ChemCam (MSL) Autofocus Capabilities

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Introduction: ChemCam is an active remote sensing instrument to investigate details of the Martian geochemistry [1,2] using the Laser Induced Breakdown Spectroscopy (LIBS) technique and micro-imaging (RMI), to be flown on the Mars Science Laboratory (MSL) rover scheduled for launch in 2011.

A telescope mounted atop the MSL mast to benefit from the mast pointing capability, concentrates the laser beam onto the target, collects laser-induced plasma light, and collects light for imaging. The optical design uses a simple and compact Schmidt telescope, with a 110 mm diameter primary mirror and a 32 mm diameter secondary mirror. Focus is achieved by mounting the secondary mirror on a translation stage with a stepper micro-motor covering a 10 mm range, yielding a focus from 2 m to infinity for RMI, 1 m to 9 m for LIBS.

The MSL rover will point ChemCam in azimuth and elevation toward the target of interest, and shall provide a target distance with accuracy ±5 %. However, the depth of field for LIBS and RMI are smaller than ±0.5 % to meet the science goals of the mission [2]. An autonomous acquisition of focus has therefore been implemented to achieve such performances.

The objective of this work is twofold: (1) present the initial calibration of ChemCam, (2) investigate if target characteristics could influence the autofocus results.

Autofocus capability: The autofocus capability uses a small CW (785 nm) laser to illuminate the target. The emission is modulated to increase the signal-to-noise ratio and to subtract ambient light. The reflected signal is amplified and demodulated. The amplification gain is automatically set to account for target albedo. As the secondary mirror moves along the optical axis, a photodiode embedded into the telescope reads the signal. The information is passed to the onboard digital processor which computes the best focus position.

The best focus position is obtained when the flux reaches its maximum (Figure 1). In reality, finding a maximum on this curve is not always possible due to electronic noise. For that reason the best focus is calculated from the symmetry of the curves, between 15% and 80% of the maximum.

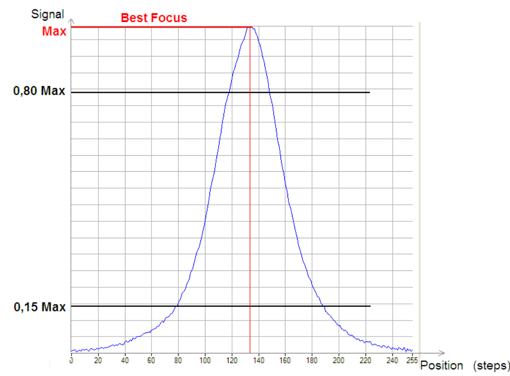

Fig. 1: Autofocus curve for a breccias at distance of 3 m.

The most significant point of the autofocus calibration is the regression between motor steps and distance to target (Figure 2). It has a simple $(ax+b)/(cx+d)$ shape, as predicted by optical simulations. The requirement for LIBS and RMI is ±0.5%, which corresponds to ±40 steps at short distances and it is more stringent, at ±5 steps, at long distances.

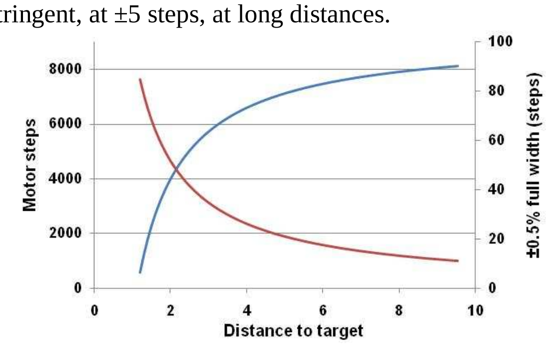

Fig. 2. Motor step vs. distance for ChemCam FM unit (blue, left scale). The width of the ±0.5% requirement is shown in red (right scale).

The depth of field for LIBS plasma collection is shown in Figure 3 for a target at 3 m. Since the telescope is nearly achromatic, this does not change with wavelength. The depth of field for LIBS plasma initiation is controlled by the laser irradiance on the target. Tracking the Al line of a plasma generated at 3 m, we see that the intensity drops by 50% over 75 steps. This corresponds to an uncertainty of ±0.5% on the focus, which agrees with the requirement shown on Figure 2. Fortunately, the autofocus dispersion is much smaller, ±5 steps, as shown in Figures 4 and 5. An additional consideration is the offset of the autofocus from the optimum plasma collection. It is due to the absolute mechanical offset of the LIBS laser with regards to the autofocus diode. This offset is under calibration. It varies with distance to target and temperature. It will be implemented onboard the rover as a look-up table.

