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The Mercury Thermal Radiometer and Thermal Infrared Spectrometer (MERTIS) for BepiColombo

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Abstract

MERTIS is a small-scale highly integrated imaging radiometer and thermal IR spectrometer on-board of ESA's BepiColombo mission. It exceeds the scientific requirements and is below the specifications for mass and power consumption. This was achieved while staying more or less within the cost and time frames.

1. Introduction

The Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) is a state-of-the-art instrument to investigate the surface composition and mineralogy of planet Mercury (Fig. 1).

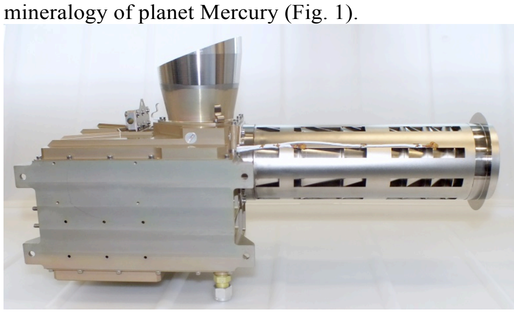

Fig. 1: The MERTIS flight model (FM). The MERTIS housing is about 180x180x130 mm large, the planet baffle (right) is about 200 mm long; space baffle on top

The scientific goals of MERTIS are:
- mapping of the surface mineralogy
- examining the composition of the surface of Mercury, as well as the identification of rock-forming minerals
- studying temperature variations and thermal inertia of the surface

From its orbit, MERTIS will map the surface globally at a spatial resolution of about 500 m and for approximately 5-10 % of the surface at a resolution of up to 280 m.
On-board of the BepiColombo Mercury Planetary Orbiter (MPO) MERTIS will arrive at Mercury in 2024 after its scheduled launch in 2016.

2. Instrument

The instrument combines an uncooled grating push-broom IR-spectrometer (TIS) with a radiometer (TIR). They will operate in the wavelength region of 7-14 µm and 7-40 µm, respectively, which offers unique diagnostic features to investigate the surface composition of Mercury [1,2]. For example, feldspars can easily be detected and characterized. These minerals exhibit several diagnostic spectral signatures in the range between 7-14 µm, which are the Christiansen feature, Reststrahlen bands, and the transparency feature. Furthermore, MERTIS will allow mapping and characterising of e.g. elemental sulfur, pyroxenes, olivines, and other rock forming minerals. MERTIS is a push-broom device that images a 1D-FOV on the whole detector array [1]. The spectral splitting is done by utilizing a reflective diffraction grating. The 1D-FOV is oriented perpendicular to the orbit track and each frame will be read out after the obiter moves a certain distance or time. The ten miniaturized highly integrated subsystems of MERTIS are: two IR detectors (bolometer and radiometer) with read-out electronics, two cold redundant instrument controllers and power supplies, two actuators (pointing unit and shutter), two on-board blackbody calibration targets at 300 K and 700 K, two baffles (planet, space), mirror optics, heater, and temperature sensors (Figs. 1, 2).
The power consumption of MERTIS is 7.9 – 9.9 W; mass is less than 3.1 kg.

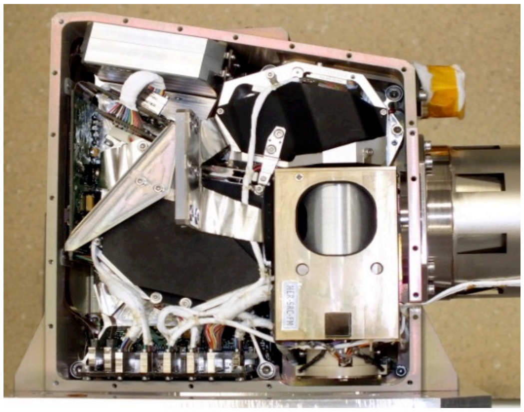

Fig. 2: The MERTIS flight model (FM) with open housing and space baffle removed. Planet baffle is to the right. Pointing unit, TMA, and Offner optics are clearly visible.

MERTIS-TIS covers the wavelength region of 7-14 µm with 78 spectral channels and a spectral resolution of $\lambda/\Delta\lambda$=78-156; MERTIS-TIR covers the wavelength region of 7-40 µm with 2 spectral channels.

We can resolve weak spectral bands of the regolith with less than 1% contrast. The spectral resolution of MERTIS can be adapted to optimize the signal-to-noise ratio (SNR), depending on the actual surface properties.

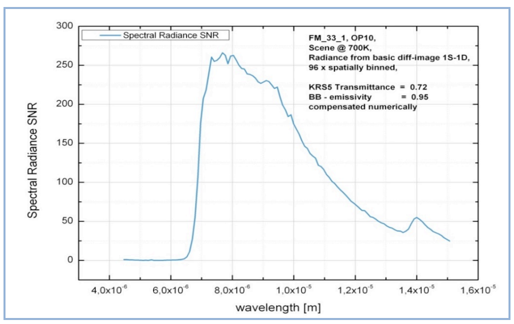

Fig. 3: Spectral radiance SNR of the FM spectrometer

The pointing unit allows looking periodically at Mercury (planet baffle) and cold space (space baffle, for calibration purposes), and at the two internal blackbody calibration targets at 300 K and 700 K, respectively. The optical design combines a three-mirror anastigmat (TMA) with a modified Offner grating spectrometer. The TMA consists of three off-axis aspherical mirrors where the second one is used as aperture stop. The Offner spectrometer uses two concentric spherical elements where the small convex element is the grating opposed by a large concave mirror [1].

3. Instrument Status

Since October 2013 the MERTIS instrument is fully functional and integrated on the spacecraft and is awaiting further spacecraft tests until launch in 2016.

4. Scientific Performance

One of the important parameters to estimate the scientific performance of MERTIS is the SNR of the spectrometer [3,4]. With a SNR larger than 100 it is possible to resolve mineral bands with low spectral contrast [1,5,6]. For a temperature of the scene of 700 K and a dwell time of 100 ms, the SNR of MERTIS is 266 at 8 µm wavelength after calibration (Fig. 3). If, in addition, to the blackbody emissivity of 0.95 the future on-board data processing is taken into account (e.g., averaging), the SNR will be further improved by a factor of 2. Details on the ongoing instrument calibration efforts are discussed in [6].

5. Summary

We have successfully built a small-scale highly integrated imaging radiometer and thermal IR spectrometer that not only exceeds the scientific requirements, but is also below the specifications for mass and power consumption. All this was achieved while staying roughly within the given cost and time frames. Besides hardware delivery and development of a new operations scenario, a strong laboratory program has been initiated that produces solid results [e.g., 7,8].

6. References

[1] Hiesinger et al. Planet. Space Sci. 58; 2010 [2] Peter et al. Proc. SPIE 8867, 2013; [3] Säuberlich et al. Proc. SPIE 7453, 2009 [4] Säuberlich et al Proc. SPIE 8154, 2011 [5] Arnold et al. Proc. SPIE Journal of Applied Remote Sensing 2, 2008 [6] Helbert et al. LPSC 45, 2014 [7] Maturilli et al. Planet. Space Sci. 56; 2008 [8] Morlok et al. LPSC 45 2014