

MULTI-SEGMENT POSITION-SENSITIVE DETECTOR FOR X-RAY IMAGING CRYSTAL SPECTROMETER

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Abstract

The position sensitive detector is fabricated for the application at Advanced X-Ray Imaging Crystal Spectrometer (XICS) at KSTAR tokamak, South Korea. The detector is aimed at high count rate operation and is based on two-dimensional multi-wire proportional counter using delay line position readout method. The present design is modified especially for the operation of detector at higher count rate capability. The sensitive area for scanning X-ray scattering spectra is 30 cm x 10 cm and the detector operation with single segment results in limiting count rate of 5×10^5 cps. Use of multi segmented displays and use of four individual readout systems for each segment is established. It has been demonstrated that use of multi-segmented display improves the photon count-rate capability of the XICS by 4 fold. The overall system of XICS with detector for Plasma fusion diagnostics at KSTAR tokamak is tested and the first calibration results are presented.

1. Introduction

XICS is selected as a basic diagnostic set of the KSTAR and will be operated from day-one plasmas. The KSTAR x-ray crystal spectrometers are designed based on a new type of high resolution imaging x-ray crystal spectrometer, and the imaging x-ray crystal spectrometer plays an important role for the diagnostics of the KSTAR tokamak [1 2]. This imaging spectrometer employs a spherically bent crystal and a large area two-dimensional position-sensitive Detector (2-D PSD) and provides simultaneous spectra from many number of lines of sight through the plasma. Therefore, it is possible to obtain radial profiles and gradients of the plasma parameters.

Use of gas filled 2-D PSD provides the advantage of large sensitive area, good position resolution, good counting efficiency and radiation hardness. A prototype 10 cm x 30 cm sensitive area 2-D PSD with delay-line readout and supporting electronics was fabricated and

calibration measurements were carried out in a laboratory. The limiting factor for use of this PSD was count rate, thus an improvement in delay line readout process allotting smaller segments of sensitive area were handled. The 2D detector was installed on the Alcator C-Mod tokamak in order to verify the detector performance. In this article, the performance test results of the 2-D PSD with single and 4-segmented readout display are presented.

2. Development and performance tests of 2D PSD

PSDs are developed with the gradual improvement in count rate capability with the modification in hardware and readout electronics with 1 segment, 2-segment and 4-segment display. The 2D PSD is made of aluminum and the window for the detector is a 0.1 mm thick Be foil with dimensions of 10 cm x 30 cm. The Be window side of PSD is directly mounted onto the vacuum tube of the spectrometer. The detector gas pressure is 1 bar, thus pressure difference of 1 bar is faced by the Be window, thus 29 supporting Al ribs, 2 mm in width and 5 mm in thickness, are used. Figure 1 shows the fabricated 2-D PSD with 4-segmented display. Individual 4 sets of X and Y readouts electronics are provided. The count rate capability of the sensitive area depends on the area accessed by the set of readout electronics. Use of 4 sets of electronics gadgets and increased number of corresponding electrical connectors makes the mechanical and electrical design quite complicated. Use of fine gold plated Limo connectors and thinner RG 59 cables and are skillfully arranged at the side and back plane of PSD. Anode used is wire array of 10 μm Au plated W wires, assembled with an automated winding machine, developed in-house. Cathode pad structures and soldering of 4 sets of X and Y arrays of delay components over the single PCB plate is artistically organized. Other fabrication details and parameters are mentioned in table 1

Table 1

| Details | | 2-D PSD with delay line readout method with | | |
|-----------------------|--------|------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|
| | | single display | 2 segmented display | 4 segmented display |
| Fill gas | | Xe 78%, C ₂ H ₆ 20%, CF ₄ 2% | Xe 78%, C ₂ H ₆ 20%, CF ₄ 2% | Kr 78%, C ₂ H ₆ 20%, CF ₄ 2% |
| Window transmission | | 100 μm 95% at 5.9 keV | 100 μm 95% at 5.9 keV | 200 μm 91.6% at 5.9 keV |
| Delay time | X grid | 235 ns | 218 ns | 220 ns |
| | Y grid | 220 ns | 168 ns each | 158 ns each |
| Cathode | X grid | 1.5 mm pad pitch | 1.25 mm wire pitch | 1 mm wire pitch |
| | Y grid | 6 mm pad pitch | 2.5 mm pad pitch | 2 mm pad pitch |
| Spatial resolution mm | | 0.6 mm in x-dir | 0.4 mm in x-dir | 0.3mm in x-dir |

