EPSC Abstracts
Vol. 11, EPSC2017-253, 2017
European Planetary Science Congress 2017

Miniaturized Raman/LIBS instrument for in situ exploration of planetary bodies without atmospheres

D. S. Vogt (1), S. Frohmann (1, 2), S. Schröder (1), K. Rammelkamp (1), U. Böttger (1), H.-W. Hübers (1, 3)
(1) Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Optische Sensorsysteme, Berlin, Germany, (2) Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany, (3) Humboldt-Universität zu Berlin, Institut für Physik, Berlin, Germany (david.vogt@dlr.de)

1. Introduction

In our solar system, there is a multitude of planetary bodies without substantial atmospheres, including asteroids, comets, moons, and minor planets. Due to the lack of atmospheres, these bodies are not affected by atmospheric alteration processes. Asteroids and comets especially are considered to be the least evolved objects in the solar system, possibly still containing pre-solar grains from the proto-solar nebula [1]. Therefore, the study of planetary objects without atmospheres can yield important information about the formation of the solar system. This makes them interesting targets for robotic exploration with instruments that are able to determine the chemical and mineralogical composition of both their surface and subsurface.

Here we present first results of the design and characterization of a miniaturized instrument for the application on planetary bodies with low or non-existent atmospheric pressure. The instrument will combine Raman spectroscopy and laser-induced breakdown spectroscopy (LIBS) and is optimized to be very lightweight and small, with working distances of up to 1 m.

2. Raman spectroscopy

Raman spectroscopy is a powerful technique for the analysis of sample compositions and structure. It is based on the Raman effect. This Raman scattering produces a spectrum that is characteristic of the scattering molecule and can be considered as a "fingerprint" of the investigated material. For Raman spectroscopy, a CW laser with a tightly controlled output wavelength is advantageous for the exact determination of the observed Raman shift.

3. LIBS

LIBS is an atomic spectroscopy method which permits rapid multi-elemental analysis. It relies on the ablation of material from the sample by focusing a pulsed laser onto its surface. This produces a plasma plume of atoms, ions, and electrons. A spectrum of the plasma will contain atomic and ionic emission lines from which the elemental composition of the sample can be determined. With the ChemCam instrument on board the NASA Mars Science Laboratory (MSL), LIBS was applied to study the surface of an extraterrestrial body for the first time [2, 3]. While the Martian atmosphere is well-suited for LIBS, lower pressures lead to a faster expansion of the plasma. This makes the detection of LIBS spectra at very low atmospheric pressures challenging. However, it has been shown that LIBS measurements can be performed with relatively low-energy lasers in ultra-high vacuum environments [4].

4. Combined Raman/LIBS

Raman spectroscopy and LIBS are highly complementary techniques. The complementary information of LIBS and Raman spectra on the composition of a sample increases the accuracy of rock/soil determination. Furthermore, material ablation by LIBS can be used to penetrate the surface to reach the subsurface material (up to mm in soft materials), while Raman spectroscopy can be used to search for potential organic compounds in these subsurface areas. Neither technique requires sample preparation and both have short acquisition times (seconds to minutes). The measured spectra can be interpreted directly. Combining both techniques in a single device also has the benefit that the spectrometer and large parts of the optical components can be shared, which helps to keep the instrument lightweight and compact.

5. Miniaturized design

Several configurations of a Raman/LIBS instrument are conceivable and have been proposed for planetary exploration already [5–8]. SuperCam will be the first instrument to combine Raman and LIBS for planetary exploration as part of the Mars2020 mission. In order to cover distances of up to 12 m, it uses a telescopic system as well as a powerful laser, which increase size and weight of the device. With a close-up setup that only covers distances of up to 1 m around the probe, a telescope is not required and less powerful lasers can be used, so that the instrument can be miniaturized. This is especially advantageous for pioneering missions with a smaller scope. We estimate that our Raman/LIBS instrument can be as light as ~3 kg in total, including lasers, spectrometer and electronics.

For our miniaturized design, one option is the combination of a custom miniaturized echelle spectrometer for both Raman and LIBS spectra with two separate lasers. The echelle spectrometer offers high spectral resolution over a large spectral range, while separate lasers for Raman and LIBS are beneficial with regards to resolution and signal strength. Separate lasers also provide more flexibility, as Raman and LIBS spectra can be measured independently from one another, and the Raman laser can be used as a focusing laser. However, a single (pulsed) laser for both Raman and LIBS is also promising due to the possibility of gating out the fluorescence in Raman spectra. Currently, a continuous wave (CW) Nd:YAG laser at 532 nm is used for Raman, and a pulsed Nd:YLF laser at 1053 nm is used for LIBS. The advantages and disadvantages of different configurations will be investigated.

6. Summary and Conclusions

Raman spectroscopy and LIBS are complementary measurement techniques that are well-suited for the robotic exploration of planetary bodies without atmospheres. The presented instrument combines these techniques, enabling the identification of both the elemental composition and the molecular structure of a sample at distances of up to ~1 m and without prior sample preparation. We strive for a miniaturized and lightweight design. First spectra and a characterization of a combination of a miniaturized laser and a miniaturized echelle spectrometer are presented.

References

[1] G. Schwehm and R. Schulz, "Rosetta goes to Comet Wirtanen," in *Composition and Origin of Cometary Materials*, K. Altwegg, P. Ehrenfreund, J. Geiss, and W. F. Huebner, Eds. Springer Netherlands, 1999, pp. 313–319.

[2] S. Maurice *et al.*, "The ChemCam Instrument Suite on the Mars Science Laboratory (MSL) Rover: Science Objectives and Mast Unit Description," *Space Sci. Rev.*, vol. 170, no. 1–4, pp. 95–166, Sep. 2012.

[3] R. C. Wiens *et al.*, "The ChemCam Instrument Suite on the Mars Science Laboratory (MSL) Rover: Body Unit and Combined System Tests," *Space Sci. Rev.*, vol. 170, no. 1–4, pp. 167–227, Sep. 2012.

[4] S. G. Pavlov, S. Schröder, I. Rauschenbach, E. K. Jessberger, and H.-W. Hübers, "Low-energy laser induced breakdown spectroscopy for in-situ space missions to solar system bodies without atmospheres," *Planet. Space Sci.*, vol. 71, no. 1, pp. 57–63, Oct. 2012.

[5] S. Maurice *et al.*, "Science objectives of the SuperCam instrument for the Mars2020 rover," in *Lunar and Planetary Science Conference*, 2015, vol. 46, p. 2818.

[6] R. C. Wiens, S. K. Sharma, J. Thompson, A. Misra, and P. G. Lucey, "Joint analyses by laser-induced breakdown spectroscopy (LIBS) and Raman spectroscopy at stand-off distances," *Spectrochim. Acta. A. Mol. Biomol. Spectrosc.*, vol. 61, no. 10, pp. 2324–2334, Aug. 2005.

[7] S. K. Sharma, A. K. Misra, P. G. Lucey, R. C. Wiens, and S. M. Clegg, "Combined remote LIBS and Raman spectroscopy at 8.6 m of sulfur-containing minerals, and minerals coated with hematite or covered with basaltic dust," *Spectrochim. Acta. A. Mol. Biomol. Spectrosc.*, vol. 68, no. 4, pp. 1036–1045, Dec. 2007.

[8] R. C. Wiens, S. Maurice, F. Rull, and SuperCam Team, "SuperCam Remote Sensing on the Mars 2020 Rover: Science Goals and Overview," *LPI Contrib.*, vol. 1980, p. 4136, Oct. 2016.