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Development of 2 Segmented Position-Sensitive Detector for X-ray Imaging Crystal Spectrometer

Jongkyu Cheon[a], Myungkook Moon[a*], Changhee Lee[a], Younghyun Choi[a], Harkrho Kim[a], Sanggon Lee[b], Jungyo Bak[b] and Ukwon Nam[c]
[a]*Korea Atomic Energy Research Institute, 150 Duckjindong, Yusung, Daejeon 305-353, moonmk@kaeri.re.kr*
[b]*National Fusion Research Center, 52 Yeoeundong, Yusung, Daejeon 305-333*
[c]*Korea Astronomy & Space Science Institute, 61-1 Whaamdong, Yusung, Daejeon 305-348*

1. Introduction

The high resolution X-ray Imaging Crystal Spectrometer (XICS) provides important profile measurements of the ion and electron temperatures, toroidal rotation velocity, impurity charge-state distribution, and ionization equilibrium for tokamak plasmas [1]. The XICS consists of two key components such as a spherically bent crystal and a large area position-sensitive detector. The principle and initial experimental results from the XICS and imaging characteristics of the spherically bent crystal are well described in the previous references [2-4]. Basic requirements of the detector for the XICS are a reasonable position resolution less than 0.4 mm, a photon count rate capability higher than 2 kcps/cm^2 over all detector area, and a time-stamped event storage.

Many advanced detector types such as a charge coupled device (CCD) and micro channel plate (MCP) have an excellent spatial resolution and high count rate capability. However, the CCD and MCP have a limitation of the detector size and time-stamped event storage. The conventional multi-wire proportional counter (MWPC) satisfies well for above-mentioned requirements except the high count rate capability. Since the maximum photon count rate of the MWPC is limited to 500 kcps due to the signal processing and data acquisition unit, it can be improved with a segmented structure in a single detector body. Each segmented structure has its own electronics and data acquisition unit so that it can provide multiple performances with the segmented quantity.

Recently, we have developed a two-segmented detector in order to increase the photon count rate capability by a factor 2. In this paper, the fabrication detail and preliminary test results of the two-segmented detector are discussed.

2. Detector Construction

2.1 Detector chamber

The effective area of the detector for XICS is designed to 10 cm in the horizontal direction and 30 cm in the vertical one. Since the ion temperature is derived from the spectral information in the horizontal direction, its resolution is more important than the vertical one. A thin beryllium foil should be used as an entrance window of the detector because the energy ranges of the incident X-ray is close to 3 keV. A transmission factor of the 3 keV X-ray energy into the 0.1 mm thick beryllium window is about 75%. Since the front part of the detector window is directly attached to the high vacuum chamber in the XICS, many rib-shaped aluminum supporting structures as shown in Fig. 1 are prepared to prevent destruction of the beryllium window due to the pressure difference. The thickness of each rib is 2mm and the space between each rib is 10 mm. The beryllium window is mounted on the rib structured and it is attached with high vacuum grade glue. Figure 1 shows the front view of the fabricated detector with the supporting rib structure.

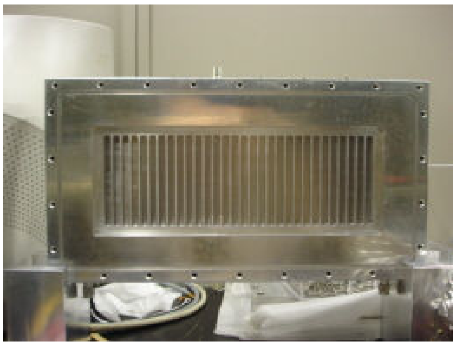

Figure 1. Front view of the detector.

2.2 Wire frames

The inside printed circuit board (PCB) of the detector consists of an anode wire frame and specially designed cathode frame. The anode frame is made of 150 gold plated tungsten wires, which are 10 μm in diameter. The anode wires are stretched with the equal tension and soldered on the PCB. The spacing between each wire is 2 mm. All wires are connected together to the same high voltage. The cathode frame is made of copper strips and pads structure [5]. The position information is derived from the cathode. We adopted a delay line readout method to get the position information. Each strip and pads are connected to a tap of lumped delay line with a 56pF capacitor and 145nH inductor so that each tap has 2.85 ns delay time.

The cathode frame is divided by two equal parts. Each part covers 10 cm by 15 cm and has its own electronics. We used a lab-made preamplifier, 715 timing discriminator from Phillips Scientific, and Time to Digital Convert from AI Solutions [6].

