EPSC Abstracts
Vol. 11, EPSC2017-297, 2017
European Planetary Science Congress 2017
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RLS Spectrometer Unit Qualified for ExoMars 2020 & Future Planetary Missions

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Abstract

ExoMars 2020 mission is an ESA-Roscosmos collaboration and will deliver a European rover and a Russian surface platform to the surface of Mars. The ExoMars rover will search for signs of life. It will collect samples with a drill that is designed to extract samples from various depths. Once collected, it is delivered to the rover’s analytical laboratory, which will perform mineralogical and chemistry determination investigations. Establishing if life ever existed on Mars is one of the outstanding scientific questions of our time.

To address these exobiological and geochemical issues, **Raman Spectroscopy technique** has been selected through to **Raman Laser Spectrometer Instrument (RLS)** that forms part of an Analytical laboratory instruments in the body of the vehicle. The Rover subsurface sampling device will drill down tomaximum 2 m. The sample will be crushed into a fine powder. By means of a dosing station the powder will then be presented to RLS and other instruments.

It is a well recognized **non-destructive** analytical tool. The shift in energy appears as a spectral distribution and therefore provides an **unique fingerprint by which the substances can be identified and structurally analyzed**.

1. Raman Laser Spectrometer Instrument

One of the key rover´s laboratory instruments is the Raman Laser Spectrometer (RLS) which capabilities and objectives are in the line of ExoMars ones. RLS is able to characterize mineral phases produced by water-related processes, to characterise water/geochemical environment as a function of depth in the shallow subsurface, to identify the mineral products and indicators of biologic activities and to identify organic compound and search for life.

The RLS working flow is depicted in Figure1; the powdered sample will be illuminated by means of the iOH optics, with the laser light coming (through the excitation fiber) from the pump diode housed at the ICEU. The Raman signal obtained will be properly filtered and delivered by the iOH (through the reception fiber) to the SPU. At the SPU the Raman signal will be sent through the transmission diffraction grating to the CCD. Image obtained will be sent to the ICEU FEE (Front End Electronics), and processed by the processor electronics, previous to be sent to the Rover.

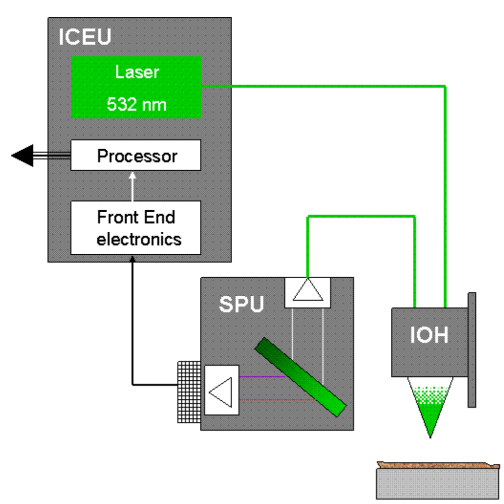

Figure 1: RLS functional Flow

2. Spectrometer Unit

One of the most critical Units of the RLS instrument is the Spectrometer Unit (SPU) that performs spectroscopy technique and operates in a **very demanding environment** (radiation, temperature, dust, etc.) with very restrictive design constraints (mass, power, schedule). It is a very small optical instrument capable to cope with 0.12 – 0.15 nm/pixel of spectral resolution and withstand with the Martian environment (operative temperature conditions: from -40ºC to 0ºC (6ºC for CCD thermal I/F while dissipating 2W)). The solution selected is based on a single transmisive holographic grating especially designed to actuate as the dispersion element.

The main driver of the design of the SPU is not only to reach the scientific requirements as spectral resolution and linear dispersion, but to reach them in 935 grams (including margins), in a very reduced envelope and maintaining performances in the operative termal range. It should be remarked that this transmission spectrometer has demonstrate to be as **flexible** as needed due to several changes in the mission along last years.

2.1. SPU Optical Design

As explained before, the design of a spectrometer unit that withstand with the Martian environment is a very demanding optical effort. The very small optical instrument required can be based on a single transmisive holographic grating especially designed to actuate as the dispersion element that separates the spectral lines in one row on the detector. Efficiency up to 70% at the whole spectral range (533-676nm).The selection of glasses is also of vital importance to assure the behaviour of the instrument in the operative thermal range.

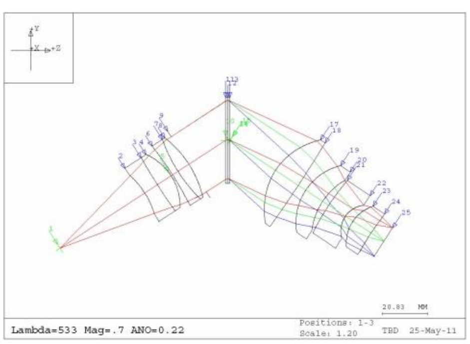

Figure 2: SPU Optical Design.

