Characterization of ChemCam (MSL) Imaging Capability. S. Maurice[1], R. Wiens[2], L. Parès[3], S. Bender[2], N. le Roch[4], J. Dalmau[4], M. Berthé[5], Y. Langevin[5], K. Herkenhoff[6], N. Bridges[7], M. Saccoccio[4] and the ChemCam team, [1]Centre d'Etude Spatiale des Rayonnements – CNRS (31400 Toulouse, France; sylvestre.maurice@cesr.fr); [2]Los Alamos National Laboratory, New Mexico; [3]Laboratoire d'Astrophysique de Toulouse, France; [4]Centre National d'Etudes Spatiales, Toulouse; [5]Institut d'Astrophysique Spatiale, Orsay, France; [6]U.S. Geological Survey, Flagstaff, AZ; [7]Jet Propulsion Laboratory, Pasadena, CA.

Introduction. ChemCam is an instrument package consisting of two remote sensing instruments: the first planetary science Laser-Induced Breakdown Spectrometer (LIBS) and a Remote Micro-Imager (RMI) [1,2]. The LIBS technique provides elemental composition, while the RMI places the LIBS analyses in their geomorphologic context. Both instruments will help determine which samples within the vicinity of the rover are of sufficient interest to use the contact and in-situ instruments for further characterizations.

RMI images targets through the same telescope as the LIBS. Imaging can be performed from 2 m to infinity. Due to optimization of the telescope for LIBS, the RMI performances are not outstanding but tailored to the ChemCam objectives: being able to distinguish a 1 mm spot at LIBS maximum distance (~ 7 – 9 m), for a field of view not smaller than 20 cm. Thus, LIBS spots on rocks will be known from the pixel mapping.

The RMI frame-transfer CCD was manufactured by Thompson with 1024 x 1024 pixels in the image area, 43 additional pixels on the left side and 12 reference pixels at the top and bottom of the image. Typical full well is 320,000 electrons; data are encoded using 10 bits. The integration time is commandable from 1 msec to 65 sec. Transfer time from the registers is 2.1 msec. At the CCD level, standard tests have been performed: dark current vs. temperature, flat field, linearity, gain, saturation level, frame transfer smear.

The imaging function sub-system is composed of the CCD, optics and the electronic acquisition board. Here we present the key characteristics of this capability onboard MSL.

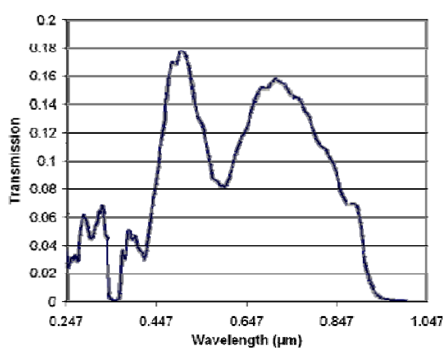

Fig. 1. Wavelength response of the flight RMI.

Wavelength response. The spectral response function of RMI is calculated from individual CCD intrinsic silicon response, surface coatings along the optical path, and transmission of the dichroic that separates outgoing laser light and incoming plasma light paths. Between 8% and 18% of the light coming into the telescope end up on the CCD (Figure 1).

Field of view. The requirement is to obtain a field of view larger than 15 mrad, which is achieved as shown Figure 2.

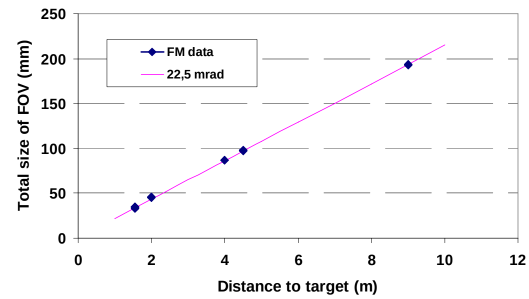

Fig. 2. Field of view as a function of distance to target

Resolution. The requirement is to obtain a contrast of 0.2 for an object separation of 80 µrad. We have been using USAF targets to calculate the true image resolution in the target frame of reference. As shown on Figure 3, the optical system produces some astigmatism: different resolutions are acquired in the vertical and horizontal directions: 78 – 85 µrad and 87 – 105 µrad respectively, without any image processing. A 1 mm object will be identified at 10 m, down to a quarter of a mm at close distance. A LIBS crater is about half a mm in diameter, which could be seen inside of ~4 m.