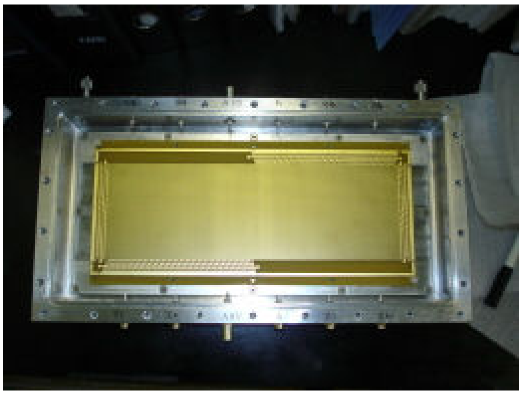

Figure 2. Inside view of the detector.

3. Experimental Results

3.1 Counting Uniformity

The detector is filled with 20 % of C_2H_6, 2 % of CF_4 and 78 % of Xenon. The gas pressure is 1 atmosphere. To test the detector performance, a ^{55}Fe X-ray source was used. Figure 3 shows the photon counts as a function of the applied anode voltage during 10 sec by illuminating the whole detector with the ^{55}Fe X-ray source. The photon counting plateau is clearly shown in each segmented-detector. The measured uniformity results from the detector 1 (Ch 1) and detector 2 (Ch 2) are shown in Figures 4 and 5, respectively. In this case, the anode voltage was set as 2250 V.

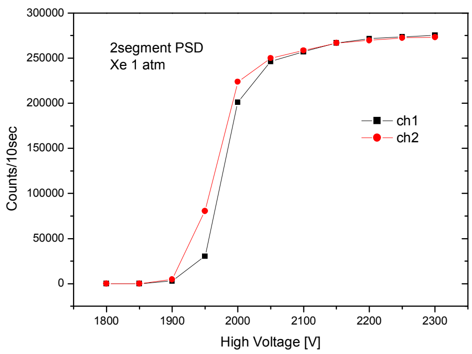

Figure 3. Counting plateau.

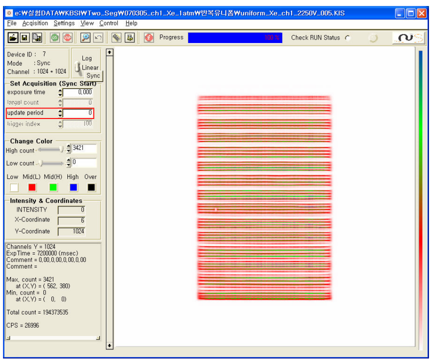

Figure 4. Counting uniformity of the detector 1.

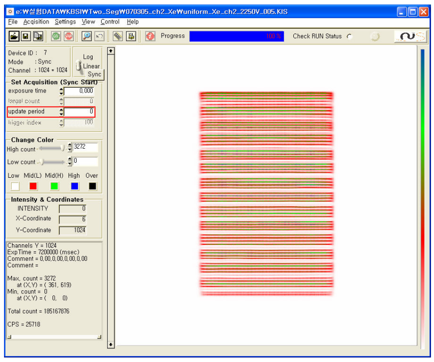

Figure 5. Counting uniformity of the detector 2.

3.2 Position Resolution

To test the position resolution, the ^{55}Fe X-ray source was placed on a narrow 50 μm wide slit, and measured the full width at half maximum (FWHM). The measured FWHM as a function of the anode voltage is shown in Fig. 6. The FWHM is decreased as the high voltage is increased and approached to about 0.4 mm, which value is the upper limit for the required spatial resolution.

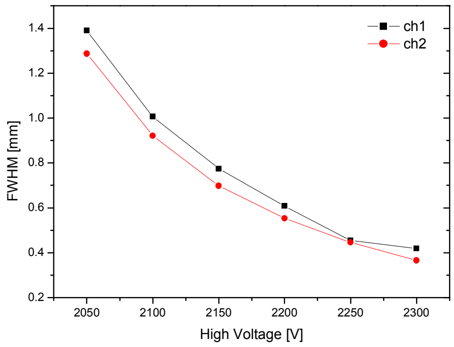

Figure 6. Position resolution of the detector.

4. Conclusion

Two segmented detector for XICS was successfully fabricated and the initial performance results are promising. The photon count rate capability is increased by a factor of 2 due to the segment concept. This improved detector will be installed in operating tokamaks in this year and the experimental results will be published elsewhere for future reference.

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