First LIBS experience(s) in space

S. Maurice[1], R. Wiens[2], S. Clegg[2], O. Gasnault[1], O. Forni[1], S. Schröder[1,3], J. l'Haridon[4], P.-Y. Meslin[1], and the ChemCam/SuperCam teams
[1]IRAP, Univ. Paul Sabatier – CNRS, Toulouse, France
[2]Los Alamos National Laboratory, Los Alamos, NM, USA
[3]Institut für Optische Sensorsysteme, DLR, Berlin, Germany
[4]LPG-Nantes, Univ. Nantes – CNRS, Nantes, France
sylvestre.maurice@irap.omp.eu

ChemCam[1] is the first LIBS experiment in space. At Gale crater, Mars, more than 360,000 single shot spectra were acquired during the first 4 years of the Curiosity mission, providing elemental composition for more than 1,450 distinct rocks and soil targets. We will present the different Research and Development programs, and other accomplishments which have led to this unique data set on Mars.

When it all started for us in 2000, LIBS at remote distances on geological targets was still embryonic but advantages for its use for planetary science were clear: no sample preparation, analysis within its petrological context, dust removal, sub-millimeter scale investigation, multi-point analysis, the ability to carry out statistical surveys and whole-rock analyses, and rapid data acquisition. With lessons learnt from ChemCam, these putative advantages can now be analyzed and quantified. We will conclude with a discussion of ChemCam performance to survey the geochemistry of Mars, and its valuable support of decisions about where and whether to make observations with more time- and resource-intensive tools in the rover's instrument suite.

With regards to the LIBS data themselves, we will describe new tools that had to be developed to account for the uniqueness of Mars data. They provide accurate compositions measured for the major elements observed geologically (Si, Ti, Al, Fe, Mg, Ca, Na, K) based on various multivariate models. ChemCam also observed H, C, O, P, and S, which are usually difficult to quantify by LIBS. F and Cl are observed and quantified through their molecular lines. We will discuss the most relevant LIBS lines for detection of minor and trace elements (Li, B, Cr, Mn, Ni, Cu, Zn, Rb, Sr, and Ba). These results were obtained thanks to comprehensive ground reference datasets, which are set to mimic the expected mineralogy and chemistry on Mars. In the end, we will present a bird's-eye view of the many scientific results: discovery of felsic Noachian crust, first observation of hydrated soil, discovery of manganese-rich coatings and fracture fills indicating strong oxidation potential in Mars' early atmosphere, characterization of soils by grain size, and wide scale mapping of sedimentary strata, conglomerates, and diagenetic materials.

Following the success of ChemCam, in 2014 NASA selected SuperCam[1] as part of its future Mars rover (launch 07/2020) to search for traces of life on the red planet. SuperCam is a suite of four co-aligned techniques at remote distances: LIBS (including acoustic sensing), Raman, visible and near-infrared spectroscopy, and high resolution color remote micro-imaging. The different investigations, their characteristic scales, and their observation modes will be described.

[1] ChemCam & SuperCam are US-French instruments, which are led jointly by the Los Alamos National Laboratory (Los Alamos, NM) and IRAP (Toulouse, France), and mounted on the NASA rovers Curiosity & Mars-2020 that are being developed and operated by Caltech-JPL.