2.2. SPU Structural Design

SPU is composed by the external Ti6Al4V structure (receptacle, collimator, main body, cover, collector and focal plane assembly) and internal optical lenses fixed by Ti6Al4V retaining rings and spacers, grating assembly and the detector assembly.

The selected material for SPU structural components is titanium due to its CTE, which is similar to the selected optical materials CTE. Titanium has a relative low thermal conductivity, however the temperature of the different SPU optical components is uniform due to the absence of dissipative components and the temperatura stability assured through SPU stands conductive I/F, by the Rover ALD thermal control.

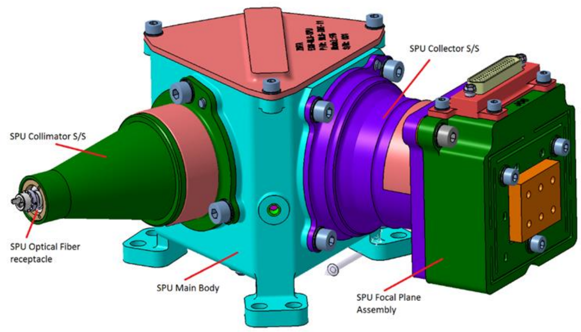

Figure 3: SPU FM Design.

2.3. SPU Thermomechanical Design

The SPU is sensitive both to operating thermal range and to the thermal stability along the Raman operation. The Thermal Control maintains the required thermal environment for proper operations of SPU taking into account the different Mars environment conditions. Two sensitive items are hosted within this unit:

- The optical elements sensitive to alignment mismatching due to temperature variations and gradients (both of them)
- CCD that requires a specific cold condition to provide the required performance.

Thermal analyses have been performed to guarantee that the different components are within their allowable and the required temperatures to assure performances, and also to verify that the required I/F heat fluxes and electrical heat power (to keep critical components at their operating range of temperatures) do not exceed the specified values for SPU operating conditions.

Thermal Design Concept assure the good performance of some critical component by means of a thermal active control; on one hand, a TEC (Thermo Electrical Cooler) implemented in the FPA (Focal Plane Assembly), is used to maintain the CCD temperature below the maximum operating temperature, and on the other hand, three heaters and several temperature sensors are used to keep SPU optics above the specified temperature limits.

3. Spectrometer current status

As part of RLS SPU Development and validation plan, the Engineering Qualification Model of the SPU has been designed, manufactured, tested and delivered to the Instrument for RLS EQM test and further delivery to ESA.

The SPU EQM is based on the optical concept design of the SPU FM (Figure 2), and is the most complete model relative to the tests. A summary of its design characteristics, objectives, functionalities and build standard are given in the Table 1 and here below.

The SPU EQM is representative of the FM in terms of:

- Optics and Electronics flight standard.
- Electrical design flight representative (pinout and grounding).
- Optical design flight representative.
- Thermal design flight representative (thermal control, although heater standard is not FM one).
- Mechanical design flight representative for structural behavior, mounting, mass, shape and alignment.
- External and internal IFs
- Compliant with PP and C&CC requirements.

SPU Model	Objectives	Functionalities	Design	Build standard
EQM	Verification of TH and mechanical models.	SPU FM functionalities.	Same SPU FM desing (Electrical, Optical, thermal and mechanical).	- Mechanical Parts, Materials and processes flight-like. - Components: Commercial not qualified but with extended temperature range. Same technology and supplier than FM with the exception of the heater.
	Verification of SPU performances		SPU FM external and internal IFs.	- Optical Fiber receptacle EQM (flight-like).
	Verification of SPU functionality and electrical performance.		Including bonding stud.	- Grating EQM (flight-like).
	Verification of SPU external and internal IFs.		PP protocol including S/S.	- Detector Assembly EQM (flight-like build).
	Radiometric model validation.		FM Grounding representative.	
	Validation of Electrical test facilities/ EGSE and related procedures.		DA: Fully functional flight-like detector assembly	

Table 1: SPU EQM characteristics

4. Summary and Conclusions

SPU is a very demanding and challenge Unit which has been successfully qualified for ExoMars2020 and that could be on board on future planetary missions. Next milestone is the Critical Design Review (CDR) expected for July 2017 and then the FM.

Acknowledgements

Authors would like to emphasize that the development of the Raman Laser Spectrometer Instrument and of the Spectrometer Unit is being feasible thanks to the Deep collaboration within all parts (national institutes, agencies and private companies) involved, from all different countries.

Finally, from UVa-CAB & INTA, we would like to thank to Spanish MINECO for the financial support to the Spanish contribution to this program.