LIBS instrument for the Lunar Polar Mission Rover: Development results and its capability to detect water ice

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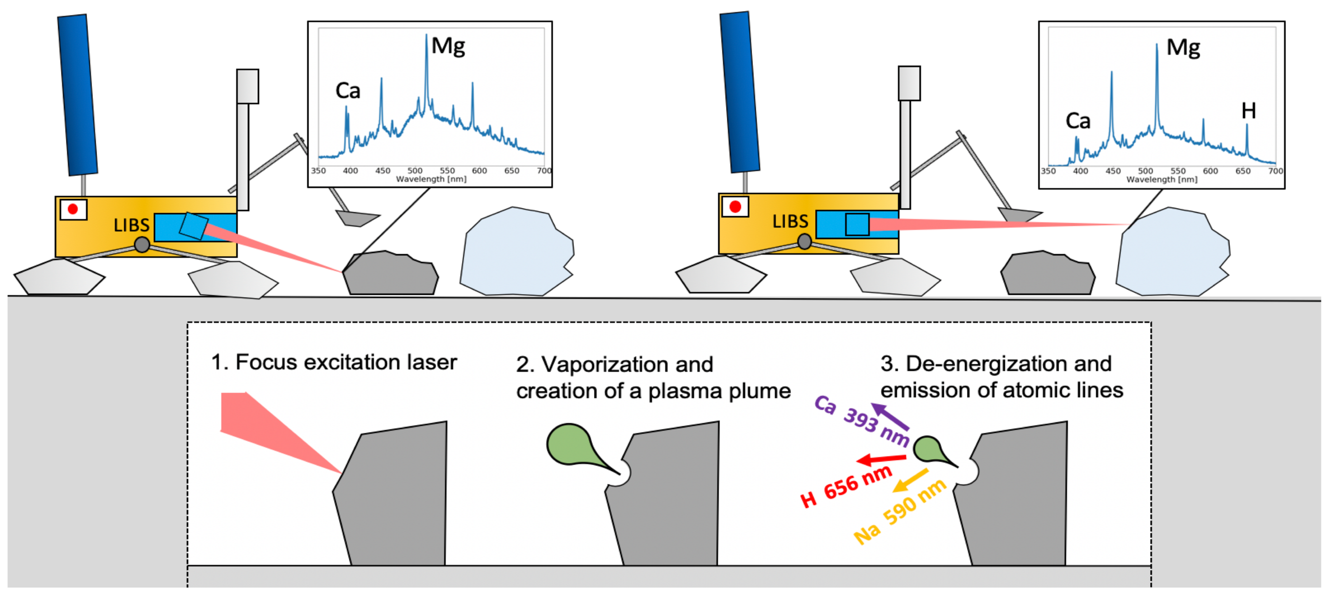
Abstract

- We developed a breadboard model of a Laser-Induced Breakdown Spectroscopy instrument for the lunar polar mission rover to map the ice content in the mm-scale surface layer.
- Performance tests were done by measurement of geological standard samples.
- Multivariate and univariate analysis methods yielded relative accuracy of ~15% for major elements and ~75% for H_2O (absolute accuracy of ~1 wt%). The limit of detection for H_2O was 0.75 wt%.
- Preparatory irradiation of the laser could be a diagnostic method for distinguishing –OH from H_2O.

1. Laser-Induced Breakdown Spectroscopy (LIBS) instrument on the lunar pole

Spectroscopy of the plasma created from the excitation laser yields atomic emission lines. These could be used to identify and quantify the elemental species on the target.



