**SELENE GAMMA RAY SPECTROMETER USING GE DETECTOR COOLED BY STIRLING CRYOCOOLER.** M. - N. Kobayashi, A. A. Berezhnoy, M. Fujii, N. Hasebe, T. Hiramoto, T. Miyachi, S. Murasawa, H. Okada, O. Okudaira, E. Shibamura, N. Yamashita, *Advanced Research Institute of Sci.& Eng., Waseda Univ., 3-4-1, Okubo, Shinjuku-ku, Tokyo, 169-8555, Japan, (masanori@mse.waseda.ac.jp)*, T. Takashima, *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa, 229-8510*, K. Narasaki, K. Tsurumi, *Niihama Works, Sumitomo Heavy Industry Ltd., Niihama, Ehime, Japan*, H. Kaneko, M. Nakazawa, *Moriya Works, Meisei Electric Co., Ltd., 3-249-1, Yuri-ga-oka, Moriya-shi, Ibaraki, 302-0192*, K. Mori, *Clear Pulse Co., 6-25-17, Chuo, Ohta-ku, Tokyo, Japan, 143-0024*, C. d'Uston, S. Maurice, *Centre d'Etude Spatiale des Rayonnements, CNRS/UPS, Colonel Roche, B.P 4346, France.*

**Introduction:** A gamma-ray spectrometer (GRS) will be on board a Japanese lunar polar orbiter at an altitude of 100 km, SELENE, to be launched in 2006. The spectrometer will observe lunar gamma ray for one year or more (possibly extended another year in lower orbit) to obtain spectral information, covering 0.1-12 MeV, on chemical abundance on the entire lunar surface. SELENE GRS employs a Ge detector (252 cc, manufactured by Eurysis) as the main detector. This will be the first lunar mission using Ge detector of which the superior energy resolution can lead to the spectral information of more elements with higher sensitivity [1,2]. Some missions utilized passive cooler for the cryostat, a two-stage passive cooler for interplanetary mission [3,4] and a V-groove type radiative cooler for martian missions [5,6] to cool Ge detector. In lunar orbit, however, a heat flow from sunlight and the lunar albedo to the detector system is very large, moreover it is difficult for heat radiator to have a sufficient field of view to exhaust the heat into cold space due to the expanse of lunar surface. Therefore, we have adopted a Stirling cryocooler as the cooling device from the point of life time and cooling capacity, which was developed (by Sumitomo Heavy Industry Co. Ltd.) and qualified for use in space environment. The Stirling cryocooler generates mechanical vibration, it was therefore considerably concerned that such the mechanical vibration could cause microphonic noise on the Ge detector. Now, the flight model of SELENE GRS was built (Fig. 1) and qualified by several environment test. It shows an energy resolution of $\sim$3 keV @ 1.33 MeV in the GRS system. This paper describes the detail of the detector-cryostat system and the performance.

**Instrument:** The GRS consists of three subsystems, GRD (Gamma-ray Detector), CDU (Compressor Driver Unit) and GPE (Gamma-ray and Particle Electronics), which is shared with CPS (Charged Particle Spectrometer). GRD subsystem is placed on the lunar side plane outside of the spacecraft, while other subsystems are installed inside the spacecraft. CDU is a power supply for driving the cryocooler, which has AC output of 52 Hz up to 55 W and controlled by GPE subsystem. GPE contains analog and digital boards for data processing and analyzing, and CPU boards for data handling and transmitting to the data bus of the spacecraft. The subsystem is shared with CPS (charged particle spectrometer) for reduction of weight and power resource.

GRD subsystem consists of a detector set, pre-amplifiers, high voltage supplies and their filters, a cryocooler and a thermal radiator. The detector set includes a high purity n-type Ge crystal and a scintillator shield consisting of BGO and plastic scintillators working for Compton suppression, rejection of energetic ion and reduction of background gamma ray from the spacecraft body. The Ge detector has a large volume of 252 cc (65 mm$\phi\times$77 mm in height, single-ended coaxial), which is hermetically encapsulated in a high vacuum-tight Al canister (manufactured by Eurisys Measures). The first stage circuit of a charge sensitive amplifier is mounted on the canister and contains an FET, a pair of feed-back resistor and capacitor, an HV coupling condenser. The components on the circuit board is cooled down to reduce thermal noise. The FET has a temperature of 130-160 K optimizing the performance. The readout signal of the preamplifier is followed by two shaping amplifiers, one for low energy part ranging 0.1-4.0 MeV, another for full energy part ranging 0.1-12 MeV, the shaping time constant is 2 $\mu$ sec. This is much shorter than usual signal processing for Ge detector, but this short time constant in the filter effectively cuts the microphonic noise induced by the mechanical vibration of the cryocooler.

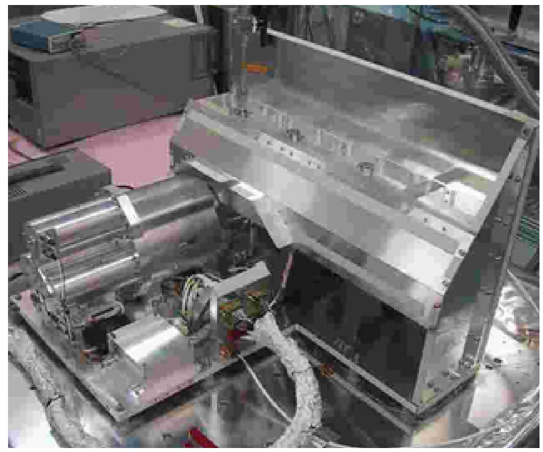

Figure 1: The flight model of the detector subsystem, GRD, of SELENE GRS in a laboratory test.

