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Analysis of planetary analogue materials by laser-induced breakdown spectroscopy

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Abstract

Laser Induced Breakdown Spectroscopy (LIBS) is a promising tool for elemental chemical analysis in planetary science, because it allows *real-time and fast in-situ* determination of the elemental composition of materials down to minute concentrations. The technique requires no special preparation of samples, can provide high lateral resolution (as low as several tenths µm), depth profiling (down to mm) and, therefore, is not disturbed by dust layers. Miniaturized LIBS instruments are currently considered for the next NASA (Mars Science Laboratory) [1] and ESA (ExoMars) [2] missions to Mars, as well as studied for the international Europa Lander Mission [3]. Here we present the LIBS laboratory facility at the German Aerospace Center in Berlin for the chemical elemental analysis under simulated planetary (Mars, Europa) conditions. The main purpose of the system is the study of the LIBS capability for in-situ spectroscopy for diverse planetary missions as well as the development of a LIBS spectral database under simulated planetary conditions for planetary analogue materials.

LIBS system

The LIBS spectrometer (Fig. 1) is equipped with two near-infrared Q-switched lasers. One is a Nd:YAG laser from Continuum Inc. It operates at 1064 nm and provides a maximum output energy of 220 mJ per pulse with a typical duration of 8 ns and repetition rate of 20 Hz and 10 Hz. The other one is a Nd:YLF laser from NeoLase GmbH operating at 1053 nm with 5 mJ maximum pulse energy, 5 ns pulse duration and variable repetition rate (1-50 Hz). In a dedicated chamber diverse planetary environmental conditions can be simulated. For example, a Martian-like atmosphere (95.55% CO_2, 2.7% N_2, 1.6% Ar, 0.15% O_2) can be provided as well as high vacuum. The total pressure range which can be covered is 10^{-4} to 1 bar. The temperature of the sample holder can be varied from about 80 K to 300 K. The laser beam is focused onto the sample surface and generates a plasma.. The emission from this laser-induced plasma is detected by a high-resolution Echelle spectrometer (manufacturer: Laser Technik Berlin GmbH), which is equipped with a gated ICCD (Andor). The spectrometer covers the wavelength range from 200 nm (UV) to 900 nm (IR) with a spectral resolution of 9400-14000 in UV-to-IR ranges. The instrument software allows time-resolved (down to ~10 ns) spectral analysis, as well as complex elemental analysis including calibration, and plasma diagnostics like electron temperature and electron density.

Figure 1: LIBS system with planetary simulation chamber.

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In addition, facilities for sample preparation, as drying, milling of rocks, pressing powders, as well as for surface characterisation, such as profiling, roughness and µm-crater/pore measurements are available.

Investigations in progress

Studies of Martian analogue materials under simulated Martian atmospheric and temperature conditions have been carried out using the DLR-LIBS system. Analyses of water-related hydrogen in wet and dry samples at variable surface temperatures have been reported in [4]. The DLR-LIBS also serves for testing of LIBS components developed for planetary missions. For example, we studied the element concentrations [5] in rocks and soils as well as the plasma temperature [6] using the ExoMars prototype LIBS laser as plasma excitation source. Special attention was paid to the radiometric and spectral calibration of the spectrometer (an example of the LIBS spectrum is shown in Fig. 2) as well as to the influence of the experimental geometry on the LIBS spectra.

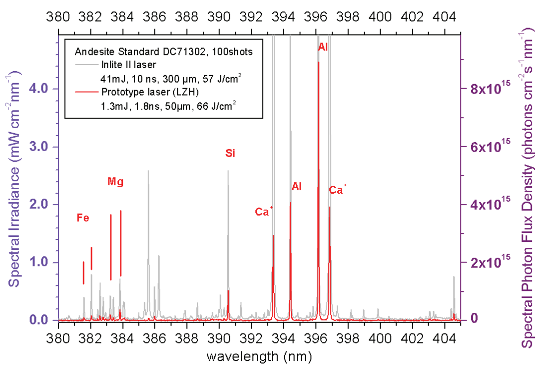

Figure 2: Typical LIBS spectrum measured for the andesite standard rock material DC71302 with different exciting lasers.

In summary the LIBS system at DLR is a valuable facility for reference measurements of planetary analogue materials and for testing prototype LIBS components. It is prerequisite for investigating fundamental effects resulting from the environment like vacuum or sample types like ices, which may occur on planetary surfaces.

References

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