Current Status of the Gamma-Ray Spectrometer on SELENE (KAGUYA) Masanori Kobayashi[1], Nobuyuki Hasebe[2], Eido Shibamura[3], Takashi Miyachi[2], Takeshi Takashima[4], Osamu Okudaira[2], Naoyuki Yamashita[2], Shingo Kobayashi[2], Makoto Hareyama[2], Yuzuru Karouji[2], Satoshi Kodaira[2], Mitsuru Ebihara[5], Tomoko Arai[6], Takamitsu Sugihara[7], Hiroshi Takeda[8], Kazuya Iwabuchi[2], Kanako Hayatsu[2], Shinpei Nemoto[2], Takeshi Hihara[5], Claude d' Uston[9], Sylvestre Maurice[9], Olivier Gasnault[9], Benedicte Diez[9], and Robert C. Reedy[10], [1]Nippon Medical School (m-kobayashi@nms.ac.jp), [2]Research Institute for Science and Engineering, Waseda University, [3]College of Health Science, Saitama Prefectural University, [4]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, [5]Dep. of Chemistry, Tokyo Metropolitan Univ., [6]National Instiutute of Polar Research, 7Japan Agency for Marine-Earth Science and Technology, [8]Research Institute, Chiba Institute of Technology, [9]Centre d'Etude Spatiale des Rayonnements, CNRS, [10]Institute of Meteorites, Univ. of New Mexico.

Introduction: The Japanese lunar polar orbiter SELENE (KAGUYA), which consists of a Main Orbiter and two small satellites (Relay Satellite and VRAD Satellite), was launched from Tanegashima Space Center on Sep. 14, 2007[1].

The main orbiter carries a gamma ray spectrometer (GRS) that has a large volume germanium semiconductor detector of 252cc as the main detector and bismuth-germanate and plastic scintillators as an active shielding [2]. With the highest energy resolution, the GRS will provide the concentrations of the major elements of the material of the lunar surface, Mg, Al, Si, Ti, Ca, Fe, natural radioactive elements tells history of heat of the moon, K, Th, and U, and also will possibly exhibit the existence of water, in which one is very interested from the viewpoint of future lunar utilization.

The primary mission of SELENE is scheduled for about 10 months and the extension of the mission period is planned, too. In the mission, the GRS will provide elemental maps of lunar surface with respect to elements described above.

In this presentation, the current status of the GRS observation and early observation data are shown.

Instrumentation: The Ge detector which is used by SELENE GRS can lead to identification of many elements and quantification with high sensitivity because of its superior energy resolution. The Ge detector is, however, necessary to be cooled down to cryogenic temperature; therefore we have adopted a Stirling cryocooler developed for space use [3]. The space cryocooler has been fully qualified from the viewpoint of tolerance to vibration in launch, long-term use in space environment and low vibration level by itself. In ground test, the flight model of the GRS showed an energy resolution of 3.0 keV (FWHM) at 1.33MeV as designed [3]. Further detail about instrumentation of the GRS, see references [2] and [3].

Current status: SELENE was injected in lunar orbit on Oct. 4, 2007, via its phasing orbit to the moon. After injection into circular orbit at 100 km altitude of approximately two hours periodicity, the GRS as well as the other onboard scientific instruments passed through a health check and a function check, it was shifted to its regular observation on Dec. 21, 2007.

In the regular observation mode, the high voltage applied to a Ge detector was 3.1 kV as of the beginning of Jan. 2008. The light outputs from a BGO scintillator and a plastic scintillator are read out by PMT applied high voltage, and the signal is provided for the anti-coincidence detector of the Ge detector. Prior to the regular observation, the Ge detector was cooled down to below 90 K in lunar orbit for the first time, eventually to be 75 K, the driving voltage was 14V. The cooling speed and the achieved temperature were as expected.

From a viewpoint of the stability of the signal gain, the temperatures of the detectors and the electronics are preferred to be stable. Sensor subsystem GRD of GRS on the nadir side panel, however, is susceptible to periodic heat input by lunar albedo. So far the checkout operation the HK data of the GRS showed the stability of the temperature of the sensor subsystem.

In the middle of Nov. 2007 when the beta angle was 40 deg, the temperature of the radiator, on which the cryocooler is attached, varied by 20 deg C around 0 deg C by temperature difference of the sunny side and the dark side of the moon. Nevertheless the temperature of the Ge detector was kept 75 K with precision to 0.5 deg C. In spite of the periodic heat input, the temperatures of baseplate of GRD, on which the detectors, the preamplifiers and high voltage supplies are placed, were well controlled by a heater to be about 0 deg C with precision to several degrees.

