Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS024-29 会場:103 時間:5 月 23 日 15:15-15:30

SELENE2 での月レーザ測距
Lunar Laser Ranging Experiment in SELENE2

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We present the development status of Lunar Laser Ranging experiment proposed to SELENE-2 landing mission. The Lunar Laser Ranging (hereafter referred to as LLR) measures the distance between laser link stations on the Earth and retroreflectors on the Moon, by detecting the time of flight of photons of high-powered laser from the ground laser stations. Since the Earth-Moon distance contains information of lunar orbit, lunar solid tides, and lunar rotation, we can estimate the inner structure of the Moon through rotation and tide. The ranges have been obtained since 1970's, when the Apollo and Luna mission put five retroreflectors on the Moon (Apollo 11, 14, 15, Lunakhod 1 and 2). The Lunakhod 1 had been lost for decades, but the LRO mission found it and the Apache Point Observatory in New Mexico, U.S.A., successfully ranged it on March 2010.

The retroreflector arrays of Apollo missions contain 100 (Apollo 11 and 14) or 300 (Apollo15) prism-type corner cube retroreflectors with diameter of 3.8 cm, mainly due to the thermal design. Because of the tilt of the retroreflector arrays from the Earth direction due to the optical libration, the returned laser pulse is broadened, causing the main range error of more than 1.5 cm per photon ([1]). Therefore the sub-cm accuracy is achieved only by the statistical manner, namely by accumulating photons within about less than 20 minutes to make one range (normal point). We propose a large single retroreflector of hollow-type so that a single shot accuracy could become sub-cm. Otsubo et al ([2]) showed that a retroreflector of 20cm diameter with appropriate dihedral angle reflects photons of 1.5 fold of Apollo 11. Moreover, optimization of three dihedral angles can result in more photons ([3]). Since the accuracy of 0.1 arcseconds is needed as the dihedral angle, the fabrication precision and the thermal stability is under study. Also, a new retroreflector in the southern hemisphere of the Moon will enlarge the retroreflector network on the Moon for better estimation of the lunar rotation and tides.

We plan to range the Moon from a Japanese ground station. Currently only two laser link stations in the United States and France range the Moon. However, because these telescopes are used as astronomical or satellite laser ranging facilities as well, the amount of LLR data are limited. Therefore new ground stations are needed to obtain more LLR range data for better estimation of the internal structure of the Moon. The 1.5 m telescope at NICT-Koganei, which is dedicated to satellite laser ranging, will be upgraded so that it can transmit high-powered laser with relatively longer pulse width (nanosecond) for the detection of returns from the Moon within several years. Within longer time span, we also plan to build a new laser station in a place like Okayama where the best seeing is available in Japan and to develop the adaptive optics for uplink laser ([4]).

[1] Murphy et al., 2008, PAPS, vol 120, pp. 20-37. [2] Otsubo et al., 2010, Adv. Space Res., vol 45, pp 733-740. [3] Otsubo, Geod. Soc, of Japan, 2010 Fall Meeting. [4] Kunimori, Geod. Soc, of Japan, 2010 Fall Meeting.

キーワード: 月, 測月学, 月探査, SELENE2, LLR
Keywords: Moon, selenodesy, lunar exploration, SELENE2, LLR