INTEGRATING MICRO-LIBS WITH THE CAMERA, HANDLENS AND MICROSCOPE PROBE FOR SPACE EXPLORATION. Greg S. Mungas[1], Yekta Gursel[1], Christopher. B. Dreyer[2] , Cesar S. Sepulveda[1], Kenneth R. Johnson[1], John E. Boynton[1] , Luther Beegle, [1] Jet Propulsion Laboratory, California Institute of Technology (M/S 306-336 4800 Oak Grove Dr., Pasadena, California 91109). [2]Colorado School of Mines, Center for Space Resources, Golden, CO 80401, kenneth.r.johnson@jpl.nasa.gov

Introduction: Detailed investigation of prepared and unprepared surfaces at the microscopic scale has been used extensively to study the origin and history of geologic samples in terrestrial labs [1] and on Mars [2]. An integrated camera, handlens, and microscope probe is in development for prospecting and science investigations that currently integrates visible reflected light imaging with Raman Spectroscopy, Raman/CHAMP. This instrument images from infinity down to high resolution microscopy (4.4x), the closer the instrument is placed to a target the higher the resultant image resolution with an associated smaller field-of-view (Fig. 1). In the vicinity of peak magnification (<3 micron/pixel resolution), a high resolution laser that can probe anywhere across the microscopic field of view is possible with a <10 micron laser spot for purposes of analyzing the surface chemistry of particular microscopic features. This instrument provides its own context imaging for progressive high resolution field microscope investigations, requiring no sample handling, and would ideally eventually incorporate micro-LIBS elemental measurements coupled with Raman spectroscopy. Furthermore, the instrument can provide a 3D microscopic surface map built from multiple image scans with slightly different working distances (i.e. image cube) that are subsequently focal-plane merged together to produce a single in-focus image with local elevation coordinates. This map and fine elevation targeting can be used to optimally focus a laser spot into target surface features by fine adjustments of CHAMP's working distance [3]. Combined LIBS and Raman spectroscopy instruments for planetary exploration has been discussed elsewhere [4,5,6], and are considered to have a high potential due to the similarities in the spectroscopic and laser source requirements of LIBS and Raman, and the complementary nature of the LIBS and Raman data sets. LIBS provides elemental information about a sample, while Raman Spectroscopy provides molecular information. Standoff LIBS and Raman Spectroscopy integrated instruments have received the most attention in the space science community. We have investigated LIBS on rock samples at the microscopic (<20 μm spot diameter) scale and with micro-joule laser pulse energy (<200 μJ), which in the LIBS community is referenced as micro-LIBS. We are investigating the potential to incorporate micro-LIBS in the Raman-CHAMP instrument.

Hardware Development: We have recently fabricated the two lens cells that provide the multiple scale imaging with a beam-split laser scannable interface that can cover the entire imaging field-of-view at microscopy (Fig. 1D). The first microscopic image acquired

