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Development of a New Exclusive Function with a Center-of-Gravity Calculation for the 2012 Model ^{6}Li Time Analyzer Neutron Detector System

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Abstract. 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 fine position resolution, has been included in this version. This device can detect neutrons with a 3 mm position resolution in a detection area of 49 × 49 mm^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) was obtained. In addition, the center-of-gravity pixel size obtained is 0.4 mm, although the actual pixel size is 3 mm.

1. Introduction

Neutron scattering experiments are indispensable for the structural analysis of various 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) has developed various other types of detector systems. This group was established to develop DAQ electronics and software for experimental spectrometers used at the Materials and Life Science Experimental Facility (MLF) in the Japan Proton Accelerator Research Complex (J-PARC). For instance, this group developed the neutron encode-module with network (NEUNET) system [1] for ^{3}He gas detectors, which is the de-facto standard in J-PARC/MLF. This system is used in more than half of the experimental spectrometers at this facility and can control thousands of ^{3}He gas detectors.

The same group also developed a ^{6}Li time analyzer (LiTA) system [2] 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 [3, 4] has been developed. This report outlines the improvements to this system, and presents a newly added exclusive

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function with 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.

2. LiTA12 system

2.1. Basic design specifications

The LiTA12 system has a high-count-rate function and an exclusive function. The high-count-rate function is usually used in high-intensity neutron environments in the histogram mode. The exclusive function prevents multi-counting of cross-talk, allowing use as a no-cut scintillator, and generates event data to calculate the center-of-gravity.

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 the multi-anode-type photo-multiplier tube (MA-PMT, Hamamatsu Photonics K.K.: H9500 series), which has a 49 × 49 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 × 2.1 × 1 mm^3 in size, corresponding to each anode, are used. With respect to the exclusive function, a no-cut scintillator of dimensions 50 × 50 mm^2 is used, which is installed on the MA-PMT, as shown in Figure 1. The amplifier consists of eight 32-channel boards, and it amplifies the signals of the 256-pixel data.

The LiTA12-VME has four LiTA12-ADC boards with 16 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.

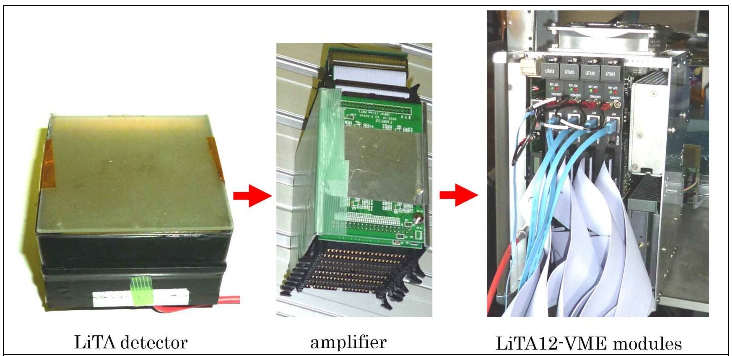

Figure 1. Block diagram of the LiTA12 system with a no-cut scintillator detector for the exclusive function.

2.2. High-count-rate function

The high-count-rate function is used in high-intensity neutron environments. It is easy to acquire a high count rate with simple composition for every pixel, provided that there is no cross-talk between pixels. Figure 2 shows a block diagram of the high-count-rate function process.

Each ADC board controls large high-speed storage in the histogram mode, and is capable of accumulating complete histogram data for every pixel. In order to access the large storage at high speed, the board has two static RAMs that can be accessed independently. Because first-in, first-out (FIFO) memories are equipped with several data flow joints, the data are accumulated without loss.

The histogram mode creates two types of histograms: a time-analyzing histogram, and a pulse-height-analyzing histogram. The time-analyzing histogram has 16,384 channels for each pixel in the memory IC, and the time resolution of the histogram can be set from 40 ns to 1.3 ms with a step of 20 ns. The pulse-height-analyzing histogram has 512 channels for each pixel in the internal memory of the field-

programmable gate array (FPGA) on the board. The VME module controls the Gbit-SiTCP in order to read data from the ADC boards and write it to an external PC at any time [5].
In this function, neutrons with 3 mm position resolution can be detected in a detection area of 49 × 49 mm^2, and it is arranged as a 16 × 16 matrix with an efficiency of approximately 40% of that of a ^{3}He detector; a maximum count rate of up to 50 million counts per second (Mcps) was obtained.

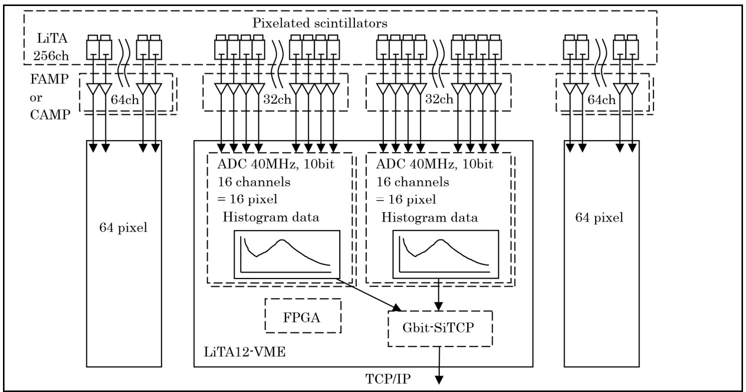

Figure 2. Block diagram of the high-count-rate function.

