The Mercury Thermal Radiometer and Thermal Infrared Spectrometer (MERTIS) for BepiColombo: A status report. H. Hiesinger[1], J. Helbert[2], G. Peter[3], I. Walter[3], M. D'Amore[2], T. Säuberlich[3], I. Weber[1]; [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (hiesinger@uni-muenster.de), [2]DLR Inst. für Planetenforschung, Berlin, [3]DLR Inst. für Opt. Informationssysteme, Berlin, Germany.

Introduction: The Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) is an innovative instrument for studying the surface composition and mineralogy of planet Mercury. In particular, the scientific objectives of MERTIS include 1.) Study of Mercury's surface composition, 2.) Identification of rock-forming minerals, 3.) Mapping of the surface mineralogy, and 4.) Study of surface temperature variations and the thermal inertia. The instrument combines an uncooled grating push-broom IR-spectrometer (TIS) with a radiometer (TIR), which will operate in the wavelength region of 7-14 μm and 7-40 μm, respectively [1,2]. The thermal infrared range offers unique diagnostic capabilities to study the surface composition of Mercury. For example, feldspars can easily be detected and characterized, because they show several diagnostic spectral signatures in the 7-14 μm range: the Christiansen feature, reststrahlen bands, and the transparency feature. In addition, MERTIS will allow identifying and mapping of elemental sulfur, pyroxenes, olivines, and other complex minerals. Scheduled for launch on-board the BepiColombo Mercury Planetary Orbiter (MPO) in 2016, MERTIS will arrive at Mercury in 2024. From its nominal 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.

Instrument: 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. MERTIS consists of more than 10 miniaturized, highly integrated subsystems, including mirror optics, two IR detectors (bolometer and radiometer) with read-out electronics, two actuators (pointing unit and shutter), two on-board blackbody calibration targets at 300 and 700 K, two baffles (planet, space), heater, temperature sensors, and two cold redundant instrument controllers and power supplies (Figs. 1, 2). MERTIS has a mass of less than 3.1 kg and during nominal science operations has a power consumption of 7.9 – 9.9 W.

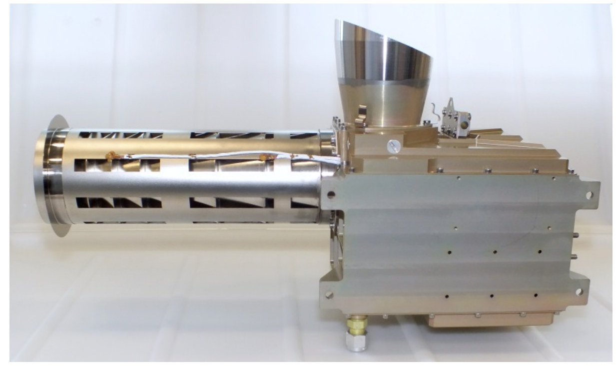

Fig. 1: The MERTIS flight model (FM). The MERTIS housing is about 180x180x130 mm large, the planet baffle (left) is about 200 mm long; space baffle on top

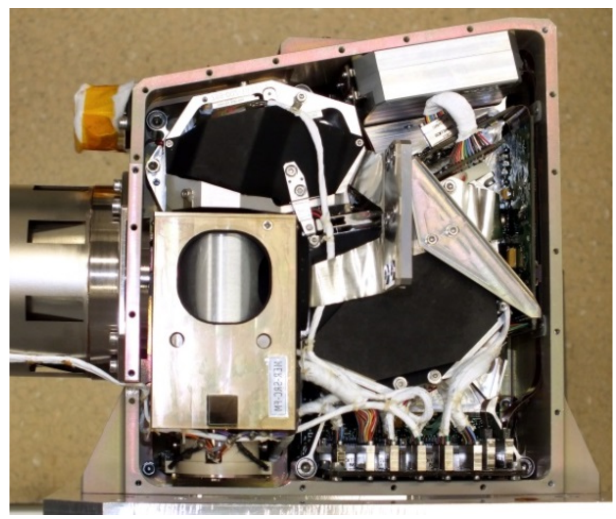

Fig. 2: The MERTIS flight model (FM) with open housing and space baffle removed. Planet baffle is to the left. Pointing unit, TMA, and Offner optics are clearly visible.

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. Depending on the actual surface properties, the spectral resolution of MERTIS can be adapted to optimize the SNR ratio. This allows us to resolve weak spectral bands of the regolith with less than 1% contrast. The SNR ratio of MERTIS at 700 K is given in Figure 3. The pointing unit allows us to look periodically at Mercury (planet baffle) and cold space (space baffle, for calibration purposes), and at the two internal blackbody calibration targets at 300 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 with the second one 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].