While the beta angle changes, the heat input varies. In the beginning of Jan. 2008 when the beta angle was

90 deg and SELENE was in the lowest temperature environment, the driving voltage of the cryocooler was lowered to 13 V so that the temperature of Ge detector kept 75 K. The driving voltage has only to be changed little by little in response to the beta angle.

Initial Observation data:

The lunar gamma ray spectra shown in Fig. 1 and Fig. 2 were accumulated over regular observation data from Dec. 14 to 17, 2007. The GRS provide with gamma-ray spectra of two different energy ranges. Fig.1 and Fig.2 show gamma-ray spectra in high energy range, 0 to 12 MeV (Low gain data) and low energy range, 0 to 3 MeV (High gain data in), respectively. High gain data shows the same gamma-ray events as ones in the energy range of 0 to 3 MeV of Low gain data, the measurement precision of gamma ray energy of High gain data is about four times as high as Low gain data. The energy threshold of these spectra is around 100keV. Those spectra were measured with anti-coincidence of BGO and plastic scintillators.

Real measurement time for the spectra is about 74 hours and the dead time in the measurement was about 22 %. On Dec. 14, SELENE went over a circular orbit of longitude 55 deg to -125 deg at about an altitude of 100 km from lunar surface by a period of about 2 hours.

With the GRS, gamma ray spectra are collected every 17 seconds and are accumulated to be one as shown in Fig.1 and Fig.2. The gain of gamma-ray energy can be variable mainly due to temperature dependence of electronics. Accordingly the individual spectra are routinely corrected before summing when the temperature environment changes.

In the period when the spectra were measured, however, as long as the peak position of 511 keV annihilation gamma ray is monitored every 2 minutes, its position was very stable with precision to about 0.4 keV (1 ADC channel in high gain spectrum), so the correction to the signal gain was not applied when accumulating. The other data corrections that should applied to spectra before accumulating are the correction to spacecraft altitude variation and the correction to cosmic ray flux variation, although not applied to the spectra in Fig.1 and Fig.2, yet.

As of preparing this abstract, only few observation data has been done with low level data processing. As the data processing is progressed, differences in gamma-ray spectra among lunar regions will be shown.

The spectra include not only gamma rays induced by high-energy cosmic rays in lunar surface materials but also gamma rays from GRD itself and the ambient materials of the spacecraft body as background gamma rays. With the individual spectra from different lunar regions, evaluation of the instrumental backgrounds will be possible because Fe and Th contents are known to be small in the highlands but Ca and the Al, in contrast, are relatively low in the maria.

References:

[1] http://www.selene.jaxa.jp/en/index.htm. [2] Hasebe, N., et al. (2008) *Earth, Planets and Space*, in press. [3] Kobayashi, M. et al. (2005) *Nucl. Instrum. and Meth.*, A548, 401-410.

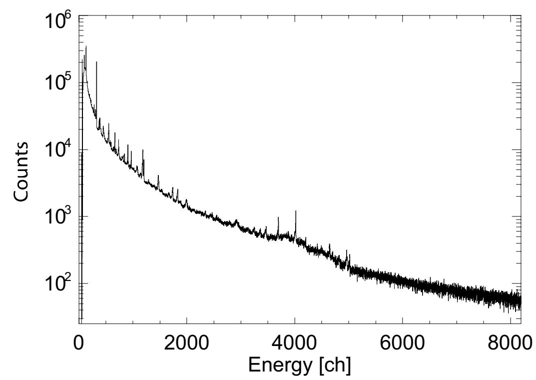

Fig.1. Gamma-ray Spectrum from “Low gain” data measured by SELENE GRS, ranging energy up to about 12MeV.

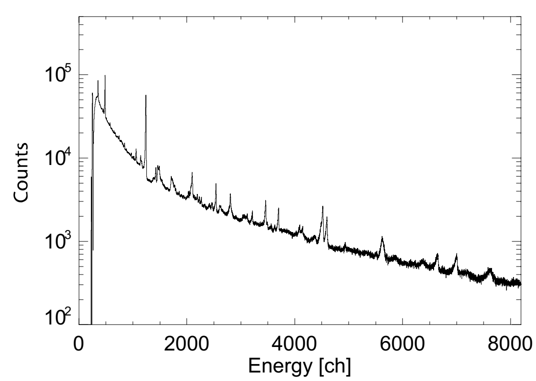

Fig.2. Gamma-ray Spectrum from “High gain” data measured by SELENE GRS, ranging energy up to about 3MeV.