3. Test setup and test results for 2-D PSD

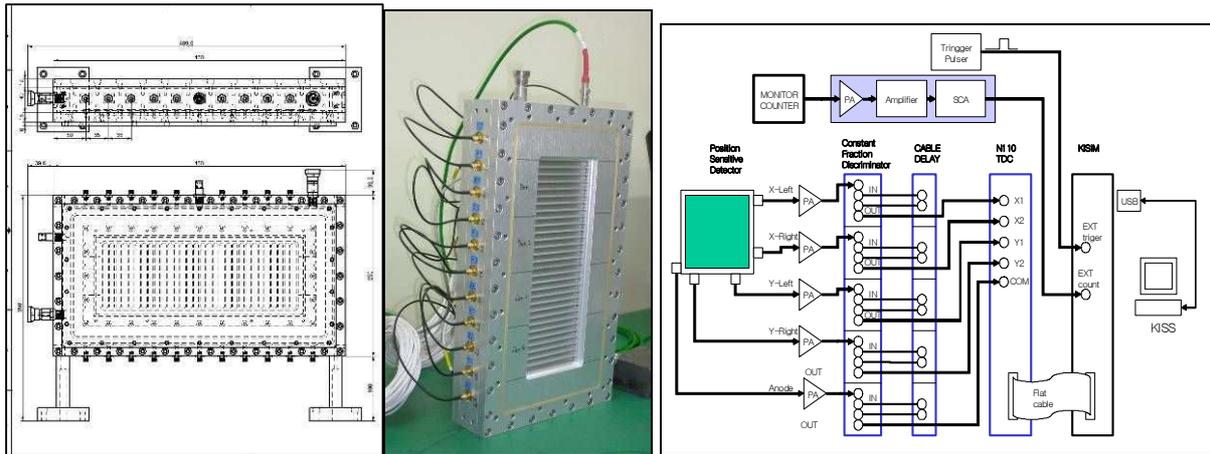


Fig 1. Four segmented PSD schematic and assembled, connected to readout setup

Fig 2. Delay time readout method electronics set used for each segment of the PS.

All the 3 geometries of PSD are assembled with great care with crucial factors such as accuracy of wire spacing, tension, cleanliness, high vacuum window adhesion and precision of X Y grid alignment and are further tested with laboratory as well as various plasma test facilities. Fig 1 shows the schematic assembly drawing of a 4 segmented PSD and with testing in progress. Fig 2 shows the flow chart of delay time readout setup used for each segmented display. High activity ^{55}Fe source is used with variable distance to verify the count rate limits of single and double display PSD. As shown in fig 3 the count rate capability with double display is improved to 1.5×10^6 cps for anode pulses. Fig 4 shows the X ray pattern at TEXTOR. Initial count rate test for PSD was performed at XICS with a 2 segmented display. The maximum photon count rate of the detector with the associated read out electronics is about 4×10^5 counts/s. After the Initial calibrations, 2D PSD was installed at Alcator C-Mod Tokamak to verify its performance.

