Development of pixel detector for ultra-cold neutrons

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A CCD-based pixel detector for ultra-cold neutrons has been developed. The detector consists of a back-thinned CCD (S7170-0909, Hamamatsu Photonics K. K.) with a thin neutron converter directly deposited onto the sensor surface. The active area is 12.3 x 12.3 mmˆ2 (512 x 512 pixels of 24 x 24 microns). Two nuclear reactions, 10B(n,alpha)7Li and 6Li(n,alpha)3H, are considered for converter design, where strongly ionizing particles are emitted via those reaction. The thicknesses for the boron based and lithium based converters are both decided to be 200 nm in consideration of conversion efficiency and production easiness. They are sandwiched between titanium layers of 20 nm thickness to prevent oxidizing and crumbling. We used the Neutron Mirror Fabrication System at the KURRI to make the detectors with the converter. Here we report about detection efficiency, uniformity and spatial resolution which were measured using cold neutron beams supplied at the MINE2 line.

The ionizing particle converted from the neutron makes a cluster of charged up pixels distributing around an incident point. Charge sum corresponds to the particle's kinematic energy and an weighted center of the pixels is a good estimation of the point. Distribution of the charge sum has two edges that correspond to the initial energies of the emitted particles (monochromatic), and has tails to the low energy region that represent an energy loss when the particle transmits through the converter and a thin insensitive volume on the CCD. To separate signal events from a background or thermal noise, we apply a cut to the charge sum distribution. The threshold corresponds to 0.15 MeV energy deposit. The detector was set on the sample stage which continuously move right and left in horizontal to be irradiated uniformly. Detector efficiency was measured to 1.7%(0.3%) with Boron(Lithium) based converter by comparing with the 3He reference detector. Uniformity was evaluated to less than 3% over the sensitive area. Spatial resolution was estimated by analyzing edges of shadow of the Gadolinium neutron mask, which is located in front of the detector surface. Fig.1 shows a neutron distribution taken with the Boron converter. By fitting with error functions for each edges, the spatial resolution was estimated to 3 microns.

In conclusion, we measured basic performances of the CCD-based pixel detector using the cold neutron beams. The results show that the detector has a fine spatial resolution and enough uniformity. Detector with Boron based converter shows better performance than that with Lithium based converter.

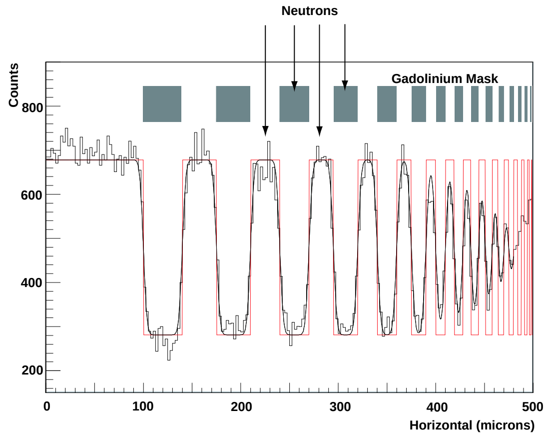

Fig. 1. Neutron distribution. Red line shows an ideal shadow of the Gadolinium mask. Black line shows the fitted distribution. Spatial resolution of 3 microns is measured.