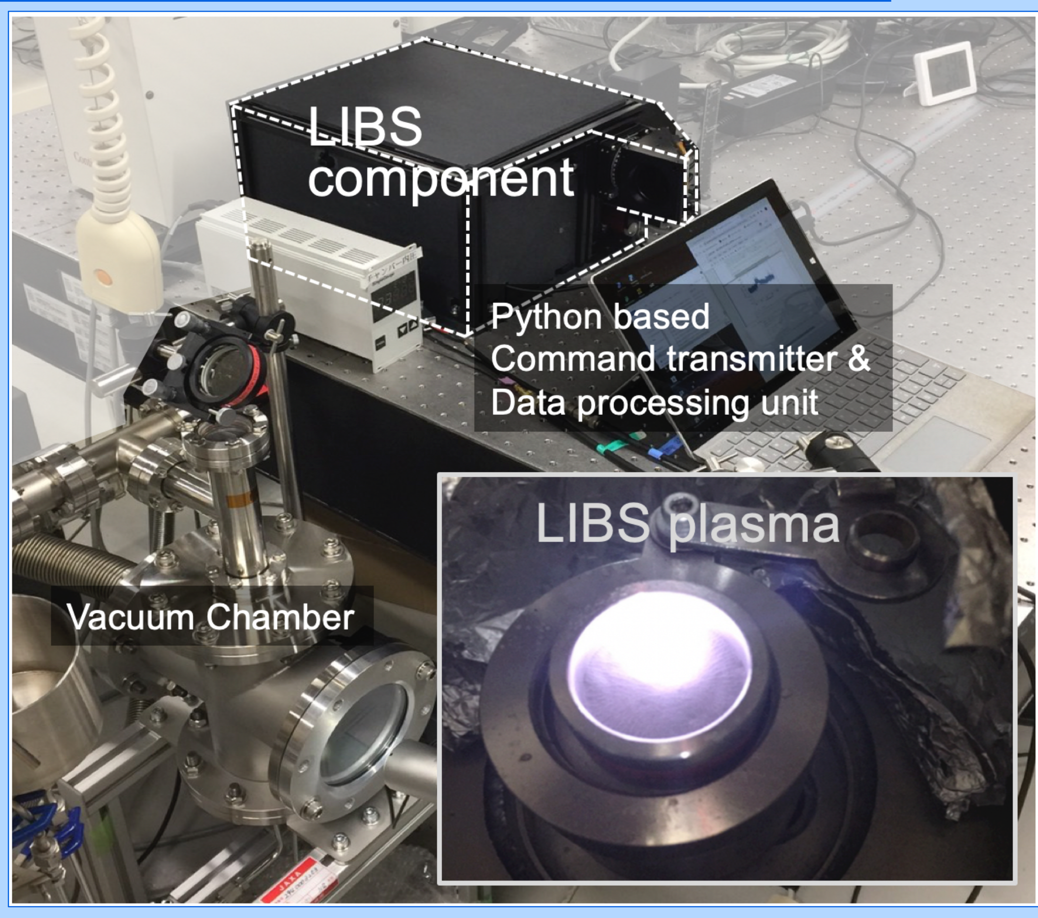
Advantages

- ✓ Rapid data acquisition: <100 ms per spectrum.
- ✓ Simultaneous multi-elemental analysis.
- ✓ Sub-mm spatial resolution.
- ✓ mm-scale depth profiling: Capable of removing the surface space-weathered layer.
- ✓ Active spectroscopic technique

2. Objective of this study

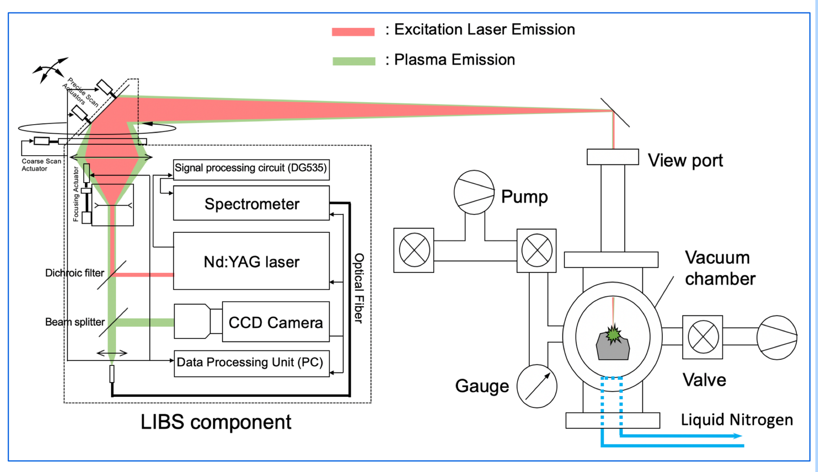
- Development of a LIBS breadboard model.
- Validate whether the performance meets the required accuracy to quantify major elements and hydrogen under lunar environments.

