WHAT'S NEW AT THE PLANETARY SPECTROSCOPY LABORATORY (PSL) A. Maturilli[1], J. Helbert[1], [1]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, 12489 Berlin, Germany – alessandro.maturilli@dlr.de

Introduction: The Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin is a well established spectroscopy facility providing spectral measurements of planetary analogues from the visible to the far-infrared range for comparison with remote sensing spacecraft/telescopic measurements of extraterrestrial surfaces [1-5]. Reflection, transmission and emission spectroscopy are the techniques used to acquire spectral data of target materials. The study of the surface composition (and its evolution) of celestial bodies relies on a solid fundament of laboratory spectroscopy. With the increasing number of missions and hyper-spectral instruments to a wide range of bodies in the solar system there is an ever-increasing demand for new measurements.

The PSL laboratory set-up is regularly updated to based on feedback from the scientific community to offer a wide range spectroscopic measurements. Recent addictions are detectors and beamsplitters to further extend the spectral range of measurements that can be performed in the laboratory, as well as the temperature range that we can cover for the measurements, and the extension of illumination angles covered in bi-directional reflectance.

An FT-IR microscope was installed at the end of 2018, allowing microscopic analysis in transmission and reflectance in the VIS+VNIR+MIR spectral range.

Set-up description: Two identical FTIR instruments are operating at PSL, in an air-conditioned room (Figure 1). The spectrometers are Bruker Vertex 80V (high-end model) that can be evacuated to ~.1 mbar. One spectrometer is equipped with aluminum mirrors optimized for the UV, visible and near-IR, the second features gold-coated mirrors for the near to far IR spectral range.

Detector	Spectral Range (µm)	Operating T
GaP Diode	0.2 – 0.55	Room T
2x Silicon Diode	0.4 – 1.1	Room T
2x InGaAs Diode	0.7 – 2.5	Room T
InSb	0.78 – 5.4	Liquid N_2
2x MCT	0.8 – 16	Liquid N_2
MCT/InSb SW	1 – 16	Liquid N_2
2x DTGS/KBr	0.8 – 40	Room T
DTGS/CsI	0.8 – 55	Room T
DTGS/PE	14 – 1000	Room T

Table 1. Detectors equipment at the PSL.

Using two identical instruments has two major benefits. The instruments can share the detectors and beamsplitters in our collection to cover a very wide spectral range, and this facilitates the cross-calibration between the two instruments. The spectrometers and the accessory units used are fully automatized and the data calibration and reduction are made with quality controlled DLR developed software. Table 1 list the spectral coverage of detectors we have available at PSL, Table 2 describes the associated beamsplitters we use at PSL.

Beamsplitter	Spectral Range (µm)
2x UV/VIS/NIR CaF_2	0.18 – 2.5
2x Si on CaF_2	0.66 – 8.3
2x Ge on KBr (Wide)	1 – 25
Ge on KBr substrate	1.2 – 25
Multilayer	14.7 – 333
50 µm Mylar	181 – 666

Table 2. Beamsplitters in use at the PSL.

High power (24V, water cooled) external sources feature the PSL set-up to cover the UV (0.2 to 0.5 µm) to the VNIR+TIR (1 to 16 µm) spectral range. 2 internal sources from VIS to FIR complete the available offer.

Figure 1. Laboratory set-up at the PSL.

Facility Support Equipment: We have a large collection of hundreds of rocks and minerals, synthetic minerals, Apollo 16 lunar sample, and meteorites. Sets of sieves (from <25µm to 4000 µm), grinders, mortars, saw, balances, microscope, two ovens (290 to 570 K and 300 to 3300 K) for sample treatments, wet chemistry materials, a pellets press (10mm or 20mm diameter), two large dry cabinets (moisture < 1%) for sample storage, 3 small exsiccators (moisture < 20%) for sample storage, purge gas generator for water and CO_2 free air, liquid-nitrogen tank, an ultrasonic cleaning unit, and microscopes characterize the sample preparation facility.

