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FLY-SPec instrument: concept and preliminary experimental results

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Abstract

The landing of rovers and human crews on planetary bodies is one of the main challenges of the next Solar System exploration era and requires the development of very compact instrumentation for in-situ analysis. Based on three combined measuring techniques, the FLY-SPec instrument is conceived for a rapid identification of minerals, soils and rocks during surface campaigns. It consists of a context camera, a laser-induced breakdown spectroscopy (LIBS) unit and a near-to-short wavelength infrared reflectometer channel.

1. Introduction

Near-term objectives of the space exploration envision the robotic and human survey of the inner Solar System, in preparation of long-term explorations of worlds that in the future could support a continuous human presence such as Mars. The Moon and Near-Earth asteroid surfaces and the cislunar space, in particular, are currently designated as training sites to accomplish a range of science and exploration objectives with human crews. Within this framework, one of the main capabilities needed for surface robotic and human missions is the sampling technique in harsh environments. Sampling, indeed, shall satisfy both scientific targets such as the understanding of origin, evolution and composition of the investigated bodies, as well as operational needs, which inter alia indicate how to sustain human and robotic space explorations using local resources. Essentially, priority samples are ancient crustal rocks, young effusive materials and (potentially) water-bearing clastic to metamorphic materials and meteoritic remnants. In particular, pyroclastic glassy spherules trapping gas phases, hydrated silicates, and steady low-temperature regoliths are considered the main potential volatile (e.g. water) reservoirs [1]. Still, priority samples include lithologies that have been identified by orbital missions but remain unsampled, like mantle rocks of the Moon's far side [2], and bulk samples from primitive bodies that can notably extend the knowledge acquired by meteorite collections, which are mainly constituted by materials just strong enough to survive the Earth atmosphere entry and are often contaminated during their journey and storage. Sampling accomplished by human-robotic synergies in harsh environments aims at a rapid but definite identification of minerals, rocks and soils, as well as of a suitable storage of compositional data where the sample collection is prevented. Those requirements can be fully satisfied with a very compact instrument that combines and contextualizes chemical and mineralogical analyses.

2. FLY-Spec concept

The FLY-SPec instrument consists of a context camera, a laser induced breakdown spectroscopy (LIBS) unit and a NIR imaging reflectometer that guarantee a multi-scale analysis of the sampling area. Each routine implies: (i) a panchromatic acquisition of the local context, which assists the measurement site selection and specific targets identification, (ii) a first hyperspectral image of the targeted sample that provides textural and mineralogical information, (iii) a grid of LIBS shootings co-registered to the hyperspectral image that provides a chemical analysis pattern and (iv) a second hyperspectral acquisition over the grid. In this way a good quite comprehensive sampling of the surface will be accomplished.

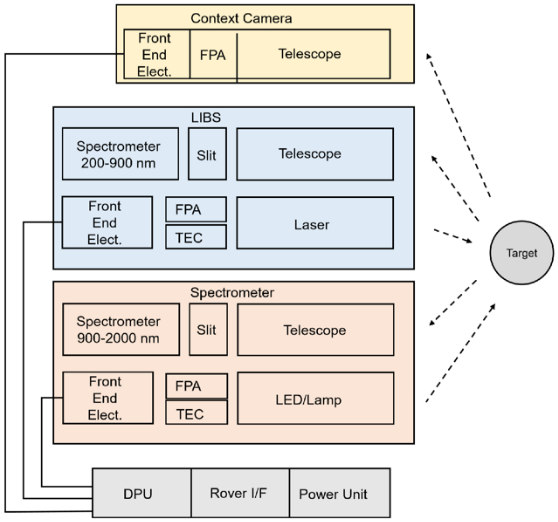

Figure 1: The functional block diagram of FLY-Spec instrument.

The CPU operates the two main systems, LIBS and reflectometer, both independently and synergistically in real time. The control and processing unit is thought to be implemented with a spectral signature archive and matching processing system. The FLYSPec suite will therefore be able to recognize and classify minerals giving the correspondent reliability degree and producing a prioritization tree in function of the scientific objectives of the mission. Specifically, FLY-SPec can achieve the following results: (i) quickly distinguish olivines from pyroxenes, which display the same primary elements (Si, O, Mg, Fe etc.) but different absorptions in the NIR; (ii) detect sialic solid solutions such as plagioclases, which are almost featureless in NIR range, but whose solid solution constituents (Ca and Na) can be easily detected in LIBS spectra; (iii) distinguish mafic solid solutions combining elemental detection with the exact position of the transition-element absorption bands; (iv) distinguish and classify different chondrites, iron and stony-iron meteorites; (v) distinguish CAI and hydrated carbonaceous material on meteorites; (vi) distinguish the presence of volatile either on regolith or trapped in pyroclastic glasses; (vii) evaluate relative phase abundances of the outcrop/soil. In addition to these characteristics is the capability to distinguish even long-term exploration materials prone to host extinct or extant biota such as sulfates, carbonates, hydrated minerals and hydrothermal associations detected on Mars.

3. LIBS preliminary results

LIBS spectroscopy is based on the interaction of relatively powerful laser pulses (in this experiment: E≈100 mJ, τ=9 ns, λ=1064 nm) focused on a target. The laser power density is enough to generate plasma (laser produced plasma LPP) that emits radiation in the form of discrete lines, characteristic of the ions and molecular species, and with continuous spectra corresponding to recombination and bremsstrahlung emission. The analysis of the LPP spectra allows the compositional and structural classification of the target materials. We recently obtained interesting results by testing several minerals in vacuum (10^{-6} mbar), including natural olivine, diamond, aragonite and dolomite. Figure 2 shows the experimental configuration: the laser beam is focused on the sample, then the radiation emitted by the plasma is collected by a VIS-NIR spectrometer.

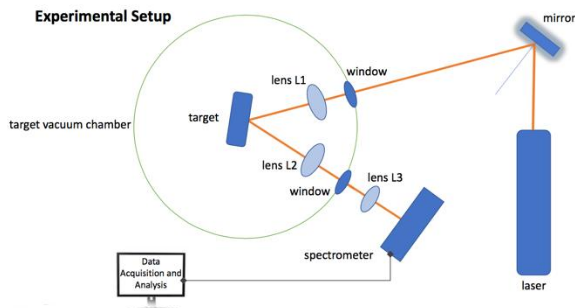

Figure 2: Experimental set-up of the LIBS prototype.

Principal Components Analysis (PCA) has been successfully used to classify the materials under investigation, which validates the technique.

References

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