§9. Development of Pulse Analyzer System Using FPGA Module for Wave-particle Interaction Analyzer in LHD

Nagaoka, K., Shibuya, M., Osakabe, M., Kobayashi, S. (Kyoto Univ.),
Fontdecaba, M. (Ciemat),
Miyoshi, Y. (Nagoya Univ.),
Kato, Y. (Tohoku Univ.)

Energetic-ion-driven Alfven eigenmodes (AEs) may degrade the performance of magnetically confined fusion plasmas and is considered to become more serious in fusion burning plasmas. Recently, nonlinear phenomena observed in experiments have been studied theoretically and numerically. In order to validate such models, the observation of phase space structure is required in experimental study. On the other hand, wave-particle interaction analyzer (WPIA) is being developed for ERG project in magnetosphere plasma science[1]. We have developed a pulse analyzer for semi-conductor particle detectors used for energetic ion measurement in LHD based on the same concept with WPIA for ERG project.

The concept of WPIA is a phase detection between particle flux and the wave for the quantitative evaluation of energy transfer between them. We have developed a high speed pulse analyzer system for WPIA using the field programmable gate array (FPGA) module, and installed the system to the large helical device (LHD). One channel of Mirnov signal and eight channels of semi-conductor fast neutral analyzer (Si-FNA) signals are digitized with sampling rate of 50MS/s (maximum), which is significantly higher (factor of 10^4) than that of conventional pulse height analyzer technique and enable us to evaluate the phase with respect to the wave. The pulse signals produced by energetic particle attack into the Si-FNA was analyzed in the FPGA module and the time of the pulse detection, pulse height, pulse width, area of the pulse are evaluated and recorded with the raw data of a Mirnov signal in the data storage disk. The raw data of pulse signals are not recorded, and the amount of the data to storage is significantly reduced. Therefore the pulse analyzer have no limitation for the pulse length of the plasma discharges.

Figure 1 shows the data viewer for a typical sample of energetic particle measurement using the developed pulse analyzer. The raw data of Mirnov signal and the frequency spectrum are shown in the top panel and second panel, respectively. The energetic ions detected by the Si-detectors are plotted in the third panel. The co-directed (red circles) and counter-directed (blue circles) fast ions are plotted separately. The y-axis is pulse height and represents the particle energy. The maximum fast ion energy changes when the NBI#3 turns off and NBI#1 turns on (t = 2.3 sec). The slowing down of beam energy can be seen in the counter-directed fast ion signals. The active charge-exchange component caused by a probe beam (NBI#4) modulation is also visible (t = 1.3 – 2.0 sec). The energy spectra are also plotted in the right-hand side. The important progress of this system is that the time of pulse detection is recorded with time resolution of 50 MHz, which is much higher than typical Alfven eigenmode frequency. Therefore the phase relation between Alfven wave and particles can be analyzed, which will be reported in near future.

1) Y. Kato, et al., JPS Conf Proc. **1**, (2014) 015100.

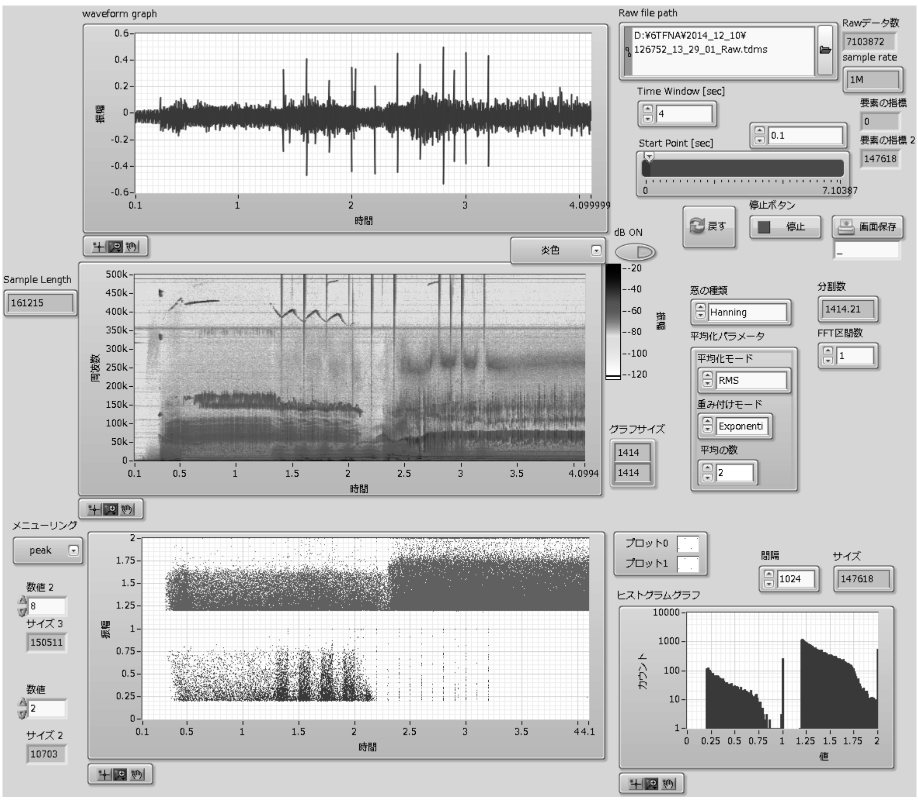

Fig. 1. Data viewer for pulse analizer for WPIA in LHD. (Top) Raw data of Mirnov signal. (Middle) Frequency spectrum of Mirnov signal. (Boottom) Pulse height as a fuction of pulse detection time. The energy spectra of fast ions are also plotted in the right-hand side. The pulse height of the co-directed particle is added by 1 in order to plot them separately from counter-directed particles.