Emissivity measurements: External simulation chambers are attached to the FTIR spectrometer to measure the emissivity of solid samples. One chamber features high efficiency induction system to heat the samples under vacuum to temperatures from 320K up to above 900K, while keeping the chamber at almost ambient temperature. A shutter allows separating the spectrometer from the external chamber. An optical window (vacuum tight) can be mounted at the entrance of the emissivity chamber to allows keeping the external chamber at ≥ambient pressure, under purged air or inert gases. The sample cups are made of stainless steel and have elevated rims enclosing the samples heating it from all sides, effectively supressing thermal gradients within. A sample carousel driven by a highly precise stepper motor allows measuring several consecutive samples without breaking the vacuum. A large number of temperature sensors in the emissivity chamber are allocated to measure the sample temperature as well as monitoring the range of equipment and chamber temperatures. A webcam is mounted in the emissivity chamber to monitor the heated sample and its vicinity. Ceramic cups enclosing a stainless steel disc are used to extend the high temperature spectroscopy capabilities of PSL to start at 700nm [6].

A second chamber (purged with dry air and water cooled to 270K or below) is used for emissivity measurements of samples with surface temperature from 290 to 420K.

Reflectance measurements: With the Bruker A513 accessory on both Vertex 80V, we measure bi-directional reflectance of samples, with variable incidence and emission angles between 0° and 85° (minimum phase angle is 26°). Samples can be measured at room temperature and currently down to 170K using a test setup cooled by liquid nitrogren inside the spectrometer sample chamber. A compact low-temperature reflectance chamber for FT-spectroscopy experiments at the PSL is currently under development [7]. The expected cryogenic temperature is in the first step approximately within the range of 70K – 100K. We recently added two integrating spheres (one with gold mirror, the other with PTFE mirror) for hemispherical reflectance measurements (soon under vacuum).

We measure bi-directional and hemispherical reflectance under purging or vacuum conditions, covering the 0.2 to above 200 µm spectral range.

Transmittance measurements: The Bruker A480 parallel beam accessory mounted on the Vertex 80V allows us to measure transmission of thin slabs, optical filters, optical windows, pellets, etc, in the complete spectral range from UV to FIR avoiding refraction, typical in this kind of measurements.

FT-IR Microscope: At the end of 2018 we successfully installed a new FT-IR Microscope in the PSL. The Bruker HYPERION2000 provides high stability and reliability, for reflectance and transmission microscopy. To investigate samples at certain temperatures from -196 to 600°C, the Linkam THM600 stage is used. ATR and Grazing Angle Objective (GAO) are available for sample viewing without sacrificing infrared light throughput and for measurement of very thin coatings. The HYPERION can be equipped with up to two detectors in parallel, where the switching between positions is controlled by the same software controlling the spectrometers.

Facility access: PSL is a Trans-national access (TA) facility supported by the European Union within the EuroPlanet Research Infrastructure framework for the next two years. In this period once per year a call for proposals will be issued for investigations using PSL. Details can be found at:

http://www.europlanet-2020-ri.eu/.

PSL is also member of the NASA SSERVI Team TREX [8] providing spectral measurements of fine particle samples (https://trex.psi.edu/).

Conclusion: The PSL is constantly improving to provide the planetary community with reflectance, transmission and emissivity measurements highly complementary to existing spectral databases, under vacuum, that cover the whole spectral range from UV (0.2 µm) to the FIR (200 µm and above), and for sample temperature from 70K to 1000K.

http://www.dlr.de/pf/desktopdefault.aspx/tabid-10866/19013_read-44267/

References: [1] Maturilli, A. and Helbert, J, PSS, Vol. 54, pp. 1057-1064, 2006. [2] Maturilli, A., Helbert, J., and Moroz L.: The Berlin Emissivity Database (BED), PSS, Vol. 56, pp. 420-425, 2008, spectral library now available at http://figshare.com/articles/BED_Emissivity_Spectral_Library/1536469. [3] Helbert, J. and Maturilli, A, EPSL, Vol. 285, pp. 347-354, 2009. [4] Maturilli A, Helbert J., Journal of Applied Remote Sensing, 2014. [5] Maturilli A, Helbert J, St. John JM, Head III JW, Vaughan WM, D'Amore M, Gottschalk M, Ferrari S. EPSL, Vol. 398, pp. 58-65, 2014. [6] Helbert et al.: ORBITAL SPECTROSCOPY OF THE SURFACE OF VENUS (2019), this meeting. [7] Rosas Ortiz et al., LPSC 49th, 2018. [8] Lane et al. TOOLBOX FOR RESEARCH AND EXPLORATION (TREX): THE FINE-PARTICLE SPECTRAL LIBRARY (2018), LPSC 49th, 2018.

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