The Suitability of Laser Induced Breakdown Spectroscopy for Determining the Compositions of Extraterrestrial Material

J. Thompson[1], R.C. Wiens[1], D.A. Cremers[2], J. Barefield[2], C. Wetteland[3]; [1]Space and Atmospheric Sciences, Los Alamos National Laboratory (MS D466, Los Alamos, NM 87545 USA; justint@lanl.gov),[2]Chemical and Advanced Diagnostics and Instrumentation, Los Alamos National Laboratory (MS J565, Los Alamos, NM 87545 USA; cremers_david@lanl.gov), [3]Materials Science and Technology Division, Los Alamos National Laboratory (MS K765, Los Alamos, NM 87545 USA; wetteland@lanl.gov).

Introduction: Laser Induced Breakdown Spectroscopy (LIBS) has been proposed as a new method for standoff detection of geological samples for use on landers and rovers on planetary surfaces [e.g. 1]. LIBS is a method of elemental analysis that uses a powerful laser pulse focused on the target sample to form a laser spark or plasma. Material within the spark is vaporized/ atomized and the resulting atoms are excited to emit light. The spark light contains the emission spectra of the elements within the plasma. The plasma light is collected, spectrally resolved and detected to determine elements in the target by their unique spectral signatures.

LIBS has the potential to be a rapid, remote, elemental analysis tool for planetary science. The following features make LIBS especially attractive for planetary surface analysis:

- Rapid elemental analysis (one measurement per laser pulse)
- No sample preparation required
- Detects all elements—high and low z
- Low detection limits (2-1000 ppm for most elements)
- Point detection capability (≤1 mm spot size)
- Samples can by analyzed at stand-off distances from the instrument (up to 20 meters)
- Repeated laser pulses at the same spot can remove dust or weathering layers to allow analysis of underlying rock

The last two points iterate LIBS ability as a unique method: It is the only instrument that can determine the elemental compositions of dust-covered rocks remotely.

LIBS is under development as part of the Mars Instrumental Development Program (MIDP), and will be proposed as a payload instrument onboard the Mars Science Laboratory. Laboratory and field studies to determine LIBS capabilities for planetary surface analysis are ongoing [2-5]. This laboratory study seeks to define LIBS capabilities by demonstrating the suitability of in-situ LIBS for determining the compositions of extraterrestrial samples by comparative analyses of meteorite samples. Two elemental analysis techniques were performed on Allende, a CV3 chondrite. LIBS elemental analysis data were compared to elemental analysis data taken by Proton Induced X-ray Emission (PIXE). At the present Admire, a pallasite meteorite sample, is being analyzed. A third sample, a Mars meteorite, is currently being obtained for future analysis.

Experimental Analyses: Elemental analysis of the sample was conducted using the LIBS experimental set-up seen in figure 1. The samples were placed on a Newport X-Y stage, connected to a Newport PMC200-P Controller. Laser pulses were provided by a Q-switched Nd:YAG laser (10 Hz, 1064 nm). The pulses were focused to ~80 μm on the sample to create a spark. The plasma light was collected by an in situ fiber optic cable connected to an echelle spectrograph (Catalina Scientific) and the detector was an intensified CCD camera (Andor ICCD).

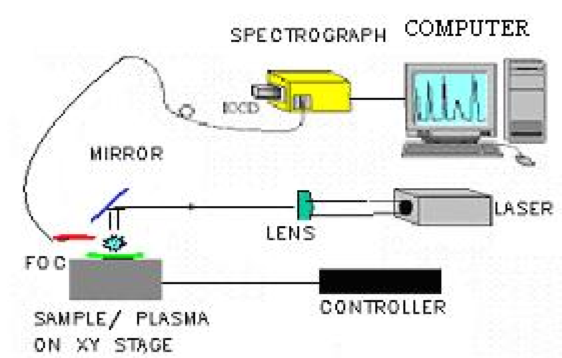

Figure 1: Experimental set-up of Laser Induced Breakdown Spectroscopy elemental surface mapping analysis.

The set-up is designed so the sample can be moved at an ~100 μm step size in both the x and y directions in order to create an elemental analysis map of the surface (~15 by 20 mm). The laser pulse had a frequency of 5 hertz with a sample exposure time of 10 seconds. An example of a LIBS spectrum from a single spot of Allende is seen in figure 2.

PIXE analysis was conducted at the Ion Beam Materials Laboratory at Los Alamos National

Laboratory in order for a comparison of elemental composition to LIBS data. The Allende sample was analyzed at a spot size resolution of 1mm, and with a step movement of 2 mm. The result was a central band of analysis across the meteorite sample (~15 by 1 mm).

Discussion: The work conducted here seeks to characterize the capability of LIBS by comparative analyses of meteorite samples with other elemental analysis techniques.

Most LIBS work for planetary exploration has demonstrated elemental composition identification at distances of at least several meters. However, in-situ LIBS can be very useful for analyzing the mineralogy of small sections of extraterrestrial materials.

From the grid of data points built up by using the x-y stage, LIBS spectra will be analyzed by an IDL program, producing a complete elemental surface map of Allende over a several mm area. Separate maps of elements contained in the meteorite sample (e.g., Si, Al, Mg, Ca, Na, Fe, Cr, Ti, Co, K, Li, Ba, Sr, C) can be produced from the data, and should be presented at the meeting. This work, which will be completed shortly, will be compared to the elemental composition data taken by other elemental analysis techniques.

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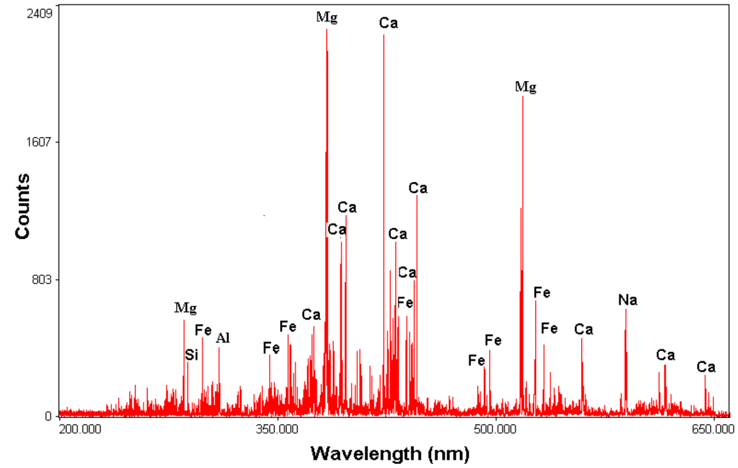

Figure 2: LIBS spectra of Allende with laser pulse frequency of 5 Hz for an exposure time of 10 s from a single ~80 µm spot on the sample.