IN-SITU RAMAN SPECTROSCOPY ON PHOBOS: RAX ON THE MMX ROVER. S. Schröder[1]*, T. Belenguer[2], U. Böttger[1], M. Buder[1], Y. Cho[3], E. Dietz[1], M. Gensch[1], T. Hagelschuer[1], F. Hanke[1], H.-W. Hübers[1], S. Kameda[4], E. Kopp[1], S. Kubitza[1], A. Moral[2], C. Paproth[1], M. Pertenais[1], G. Peter[1], K. Rammelkamp[1], P. Rodriguez[2], F. Rull[5], C. Ryan[1], T. Säuberlich[1], F. Schrandt[1], S. Ulamec[6], T. Usui[7], R. Vance[1]. [1]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin, Germany. [2]Instituto National de Técnica Aerospacial (INTA), Torrejón de Ardoz, Spain. [3]Department of Earth and Planetary Science, The University of Tokyo, Tokyo, Japan. [4]Department of Physics, College of Science, Rikkyo University, Tokyo, Japan. [5]Universidad de Valladolid –Unidad Asociada UVa-CSIC Centro de Astrobiologia, Valladolid, Spain. [6]German Aerospace Center (DLR), Microgravity User Support Center, Cologne, Germany. [7]Japan Aerospace Exploration Agency (JAXA), Institute of Space and Astronautical Science, Department of Solar System Sciences, Kanagawa, Japan. (*Susanne.Schroeder [at] dlr.de).

Introduction: JAXA's Martian Moons eXploration (MMX) mission is dedicated to study Phobos and Deimos, with a focus, in particular, on shedding light on the moons' origins [1,2]. The mission will be launched in 2024 and will bring samples from Phobos back to Earth but also deliver a small rover (about 29 kg) to Phobos to study in-situ the regolith at the surface [3]. The MMX rover is a joint contribution of the Centre National d'Etudes Spatiales (CNES) and the German Aerospace Center (DLR) and will carry a thermal mapper (miniRAD, based on MASCOT's MARA [4]), a Raman spectrometer (RAX) [5], a stereo pair of navigationcameras looking forward (NavCAM), and two cameras looking at the interface wheel-surface (WheelCAM). We will report here on the design and status of the RAX instrument development.

Raman spectroscopy: An important feature of the Raman technique is that fingerprint spectra are measuered which allow for a straightforward identification of the sample under investigation. Incoming photons of a light source are inelastically scattered by the sample and the spectral features in a typical Raman spectrum can be attributed to vibrational modes, giving information on the substance's structure and bonds. For Solar System exploration, there is increasing interest in applying Raman spectroscopy in-situ for the analysis of extraterrestrial surfaces. Three Raman instruments with three very different configurations have been developed for the two Mars rovers by NASA and ESA, that will be launched in summer 2020: NASA's Mars 2020 rover will have a continuous wave (cw) deep UV Raman spectrometer attached to the robotic arm with a working distance of 48 mm [6] as well as a pulsed (532 nm) Raman instrument integrated into the SuperCam instrument suite on the rover's mast for remote analyses at distances of up to 12 m [7]. The Raman Laser Spectrometer (RLS) on ESA's ExoMars rover is designed to analyze samples obtained with the rover's drill, crushed and prepared inside the rover with a cw 532 nm laser, covering a spectral range of up to 3800 cm^{-1} with a spectral resolution of < 8 cm^{-1} [8].

RAX (Raman spectrometer for MMX): The RAX is a very compact, low-mass Raman instrument with a volume of approximately 81x98x125 mm³ and a mass of less than 1.4 kg that is jointly developed by DLR, Instituto Nacional de Tecnica Aerospacial (INTA), University of Valadolid (UVa) and JAXA/UTokyo/Rikkyo U. It will perform Raman spectroscopic measurements at a working distance of approximately 8 cm with a cw 532 nm excitation. The optical design is driven by 1) the tight constraints of volume and mass available on the 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 a spectral range up to 4000 cm^{-1} with a resolution of 10 cm^{-1}.

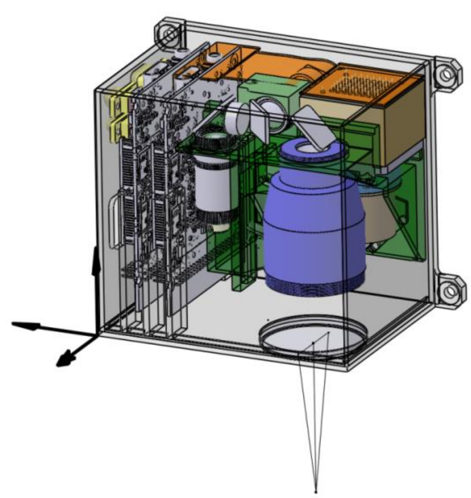

Figure 1. *Preliminary design of the RAX spectrometer module (RSM) with a volume of 81 × 125 × 98 mm³, a mass of <1.4 kg, and a working distance of 8 cm.*

