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The Raman Spectrometer RAX on the MMX IDEFIX Rover for in-situ Mineralogical Analysis on Phobos

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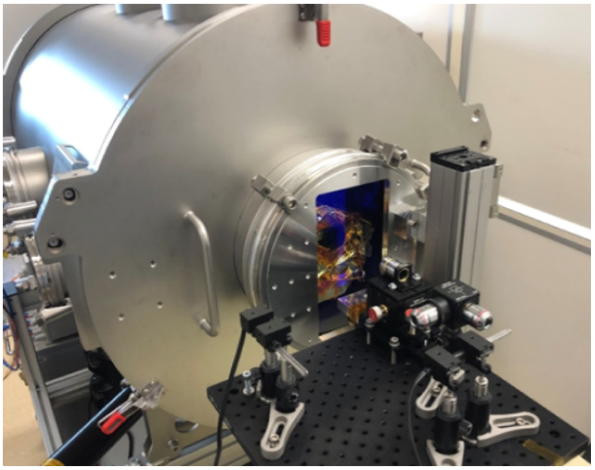
A compact Raman spectrometer [1] was developed for in-situ science on Phobos with the IDEFIX rover [2], which will be launched as part of JAXA's Martian Moon eXploration (MMX) mission in 2026. The MMX mission is dedicated to study the two Martian moons, Phobos and Deimos, with the aim of better understanding their origin and evolution [3, 4]. Orbital observations with the main MMX spacecraft and in-situ science on Phobos with the IDEFIX rover will be complemented by returning samples (>10 g) from the surface of Phobos back to Earth. The rover is expected to land between late 2028 and early 2029, in conjunction with the rehearsal for the first landing of the main spacecraft.



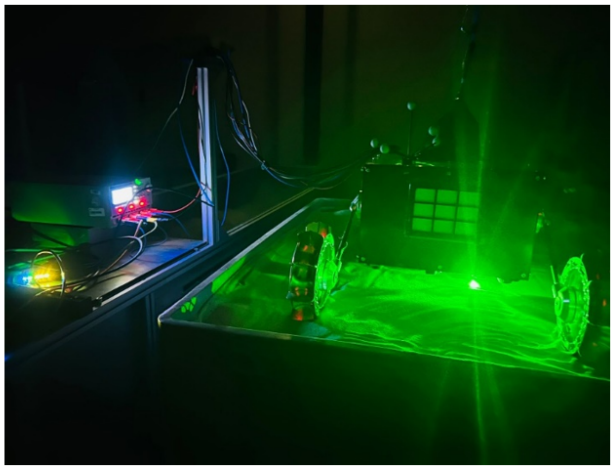


Figure 1. left: RAX flight model (FM) during thermal vacuum testing at DLR. Right: RAX development model (DM) combined locomotion test with MMX demonstration rover in DLR testbed during a Raman measurement.

The RAman spectrometer for MMX (RAX) contributes directly to the high level mission objectives by characterizing the mineral composition of the Phobos surface in-situ, providing ground truth. While different mineral phases can be associated with different formation scenarios (e.g. captured asteroid or major impact) and surface alteration processes on Phobos, the mineralogical information obtained with RAX can also help inform decisions about sampling with the main spacecraft and be compared with data obtained from the returned samples and in-situ data from the surface of Mars. The rover's mobility allows measurements to be taken from multiple positions along the rover's traverse, allowing local variations in composition to be studied. RAX measures down to the ground below the rover. RAX is extremely compact, with a mass of only 1.5 kg and a volume of about 1 dm^3. The optical design of RAX was driven by 1) the tight volume and mass constraints available of 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. Raman excitation (λ = 532 nm, typical optical power on sample 20 mW) is provided by a separate laser module based on the Raman Laser Spectrometer (RLS) laser developed for the Rosalind Franklin rover of the ExoMars mission [5]. The laser emission is transmitted to the RAX Spectrometer Module via a multimode optical fiber with a core diameter of 50 µm. To focus the laser on the Phobos surface below the rover, the spectrometer is equipped with an opto-mechanical autofocus subsystem. It allows fine-tuning of the focus position at a working distance of about 8 cm, within a range of 13 mm and an accuracy of 50 µm. The RAX instrument covers a spectral range of 535 to 680 nm, corresponding to a Raman shift of approximately 90 to 4000 cm^{-1} and therefore enabling the identification of water-bearing minerals. The spectral resolution across the entire spectral range is about 10 cm^{-1}. To demonstrate the functionality of the RAX instrument after launch and to monitor its performance, a Verification Target (VT) is part of the payload. The VT is a 13 mm diameter pellet made of deuterated polyethylene terephthalate (PET) and was developed and space-qualified specifically for this mission [6]. The VT is placed in the field of view of the RAX instrument and can be measured during the cruise until the rover separates from the MMX spacecraft for landing on Phobos.

For a Raman measurement on Phobos, the rover's locomotion system is needed for the main height adjustment: the rover will gradually lower its body height until the RAX instrument is within its working range. After autofocusing, RAX will measure what is exposed beneath the rover from a footprint of 50 µm. Visual context is provided by the rover's cameras. To improved data acquisition, Raman data will be collected during Phobos nights.

Representing a collaborative effort, RAX is a joint contribution from the German Aerospace Center (DLR), Instituto Nacional de Técnica Aerospacial (INTA), and JAXA. Delivered to the MMX Phobos Rover in August 2022, the RAX flight model was successfully integrated into the IDEFIX rover in October 2022. The flight model of the rover has been delivered to JAXA/MELCO where it is currently being integrated into the main spacecraft for further qualification and functional testing. Operational sequences, e.g. defining the interaction between locomotion and science instruments, are currently being prepared. RAX scientific measurements are being prepared with laboratory studies using the RAX development model.

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