RAX: The Raman Spectrometer on the MMX Rover for in-situ Surface Analysis on Phobos. S. Schröder[1]*, U. Böttger[1], M. Buder[1], Y. Bunduki[1], Y. Cho[2], E. Dietz[1], T. Hagelschuer[1], H.-W. Hübers[1], S. Kameda[3], E. Kopp[1], A. G. Moral Inza[4], M. Pertenais[1], G. Peter[1], A. Pohl[1], O. Prieto-Ballesteros[5], K. Rammelkamp[1], S. Rockstein[1], S. Routley[1], S. Rufini[1], F. Rull[6], C. Ryan[1], T. Säuberlich[1], F. Schrandt[1], S. Ulamec[7], T. Usui[8], K. Westerdorff[1]. [1]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin, Germany. [2]Department of Earth and Planetary Science, The University of Tokyo, Tokyo, Japan. [3]Department of Physics, College of Science, Rikkyo University, Tokyo, Japan. [4]Instituto National de Técnica Aerospacial (INTA), Torrejón de Ardoz, Spain. [5]Centro de Astrobiologia (CAB-INTA-CSIC), Torrejón de Ardoz, Spain. [6]Universidad de Valladolid, Valladolid, Spain. [7]German Aerospace Center (DLR), Microgravity User Support Center, Cologne, Germany. [8]ISAS/JAXA, Kanagawa, Japan. (*Susanne.Schroeder[at]dlr.de).

Introduction: In 2024, JAXA's Martian Moons eXploration (MMX) mission will be launched, dedicated to study Phobos and Deimos with the goal on shedding light on the moons' origins [1,2]. An orbiter and a rover will be sent for remote and in-situ exploration, and samples (> 10 g) will be brought from Phobos back to Earth.

The small rover (about 25 kg) to study in-situ the regolith at the surface is a joint contribution of the Centre National d'Etudes Spatiales (CNES) and the German Aerospace Center (DLR). It is planned to be delivered to Phobos in 2027 [3]. The rover is equipped with several instruments such as cameras for navigation and inspection of the wheels, the surface and their interaction (NavCams, WheelCams) as well as a radiometer measuring the surface brightness temperature, and a Raman spectrometer to study the mineralogy of Phobos' surface. The Raman spectrometer for MMX (RAX) [4-7] was developed under the lead of DLR with contributions from international partners: Instituto Nacional de Tecnica Aerospacial (INTA), University of Valladolid (UVa) and JAXA, University of Tokyo, and Rikkyo University. The RAX flight model (FM) was delivered to CNES in August 2022 and successful integration into the rover was accomplished in October 2022. The fully integrated MMX rover will be delivered to JAXA in summer 2023.

The optically equivalent RAX Development Model (DM) is the most FM-similar instrument in terms of both, hardware and software and is currently still being used to test and verify software updates for the FM. It will stay at DLR-OS as reference instrument providing laboratory Raman data that can be compared to the Raman data that will be obtained in-situ on Phobos.

Science Objectives: The scientific objectives of the RAX instrument follow from the global MMX mission objectives and requirements as defined by JAXA [1]. With RAX, the surface mineralogy of Phobos will be studied in-situ, giving ground truth and input about the question of the origin of the Martian moon and its alteration and evolution. The fingerprint-like Raman spectra allow for mineral and molecule identification which can be linked to different formation scenarios (such as captured asteroid vs. major impact) and can also give insights into surficial alteration processes. Due to the mobility provided by the MMX rover, Raman spectra of multiple positions can be acquired along the rover's traverse and the heterogeneity of the materials can be studied. The in-situ Raman data from Phobos will also be compared to data obtained on the surface of Mars to differentiate between Martian and non-Martian materials and eventually also to the returned samples of the MMX mission.

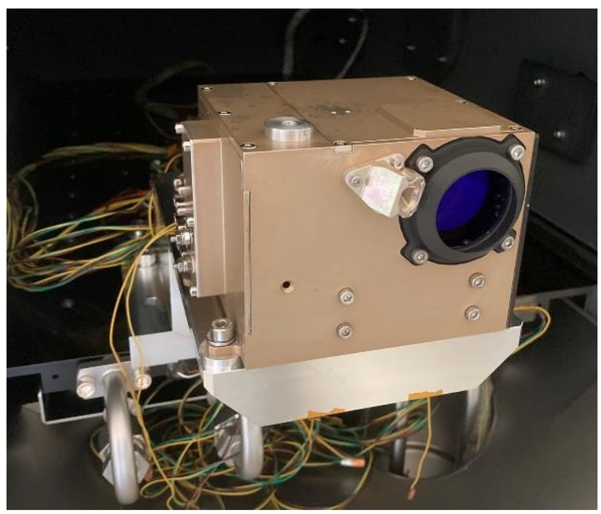

Figure 1: *Picture of the RAX Spectrometer Module (RSM) Flight Model (FM) as prepared for thermal vacuum testing at DLR-OS.*