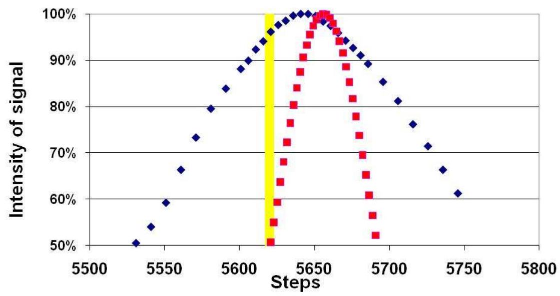

Fig. 3. Depth of field and autofocus at 3 m. Red: intensity of LIBS 396.5 nm Al line, indicating best focus for the laser. Blue: Telescope relative efficiency of light collection at 631 nm. Yellow: Autofocus result. The width of the line shows the dispersion.

Robustness of autofocus capability: At the surface of Mars, "non-cooperative" targets will be analyzed with ChemCam. We are reporting here on the putative effects of target roughness or grain size on autofocus results.

We have used the Engineering Qualification Model of the ChemCam experiment for that purpose. Different samples were placed at 3 m and 7 m distance, perpendicularly to the beam. The samples were chosen to cover a wide range of physical properties.

We used the same procedure for each sample: 15 autofoci were done, but every five of them, the translation table (on which the secondary mirror is fixed) was moved across the whole range and then back to the close focus position, in order to lubricate the mechanism.

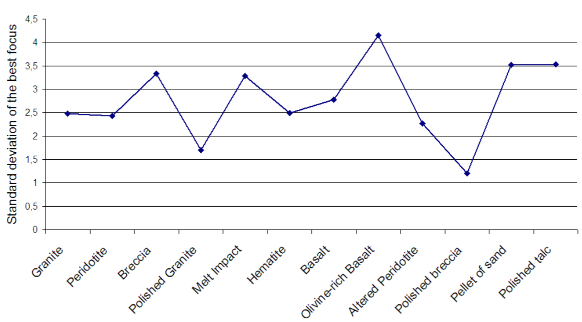

Fig. 4. Standard deviation, in steps, of the best focus for all the targets at 3 meters.

We first explore the dispersion of series of 15 autofoci at 3 m. On Figure 4, the standard deviation shows to be between 1 and 4 steps, an average of 2.8, independently of the rock type. At 3 m, 3 steps correspond to 0.09% of the distance, which is well within the specifications. Simulations show that electronic noise on the signal contributes to 1/3 of this dispersion.

At 7 m, a smaller set of rocks was used. The average standard deviation is 3.7, which correspond to 0.27% of the distance. The work is still in progress.

For both data sets at 3 m and 7 m, we have studied whether a fraction of the dispersion is due to roughness and grain size. Figure 5 shows no particular trend with these rock parameters, even between a polished surface (low roughness) and a basalt with vesicles (high roughness), between a talc (small grains) and a granite (large grains), or between sand and rocks.

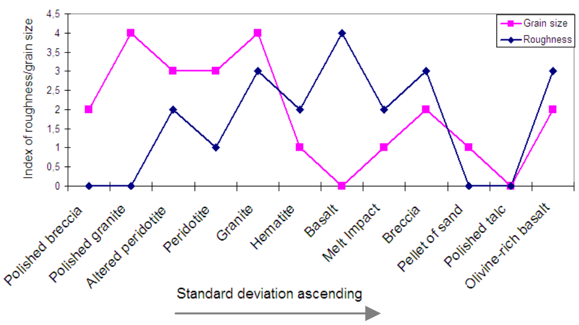

Fig. 5. Roughness and grain size index versus standard deviation of best focus (ascending sorting).

To know if the orientation of the target with regard to ChemCam optical axis is important for the stability of the autofocus function, we took three polished rocks which were firstly placed perpendicular to the beam, then tilted at 45°. Results (not shown) show dispersion with target orientation, but no correlation with the tilt angle.

Conclusion: Calibration shows that the autofocus function meets the expectations: autofocus dispersion is better than the required ≤0.5% of the distance. The autofocus was tested in the same conditions for rocks with different roughness and grain size. It was observed that this dispersion is not linked, whatever the distance, to the physical properties of the targets. The work is still under study to characterize in details the offset with regards to LIBS, and the actual LIBS depth of field.

References : [1] Wiens et al. (2005), *LPSC 36th*, #1580. [2] Maurice et al. (2005), *LPSC 36th*, #1735.