The Ge canister set is secured within a vacuum cryostat. The vacuum cryostat closely fits the canister because a horseshoe-shaped BGO detector surrounding the Ge detector should be compact in terms of weight resource and anti-coincidence shield, resulting in disadvantage for the cryostat design. The BGO shield opens to lunar direction, while a 5 mm plastic scintillator covers the lunar side of the Ge detector so that lunar gamma ray easily enter to the Ge detector but energetic ion should be rejected. The BGO shield facing the spacecraft is thicker to reduce background from the spacecraft. The scintillator shield are equipped with three photomultipling tubes (PMTs), one for the plastic scintillator, two for the BGO scintillators. The output signal of the PMTs are followed by pre-amplifiers and processed in GPE box for anti-coincidence logic to reject background event.

**Cryosystem Configuration:** To secure the Ge detector in operational temperature, the GRS has a cryosystem on GRD subsystem. The cryosystem consists of three components: the Stirling cryocooler, the Ge detector's cryostat and the thermal radiator. The Ge canister is secured within the vacuum cryostat and connected to the cold-tip of the cryocooler through a thermal link, then the heat generated in the cryocooler is evacuated into space through the radiator.

The Stirling cryocooler consists of a cold-tip and a compressor, driven with 17 V at 52 Hz. Both the components are mounted on the thermal radiator as the heat flow can be evacuated easily. The cooling capacity is 2.0 W at 80 K with an input power of 53 W. The cryocooler has two features: dual opposed pistons compressor and free displacer in the cold head. These features reduce greatly mechanical vibration from the compressor, by which the energy resolution of the Ge detector can be degraded seriously; the self-induced vibration is less than 0.01 N-sec/peak. The same model of the cryocooler has been successfully operating over 33,000 hours in a laboratory life-time test.

The cryosystem has been designed from viewpoints of the background rejection in radiation measurement, the structure stiffness in launching vibration and the reduction of the compressor-induced vibration.

**Performance:** Now the flight model of SELENE GRS has been built and checked on the performance. The flight model of GRD subsystem has been qualified in vibration tests applying equivalents of the launching vibration, which is 10 $G_{rms}$ equivalent to one during launching. For the cryocooling performance, eventually, the canister has a heat load of 1.8 W in total and the cooling capacity of the cryocooler is sufficient to maintain the Ge canister in the operational temperature, $\sim$80 K when the ambient is room temperature. For the energy resolution, the Ge detector is cooled down to 80 K spending less than 24 hours. Fig. 2 shows an energy spectrum of various radioactive gamma-ray source measured by the flight model of SELENE GRS in the integration test of SELENE system. The measurement shows the energy resolution of 3.0 keV fwhm @ 1.33 MeV, as expected, that is sufficient to identify 2.223 MeV photons from hydrogen via neutron capture between 2.210 MeV photons from Al and 2.235 MeV photons from Si via neutron inelastic scattering, which are abundant on the lunar surface.

In summary, the GRS, which employed a Ge detector and will be on board SELENE lunar explorer, has been developed. That will observe lunar gamma ray for one year or more to obtain spectral information, covering 0.1-12 MeV, on chemical abundance on the entire lunar surface. To cool the Ge detector down to the opearting temperature 80 K, we adopted a Stirling cryocooler and succeeded to suppress the mechanical noise effectively. Now, the flight model of SELENE GRS was built and achieved an energy resolution of $\sim$3 keV @ 1.33 MeV in the GRS system. After several environment tests, the GRS will go for launch to the Moon.

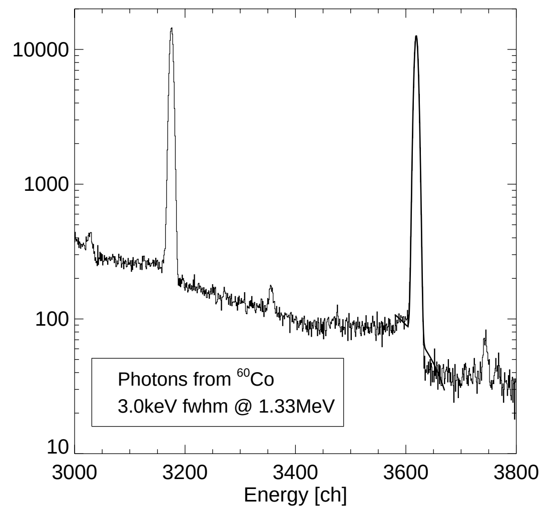


Figure 2: The energy spectrum of photons emitted from $^{60}$Co radioactive source measured with the flight model of SELENE GRS.

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**References:** [1] N. Hasebe et al., Adv. Space Res. 23 (1999) 1837–1840. [2] M. N. Kobayashi et al., Adv. Space Res. 30 (2002) 1927–1931. [3] B. J. Teegarden et al., ApJ Lett. 236 (1980) L67–L70. [4] H. Seifert et al., A&A Suppl. 120 (1996) C653+. [5] W. V. Boynton et al., JGR 97 (1992) 7681–7698. [6] W. Boynton et al., AGU Spring Meeting Abst. (2002) A7+.