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Development of wide area detector for the 2012 model of the ^{6}Li time analyzer neutron detector system

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Summary. — A 2012 model ^{6}Li time analyzer neutron detector (LiTA12) system has been developed as a high-count-rate neutron detector. An exclusive function with a center-of-gravity calculation, which not only prevents over-counting due to cross-talk, but also obtains a fine position resolution, has been included. As a high-count-rate detector, this device can detect neutrons with a 3 mm position resolution in a detection area of $5 \times 5\,\text{cm}^2$ and is arranged as a 16×16 matrix with a detection efficiency of approximately 40% of that of a ^{3}He detector. A maximum count rate of 50 million counts per second (Mcps) is obtained. Using the exclusive function, the center-of-gravity pixel size obtained is 0.4 mm, although the actual pixel size is 3 mm. Furthermore, this function also enables a wide area detector in an area of $10 \times 10\,\text{cm}^2$ using four multi-anode (8×8 matrix) photomultiplier tubes. In this case, the pixel size is 0.8 mm, although the actual pixel size is 6 mm.

1. – Introduction

Neutron scattering experiments are indispensable for the structural analysis of condensed matter and in the development of advanced materials. Therefore, large-scale experimental facilities where these experiments can be performed are being constructed globally. However, the efficiency of existing neutron detectors is sub-optimal owing to the difficulties involved in direct neutron detection. A ^{3}He gas detector, which is the most frequently used apparatus, is also the best neutron detector available. However, it has a low count rate and low position resolution. A neutron scintillator detector is one of the solutions for overcoming these drawbacks.

A data acquisition (DAQ) group at the Neutron Science Laboratory (KENS) in the High-Energy Accelerator Research Organization (KEK) developed a ^{6}Li time analyzer (LiTA) system [1] as a high-count-rate and high-efficiency detector, which is still used in a small number of experimental spectrometers. However, the LiTA system is large and unstable. Therefore, a 2012 model LiTA (LiTA12) system [2, 3] has been developed. It

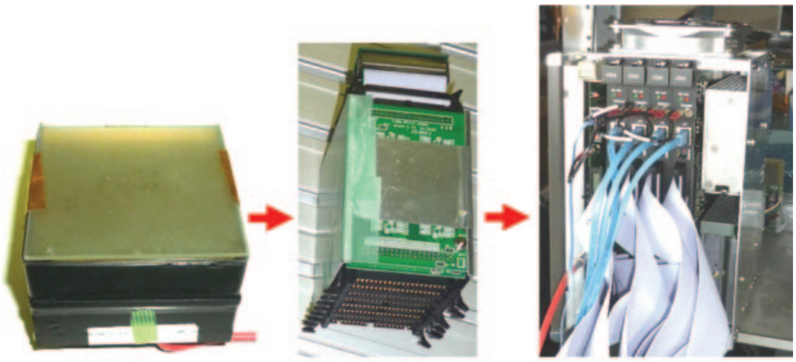

Fig. 1. – LiTA12 system.

includes a center-of-gravity calculation that not only prevents cross-talk between pixels, but also obtains fine position resolution. Although the real pixel size is 3 mm, the obtained center-of-gravity pixel size is 0.4 mm. This report outlines the usage of a wide area detector in $10 \times 10\,\mathrm{cm}^2$ using four multi-anode (8×8 matrix) photomultiplier tubes.

2. – LiTA12 system

2·1. *Basic design specifications.* – The LiTA12 system has a high-count-rate function and an exclusive function with a center-of-gravity calculation. The high-count-rate function is usually used in high-intensity neutron environments. The exclusive function prevents multi-counting of cross-talk and allows the system to use a no-cut scintillator without changing readout circuit. Furthermore, the wide area detector is fabricated from changing photomultiplier tubes.

The LiTA12 system consists of a LiTA detector, an amplifier, and four LiTA12 Versa Module Europa (VME) modules. Figure 1 shows the main components of the LiTA12 system with a no-cut scintillator detector for the exclusive function.

