Gamma-ray spectrometer onboard Chang’E-2

T. Ma, a,b,⁎ J. Chang, a,b, N. Zhang, a,b, W. Jian, a,b, M.S. Cai, a,b, Y.Z. Gong, a,b, H.S. Tang, a,b, R.J. Zhang, a,b, N.S. Wang, a,b, M. Yu, a,b, J.P. Mao, a,b, Y.M. Hu, a,b, A.A. Xu, c, M.H. Zhu

a Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China
b Key Laboratory of dark matter and space astronomy, Chinese Academy of Sciences, Nanjing 210008, China
c MACAU University of Science and Technology, Avenida Wai Long, Taipa, Macau, China

⁎ Corresponding author at: Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China. Tel.: +86 025 83332168.
E-mail address: matao@pmo.ac.cn (T. Ma).

Contents lists available at SciVerse ScienceDirect
Nuclear Instruments and Methods in Physics Research A
journal homepage: www.elsevier.com/locate/nima


A R T I C L E I N F O
Article history:
Received 26 April 2013
Received in revised form 28 May 2013
Accepted 28 May 2013
Available online 2 June 2013

Keywords:
Lunar
Gamma-ray spectrometer
Remote sensing
GEANT4
Chang’E-2

A B S T R A C T
Chang’E-2 gamma-ray spectrometer (GRS) is included in the payload of Chinese second lunar mission Chang’E-2 that has been launched in October 2010. Specific objectives of the GRS are to map abundance of O, Si, Fe, Ti, U, Th, K, and, perhaps, Mg, Al, and Ca, to depth of about 20 cm. The energy resolution and detection efficiency were improved compared with Chang’E-1 GRS. We will describe the design of GRS, which used LaBr3 for its main detector, and present its performance in this paper. Moreover, the initial result of Chang’E-2 GRS is reported.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Gamma-ray spectroscopy (GRS) is a powerful technique for remotely measuring the abundance of chemical elements on planetary surfaces. That has been proven by many missions such as Apollo 15,16 [1], Lunar Prospector [2], Mars Odyssey [3] for the Mars, Selene [4] and Chang’E-1 mission. GRS was also one of the payloads of Chang’E-2 mission.

The Chang’E-2 satellite was launched in October 2010 and circled in a lunar polar orbit at the altitude of 100 km and in operation for almost eight months before leaving the Moon to the Sun–Earth L2 Lagrange point.

The main detector of Chang’E-2 GRS is redesigned with obvious improvement while the scientific objective is the same as Chang’E-1 GRS [5]. The mission goal is to give the major elements’ distribution, such as U, Th, K, Fe, Ti, Si, O, Al, Mg, and Ca.

As a new material, LaBr3(Ce) has been proven to be a more powerful scintillator than prior scintillators. Its energy resolution is close to the level of a semi-conductor detector. And the technique is easy to implement relatively to high purity Ge detector because of its temperature requirement. The self counting rates due to the radioactivity of LaBr3 detector can be reduced by subtracting the gamma ray spectrum obtained in a low background chamber and computationally removed [6]. The GRS onboard Chang’E-2 adopts a 4 in. LaBr3(Ce) as main detector and the energy resolution is 3.6% at 662 keV that is obtained in the lab. Fig. 1 is the structure of Chang’E-2 GRS.

2. Instrument overview

The GRS has a geometry area with a diameter of 10.8 cm. It is body-mounted to the spacecraft and relies on a passive thermal design. Anticoincidence crystal is made of CsI, of which the anticoincidence efficiency to low energy photons is about 30%.

The GRS consists of two parts, gamma-ray detector (GRD) and electronics control box (ECB). There are also two cabling harnesses connected with them. The GRD includes all the scintillation detectors and photomultiplier tubes (PMT). The high voltage electronics box and preamplifiers are also installed on the GRD. The data processing unit executing all instrument software is included in the ECB, which provides the digital interface, power supply and control. The characteristics of the instrument are shown in Table 1.

The energy resolution of GRS has been tested and the result is as good as expected. The 137Cs source was used and the resolution is about 3.6%. The detector efficiency is also tested. Figs. 2 and 3 show the corresponding results.

3. Instrument design and operation

The design is based on Chang’E-1 GRS and the structural design is retained. A different material of the main detector, LaBr3(Ce) is used to improve the sensitivity of the instrument. Detailed design
is the same as ChangE-1 GRS and the operation of the GRS is very simple during the mission. The first job of the GRS is to collect cruise spectrum after the instrument is powered on and the count rate of the spectrum is recorded.

When the spacecraft was close to the Moon, the count rate incremented significantly and this signal was used to discriminate background spectrum with the gamma spectrum from the lunar surface. Fig. 4 shows the process, and the gain was reduced by 4% from level 4 to level 3.

We calibrated the instrument for one month to testify the performance and get characteristics of the GRS. For the next 7 months the instrument continually worked to collect data. The energy resolution of the peak at the energy of 1460 keV was resolved and recorded every day. Fig. 5 shows the energy resolution of the GRS during the working time. The instrument was powered off on May 20th, 2011. Meanwhile the spacecraft left the Moon for the Sun–Earth L2 Lagrange point.

4. First result

The gamma ray spectrum was accumulated every 3 s in all working times. The energy interval of the energy spectrum is about 20 keV, and 512 channels are recorded. Before measuring the gamma spectrum from lunar surface, the cruise spectrum was well measured. Fig. 6 shows the cruise spectrum. Fig. 7 is the total gamma spectrum from the Moon showing the energy of the peak relating to the elements on the lunar surface. Fig. 8 is the map of count rate in the energy interval from 0.55 MeV to 2.75 MeV and the corresponding radioactivity elements.

Fig. 1. The structure of the ChangE-2 gamma-ray spectrometer (GRS).

Table 1. Characteristics of ChangE-2 GRS.

<table>
<thead>
<tr>
<th>Component</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime detector</td>
<td>LaBr₃ scintillator, 10.8 x 7.8 cm</td>
</tr>
<tr>
<td>Shield detector</td>
<td>CsI(Tl) scintillator cup, 17.8 x 10.8 cm</td>
</tr>
<tr>
<td>Energy range</td>
<td>0.3 to 10 MeV, 512-channel spectra for prime detector, 256-channel spectra for shield detector</td>
</tr>
<tr>
<td>LaBr₃, energy resolution</td>
<td>3.6% fwhm@662 keV</td>
</tr>
<tr>
<td>CsI (shield) energy resolution</td>
<td>12% fwhm@662 keV</td>
</tr>
<tr>
<td>Anticoincidence background rejection</td>
<td>&gt; 97% above 5 MeV</td>
</tr>
<tr>
<td>Counting rate</td>
<td>10 kHz nominal</td>
</tr>
<tr>
<td>Maximum power dissipation</td>
<td>8.7 W</td>
</tr>
<tr>
<td>Mass</td>
<td>31 kg</td>
</tr>
<tr>
<td>Integration times</td>
<td>1, 2, and 3 s adjustable</td>
</tr>
</tbody>
</table>
5. Conclusions

A good energy resolution gamma ray detector (GRD) with a large effective area is presented, which was able to work for a long-duration mission and provide sufficient sensitivity and resolution to map the material of lunar surface. The calibration results show a good performance during the mission. The data analysis is going on. We present the result by the energy band analysis technique. The spectrum response-function analysis should be used to analyse the data in the future and some new results will be achieved soon.

Acknowledgements

The authors thank all GRS team members for their outstanding performance in developing this instrument. This work was supported by NSFC (Nos. 11103089 and 11203090).

References