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Performance evaluation of the MoMoTarO detector as a moisture meter for lunar and ground operation

Recently, lunar exploration has gained momentum internationally, as represented by the ARTEMIS Plan. Especially, exploration of lunar water resources is important not only for space resource exploration but also for scientific purposes. Lunar water resources can be used as drinking water and fuel at lunar bases and steps to the Mars exploration. Location and abundance of lunar water resources are key to elucidating the origin, migration and concentration of water resources on the Moon.

We have developed a new compact neutron and gamma-ray radiation detector, the Moon Moisture Targeting Observatory (MoMoTarO), aiming to mount it on a future lunar rover to explore water resources in a contactless way. Fast neutrons are produced by collisions of galactic cosmic rays with the lunar surface materials. They lose energy due to collisions with light elements such as hydrogen contained in water and then become thermal/epi-thermal neutrons. The MoMoTarO can measure the count rates of thermal/epi-thermal neutrons and gamma-rays respectively using a new technology. The MoMoTarO on the lunar rover can realize a more detailed map of water resources potentially with a spatial resolution of a few meters, compared to previous satellite-based exploration of water resources.

The MoMoTarO detector uses a new technology with a lithium-doped plastic scintillator (EJ-270) readout by silicon photomultipliers (SiPMs). The MoMoTarO is expected to be an alternative candidate to He-3 gas detectors because of its advantages, such as lower cost, lower power consumption, and stronger vibration resistance. Thermal/epi-thermal neutrons, fast neutrons, and gamma-rays trigger specific signal waveforms due to their different interactions in the scintillator. We can discriminate between neutron and gamma-ray signals by analyzing the ratio of the amount of charge of the entire signal to that of the signal tail since neutron signals typically have a longer decay time than gamma-ray signals. Initially, the discrimination performance was low due to the difficulty in detecting slight waveform difference using SiPMs. However, we have improved the performance by updating the circuit and analysis algorithm to handle the detailed signal waveforms. We continue to optimize the discrimination performance by improving analog circuits, digital processing, and analysis methods. We have conducted lunar simulant experiments to simulate the water resources exploration on the lunar surface. We prepared lunar simulants with very low (0.3 wt%) to low water content (2.0 wt%), and measured neutron count rates from simulants using a neutron radiation source and MoMoTarO detector. We found that the count rates of thermal/epi-thermal neutrons varied depending on the water content of the simulants even in very low water content. In addition, we will utilize the MoMoTarO on the ground operation, so we conducted experiments simulating the investigation of soil compositions on the ground. We use acrylic plates with many hydrogen and glass plates with less hydrogen to simulate water and soil respectively. We will report on the progress of discrimination performance optimization, the results of a lunar simulants experiment, and ground simulating experiments.

Collaboration(s)

Author: Mr OMATA, Yuya (Kyoto University)

Co-authors: Mr KUSANO, Hiroaki (RIKEN); Mr TAKAHASHI, Hiromitsu (Hiroshima University); Mr NAGAOKA, Hiroshi (Ritsumeikan University); Mr NAKAZAWA, Kazuhiro (Nagoya University); Mr NAKAYAMA, Kazuya (Kyoto University); Mr HOTOKEZAKA, Kenta (The University of Tokyo); Mr HAREYAMA, Makoto (St. Marianna University School of Medicine); Ms TSURUMI, Miwa (Kyoto University); Mr UENO, Munetaka (JAXA); Mr OZAKI, Naoya (JAXA); Mr TSUJI, Noki (Kyoto University); Mr MAEDA, Ryota (Kyoto University); Mr KISAKA, Shota (Hiroshima University); Mr IKENAGA, Taichi (Soil and Rock Engineering Co.,Ltd.); Mr KOBAYASHI, Taizo (Ritsumeikan University); Mr TAKANASHI, Takaoki (RIKEN); Mr HOSHINO, Takeshi (JAXA); Mr ENOTO, Teruaki (Kyoto University); Mr TAMAGAWA, Toru (RIKEN); Mr WAKABAYASHI, Yasuo (RIKEN); Mr KATO, Yo (RIKEN); Ms OTAKE, Yoshie (RIKEN); Mr TSUKAMOTO, Yushi (Soil and Rock Engineering Co.,Ltd.); Mr NAKANO, Yuuki (Soil and Rock Engineering Co.,Ltd.)

Presenter: Mr OMATA, Yuya (Kyoto University)

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