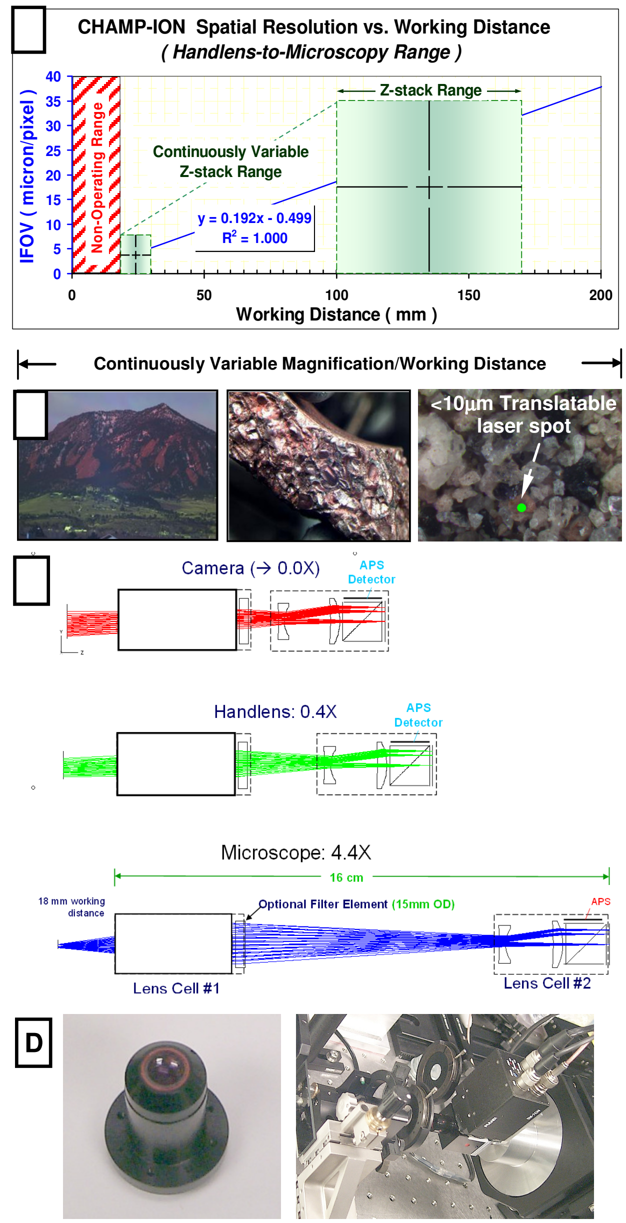

Figure 1. A) Raman/CHAMP instrument pixel resoluteion vs. working distance. B) Images from eariler MIDP version of CHAMP instrument continuously variable magnification with simulated scan-able object-plane Raman laser spot (exaggerated in size for clarity) at peak magnification; C) Instrument optical layout and lens cell variable magnification/working distance actuation; D) Fabricated Lens Cells integrated into brassboard test seup.

of an optical transmission grid with these lens cells is shown in Fig. 2.

The optical design of this instrument is discussed in more detail in [3]. The nominal bandpass of this instrument is 335nm-950nm which is sufficient to support micro-LIBS observations. Table 1 summarizes the number of elemental emission lines per element that have been selected out of the strongest 8,250 lines from the NIST atomic emission database available over this spectral range that have time-integrated emission cross-sections that fall within a dynamic range of 100 of one another. The multiple emission lines available for observation will be used to provide estimates on both the thermal emission profile of the laser-generated micro-plasma and relative elemental abundances [7].

In prior work, we have demonstrated micro-LIBS measurements with similar distal beams in simulated Mars atmospheres (Fig. 2) [8]. We have also investigated possible optical contamination of distal windows when conducting micro-LIBS measurents in close proximity to surfaces (Fig. 4).

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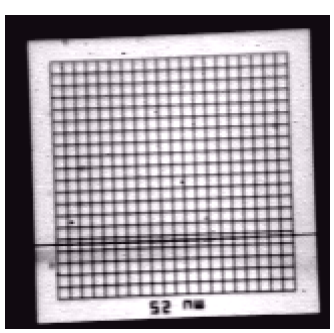

Figure 2. First 10X high resolution microscopic image acquired with optical setup shown in Fig. 1D.

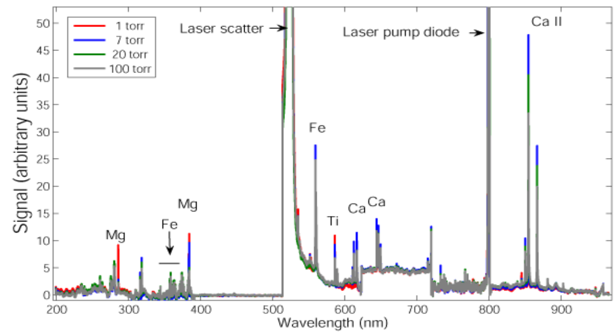

Figure 3: Full spectrum of micro-LIBS on hematite [8].

Table 1. Micro-LIBS emission spectral bands per element over the range 335nm-950nm ordered in terms of relative line strength at T_e=15,000K.

Element	Spectral (nm)	# Lines
H	486 - 656	11
C	711 - 940	13
N	744 - 939	20
O	715 - 926	19
Na	498 - 946	9
Mg	384 - 941	42
Al	394 - 877	29
Si	391 - 794	12
P	533 - 930	12
S	675 - 924	22
Cl	510 - 919	18
K	534 - 890	13
Ca	393-866	20
Ti	346 - 802	57
Cr	427 - 698	53
Mn	342 - 652	10
Fe	340 - 709	47
Ni	343 - 773	25

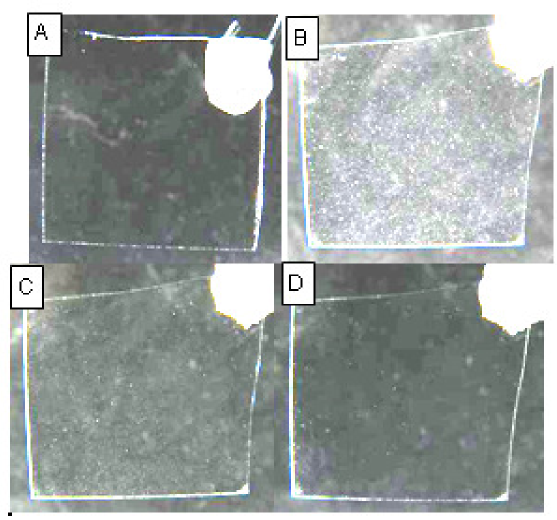

Figure 4**. micro-LIBS condensate deposit on window before and after laser shots at 100 µJ, working distance of 15mm, with F/#4 CHAMP-like distal beam. A) Typical slide before image, B) slide after 17,700 laser shots, C) used window after 3 sec air blast and D) following 3 wipes with lens brush [9].**