Instrument status: We have built, calibrated, and delivered the MERTIS instrument to ESA for integration on the spacecraft. The instrument is now fully functional and integrated and is awaiting further spacecraft tests until launch in 2016.

Scientific performance: One of the important parameters to judge the scientific performance of MERTIS is the signal-to-noise ratio (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]. Figure 3 demonstrates that after calibration, the SNR of MERTIS is 266 at 8 μm wavelength and a temperature of the scene of 700 K and a dwell time of 100 ms. While the blackbody emissivity of 0.95 was taken into account, the SNR did not take into account on-board data processing (e.g., averaging) that will further improve the SNR by a factor of 2. Details on the ongoing instrument calibration efforts are discussed in [6].

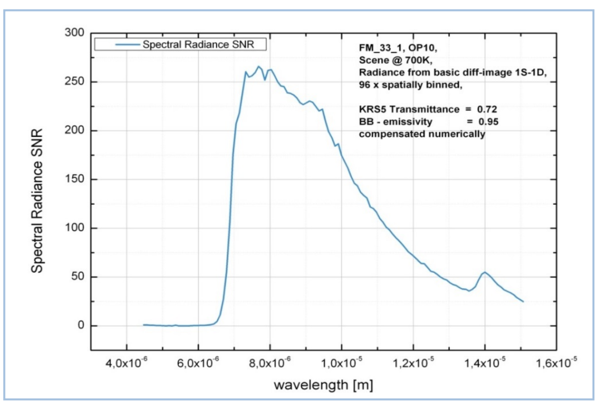

Fig. 3: Spectral radiance SNR of the FM spectrometer

Operations: We will map the surface of Mercury at aphelion when the spacecraft is at periherm on the illuminated day side of Mercury. During this period, operating the spectrometer (TIS) of MERTIS will have highest priority. During perihelion when the spacecraft is closest to the night side during periherm, the best radiometric and temperature measurements can be obtained. Thus, in this orbital phase the radiometer (TIR) of MERTIS will have highest priority. Unfortunately, BepiColombo faces a serious problem in total data volume that can be transmitted to Earth. To alleviate this situation, we have created a highly optimized operational scenario to reduce the data rate by about 60% from the original plan (Fig. 4). More details on the new instrument operations plan are given in [6].

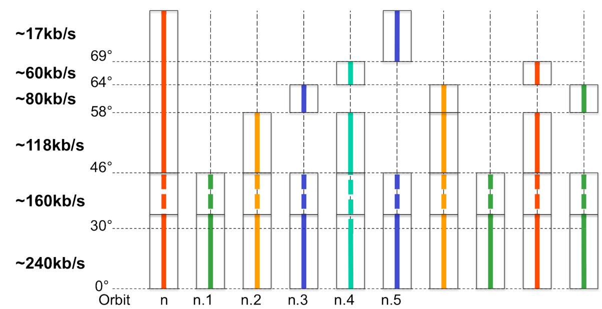

Fig. 4: Optimized operations scenario for MERTIS

Laboratory: Substantial progress has been made in our laboratory programs in Münster (InfraRed spectroscopy for Interplanetary Studies (IRIS)) and Berlin (Planetary Emissivity Laboratory (PEL)) that produce reference spectra of Mercury-relevant minerals to be incorporated in the Berlin Emissivity Database (BED) [7,8]. In addition, temperature effects on the spectral information are studied in Berlin [9,10] and effects of space weathering are studied in Münster. We also made significant progress in developing thermal models of the lunar surface, which we now test and apply to the mercurian surface.

Summary: We have successfully built a state-of-the-art 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 within the given cost and time frames. Since October 2013, the instrument is fully functional and integrated on the BepiColombo MPO. We have substantially modified our operations scenario to react to the reduced BepiColombo data downlink capabilities. Besides hardware delivery and development of a new operations scenario, a strong laboratory program has been initiated that produces solid results.

References: [1] Hiesinger et al. (2010) Planet. Space Sci. 58; [2] Peter et al. (2013) Proc. SPIE 8867; [3] Säuberlich et al (2009) Proc. SPIE 7453; [4] Säuberlich et al (2011) Proc. SPIE 8154; [5] Arnold et al. (2008) Proc. SPIE Journal of Applied Remote Sensing 2; [6] Helbert et al. (2014) LPSC 45; [7] Maturilli et al. (2008) Planet. Space Sci. 56; [8] Morlok et al. (2014) LPSC 45; [9] Helbert et al. (2013) EPSL, 371-372; [10] Helbert et al. (2013) EPSL, 369-370