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Elemental analyzer for landed lunar and planetary explorations: Laser-induced breakdown spectrometer (LIBS)

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A laser-induced breakdown spectrometer is one of the elemental analyzers, which is composed of a laser, a spectrometer, and an optical system. The measuring principle of LIBS is as follows: Samples are irradiated with pulsed laser beams in order to generate plasma plumes of a small amount of the sample. When atomic and ionic species excited in the plumes are deexcited, the emission of lights occurs according to the difference in energy levels before and after the deexcitation. These lights are measured with a spectrometer as emission lines on spectra. The wavelength of emission lines is unique to each element, and the intensity of emission lines is correlated with the elemental abundance. Both qualitative and quantitative analyses, such as elemental abundance determination and mineral classification, are carried out by analyzing the acquired spectra.

LIBS has several advantages such as (i) capability of remote analysis (up to ten meters or more depending on laser intensity), (ii) rapid data acquisition (a few second to a few minutes), (iii) ability to analyze almost all elements including light elements, (iv) high spatial resolution (several tens to several hundred of micrometers), and (v) unnecessity of sample preprocessing. LIBS has potential for being a powerful elemental analyzer in landed lunar and planetary explorations. Actually, LIBS is loaded on Mars Science Laboratory, which is the first use of LIBS in space. LIBS would be a standard elemental analyzer in landed missions.

Now we are developing a LIBS for landed lunar explorations. We have had decided basic design of the LIBS and finished detailed designing of the measurement distance variable optical system. We have had also done the improvement of spectral analysis method for determining elemental composition with high accuracy. Then, last year we carried out two types of field tests with LIBS test models. One is an elemental composition measurement test, and the other is an onboard LIBS test on a rover. These tests were conducted at Mount Mihara on Izu-Oshima island.

We made a small portable LIBS, and carried out the field elemental composition measurement test with it. The LIBS we made is for a short range measurement and has a fifty-millimeter fixed focal length. Standard igneous rock samples have been measured with the LIBS in the laboratory in advance to make regression models for spectral analysis to determine elemental compositions. In the field we measured many samples such as bounding stones and lava flows under the Sun and obtained spectra with high signal-to-noise ratio. The elemental compositions determined with those spectra shows reasonable values for basalt. The determined values had, however, large error bars, which may be due to a small number of standard igneous rock samples used for making the regression models. We are going to prepare more standard samples to improve the determination precision.

We also carried out the LIBS onboard test on a rover (Micro 6 rover, JAXA). A test model of the measurement-distance adjustable optical system was made, and autofocus test and laser irradiation test through the optical system were carried out on the rover.

We plan to carry out field test with a test model of the measurement-distance adjustable LIBS. We are going to perform a sequence of measurement with it on a rover: Selecting a measurement point, autofocusing, laser irradiation, spectra acquisition, elemental composition determination. Through this we will confirm the operational procedure and quantitative measurement under onboard and natural terrain conditions.

Keywords: landed exploration, elemental analyzer