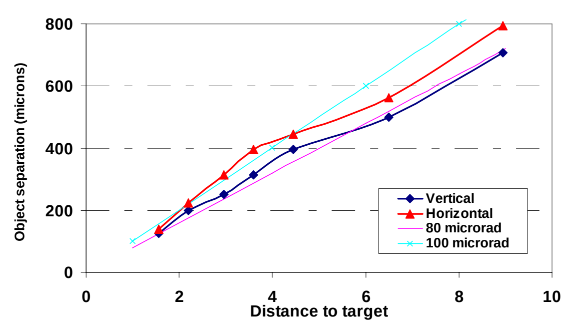

Fig. 3: Resolution in the vertical / horizontal directions.

Flat field. Because of various vignetting along the RMI optical path, such as the central obscuration of the telescope, we cannot expect a uniform distribution of light on the CCD. As shown Figure 4, images shall be brighter at the centre and darker on the edges. The decrease is nearly linear with distance to the image centre, down to 20% on the edges. This will be corrected during image processing. The image centre is less than 80 µm from the telescope optical centre.

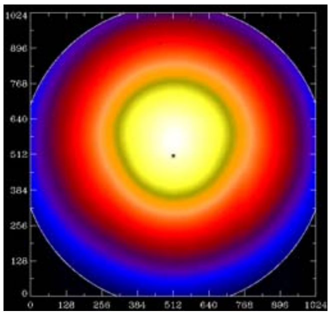

Fig. 4 : RMI flat field at 3 m distance. The color scale ranges from 100% (white) to 20% (blue). The small black star locates the image center.

Miscellaneous characteristics. There are many other effects that required characterisation for the RMI: Ghost light, because of reflection on the rear face of the separator which diverts light to the CCD; Stray light; Distortion, which is less that 0.2%. Finally the exposure time is expected to be 50 msec (Sun at 45°, albedo 0.4) and can increase to several seconds. An auto-exposure, which simultaneously minimizes the number of saturated and dark pixels, is implemented to increase the image contrast. The RMI is not radiometrically calibrated..

Coalignments of optical paths. It is paramount to the success of LIBS science that the fibre which runs to the spectrographs, which has a narrow field of view, is aligned to collect the LIBS plasma. To a lesser extent, the autofocus CW laser needs to pinpoint the spot where the plasma will occur. Thus three separated optical paths require being co-aligned. During ground calibration of ChemCam, the RMI is being used to track such alignments in the fixed frame of the CCD.

Figure 5a captures the different beam registrations in the fixed frame of the CCD at ChemCam closest distance, 1.56 m, which corresponds to the distance to the onboard calibration targets. The image is a 180-pixel subframe of the whole RMI image. A scale in the target frame of reference shows that this corresponds to a ~5 mm field of view. RMI can view the CW autofocus laser (yellow contour), which will be useful for engineering purposes at the surface of Mars. It appears as a ~2 x 4 mm spot, which is elongated because of the shape of the emission slab. The fibre has been backlighted to visualize the plasma collection (red contour). It shows as being 1.5 mm diameter. The LIBS spot is located by image subtraction before and after an impact on an aluminium plate. This location is where we shall always locate the LIBS spot in the RMI context image. Finally we assume that the plasma size around this location is 2 mm diameter (green contour) or smaller [3]. At short distance, the plasma overflows the fiber. The alignment is very good for LIBS and is covered by the autofocus spot.

Nine meters is the furthest distance for LIBS analyses (Figure 5b). The fiber field of view has increased to 5 mm diameter. It now captures the entire plasma, which is slightly offset with regards to the fiber center. The CW beam is collimated so that the spot size remains the same.

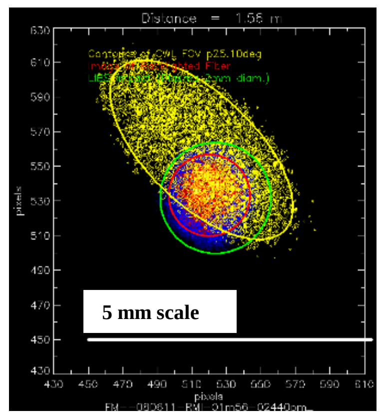

Fig. 5a : Coalignements of optical paths at 1.56 m . See text for color-coding.

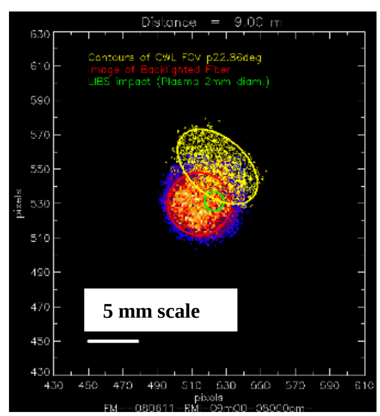

Fig. 5b : Coalignements of optical paths at 9 m

References : [1] Wiens et al. (2005), *LPSC 36th*, #1580. [2] Maurice et al. (2005), *LPSC 36th*, #1735. [3] Sallé et al. (2005), *Spectrochim. Acta*, 60, 479.