The LiTA detector uses a multi-anode-type photo-multiplier tube (MA-PMT, Hamamatsu Photonics K.K.: H9500 series), which has a $49 \times 49\,\mathrm{mm}^2$ detection area, arranged as a 16×16 matrix of a two-dimensional (2D) detector with a 3.04 mm pitch. For the high-count-rate function, 256 pixelated ^{6}Li glass scintillators, $2.1 \times 2.1 \times 1\,\mathrm{mm}^3$ in size, corresponding to each anode, are used. With respect to the exclusive function, a no-cut scintillator with dimensions of $5 \times 5\,\mathrm{cm}^2$ is used, which is installed on the MA-PMT, as shown on the LiTA detector in fig. 1. The H9500 tube can be replaced with four MA-PMTs (H8500 series, 8×8 matrix) for a wide detection area of $10 \times 10\,\mathrm{cm}^2$. The amplifier consists of eight 32-channel boards, and amplifies the signals of the 256-pixel data.

The LiTA12-VME module has 64 analog-to-digital converters (ADCs), and each module can convert 64 pixels to digital data. Therefore, 256-pixel data is converted by four LiTA12-VME modules.

2·2. *Exclusive function with center-of-gravity calculation.* – The exclusive function with the center-of-gravity calculation (Anger camera) has been integrated by changing the field-programmable gate array (FPGA) program without changing the hardware. Because it is difficult to perform the center-of-gravity calculation in the FPGA, it is calculated by the control-personal computer (PC) in event mode.

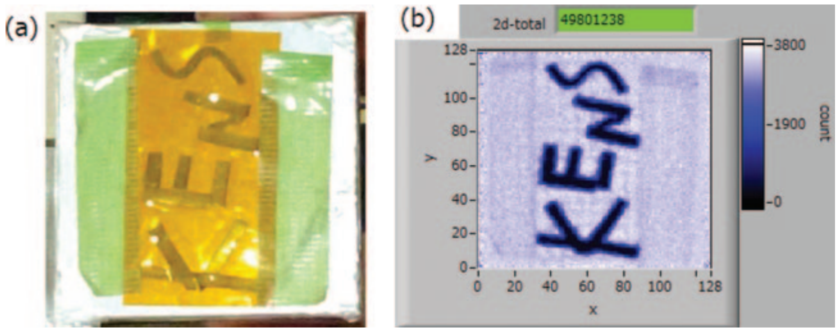

Fig. 2. – (a) Cd “KENS” characters and (b) 2D graph of 128 × 128 pixels compensated by the data without the Cd characters.

All neutrons are obtained by comparing a cluster of adjacent pixels. For each comparison period, the signal strength of all the pixels is compared to that of the adjacent pixels. When the signal strength of all the pixels is greater than that of the adjacent pixels, the cluster is regarded as neutron data, and the data from the largest pixel and the eight adjacent pixels are sent to the PC as event data.

In order to compare every pixel to its adjacent pixels, the pixel data must be allocated according to the actual 2D pixel arrangement of the MA-PMT. Because the detector requires four VME modules, the modules must be connected to each other by extended cables for collecting the adjacent pixels.

3. – Experimental data

The exclusive function with the center-of-gravity calculation was tested at the Hokkaido University Neutron Source (HUNS) in Hokkaido University. The data were obtained using a direct neutron beam at 6.1 m position from the target of the No.3 port. The pulse neutron cycle was 50 Hz, and the collection time was 100 s. The integration TOF time of the 2D graphs is 1–20 ms (0.5 meV–0.19 eV).

