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Performance of the gamma-ray camera based on GSO(Ce) scintillator array and PSPMT with the ASIC readout system

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Abstract

We have studied the performance of a readout system with ASIC chips for a gamma-ray camera based on a 64-channel multi-anode PSPMT (Hamamatsu flat-panel H8500) coupled to a GSO(Ce) scintillator array. The GSO array consists of 8×8 pixels of $6 \times 6 \times 13\,mm^3$ with the same pixel pitch as the anode of the H8500. This camera is intended to serve as an absorber of an electron tracking Compton gamma-ray camera that measures gamma rays up to ~1 MeV. Because we need a readout system with low power consumption for a balloon-borne experiment, we adopted a 32-channel ASIC chip, IDEAS VA32_HDR11, which has one of the widest dynamic range among commercial chips. However, in the case of using a GSO(Ce) crystal and the H8500, the dynamic range of VA32_HDR11 is narrow, and therefore the H8500 has to be operated with a low gain of about 10^5. If the H8500 is operated with a low gain, the camera has a narrow incident-energy dynamic range from 100 to 700 keV, and a bad energy resolution of 13.0% (FWHM) at 662 keV. We have therefore developed an attenuator board in order to operate the H8500 with the typical gain of 10^6, which can measure up to ~1 MeV gamma ray. The board makes the variation of the anode gain uniform and widens the dynamic range of the H8500. The system using the new attenuator board has a good uniformity of min:max~1:1.6, an incident-energy dynamic range from 30 to 900 keV, a position resolution of less than 6 mm, and a typical energy resolution of 10.6% (FWHM) at 662 keV with a low power consumption of about 1.7 W/64ch.

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Keywords: Gamma-ray camera; Scintillator; PSPMT; ASIC

1. Introduction

We have been developing a balloon-borne electron-tracking Compton camera for sub-MeV to MeV gamma-ray astronomy [1]. The camera needs a scintillation camera to serve as an absorber for Compton-scattered gamma rays, which has good energy and position resolution, a wide dynamic range, and a large area. This is because their resolution, the range, and the detection efficiency of Compton-scattered gamma rays contribute to the angular resolution, the range, and the efficiency of the Compton camera. For these requirements, we use a scintillation camera that consists of a position-sensitive photomultiplier (PSPMT) and a pixelated scintillator array (PSA). We adopt the Hamamatsu 64-channel multi-anode PSPMT H8500 [2] and a GSO(Ce) (Gd_2SiO_5:Ce) crystal array that fits to the anode pitch of the H8500 [3]. The H8500 was recently developed for applications in nuclear physics and medicine: for example, a Cherenkov detector, PET, and SPECT [4–8]. It has the advantage of a much smaller dead space and a larger effective area (89% of the package size) than previous multi-anode PMTs. GSO(Ce) has advantages of greater radiation hardness than most of the known scintillators, and easy processability as it is nonhydroscopic.

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In addition, a readout system with low power consumption ($\leqslant$2 W/64ch) for our scintillation camera is required because we need 108 scintillation cameras corresponding to 6912 channels, and the power is limited in the sky for the balloon experiment. In order to satisfy this requirement, we chose for the readout system of the scintillation camera the ASIC chips, VA32_HDR11 produced by IDEAS, with 147 mW/64ch and a dynamic range of ~ -35 pC, which has the widest range among commercial chips. However, in the case of using a GSO(Ce) crystal, we have to operate the H8500 with a low gain of about 10^5, because with a typical gain of about 10^6 it measures at most 100 keV gamma rays. We have therefore developed an attenuator board in order to operate the H8500 with the typical gain, which can measure up to ~1 MeV gamma rays.

In this paper, we report on the performances of the readout system of the scintillation camera with commercial ASIC chips and the attenuator board developed by us.

2. Scintillation camera

The H8500 has a compact size of $52 \times 52 \times 28\,mm^3$ with 12-stage metal channel anodes. The active photocathode area is $49 \times 49\,mm^2$ with a matrix of 8×8 anodes. Each anode pixel size is $5.8 \times 5.8\,mm^2$, and the pitch between the centers of the anodes is 6.08 mm. The typical anode gain is about 10^6 under a high voltage (HV) of -1000 V, and the typical anode gain uniformity (ratio of the maximum to a minimum gain) is about 3.0.

