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LiRS combined LIBS, Raman and Fluorescence Astrobiology Payload for potential Europa Lander

Kruzelecky, Roman (1), Latendresse, Vincent (1), Murzionak, Piotr (1), Lavoie, Jonathan (1), Mena, Martin (1), Sinclair, Ian (1), Schinn, Greg (1), Cloutis, Ed (2), Skulinova, Michaela (3), and Scott, Alan (4).
(1)MPB Communications Inc. (roman.Kruzelecky@mpbc.ca) (2) University of Winnipeg (ecloutis@uwinnipeg.ca), (3) CINTECH, (mskulinova@cintech.ca), (4) Honeywell Aerospace (Alan.Scott@Honeywell.com).

Abstract

The water moons Europa and Enceladus are of great scientific interest as their ice-covered oceans may shelter evidence of prior or current life. Active geysers allow some interchange of material between the ice encrusted oceans and the surface. The LiRS combined **LI**BS and **R**aman **S**pectrometer elegantly integrates laser-induced breakdown spectroscopy using 1064 nm excitation for elemental composition, deep UV (DUV) Raman using 248.6 nm excitation to provide information on the molecular bonding structure of the elements, fluorescence for the ppm sensitive detection of the presence of organics, and a bore-sighted colour micro-imager for complementary information on the sample morphology. This paper discusses the preliminary configuration of LiRS for the potential NASA Europa lander.

1. Introduction

A key objective of space exploration is the search for indicators of prior or current habitability and life. Science objectives and requirements for Europa include:

- sampling the Europa water/ice beneath the heavily irradiated surface layer,
- understanding the habitability of Europa's ocean through its chemistry and composition,
- detecting bioindicators and processes (in an aqueous solution).

There are many chemical biosignatures that can be detected by in-situ LIBS/Raman analysis, including molecular fossils, molecular evidence for metabolism, disequilibrium, and biominerals. The ChemCam Laser-Induced Breakdown Spectrometer (LIBS) aboard the MSL Mars rover has conducted relevant elemental analysis of a myriad of Martian rock and soil samples. A combined LIBS/Raman SuperCam [1] is planned for the Mars 2020 rover.

1.1 LiRS

LiRS [2], as shown schematically in Figure 1, provides elegant bore-sighted integration of:

- 0.1 to 1 m auto-focus imaging telescope;
- passive dichroic optical beam distribution;
- Raman/fluorescence molecular composition analysis using 248.6 nm NeCu laser excitation, similar to the laser used by SHERLOC [3];
- LIBS elemental analysis from 250 to 830 nm using a miniature single-mode micro-chip pulsed laser operating at 1064nm;
- bore-sighted color imager;
- supporting FPGA-based avionics.

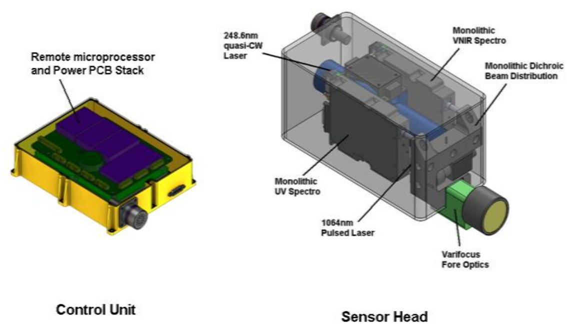

Figure 1: Preliminary schematic of a packaged LiRS system with separate avionics and net mass under 6 kg with 20% margin.

The LiRS system shares common resources to minimize its mass and volume, including the auto-focus telescope, the beam distribution dichroic optics, the three miniature spectrometers and the avionics.

The use of the DUV Raman excitation at 248.6 nm provides some resonance effects that enable Raman spectroscopy of trace amounts of organics in various matrices. Moreover, the Raman excitation at 248.6 nm allows the spectral separation of the Raman spectrum that occurs largely between 249 nm and about 270 nm from the much stronger fluorescence occurring at longer wavelengths.

Figure 2 shows the DUV Raman spectra of D-alanine mixed with H_2O at different weight concentrations (99%, 10%, 1.0% and 0.1%). The strong peak near 3000 cm^{-1} is attributed to the C-H stretching mode of alanine. The moderate intensity Raman lines attributed to C-O, C-N and C-C near 800-1700 cm^{-1} begin to vanish for concentrations under 0.1%. For every concentration, a broad peak due to H_2O can be observed around 3200-3700 cm^{-1}.

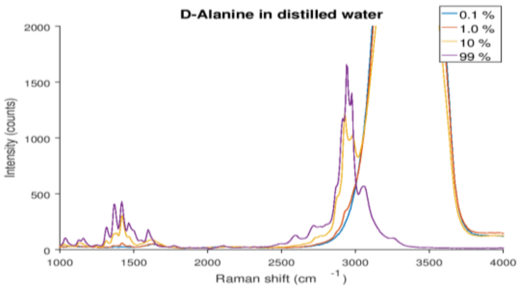

Figure 2: LiRS DUV Raman spectrum of D-alanine 99% (purple), 10% (yellow), 1.0% (red) and 0.1% (blue) dissolved in water.

The feasibility of ice drilling using the LiRS 1064 nm pulsed laser was lab tested. The ice penetration depth after 30 laser pulses was about 0.5 mm.

2. LiRS Europa Lander Option

Figure 3 shows a potential LiRS deployable Pod that is positioned by the lander arm on the Europa surface. The Pod outer Al shield would be used to protect the exposed Europa target area from the near-surface radiation to assist preserving any bio_signatures.

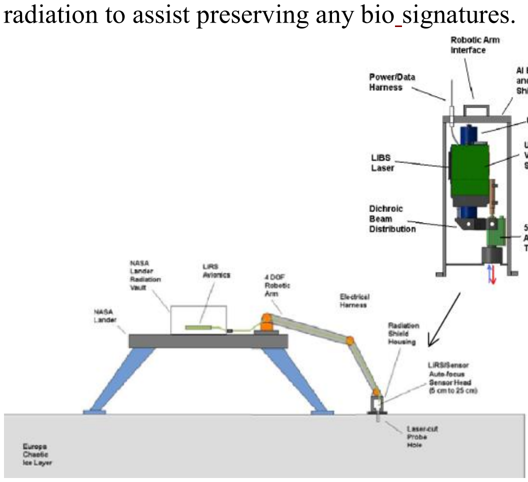

Figure 3: Schematic of the LiRS Sensor Pod deployment on Europa surface using the lander robotic arm.

At a given surface placement, LiRS would autonomously perform a sequential set of measurements, alternating between Raman/fluorescence and LIBS, to a net target depth of about 12 cm in mm depth steps, using the 1064 nm pulsed laser to perform the ice drilling. The lander arm would then be used to reposition the LiRS Pod to a different target position on the Europa surface to provide measurements at several different locations near the lander within reach of the lander robotic arm.

3. Summary and Conclusions

The LiRS lab breadboard has demonstrated the feasibility and utility of combining LIBS for elemental analysis with DUV Raman for complementary information on the molecular structures. With the 248.6 nm deep UV Raman excitation, the resultant fluorescence spectra occur at longer wavelengths above the Raman spectrum, allowing simultaneous measurement of both. The LiRS lab validations have shown that LiRS is capable of providing Raman and LIBS spectra of organics diluted in water, as relevant to a potential science payload to study astrobiology on Europa.

Acknowledgements

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