Development of the control and acquisition program for the charge exchange spectroscopy system on the KSTAR

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1. Introduction

Charge-exchange spectroscopy (CES) has been used as a diagnostic tool for measuring the concentrations of impurity ions and studying impurity behaviors in fusion plasmas since the recognition that charge-transfer reactions between neutral hydrogen and ionized impurities can be employed for measuring the concentrations of impurity nuclei [1]. Furthermore, it has been applied extensively for obtaining ion temperatures and plasma rotation [2-4].

The CES system on the Korea Superconducting Tokamak Advanced Research (KSTAR) was designed to be installed in this year and will be facilitated to measure the impurity ions densities, plasma ion temperature and rotation velocity profiles using modulated Neutral Beam Injection (NBI) [5].

A Czerny-Turner type spectrometer with variable wavelength and a thinned back-illuminated Charge Coupled Device (CCD) which has high quantum efficiency and high readout speed were utilized in the KSTAR CES system. To control KSTAR CES data acquisition system remotely and automatically, specific automation program composing KSTAR CES data acquisition (DAQ) system was developed.

2. Methods and Results

In this section, brief introduction to the present status of the KSTAR CES system are provided. In addition to the introduction, some considerations on the development of the KSTAR CES data control and acquisition program and several features of the program were presented.

2.1 Objectives and Requirement

The objectives of the KSTAR CES system are to measure the impurity ions densities, plasma ion temperature and rotation velocity profiles in the regions of core and edge during steady-state tokamak plasma operation. Several requirements to fulfill the objective are addressed as followings : (1) 10 ms time resolution, (2) 3 cm (core) and 5 mm (Edge) spatial resolution, (3) temperature range of 100 eV ~ 20 keV, (4) rotation velocity range of 4 ~ 200 km/s, and (5) accuracy of 10% .

The purpose of the KSTAR CES system for the 2010 experimental campaign is limited to the measurement of the ion temperature and toroidal rotation velocity profiles of the plasmas by mainly exploiting the 8 → 7 transition of C VI at 529 nm after charge exchange between injected neutral particles and carbon impurity ions.

2.2 NBI system

The KSTAR NBI system will be installed and operated for the first time in the 2010 experimental campaign. The NBI system will be applied for plasma heating, current drive, control of plasma pressure, and diagnostic support.

The beam species of the NBI is hydrogen and the expected beam energy and power are 80 keV and 1.0 MW, respectively for the 2010 campaign. The NBI beam is required to be modulated with a duty cycle of 5 ~ 10 Hz for the CES diagnostic support. The NBI system will be installed at the L port as shown in Fig. 1.

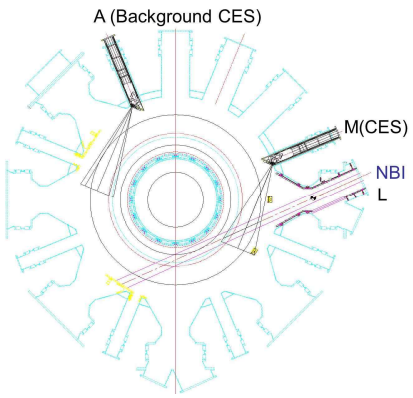

Fig. 1. The schematic diagram of the KSTAR CES and NBI system

2.3 The KSTAR CES data acquisition system

The KSTAR CES data acquisition system is composed of a window, collection optics, fibers, a spectrometer, and a CCD as shown in Fig. 2. Optics and fibers were assembled and aligned on an optics table placed in the cassette system that is required for the diagnostic system to be installed near the vacuum vessel. Two cassette systems were manufactured for the active CES and the background CES system. As shown in Fig. 1, the one is installed at M port for the active CES system viewing the plasma and beam to measure active charge exchange spectrum and the other is installed at A port for the background CES system viewing only the plasma to obtain the background spectral lines. The Czerny-Turner spectrometer with holographic gratings of 2400 g/mm and a focal length of 1.33 m was located

in the diagnostic room. 16 spatial channels composed of 8 channels across the plasma and beam and 8 channels across only the plasma were installed in the spectrometer to detect spatial lines from different spatial regions of plasmas. The Photon Max 512B CCD which has high quantum efficiency and high readout speed will be used to measure and analyze the spectral lines by being attached to the spectrometer.

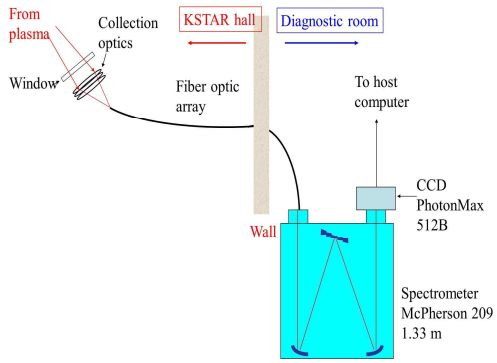

Fig. 2. KSTAR CES data acquisition system is composed of a window, collection optics, a spectrometer, and a CCD

2.4 Development of the KSTAR CES control and acquisition program

To operate the KSTAR CES data acquisition system, a DAQ system was developed to control the CES system and obtain the measured signals remotely and automatically. The DAQ system includes the automation program which controls the CES data acquisition system and transfers the data acquired from the CCD to analysis program.

The CCD used for the KSTAR is an electron-multiplying CCD with 512×512 pixels. The pixels on the chip are square and 0.016 mm on a side. The readout rate of the CCD is up to 1 MHz. The CCD can be controlled manually by its DAQ program called by WINSPEC®. However, the CES control and acquisition program was developed since it is required to trigger the CCD and start data acquisition remotely and automatically during a plasma discharge. The program reads out the initiation time of a plasma discharge and triggering time of the NBI to decide the time to control the CCD and initiate data acquisition. Especially, the program can apply the information of the NBI modulation signals for each plasma shots to distinguish the charge exchange spectrum data from background one.

The signals from the spectrometer is detected by the CCD and converted to ASCII file. This raw data file should be converted to the specific data form available for the analysis program. Also, the data group for one plasma shot should be archived and stored not to be mixed with another data group. Above all, this job should be conducted between plasma shots robustly and automatically. The CES control and acquisition program is also developed to accomplish this task successfully.

3. Conclusions

The CES system on the KSTAR was designed to be installed in this year and will be applied to measure the plasma ion temperature and rotation velocity profiles for the first time. The CES control and acquisition program composing the KSTAR CES DAQ system was developed to control the CES data acquisition system and obtain the measured signals remotely and automatically during a plasma discharge. Also, the program was developed to transfer the data acquired from the CCD to analysis program and stores the data group not to be mixed up another data group between plasma shots.

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