The GSO(Ce) PSA consists of 8×8 pixels of $6 \times 6 \times 13\,mm^3$ with the same pixel pitch as the anode of H8500. Each of the 64 pixels is optically isolated by a Vikuti 3M ESR, which is a multilayer polymer mirror with a thickness of 65 μm and a reflectance of 98%. The PSA is glued to the H8500 with OKEN-6262A optical grease. Fig. 1 shows a picture of our scintillation camera.

3. Readout system

3.1. CP80168 system

Fig. 2 shows the individual anode readout system, a Clear Pulse Co. Ltd. CP80168. It is designed for a two-dimensional array of the H8500, and has a size of $52 \times 52 \times 95\,mm^3$. The CP80168 is based on two types of analog ASIC: one is a 32-channel VA32_HDR11, manufactured by IDEAS, which has a power consumption of 147 mW/64ch and contains pre-amplifiers with an input dynamic range of about 20 to -35 pC, shapers with a gain of 58 mV/pC and a peaking time of 0.7 μs, sample and hold circuits and a multiplexer. The other is a 32-channel TA32CG2, manufactured by IDEAS, which has a power consumption of 60 mW/64ch, contains fast shapers with a peaking time of 75 ns and discriminators, which produce the trigger signals. CP80168 consists of two VA32_HDR11 chips and two TA32CG2 chips. The multiplexed 64-channel data are digitized by a flash ADC in CP80168 and sent to a VME sequence module via FPGAs. It takes 80 μs to read 64 channels. The CP80168 and the VME sequence module have power consumptions of 1.3 W/64ch and 1.5 W/256ch, respectively. The sum of these power consumptions is about 1.7 W/64ch, half of which is loss in the voltage regulator of the CP80168.

3.2. Attenuator board

When using a GSO(Ce) crystal and the H8500, the dynamic range of VA32_HDR11 is narrow, and therefore the H8500 has to be operated with a low gain of about 10^5. Our previous paper [9] reported that if the H8500 is operated with a low gain, the incident-energy dynamic range is narrow and the energy resolution is bad, compared to the operation of the H8500 with the typical gain. Actually, using the GSO(Ce) and the H8500 with a low gain, we measured a range of from ~120 to 800 keV and an energy resolution of 12.5% (FWHM) at 662 keV. In order to resolve their problems, we developed an attenuator board. The concept of the attenuator board is to obtain a scintillation camera with a good energy resolution, and thus signals with a gain of about 10^6 in the H8500 are obtained. Because of the narrow dynamic range of the VA32_HDR11, the obtained signals from the H8500 are

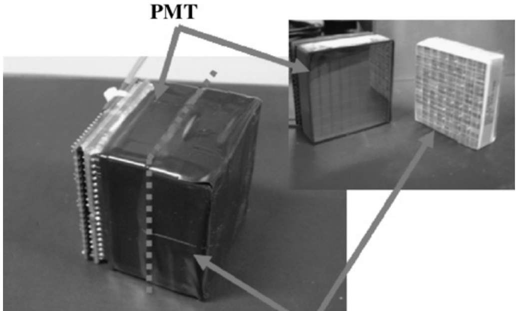

Fig. 1. The GSO(Ce) PSA with the H8500.

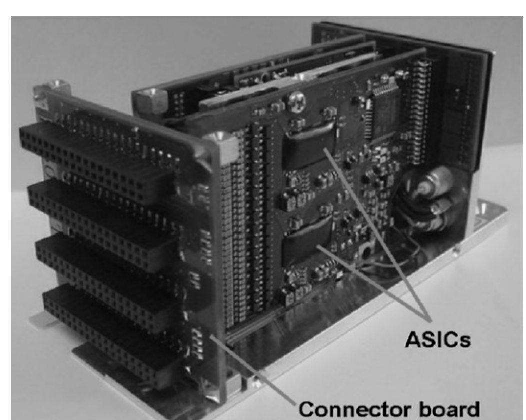

Fig. 2. The CP80168. It consists of a board containing two VA32_HDR11 chips and two TA32CG2 chips, and a connector board that connects ASIC chips to the H8500. The connector board is replaceable.