



Laser ablation ion funnel (LAIF) for *in situ* mass spectrometry on Mars

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Introduction: One of the major goals in the exploration of Mars is a thorough geochemical study of its surface, particularly its diverse elemental and mineralogical composition. This knowledge feeds into an understanding of the history and current disposition of Mars, as well as providing a context for investigations of astrobiological interest. Many extant *in situ* analysis techniques require extensive sample handling and preparation before interrogation by the instrument. We are developing an instrument to address this issue, by combining laser ablation ionization with an ion funnel. Laser ablation ionization allows for sampling of surfaces without preparation, while the ion funnel enables the capture and transport of ions through the ambient Martian atmosphere. Some advantages of the laser ablation ion funnel (LAIF) are described in the table below.

Advantages of the LAIF concept.

Advantages	Description
Operates in Mars Atmosphere	The LAIF is capable of ionization and ion collection, transport and focusing within the ambient martian atmosphere. No further sample preparation or manipulation is required.
High Sensitivity	Ion capture and transport efficiencies approach 100%. Therefore, the LAIF, when coupled to a suitable MS, offers sensitivities that far exceed other laser ablation ionization or laser desorption/secondary ionization mass spectrometry schemes.
Surface Cleaning	Knight et al. (2000) have shown that surface weathering material or dust can be removed from a sample with a number of 'pre-analysis' laser pulses. We have verified this result in our lab. In fact, we have 'drilled' through 0.25 inch thick samples with a train of laser pulses.
Low Complexity	The LAIF requires no sample handling and minima or no sample manipulation. This greatly reduces the complexity of an <i>in situ</i> robotic experiment.

Figure 1. The ion funnel consists of a series of equally spaced, axially concentric, ring shaped electrodes whose IDs decrease over the length of the funnel. AC and DC potentials are applied such that ions drift toward the exit, and are repelled from the walls.

Results: Figure 3 shows the mass spectrum of a sample of pure copper, obtained under a few torr N_2 , $\text{CaSO}_4 \cdot \text{H}_2\text{O}$; average of 350 shots. Figure 4 shows the mass spectrum of gypsum, $\text{CaSO}_4 \cdot \text{H}_2\text{O}$, acquired with our ion funnel under ~ 5 torr CO_2 . The spectrum is dominated by ions characteristic of gypsum. In this instance, a laser power density at the threshold of plasma production was used ($\sim 4.5 \times 10^8 \text{ W cm}^{-2}$), resulting in the formation of molecular ions, rather than elemental ions. This demonstrates the ability of lower laser power densities to provide molecular information about the composition of the sample, in addition to the elemental analysis provided at higher laser power densities.

The laser ablation ion funnel shows promise as a preparation-free means to sample the Martian surface. Both elemental analysis at high laser power density and the use of lower power densities to form molecular ions seems feasible.

Future work will focus on characterizing the energy dependence of the ionization process under a CO_2 atmosphere, and integrating the funnel with a miniature mass spectrometer.

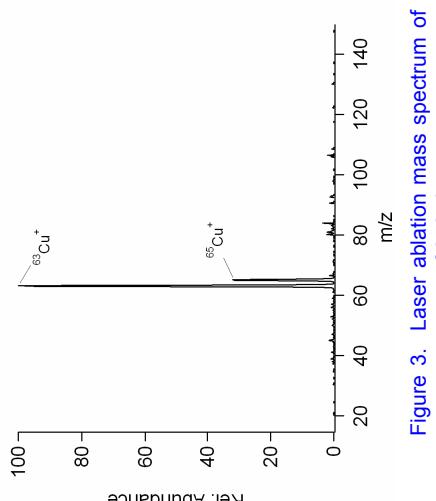


Figure 3. Laser ablation mass spectrum of copper; average of 350 shots

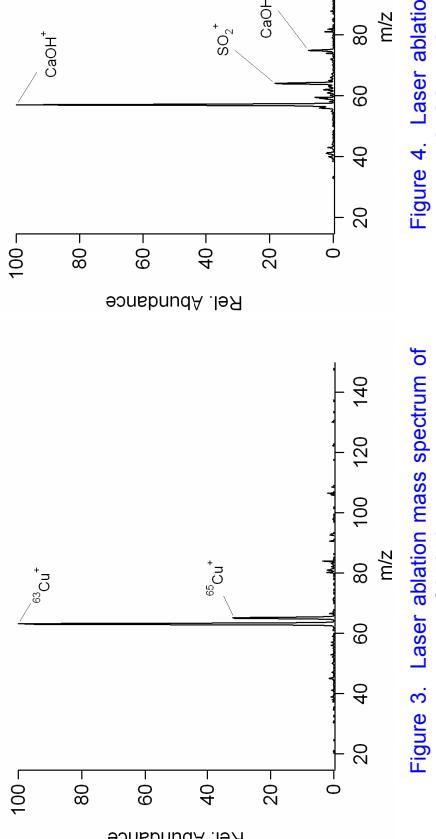


Figure 4. Laser ablation mass spectrum of gypsum, $\text{CaSO}_4 \cdot \text{H}_2\text{O}$; average of 300 shots

Figure 2. The JPL ion funnel. The funnel is operated as the front end for a commercial ion trap MS (LCQ Deca XP), under a simulated Martian atmosphere of 5 torr CO_2 . Laser ablation is performed with the 532 nm second harmonic of an Nd:YAG laser.

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