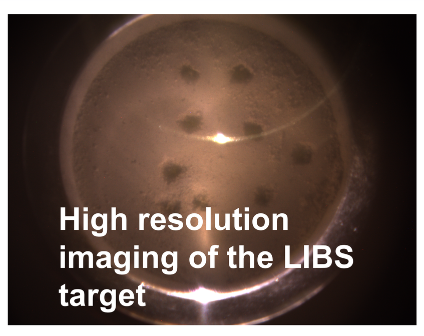
3. Developed Instrument



Specifications

- ✓ Dimension: 300 x 350 x 190 mm
- ✓ Weight: 8 kg (with breadboard and electronics)
- ✓ Laser energy: <45 mJ
- ✓ Distance to target: able to auto-focus in the range of 0.8 m to few m.
- ✓ Communication I/F: USB x 4
- ✓ Precise XY scanning within ± 70 mrad. Coarse scanning of 2π rad in the rover moving direction.





Experimental

- Distance to the target was set to 1m and was placed in < 3×10^{-2} Pa vacuum.
- Samples were pressed and dried in an oven with >100℃ for >8 hours.
- 100 spectra were acquired per spot.
- 5 to 9 spots were measured per sample

4. Testing results

Omitted (unpublished data)

The intensities of atomic lines in the LIBS spectra reflect the composition of the sample. Multivariate and univariate analysis of these spectra are shown below.

Major elements

Multivariate analysis (PLS2)

Omitted (unpublished data)

PLS2 cross validation have been done. A relative accuracy of ~15% could be achieved and meets mission requirements for most major elements.

Table1: Result of PLS2 cross validation

	SiO_2	TiO_2	Al_2O_3	MnO	MgO	CaO	Na_2O	K_2O	T-Fe_2O_3	Mg #
Relative error %	**Omitted (unpublished data)**									
RMSEP wt%										

Hydrogen

Multivariate analysis (PLS1)

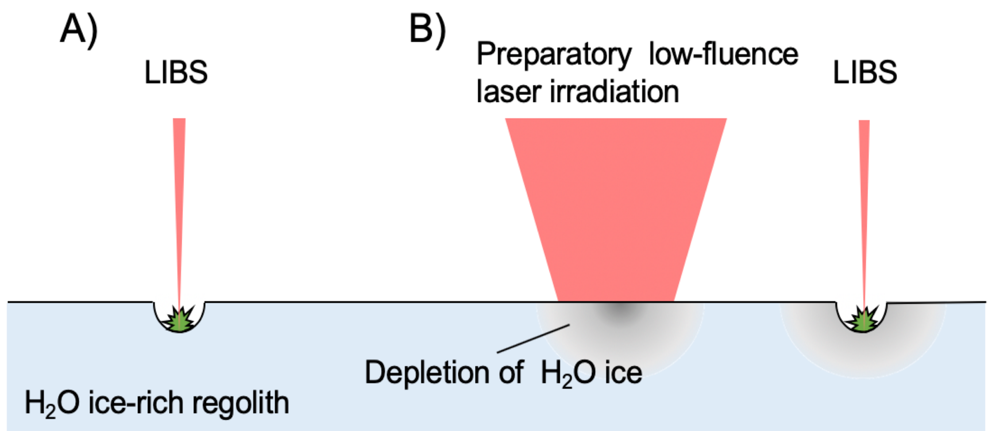
Univariate analysis (Intensity of Hα line)

Omitted (unpublished data)

	H_2O+
Relative error %	
RMSEP wt%	

	H_2O+
Error wt%	
LOD wt%	

5. Possible diagnostic method for discrimination between –OH and H_2O



Omitted (unpublished data)

LIBS cannot distinguish -OH from H_2O derived hydrogen. However, our preliminary study showed the possibility that irradiation of low-fluence laser irradiation could heat the target surface and induce the exclusive depletion of H_2O. Thus, change in LIBS spectra after such irradiation could be a criterion to distinguish the source of H on the target.

Future studies

Miniaturization, thermal vacuum test of the laser, measurement of power consumption, performance test with varying distance to target will be conducted.

Conclusion

- BBM-level study showed that LIBS could detect lunar ice with an accuracy of ~1 wt% and a detection limit of ~0.75 wt%. Simultaneous acquisition of other regolith composition and high-resolution images of the measured points should further constrain the situated condition of ice on lunar poles.

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