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Study on tangentially viewed 2D-SXR imaging system in the QUEST tokamak

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論　文　内　容　の　要　旨
Thesis Summary

This thesis reports investigations of soft x-ray (SXR) emission from the Q-shu University experiments with Steady State Spherical Tokamak (QUEST) plasma using a developed 2D-SXR imaging system. The system is a routine diagnostic on the QUEST. The purpose is to develop a fast and high spatial resolved SXR imaging system that can be applied to widely different plasma parameters in the various operational scenarios. Since the intensity of SXR emission is related to plasma density, temperature and impurity contents, the system in so-called imaging mode is used for monitoring of fast changing plasma events, although the obtained images are the line-integration of SXR emissivity at only center of QUEST chamber due to limited field of view (FOV). By extrapolating the core signal to the edge, a tomography reconstruction method—Abel inversion is expected to be performed to obtain the emission profile with high accuracy.

In addition, owing to the fast time response of soft x-ray detector—microchannel plate assembly and high framing rate of fast camera (up to 100 kHz), the system can be used as soft x-ray photon counting device, which can provide the SXR energy spectra and electron temperature measurement at the sacrifice of time resolution. It is called the photon counting mode. The mode can be applied in only plasma being kept constant during 1~2 seconds of sampling time. The photon counting mode was used in the steady state operation with non-inductive current drive.

The thesis is organized as follows:

Chapter 1 is the introduction to SXR emission and SXR diagnostics on tokamak devices. One type of regular SXR diagnostics is one-dimensional (1D) scintillator-based arrays or diode-based arrays. With a wide coverage of the target plasma, it can be used for tomographic reconstruction of two-dimensional (2D) soft x-ray emissivity. Another type is direct 2D imaging of SXR emissivity, including SXR camera or image intensifiers.

Chapter 2 is the introduction to the QUEST device and the 2D-SXR system. QUEST is a medium sized spherical tokamak with all metal plasma facing wall (PFW) and a temperature controllable "hot wall". It is capable of generating long-duration discharges. One of the main goals of QUEST operation is to demonstrate the ability to steady state operation. The schematic of 2D-SXR imaging system, including key components of metallic filters, pinholes, MCP assembly and high-speed camera are introduced in chapter 2. A mathematic gain model of the image intensifier is proposed based on the characteristics of microchannel plate (MCP) and phosphor. The model is consistent with bench test result of voltage scan on MCP and phosphor.

In chapter 3, the result of photon counting mode and SXR spectra are presented. The algorithm of processing photon counting data is introduced, including the integration of photons that occupy two or more pixels due to spreading of the finitely sized electron clouds into neighboring pixels. Because energy calibration is not available in 2D-SXR imaging system, a novel method of in-situ energy calibration using Be filter transmission is proposed. It is applied in calculating SXR spectra and electron temperature, and the error is evaluated.

In chapter 4, the result of imaging mode is presented. Spikes of SXR radiation caused by slide-away electrons is detected by 2D-SXR imaging system. The temporal waveform is consistent with other visible measurement on QUEST. With the co-application of 8.2 and 28 GHz electron cyclotron waves (ECW), ~20 Hz low-frequency plasma oscillation is observed. The imaging mode is used to study this phenomenon in detail.

In summary, the innovative research works in this thesis focus on a compatible use of the 2D SXR system such as photon counting mode and imaging mode. These techniques were applied to QUEST plasmas and I could obtain the results of electron

temperature and slow plasma oscillation. Future work would include upgrading “bare” MCP to KBr-coated MCP as well as improving the FOV of the system.