2.3. Exclusive functions
The exclusive function with the center-of-gravity calculation has been integrated by changing the 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-PC in event mode.
All neutrons are obtained by comparing a cluster of adjacent pixels. For each comparison period, the signal strength of all pixels is compared to that of the adjacent pixels. When the signal strength of all pixel is greater than those of all adjacent pixels, the cluster is regarded as the neutron data, and the data from the largest pixel and the eight adjacent pixels are sent to the PC as event data. Figure 3 illustrates a principle of the exclusive function.
In order to compare every pixel to the adjacent pixels, the pixel data must be allocated to the actual 2D pixel arrangement of the MA-PMT. Because the detector requires four VME modules, they must be connected to each other by extended cables. Therefore, the VME module collects pixel data from the four ADC boards and the two neighboring VME modules contain pixels adjacent to the edge pixels of this module.

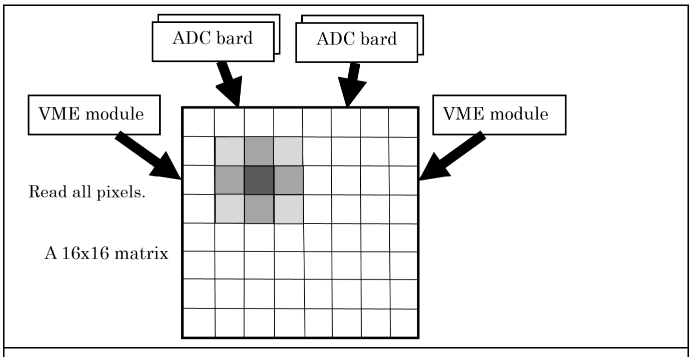

Figure 3. Principle of the exclusive function.

2.4. Event mode
The high-count-rate and exclusive functions generate event data in the event mode without a change of hardware. The event data, which are basically 64 bits, allow off-line analyses. The high-count-rate

function and the exclusive function without the center-of-gravity calculation consist of a header (8 bits), a time-of-flight (TOF) (24 bits), a pixel number (14 bits), a pulse height (10 bits), and reserved bits (8 bits). The exclusive function with the center-of-gravity calculation consists of two headers (16 bits), a TOF (24 bits), a pixel number (6 bits), nine pulse height data (81 bits), and a reserved bit (1 bit), which is sent as two event data.

3. Experimental data

3.1. Exclusive functions with the center-of-gravity calculation

The exclusive function with the center-of-gravity calculation was tested at BL16 at MLF in J-PARC. Figure 4 shows the data of the function. Figure 4(a) is a "KENS" character of Cd on the front of the ^{6}Li glass scintillator detector with dimensions of 50 × 50 ×1.0 mm^3; (b) is a 2D graph as a 16 × 16 pixel (real data size, 3 mm), and it is difficult to read the characters; (c) is a 2D graph as a 128 × 128 pixel with the center-of-gravity calculation (eight times position-resolution, 0.4 mm), and the characters are easy to read, but there is a significant amount of noise; (d) is a 2D graph as a 128 × 128 pixel with the center-of-gravity calculation that is compensated by the data without the Cd character, and the characters are visible with high accuracy. Shadows of two tapes that include hydrogen are seen. In addition, because a maximum count rate of up to approximately 3 Mcps was obtained, the count rate achieved by the exclusive function with the center-of-gravity is suitably high.

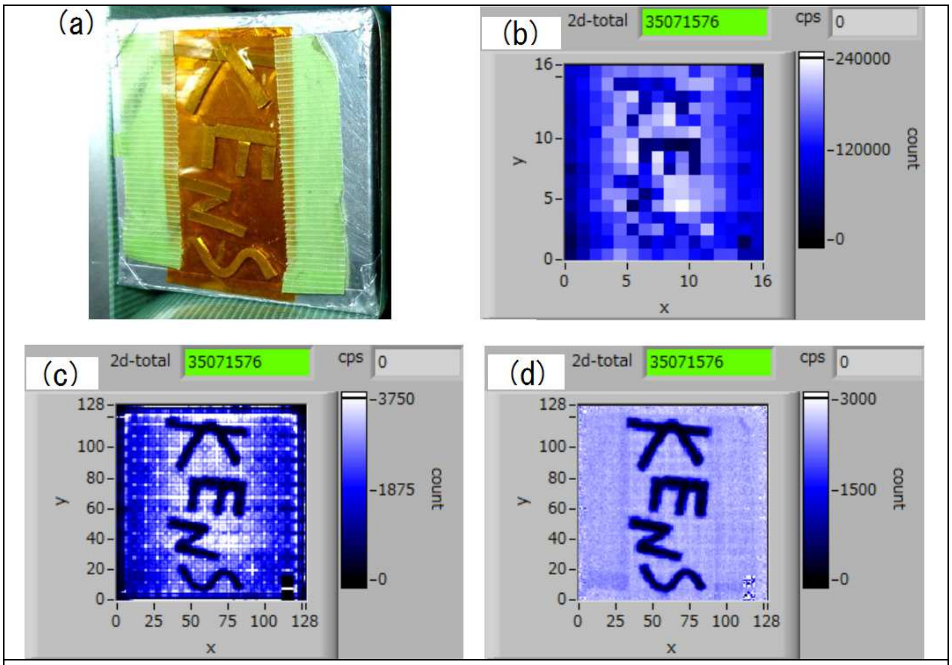

Figure 4. (a) Cd "KENS" character, (b) 2D graphs as a 16 × 16 pixel, (c) those as a 128 × 128 pixel, (d) those as a 128 × 128 pixel compensated by the data without the Cd character.

4. Conclusion

In this study, a new exclusive function was developed with a center-of-gravity calculation for the LiTA12 system, which obtains fine position resolution compared to the actual position resolution. Although the real pixel size is 3 mm, the obtained center-of-gravity pixel size is 0.4 mm. This new function is useful for high position-resolution experiments involving a high-intensity neutron source, such as those performed at J-PARC.

5. Acknowledgments
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6. References
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