The miniaturized laser unit that is used for RAX was originally developed by INTA and UVa for the RLS instrument aboard the ExoMars 2020 mission. The laser is designed for an optical output power of about 30 mW in the thermal operating range of +20 to +30°C. Since the laser linewidth defines the resolving power of the instrument, the laser temperature will be stabilized during RAX operations to an accuracy of ±0.1 K by a thermoelectric module. A lightweight, already space qualified CMOS detector with a mass of only 64 g and a volume of approximately 35 × 35 × 23 mm³ (3DCM734, 3Dplus [9]) is used for the detection of the Raman light. The CMOS sensor consists of 2048 × 2048 pixels with a pixel pitch of 5.5 µm. Each pixel is based on pinned photodiode architecture with several transistors.

A CAD drawing of the preliminary design of the RAX instrument is shown in Fig. 1. The RAX instrument consists of two physically separated units, the RAX Laser Assembly (RLA) and the RAX Spectrometer Module (RSM). The blue and green components highlight the Auto-Focus Subsystem (AFS) and some mounting structure of the spectrometer optics, respectively. The black lines at the bottom of the RSM indicate the focused laser beam with an expected working distance of 80 mm, calculated from the Light Shuttle Objective (LSO) entrance lens to the soil of Phobos. The Front Panel Assembly (FPA) and the detector are indicated by the orange components, which are connected to the auxiliary electronics board via flex harness. Next to the laser control board, on the left side of the RSM, several connectors are highlighted in yellow color, providing an electrical and optical interface to the RLA, as well as a power and SpaceWire interface to the MMX rover. The current model of the MMX rover design is shown in the front view in Fig. 2.

Status: The RAX project is currently in its phase B and the RAX Flight Model will be delivered for the integration into the rover in 2022. At DLR Berlin a RAX breadboard model was recently realized with an RLS flight spare laser module provided by INTA and UVa and with the original detector integrated. We will present Raman spectra obtained with the latest breadboard model from different pure mineral phases and material mixtures that aim to represent Phobos' surface materials.

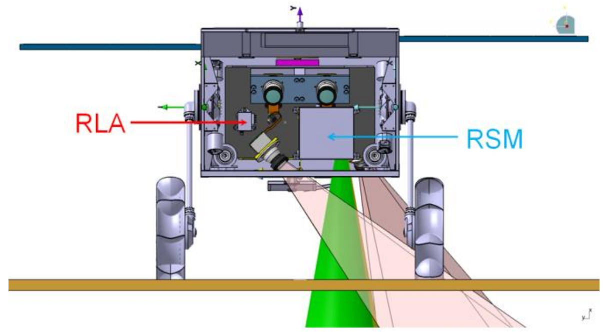

Figure 2. *Front view of the current MMX rover design with the RAX instrument onboard the internal module. The two units RLA and RSM are indicated by the red and blue arrow, respectively. The green cone indicates the field-of-view of the RAX instrument. (Credit: CNES/DLR)*

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References:

[1] Kuramoto, K., Kawakatsu, Y., Fujimoto, M. and MMX study team, Martian Moon Exploration (MMX) Conceptual Study Results, Lunar and Planetary Science Conference XLVIII, Abstr. #2086, 2017. [2] Kawakatsu, Y., Mission Definition of Martian Moon Exploration (MMX), 70th Int. Astronautical Congress, 2019. [3] Ulamec, S., Michel, P., Grott, M., et al., A Rover for the JAXA MMX Mission to Phobos, 70th Int. Astronautical Congress, 2019. [4] Grott, M., Knollenberg, J., Borgs, B., et al., The MASCOT Radiometer MARA for the Hayabusa 2 Mission. Space Sci. Rev. 208, 413-431, 2017. [5] Hagelschuer, T., Belenguer, T., Böttger, U., et al., The Raman spectrometer onboard the MMX rover for Phobos, 70th Int. Astronautical Congress, 2019. [6] Beegle, L., Bhartia, R., White, M., et al., SHERLOC: Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals, IEEE Aerosp. Conf. Proc., 2015. [7] Wiens, R., Maurice, S., Rull Perez, F., The SuperCam remote sensing instrument suite for the Mars 2020 rover mission : A preview, Spectroscopy 32, 2017. [8] Rull, F., Maurice, S., Hutchinson, I., et al., The Raman laser spectrometer for the ExoMars mission to Mars, Astrobiology 17, 627-654, 2017. [9] Sellier, C., Gambart, D., Perrot, N., et al., Development and qualification of a miniaturized CMOS Camera for Space Applications (3DCM734/ 3DCM739), Int. Conf. on Space Optics – ICSO, 2018.