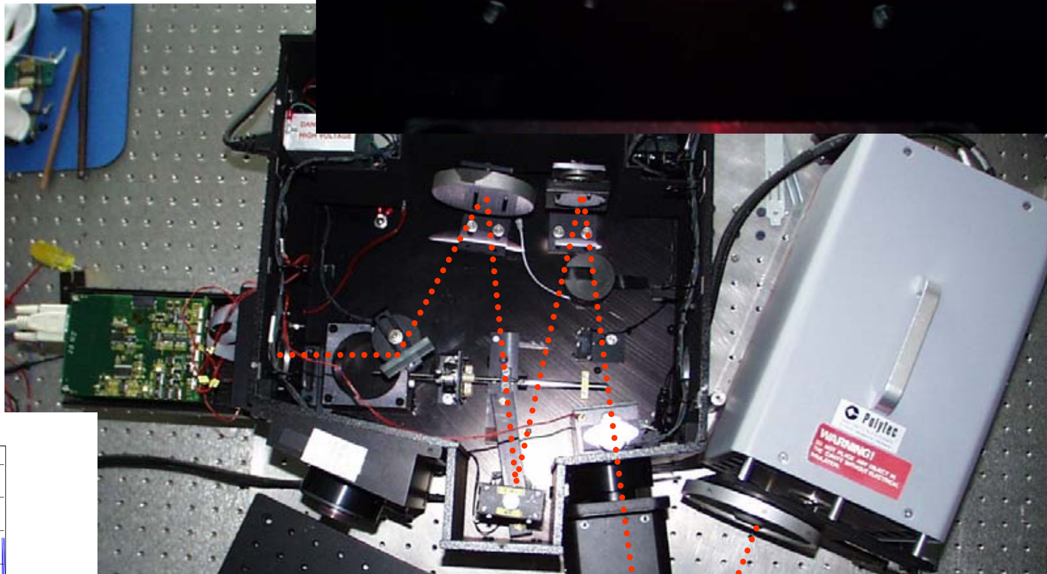


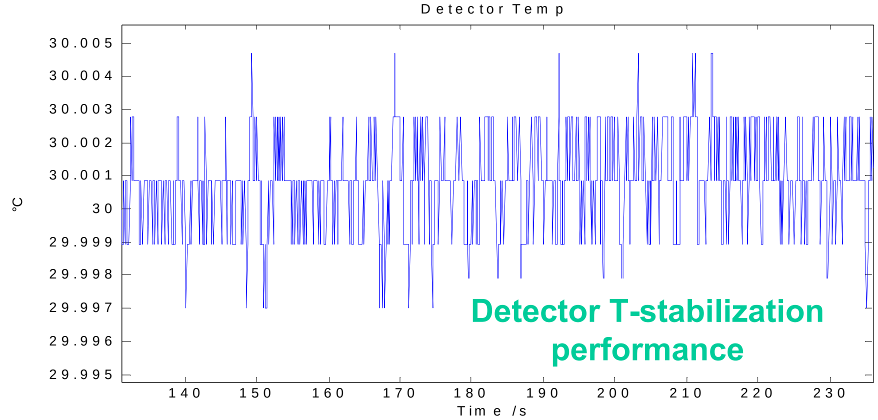
Offner mirror surface (data ref. IOF Jena)

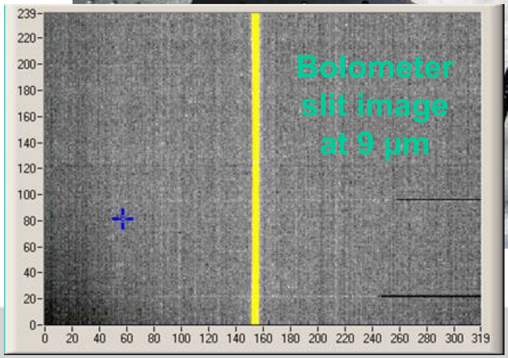
Development – Laboratory Work

- o Radiometric Analysis Breadboard (RAB)
  - Investigations of the environment stability (lab conditions), pattern correction and calibration approach
  - Adaptation and verification of MERTIS components (detector, proximity electronics, EGSE)
- o Spectro Radiometric Breadboard (SRB)
  - Investigations of the optical performance of TMA and spectrometer (grating, detector)
  - Verification of the MERTIS baseline design (grating, detector, F#, D*)









See you in 2018 !