§42-16 Development of Neutron Spectroscopy System for Deuterium Experiment on LHD

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Deuterium plasma experiments are prepared in the Large Helical Device (LHD). In deuterium fusion plasma heated by neutral beam injection, 2.5MeV neutrons are emitted as accompanying products of DD reactions, which are mainly occurred as beam-plasma interactions. Thus, the neutron energy spectrum emitted from the deuterium plasma reflects the velocity distribution of fast ions in high temperature plasma. Toward LHD deuterium phase, two types of neutron energy spectrometer (NES), the Associated Particle Coincident Counting (APCC)-NES and the nuclear emulsion based NES, are under development to understand beam ions behavior in the plasma.

Figure 1 shows an overview of the APCC-NES system. The system is based on coincident detections of a scattered neutron and a recoil proton associated to an event of neutron elastic scattering. The incident neutron energy is simply derived from the sum of the recoil proton energy and the scattered neutron energy. Therefore the system consists of three detectors: a thin plastic scintillator worked as an incident neutron target and ΔE detector for recoiled protons (called as a radiator), a Si surface barrier detector for recoiled proton detection (RPD), and a plastic scintillator for scattered neutron detection (SND). The scattered neutron energy is measured by time-of-flight (TOF) method between the radiator and the SND.

The prototype APCC-NES system and the nuclear emulsion based NES were installed at J-port in the KSTAR in 2012. However, coincidence detection of three detectors in the APCC-NES, which was already demonstrated at an accelerator-based DD neutron source, was failed because the radiator and the scattered neutron detector did not work properly due to problems in high counting rate conditions and in noise caused by the power supply. To improve acceptable counting rate of these detectors, digital signal processing (DSP) to the APCC-NES was applied.

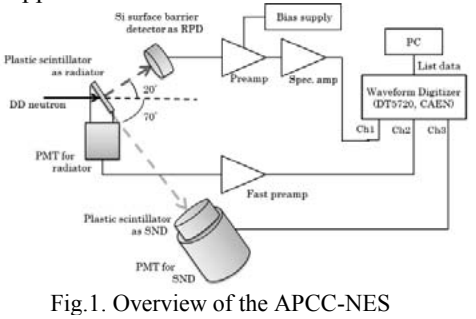

Fig.1. Overview of the APCC-NES

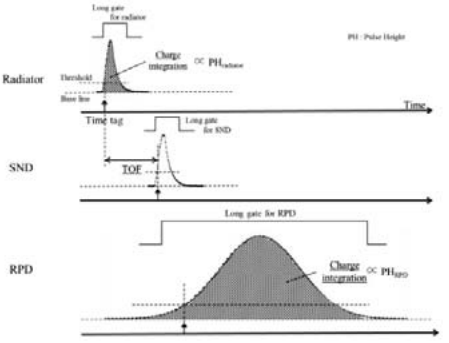

Fig. 2. Schematic diagram of on-line DSP in the digitizer for the APCC-NES

We used a waveform digitizer (DT5720, CAEN) for on-line DSP of outputs of these detectors. The digitizer allows analog to digital conversion and following on-line DSP for the charge integration. A fast preamplifier was used for photomultiplier tube (PMT) output for the radiator. For output of the RPD, a preamplifier and a spectroscopy amplifier were used. Figure 2 shows a schematic diagram of on-line DSP in the digitizer for the APCC-NES. Long gates for inputs for the detectors were optimized for the better energy resolution and time resolution. For the RPD output, the integration time of the spectroscopy amplifier was also optimized. List mode data, *i.e.* series of the timing and pulse height of each pulse was recorded in PC. After the measurement, the pulse height spectrum with/without coincidence events and the time-of-flight spectrum were obtained by off-line data analysis. The energy resolution of the RPD and the radiator, and the time resolution by the radiator and the SND were comparable with those by a conventional analog data acquisition system. On test operation of the DSP in the prototype APCC-NES system installed in the KSTAR, the digitizer worked properly at counts rate of up to 10^5 cps.

The nuclear emulsion based NES was also installed at J-port in the KSTAR. Scanning of the emulsion and analysis of experimental data is ongoing.

[List of Publications]

1) S. Hayashi, H. Tomita, *et al*, "*Application of digital signal processing to neutron energy spectrometer for deuterium experiments in LHD/KSTAR*", Proc. of PLASMA2014, Nov. 18-21, Niigata, Japan (2014), 19PB-066.

2) H. Tomita, F. Yamashita, *et al.*, "*Progress in development of neutron energy spectrometer for deuterium plasma operation in KSTAR*", Review of Scientific Instruments, **85** (2014) 11E120-1-11E120-3.

3) Y. Nakayama, H. Tomita, *et al*., "*Development of Fusion Neutron Measurement by Advanced Nuclear Emulsion Technique*", 7th Japan-Korea Seminar on Advanced Diagnostics for Steady-State Fusion Plasmas, August 17-20, 2014, Hotel Rubino Kyoto Horikawa, Kyoto, Japan.

4) F. Yamashita, H. Tomita, *et al*., "*Progress in development of neutron energy spectrometer based on coincidence counting of associated particles for deuterium plasma operation in LHD and KSTAR*", 7th Japan-Korea Seminar on Advanced Diagnostics for Steady-State Fusion Plasmas, August 17-20, 2014, Hotel Rubino Kyoto Horikawa, Kyoto, Japan