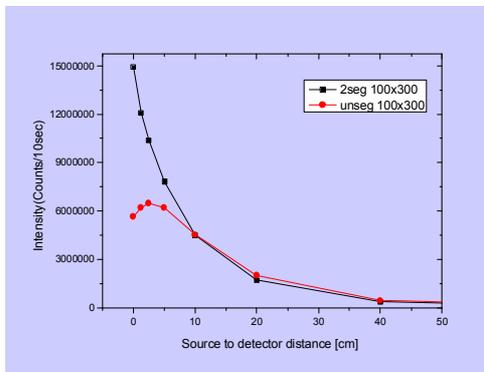


Fig 3. count rate capability behaviour of 1 and 2 segmented PSD with Fe source

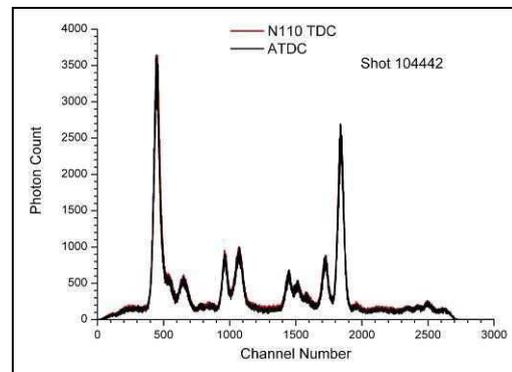


Fig 4. Photon count pattern at Textor with single display PSD

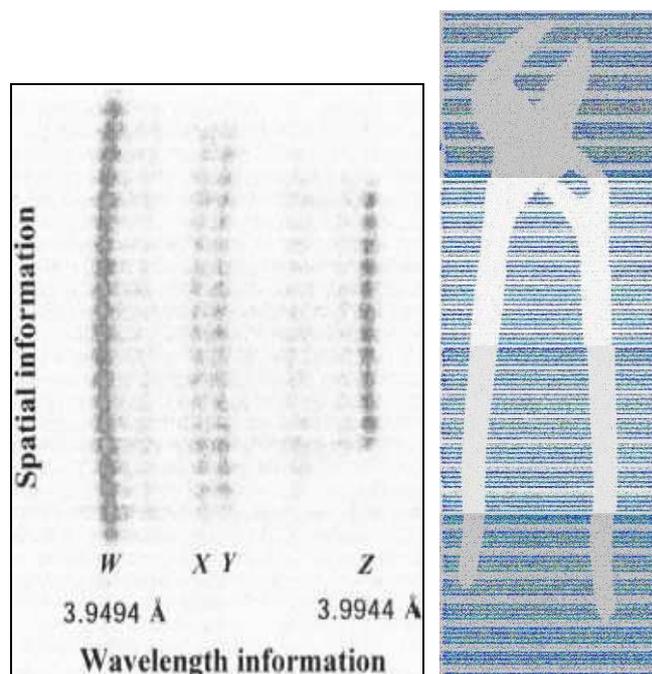


Fig 5 A spatially resolved image of He like Ar lines



Fig 6 Image of wrench with 4 segmented detector.

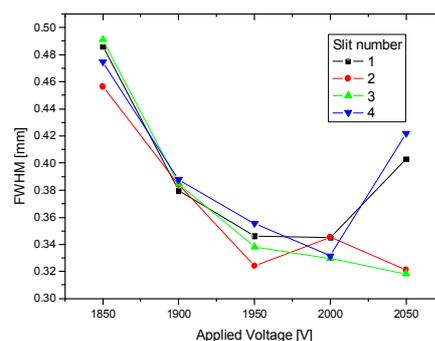


Fig 7 Variation of FWHM of 4 seg PSD with HV

Figure 5 shows a spatially resolved spectrum of Ar XVII on the detector under optimum conditions. The spectrum consists of the helium-like lines w , x , y , and z of Ar XVII and the associated $n=2$ and $n=3$ satellites. The possible optimization of the spectrometer includes reducing the effective area of the crystal or using several smaller segmented detectors. Which is successfully achieved using multiple electronics display systems. Fig 6 and 7 show the characteristics of 4 segmented PSD as a image of wrench and variation of resolution with HV.

Conclusion

1, 2 and 4 segmented detectors with improved count rate limits are successfully developed. Each segment shows uniform operational characteristics and performance. Maximum count rate achieved for the 4 segmented detector is $> 2\text{MHz}$. Dead space between each 2 consecutive segments is 3.2 mm. Future proposal of 8-segmented PSD higher count rate capability will be constructed until end of this year.

References

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