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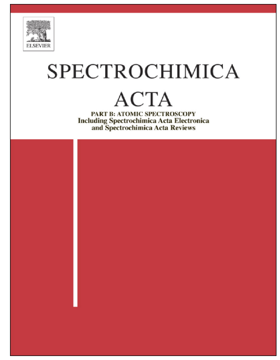


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# Simulated laser-induced breakdown spectra of graphite and synthetic shergottite glass under Martian conditions

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**Abstract**

We report the results of a simulation of the laser-induced breakdown spectra of graphite and synthetic shergottite glass in an atmosphere similar to that of Mars using a 1-D, Lagrangian hydrodynamic model, a spherical geometry description of the laser ablation and plume expansion and a local thermodynamic equilibrium (LTE) approach for the emission spectra. We compare the LIBS spectra of two calibration targets on board of the Curiosity rover to the simulated ones calculated under nominally the same conditions as those encountered on Mars. The simulations provide an additional way, to laboratory based comparative studies, to better understand the effects of laser parameters and atmospheric pressures. We report on the effect of laser irradiance and ambient pressure on the electron and ion temperature, electron number density, and fluid velocity parameters characterizing the plasma. Finally, we show the effects of laser irradiance and ambient pressure on the simulated emission spectra of graphite and shergottite and compare them to those acquired by ChemCam. The agreement between the two is good, particularly for the prominent emission lines.

Keywords: LIBS; Mars; ChemCam; Plasma Physics; Graphite; Shergottite



## 1 Introduction

Laser Induced Breakdown Spectroscopy (LIBS) is currently used as an analytical technique as part of the Chemistry Camera (ChemCam) instrument on board the Mars Science Laboratory Rover Curiosity [1–4]. In an effort to better understand ChemCam LIBS spectra, we have performed numerical simulations that yield spectra calculated from fundamental LIBS equations [5–8]. The theoretical model and numerical simulations used for this work account for the dominant interaction processes between the laser and target from which the LIBS spectra are obtained. This approach can yield multiple characteristics of the simulated LIBS spectra such as the time evolution of the continuum radiation background, the behavior of spectrum structure in response to changes to laser and ambient characteristics, and the spatial evolution of the craters created by the ablation process. This work focuses on comparing the measured spectra to the simulated ones calculated under nominally the same conditions as those encountered by ChemCam. This approach is complementary to that based on mimicking the experimental conditions on Mars in an Earth-based laboratory [9–14]. However, in contrast to laboratory based comparative studies, numerical simulations offer advantages. These include ease of changing parameters such as laser wavelength, energies and profiles; and atmospheric pressures. In addition, they suffer from limitations due principally to our inability to have accurate knowledge of the various physical, chemical, optical and environmental parameters that contribute to plasma and spectral formation. Thus, the simulated spectra and the ones measured in Earth-based laboratories can be viewed as complementary.

Researchers have addressed different aspects of the plasma formation process. These include: laser-target interaction and plume hydrodynamics [15, 16], processes occurring in the plasma [17, 18] and diagnostic parameters characterizing the spectra [3, 19, 20]. Rezaei [21] and Aghaei [22] simulated the spectra of aluminum and copper, respectively, in a helium environment by modeling the laser-target interactions, plume hydrodynamics, and the processes occurring within the plasma. Multi-dimensional simulations of the plasma plume have also been performed. Le et al. performed two dimensional hydrodynamics