RAMAN SPECTROMETER FOR PLANETARY EXPLORATION, EXOMARS 2020

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Abstract

The Spectrometer Unit (SPU) is part of the Raman Laser Spectrometer (RLS) Instrument that is on-board in the future ESA/Roscomos ExoMars 2020 mission[1]. The RLS Instrument is in the Analytical Laboratory Drawer (ALD), which is accommodated inside of the rover and with the scientific objective of “Searching for evidence of past and present life on Mars".

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 Martian environment (radiation, temperature, dust, etc.) and at the same time with very restrictive conditions of mass and volume. The SPU optical design is totally refractive, based on a transmission holographic diffraction grating with a modular configuration makes up of a collimator subsystem, responsible of collimating the Raman signal to lead the energy to the dispersive element, and a collector subsystem that focus the dispersed light on a detector assembled on a thermoelectric device and based on a CCD technology.

The main goal of the design of the SPU is not only to reach the scientific requirements, as spectral resolution and SNR, but also to reach them in a reduced lightweight, volume, mechanical loads and maintaining performances in the operative thermal range with low power consumption. SPU EQM had been successfully qualified and FM has been manufactured, tested and delivered to RLS satisfactorily in order to achieve the final desired Technology Readiness level, TRL 8.

1. SPU OVERVIEW

As stated before, one of the most critical Units of the RLS instrument is the SPU [2] that has been designed and developed with very restrictive design constraints of schedule, Size, Weight and Power (SWaP). It is a small optical instrument [3] capable to cope with 0.12–0.15nm/pixel of spectral resolution and withstand with the Martian environment (operative temperature conditions: from -40ºC to +6.3ºC). The design selected is based on a single transmissive holographic diffraction grating especially designed to actuate as the dispersion element.

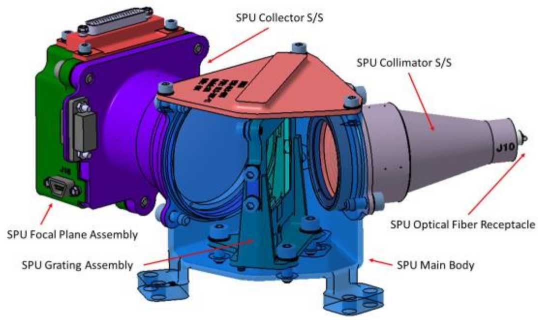

Figure 1. *SPU FM Design (main body transparent).*

The SPU represented above is mainly composed by:

- Optical Fibre Entrance Assembly: with a 50 microns core multimode it is housed on a MiniAVIM connector through a receptacle to rout the reception signal from the iOH to the SPU.
- Collimator: This optical subsystem (SS) collects the light supplied by the fibre and collimates it to reach the diffraction Grating Assembly (GA) element.
- Main body. It is the main structural housing and holds inside the GA, composed by a transmission grating that disperses spectrally the flux produced by the collimator subsystem. The grating is the key element of the SPU and the GA has been re-designed from the EQM to FM in order to avoid the risk of get some micro-cracks observed near the Titanium-glass contact areas after the qualification mechanical tests. [3].
- Collector: This optical SS collects the energy dispersed through the grating and focuses it onto the detector located inside the FPA.

- SPU Focal Plane Assembly (FPA): contains the Detector Assembly (DA). The DA has a thermally controlled two-dimensional CCD array. The CCD detector provided from e2v technologies was previously fully qualified at SPU unit level by Leicester University.

2. SPU FM EXPERIMENTAL RESULTS

SPU FM functional tests consist of verifying, through the optical fibre image on the focal plane, the optical and electro-optics performances by means of spectral resolution and signal to noise ratio (SNR) in room conditions and relevant ambient (Mars conditions).

The spectral resolution is calculated through the linear dispersion measured between two wavelengths separate less than 0.2nm depending on the spectral range zone.

The SPU has a 0.7x magnification which translates the optical fibre to the image plane of the detector, reaching the resolution necessary to resolve the Raman peaks separated by 0.17-0.37nm, depending on the area of the visible spectral range. The quality of the instrument was also evaluated and verified in terms of MTF and impact diagram [5].

After the in-lab conditions integration and attending to the optical performance checks carried out before, during and after AIT campaign can be concluded to be successfully passed (Tab. 1).

SPU Linear dispersion (nm/mm)			
Spectral Zone	FM Tamb(23ºC)	TVT(-20ºC)	*(Theorical)*
Large (670 nm)	10.3±1.0	8±1	*(7.6±0.8)*
Mid (600 nm)	8.3±1.0	10±1	*(9.6±0.8)*
Short (530 nm)	8.3±1.0	11±2	*(9.9±0.8)*
SPU Image size (spectral; spatial) (pixel ±1)			
Spectral Zone	FM Cold(-45ºC)	Relevant (-20ºC)	Hot (11ºC)
Large (670 nm)	8;3	7;3	8;3
Mid (600 nm)	6;3	6;3	7;3
Short (530 nm)	6;3	6;3	6;3

***Table 1**: SPU FM experimental optical performances*

Fig. 2 shows the image in the CCD of the entire spectral working range of the spectrometer FM.

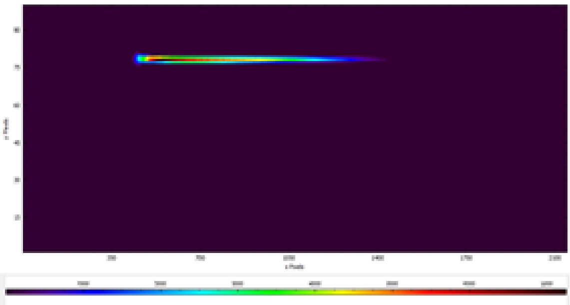

***Figure 2**. SPU FM image with white light*

3. Summary and Conclusions

SPU is a very demanding and challenge Unit which had been successfully qualified for ExoMars2020 under tight environmental conditions (ambient, cruise phase and operation in Mars). Therefore, SPU FM has been, manufactured, tested (acceptance) and delivered to the Instrument for RLS FM test and further delivery to ESA.

Although these plans have been developed for a mission to Mars, the protocol and procedure applied are valid for any planetary exploration mission.

It should be also remarked that this SPU has demonstrated to be as flexible as needed due to several changes in the mission along the last years.

4. References

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