Temporally and Spatially Resolved Profile Measurements of Tokamak Plasmas from X-ray Imaging Crystal Spectrometer

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1. Introduction

The X-ray imaging crystal spectrometer for the KSTAR tokamak will be used to provide temporally and spatially resolved spectra of helium-like argon (or krypton) from a large cross section of the plasma[1,2]. The spectral data from the spectrometer both within and perpendicular to the horizontal midplane of KSTAR are used for profile measurements of the ion and electron temperatures, the rotation velocity, and the ionization equilibrium. The spectrometer consists of a spherically-bent quartz crystal and large area two-dimensional (2D) position-sensitive multi-wire proportional counter.

A proto-type of the imaging crystal spectrometer was fabricated and installed on NSTX tokamak at PPPL, Alcator C-MOD tokamak at MIT and TEXTOR tokamak at IPP in order to verify a proof-of-principle concept of the imaging spectrometer and advanced profile measurements of tokamak plasmas[3]. In addition, performance tests of the 2D detector, further improvement of the detector, and effective data analysis procedures for the spectrometer were carried out simultaneously.

2. Experiments

In this section, installation results from NSTX tokamak at PPPL, Alcator C-MOD tokamak at MIT and TEXTOR tokamak at IPP are shown. A proof-of-principle concept of the X-ray imaging crystal spectrometer was verified on Alcator C-MOD tokamak and initial profile measurement was successfully carried out from the other two tokamaks.

2.1 Tokamak Experiments

The experimental layout of the proto-type of the X-ray imaging crystal spectrometer installed on Alcator C-MOD tokamak at MIT, NSTX tokamak at PPPL, and TEXTOR tokamak at IPP are shown in Figs. 1-3, respectively. The spectrometer is equipped with a spherically-bent quartz crystal and 2D multi-wire proportional counter.

Figure 4 shows a typical example of helium-like argon x-ray photon count rate of the detector vs. plasma discharge time during ICRH conditioning. The radiation starting at 1.2 sec was extremely intense so that the photon count rate was saturated because the maximum photon count rate of the detector with the associated electronics is about 400,000 counts/sec. Therefore, the spectrometer needs to be optimized during ICRH or other severe experimental conditions. The possible optimization of the spectrometer includes reducing the effective area of the crystal or using several smaller segmented-detectors. We reduced the crystal effective area until the system throughput was below the photon count rate limit.

Figure 5 shows a spatially resolved spectrum of ArXVII on the detector under the optimum conditions. The wavelength is shown on the x-axis and the spatial information is given on the y-axis. The spectrum consists of the helium-like lines **w**, **x**, **y**, and **z** of ArXVII and the associated $n = 2$ and $n = 3$ satellites. The shadows in the horizontal direction are caused by the 2 mm wide supporting ribs on the beryllium entrance window of the detector. The separation between adjacent ribs is about 1 cm.

Figure 1. Experimental layout of the proto-type of the X-ray imaging crystal spectrometer installed on Alcator C-MOD tokamak at MIT.

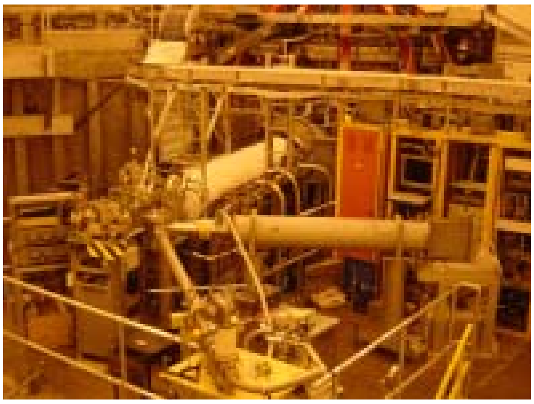

Figure 2. Experimental layout on NSTX tokamak.

Figure 3. Experimental layout on TEXTOR tokamak.