Raman spectrometer for MMX (RAX): RAX is a particularly compact, low-mass Raman instrument with a volume of only approximately 1 dm^3 (see Fig. 2) and a mass of 1.5 kg. Excitation is done with continuous wave 532 nm with a miniaturized laser unit that was initially developed by INTA for the RLS instrument aboard the Rosalind Franklin ExoMars rover [8]. The optical design of RAX was driven by 1) the tight constraints of volume and mass available on the small

MMX rover and 2) optimizing the collection and detection capabilities of the Raman signal from a sample at several centimeters distance below the rover's body. The result is a highly sophisticated and very compact confocal optical assembly enabling the coverage of Raman shifts of 90 up to 4000 cm^{-1} (spectral range 535-680 nm) with a resolution of about 10 cm^{-1}. The RAX instrument consists of two physically separated units, the RAX Laser Assembly (RLA) and the RAX Spectrometer Module (RSM). A multimode optical fiber with a core diameter of 50 µm is used to transfer the laser emission from the RLA to the RSM. Details on the instrument system and optical design can be found for instance in [4,9]. RAX will perform Raman spectroscopic measurements at a working distance of approximately 8 cm. To do so, the rover will lower its body and decrease the distance to the ground until the RAX instrument reaches its working distance. Then, with the integrated opto-mechanical autofocus subsystem (AFS) and using image data of the surface illuminated with the autofocus photodiode integrated in the RLA, the RAX laser will be focused onto the rock or regolith in the field-of-view under the rover. Raman data is acquired from a spot of 50 µm in diameter.

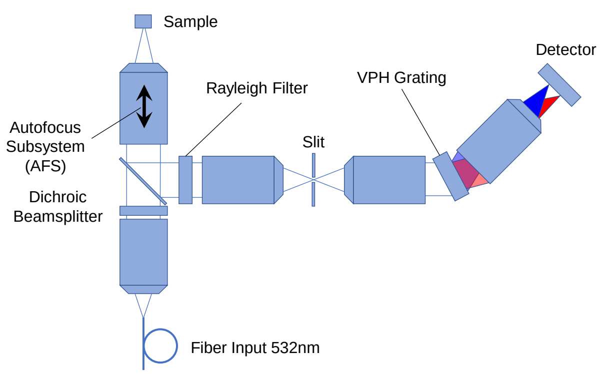

Figure 2: *Scheme of the RAX optical system [9].*

To demonstrate the functionality of the RAX instrument after the launch and to monitor its performance, a Verification Target (VT) is part of the payload. It is composed of deuteriated polyethylene terephthalate (PET) produced and tested by INTA and UVa [10]. The VT is placed in the field-of-view of the RAX instrument mounted on the MMX rover Mechanical Electrical Communication and Separation Subsystem (MECSS) and can be measured during cruise and in orbit until the rover will separate from the MMX spacecraft for landing on Phobos.

Data acquisition and processing: Dark images, i.e. without the laser, are acquired before every Raman measurement to account for dark current and instrument noise. These are subtracted from the images with the Raman data. The curved illuminated area on the detector is fitted along the maximal intensity. The binning both in spectral as well as in spatial dimension is chosen to optimize the detection of the Raman features. Exemplary Raman spectra obtained with RAX are shown in Fig. 3.

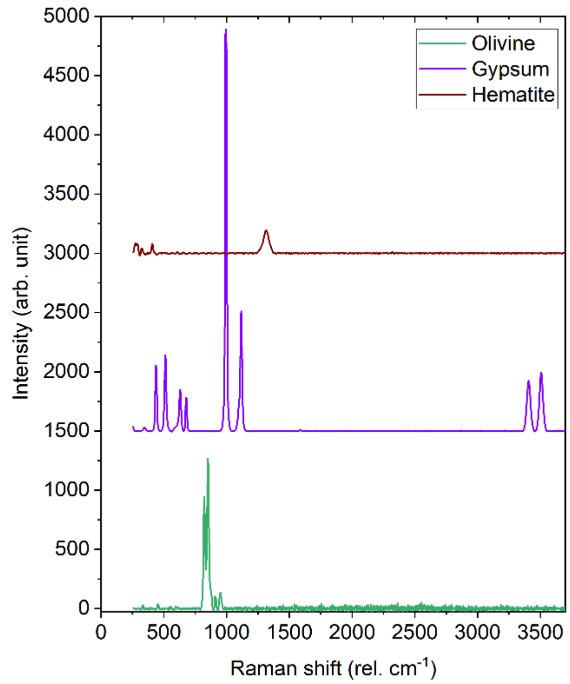

Figure 3: *Raman spectra of olivine, gypsum and hematite measured with RAX with integration times of 1 s. The background was analytically removed with a Whittaker algorithm.*

Acknowledgements

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