CRYOGENIC REFLECTANCE SPECTROSCOPY CHAMBER UNDER HIGH VACUUM CONDITIONS FOR SMALL BODIES EXPLORATION. A. Maturilli\(^1\), J. Helbert\(^1\), A. Lorek\(^1\), S. P. Garland\(^1\), G. Alemanno\(^2\), J. G. Lukas\(^1\), \(^1\)German Aerospace Center (DLR) - Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany (alessandro.maturilli@dlr.de).

**Introduction:** Exploring the small bodies and icy moons in the outer solar system is a priority after the successful JAXA Hayabusa2 and NASA Osiris-Rex missions (both returning asteroid samples to Earth), with the NASA Lucy mission soon exploring the first trojan asteroid and with the upcoming missions including ESA JUICE and NASA Europa Clipper, as well as plans for mission to Enceladus [1,2]. There is high demand for laboratory spectra of small body and icy moons analog materials obtained at low pressure or in vacuum at cryogenic temperatures.

To meet this demand PSL (the Planetary Spectroscopy Laboratory of DLR – German Aerospace Center in Berlin) has constructed a compact low-temperature vacuum chamber for angle dependent bi-directional reflectance measurements that attaches directly to an existing spectrometer. The system allows for measurements from UV to far infrared for up to 4 samples at temperatures lower than \(-150^\circ\text{C}\) under vacuum down to \(10^4\) hPa. The samples are prepared in a glovebox under dry air and controlled temperature conditions down to \(-50^\circ\text{C}\) and are directly transferred on the sample holding dish (also at \(-50^\circ\text{C}\)) to the vacuum chamber via an airlock.

**Set-up implementation:** The implementation of the cryogenic setup is part of a Joint Research Activity that has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 871149. The development of this activity was delayed first by the COVID-19 pandemic and then again by the global supply chain problems at the beginning of 2022. The final implementation could only start in early summer of 2023 with the whole system being assembled at PSL in July of 2023 [3]. In September 2023 the new facility was fully assembled and functional tests could start. The functional tests and relative set-up improvements ended in December 2023.

**Cryochamber description:** The system features 5 core points to allow spectral measurements on small body and icy moon analogs under optimal conditions:

1- The samples are prepared on a cooling unit up to \(-50^\circ\text{C}\) then transferred to the cooled cylindric sample shuttle, that keeps them at \(-50^\circ\text{C}\) until inside the chamber

2- The samples once transferred inside the chamber (after closing the airlock) can be exposed to high vacuum \((10^4\) hPa).

3- Up to 4 samples can be prepared and transferred in the chamber and measured without breaking the vacuum.

4- Mirrors mounted on two moving arms allow for a wide range of illumination angles.

5- External light sources allow for measurement of the samples under cryogenic condition in high vacuum for a wide spectral range (UV to TIR/FIR).

Figure 1 shows the fully assembled system at PSL [4] connected to the Bruker VERTEX 80V spectrometer on the optical bench. The left panel shows a view of the dry air-purged glove box for sample preparation. The middle panel shows the actual vacuum chamber with an attached light source. The right panel shows the support equipment for the cryocoolers and vacuum pumps.

![Figure 1. Views of the completed assembly in PSL. From left to right - glove box for sample preparation, high vacuum chamber, and support equipment for pumps and cryocooler (for details see [3])](image1)

![Figure 2. Vacuum chamber as assembled in PSL with all main external components labelled (for details see [3]).](image2)

One of the major highlights of the chamber design is the possibility to mount different external light sources allowing measurements under cryogenic conditions over the whole wavelength range covered by PSL without interrupting the cold cycle of the samples inside the chamber. Figure 2 shows the fully assembled chamber at PSL and all its external components.
Figure 3 shows a view inside the vacuum chamber with the main lid open during early integration. Two motor-driven arms carry the mirrors that form the bi-directional reflectance system. Illumination is achieved using an external light source. In order to maximize compatibility with the existing systems at PSL, the illumination port of the vacuum system uses the same adapter as the Bruker VERTEX 80V spectrometer. Therefore, all lamps already in use at PSL can be used with the cryogenic setup. The spectrometer port of the chamber is connected to one of the external ports of a Bruker VERTEX 80V spectrometer. An exchangeable window allows maintenance of the high vacuum in the cryogenic chamber while the spectrometer itself is only evacuated to a medium vacuum.

The cooling block is connected to a Lihan TC4189 cryocooler that is mounted underneath the vacuum chamber. The TC4189 integrates a gas-bearing linear pressure-wave-generator with a pulse tube cold finger. The shuttle for the 4 samples is mounted on the cooling block and can be actuated using a linear motor.

Figure 3. View inside the vacuum chamber with the main lid opened.

A key component of the sample preparation glove-box is a cold finger with a cryocooler which allows preparation of icy samples as well as ice-dust mixtures under a dry air atmosphere. The prepared samples are fed into the vacuum chamber via the air lock at the back of the glove box. This provides maximum flexibility in preparing cryogenic samples while minimizing the risk of contamination and frost forming on the samples.

Summary and outlook: The assembly of the cryogenic chamber at PSL is essentially completed and commissioning activities have started. The focus of the first part of the commissioning phase is on the vacuum system and the cryocooler. In the second phase the optical system will be verified. In the final phase of verification, the first test spectra will be obtained.

Once all parts are verified the operational procedures will be extensively tested and when needed optimized. This will then lead into the operational phase with internal and external users.

The capability of obtaining bi-directional reflectance measurements from UV to infrared on dust, ice and ice-dust mixtures will support science for outer solar system exploration [6-9] as well as our understanding of the permanently shadowed regions on the Moon and Mercury. The latter will directly feed into the analysis of the data returned by the MERTIS instrument on the ESA-JAXA BepiColombo mission after its arrival at Mercury in 2026 [5, 10].

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