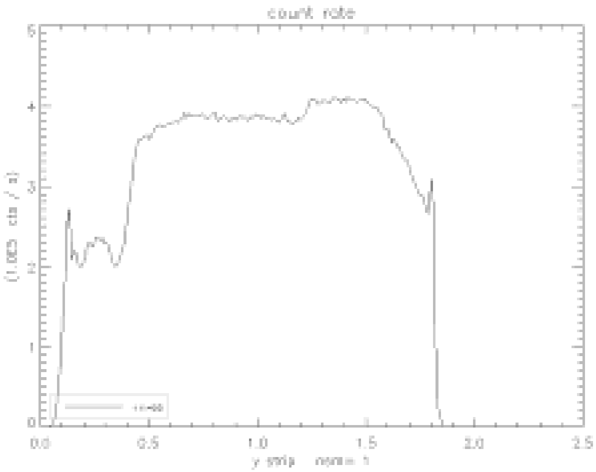

Figure 4. The helium-like argon x-ray photon count rate of the detector vs. plasma discharge time.

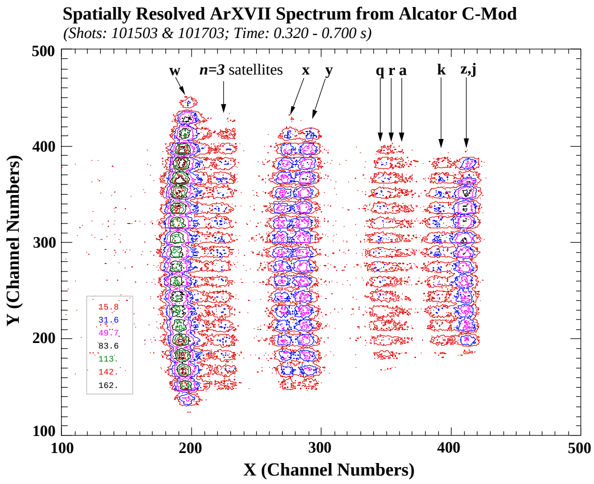

Figure 5. A spatially resolved spectrum of ArXVII.

2.2 Temporally and Spatially Resolved Profile Measurements

Figure 6 shows temporally and spatially resolved ion and electron temperature profiles from Alcator C-MOD tokamak time intervals from 400 to 500 ms and 500 to 600 ms. These experimental results confirm that the profile measurements from the imaging crystal spectrometer are satisfactory.

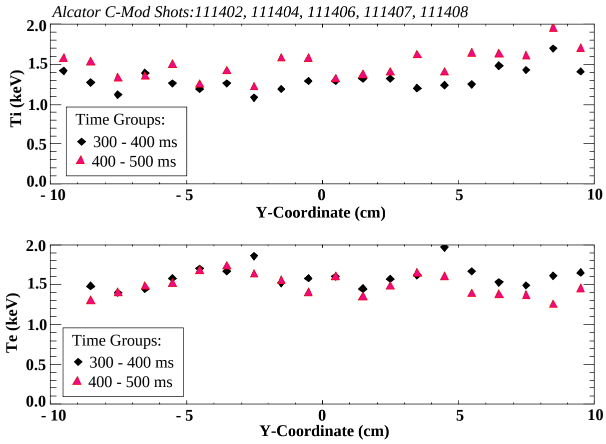

Figure 6. Temporally and spatially resolved profile measurement results.

3. Conclusion

A proto-type of the imaging crystal spectrometer was fabricated and installed on NSTX tokamak at PPPL, Alcator C-MOD tokamak at MIT and TEXTOR tokamak at IPP. Initial proof-of-principle concept of the imaging spectrometer was verified on Alcator C-MOD tokamak at MIT. Although not shown in the main text, similar experimental results were also observed the other two tokamaks so that the X-ray imaging crystal spectrometer is reliable fusion tokamak diagnostic and it can contribute for many advanced tokamak plasma measurements for future large tokamaks include KSTAR and ITER. Upgrade activities of the X-ray imaging crystal spectrometer have performed by modifying the two-dimensional detector, and further improvement of the detector is still necessary. Effective data analysis program for the X-ray imaging crystal spectrometer have prepared and the results from the program were already shown in Figs. 4 - 6.

REFERENCES

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