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Ma_Miss for ExoMars mission: miniaturized imaging spectrometer for subsurface studies

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Abstract

The study of the Martian subsurface will provide important constraints on the nature, timing and duration of alteration and sedimentation processes on Mars, as well as on the complex interactions between the surface and the atmosphere. A Drilling system, coupled with an in situ analysis package, is installed on the ExoMars Rover to perform in situ investigations up to 2m in the Mars soil. Ma_Miss (Mars Multispectral Imager for Subsurface Studies) is a spectrometer devoted to observe the lateral wall of the borehole generated by the Drilling system [1,2]. The instrument is fully integrated with the Drill and shares its structure and electronics.

1. Introduction

The study of surface and subsurface mineralogy of Martian soil and rocks is the key for understanding the chemico-physical processes that led to the formation and evolution of the Red Planet. The water and other volatiles history, as well as weathering processes are the signatures of present and past environmental conditions, associated to the possibility for life. Surface samples are highly influenced by exogenous processes (weathering, erosion, sedimentation, impact) that alter their original properties. Subsurface access, sampling material below the oxidized layer, can be the key to “assess the biological potential of the target environment (past or present)”. The analyses of uncontaminated samples by means of instrumented Drill and in situ observations and physico-chemical analysis are the key for unambiguous interpretation of the original environment that leading to the formation of rocks.

2. Instrument set-up

Ma_Miss experiment is perfectly suited to perform multispectral imaging of the drilled layers. Ma_Miss is a miniaturized near-infrared imaging spectrometer in the range 0.4-2.2 μm with 20nm spectral sampling [1,2]. The data are acquired through a sapphire window on the drill wall. The task of illuminating the borehole wall and collecting the diffused light from the illuminated spot on borehole wall requires a transparent window on the Drill tool, which shall prevent the dust contamination of the optical and mechanical elements inside. For this reason a transparent sapphire window has been integrated on the external surface of drill tool. Inside the Drill tool we find the Lamp assembly that through a fiberoptic bundle brings the light to the optical head where the light is focused on the expected position of the borehole wall (at a few tenths of mm out of the window) by means of an optical relay. In a symmetrical way a second relay collects the scattered light and focuses it in a single optical fiber (acting as a slit) that will bring this signal up to the remote spectrometer. In figure 1 the relays that are part of the Optical Head and the Drill tool with the sapphire window are shown.

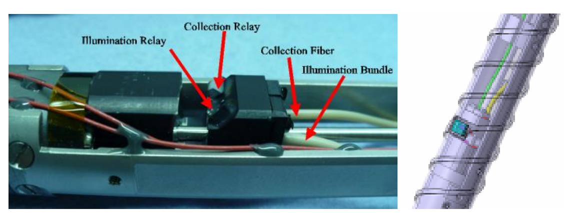

Figure 1: Left: miniaturized optical head with the illumination and collection relays depicted. Right: internal structure of Drill Tool where the optical head is integrated behind the sapphire window. *Credit: SELEX ES*

Optical Head performs the double task of illuminating the borehole with a spot around 1 mm diameter and collects the scattered light coming from a 0.1 mm diameter spot. The Optical Head is interfaced with the illumination bundle and the single optical fiber signal link. It is extremely miniaturized for complying with the available room inside Drill Tool. The Spectrometer, VIS/NIR detector and Proximity Electronics are integrated in a box placed on the external wall of Drill Box. The signal from the optical head to the spectrometer is transferred through the different elements of the drill by means of an optical rotary joint implemented in the roto-translational group of the drill.

Ma_Miss provides high flexibility in the acquisition of borehole wall spectra exploiting the translational and rotational agility of the drill tool. The spectrometer observes a single point target of the borehole wall surface. Depending on the surface features we are interested in, the observation window can scan the surface by means of the drill tip rotation or translation. When the drill is vertically translated a “Column Image” is acquired; the translation step can be equal to the observation spot. The “Ring Image” can be obtained by rotation of the drill tip. The acquisition of adjacent rings will permit to reconstruct a complete image of the borehole wall. Given the high flexibility in the Ma_Miss operations, a large variety of acquisition strategies (i.e. how to sample the borehole wall) can be implemented, depending on the specific target.

4. Ma_Miss Breadboard

The Optical Head of Ma_Miss instrument has been tested after integration in ExoMars Drill. Measurements have been carried out in realistic media (tuff, red brick). Illumination spot is focused at the nominal distance of 0.6 mm from the sapphire window. The light beam coming out from the drill window is shown in figure 2.

Figure 2: Two different moments of the Ma_Miss tests during the drilling. The light beam comes out from the sapphire window on the Drill wall. *Credit: SELEX ES*

The embedded Optical Head captures the diffused light from the observed target and transfers it to a laboratory spectrometer for subsequent analysis. Acquisitions of reflectance spectra of representative samples have been performed with Ma_Miss breadboard [3,4], demonstrating the capability to acquire meaningful spectra. Details on the laboratory breadboard setup are in [4].

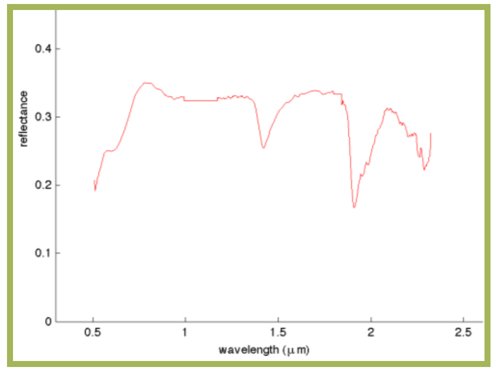

Figure 3: Example of prototype Ma-Miss instrument response signal taken for volcanic rock.

5. Conclusions

During the Exomars-Pasteur Rover mission, the Ma_Miss experiment will allow collecting valuable data of the drilled stratigraphic column, will document “in-situ” the nature of the samples that will be delivered to the Pasteur Laboratory and will be able to identify hydrated minerals, sedimentary materials and different kind of diagnostic materials of Martian subsurface.

Acknowledgements

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References

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