3˙1. *H9500*. – Figure 2 shows the data of the function. Figure 2(a) shows a “KENS” characters of Cd on the front of the ^{6}Li glass scintillator detector with dimensions of $50 \times 50 \times 1.0\,\mathrm{mm}^3$ and (b) shows a 2D graph of 128 × 128 pixels resulting from the center-of-gravity calculation that is compensated by the data without the Cd character. As shown, the characters are clearly visible. Shadows of the two pieces of tape, which contain hydrogen, are seen. In addition, because a maximum count rate of approximately 5 million counts per second (Mcps) was obtained, the count rate achieved using the exclusive function with the center-of-gravity calculation is suitably high.

3˙2. *H8500* × *4*. – Figure 3 shows a sample of the wide area detector of $10 \times 10\,\mathrm{cm}^2$ with four H8500 MA-PMTs. Figure 3(a) shows the four MA-PMTs; (b) shows a “f K KENS” characters of Cd on the front of a ZnS/^{6}Li scintillator detector with dimensions of $100 \times 100 \times 0.41\,\mathrm{mm}^3$; (c) shows a 2D graph of 128 × 128 pixels resulting from the center-of-gravity calculation (0.8 mm pixel size) in which the characters are easy to read, but there is a significant amount of noise on the joint portions; (d) shows a 2D graph of 128 × 128 pixels that is compensated by the data without the Cd characters in which the characters are clearly visible. The small “KENS” characters on the bottom left are the same in fig. 2, owing to the use of the wide area detector.

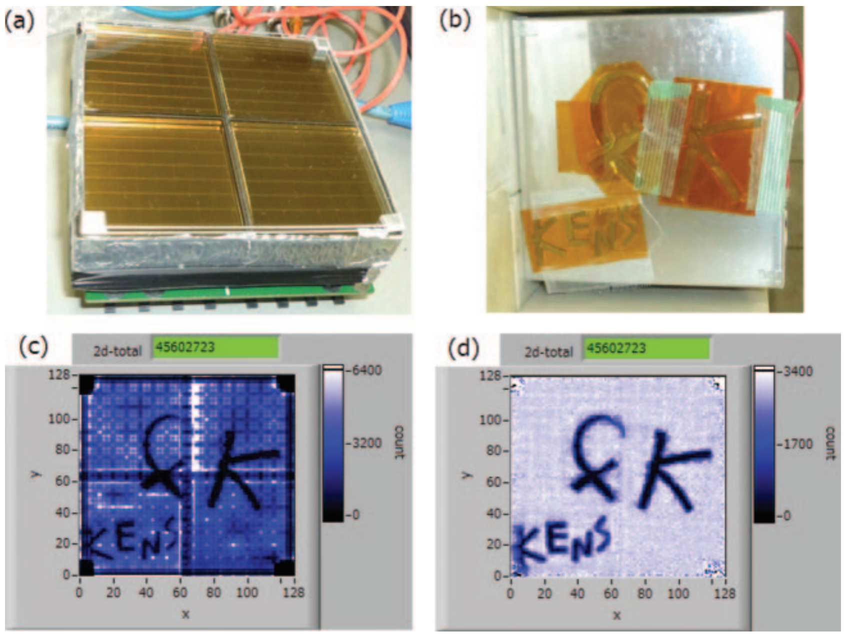

Fig. 3. – (a)4 H8500 MA-PMTs, (b) Cd "f K KENS" characters, (c) 2D graph of 128×128 pixels, (d) corresponding 2D graph of 128×128 pixels compensated by the data without the Cd characters.

In case of the H9500, it used the ^{6}Li glass scintillator, and was tendency to be influenced by gamma rays. In case of the H8500 $\times$ 4, they used the ZnS/^{6}Li scintillator, and did not sense gamma rays. The common noise was eliminated by the compensation of the data without the Cd characters.

4. – Conclusion

In this study, a new wide area detector in an area of $10 \times 10\,\text{cm}^2$ was developed for a LiTA12 system, which achieves fine position resolution compared to the actual position resolution. Although the real pixel size is 6 mm, the obtained pixel size is 0.8 mm. This new detector is useful for high position-resolution experiments involving a high-intensity neutron source, such as those performed at J-PARC.

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