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A Raman Spectrometer for the ExoMars 2020 Rover

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1. Context

The Raman project is devoted to the development of a continuous wavelength Raman spectrometer and to support the ExoMars-2020 rover science.

ExoMars is a twofold mission with different launch opportunities: the first one (ExoMars-2016, launched March 2016) put into orbit the Trace Gas Orbiter (TGO) with a scientific payload to study Mars atmosphere and a communication system for the following mission. The second one (ExoMars-2020, to be launched July 2020) will land and deploy a rover which includes for the first time in the history of Mars exploration, a drill that is capable of obtaining samples from the surface down to 2 m depth. These samples will be crushed into fine powders and delivered to the analytical instruments suite inside the rover by means of a dosing station.

The ExoMars rover will carry a suite of instruments dedicated to exobiology and geochemistry research. Its main scientific objective is “searching for evidence of past and present life on Mars". A continuous wavelength Raman instrument (Raman Laser Spectrometer – RLS) has been selected as part of this analytical suite inside the body of the vehicle.

Raman spectroscopy is related with the inelastic scattering of coherent light. When a monochromatic beam impinges a material, a tiny part of the scattered radiation is emitted at different wavelengths of the incident light. This wavelength shift contains structural and chemical information of the irradiated material through their atomic and bounding vibrations. This makes Raman spectroscopy a powerful technique since no direct contact with samples is necessary. It is very fast, non-destructive, and very selective for molecular identification.

The RLS is being developed by a European consortium composed by Spanish, UK, French, and German partners. The science team also includes members from the US and other countries.

2. The RLS instrument

The RLS consists of three main units: 1/ the spectrometer is a transmission spectrograph using a holographic grating that disperses the Raman signal which is projected on a 2048 x 512 pixel CCD operating at cold temperature; 2/ the control and excitation unit includes the DC/DC power converters and the data processing capability. This unit includes the laser with two redundant excitation outputs. Its role is also to capture state-of-health parameters, to drive the autofocus, and to run the thermal management; 3/ the optical head focuses the laser on the sample mineral grains and collects light from the same spot. The range of focus is ±1 mm for both the excitation and the collection. The three units are connected by optical fibers and electrical harnesses. RLS carries its own calibration target.

3. First performance results

The RLS Engineering and Qualification Model (EQM) has been manufactured, integrated, and tested end of 2016, early 2017. The EQM has been qualified for the mission thermo-mechanical and EMI/EMC specifications, finally achieving flight qualification with the required scientific performances. It was finally delivered to ESA by July 2017.

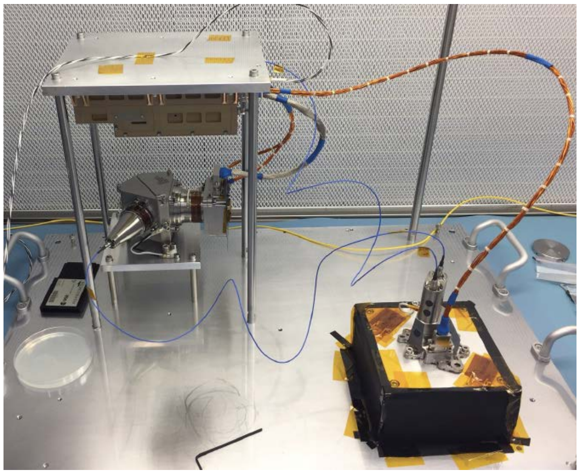

Figure 1: RLS EQM test setup. The 3 units are shown: top left, mounted upside-down, the excitation unit; below, the spectrometer; bottom right, the optical head

The EQM was used to characterize RLS baselined performances:

- Laser excitation: 532 nm (stable to ±20 pm)
- Irradiance on sample: 0.6 - 1.2 kW/cm^2
- Spectral range: 150 – 3800 cm^{-1}
- Spectral resolution: 6 – 8 cm^{-1}
- Spectral accuracy: < 1 cm^{-1}
- Spot size: 50 microns

The EQM was also used to produce Raman spectra under different operating conditions (temperature, integration time, electronic bias, etc.). 2D spectra are presented Figure 2 for the PET cal target.

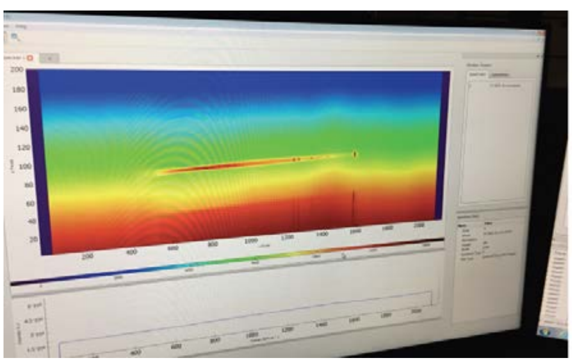

Figure 2: RLS EQM 2D spectra of the PET calibration target.

Standard processing was used to remove the darks, denoise the spectra, co-add several acquisitions, and to collapse the meaningful lines to obtain 1D spectra (Figure 3). The known molecular signature of this type of material is clearly observable.

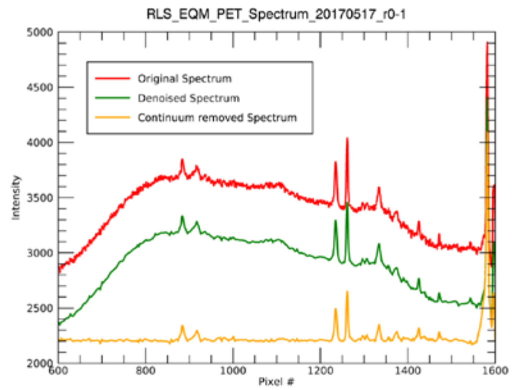

Figure 3: RLS EQM 1D spectrum of the PET calibration target. 1s Integration Time

4. Path forward

Next step is the RLS FM delivery to TAS-I (Q1 2018) for its final integration on the ExoMars-2020 Rover. As part of the final characterization, a library of reference spectra will be acquired under different operating conditions.