§18. High Speed Detection of Doppler-shifted Hα Lights from Charge Exchange Interaction for Measurement of Fast Ion Distribution

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Local measurement of fast ion distributions is important to investigate the fast ion transport and wave-particle interactions with MHD modes. In particular for Alfvén eigenmodes, the fast ions having Alfvén velocity and large ion-diamagnetic drift frequency can strongly interact and cause both transports in real space and velocity space. High temporal resolution is required for a measurement of local velocity distribution of fast ion because of the microsecond time scale dynamics of Alfvén phenomena.

Beam probe spectroscopic approach[1] for identification of fast ion velocity distribution has been developed on LHD, so-called fast ion charge exchange spectroscopy(FICXS)[2,3]. A brief description of this measurement technique is that reneutralized fast ions via charge exchange recombination interaction emit Hα lights that are observed as Doppler-shifted lines corresponding to each velocity and viewing geometry. Thus, it can be proposed that a time evolution of the specific area of fast ion velocity space can be measured by Doppler shift Hα lights on the specific wavelength range by using photomultiplier tube(PMT) and high-speed digitizer. The first experiment by using this kind of measurement is performed at the NSTX tokamak[4].

On LHD, we have added a new instrument for measurement by high temporal resolution to the tangential LOS of FICXS diagnostic, so-called fast-FICXS. The optics for fast-FICXS consists of the spectrometer with *f*/2.8 and multichannel fiber for observation at desired wavelengths. The width of wavelength for the integration of the Doppler-shifted Hα spectrum is 1.5nm. It is important to evaluate which the area of the velocity space of fast ion can contribute to the spectrum in the measurement. As shown in Fig. 1, the specific wavelengths projects to the specific area of velocity space determined by LOS geometry, fast ion motion depending on magnetic field structure, neutralization rate and polarization effects. Therefore, the profile as shown in Fig.1(b) means a sensitivity on the measurement of fast ion velocity distribution for the tangential LOS. The sensitivity for $\upsilon_{//}$ component of fast ion velocity is stronger than for the $\upsilon_{\perp}$ component on the fast-FICXS measurement.

The initial experiment by using fast-FICXS diagnostic has been performed, as shown in Fig. 2. The fast ion charge exchange(FICX) signal is obtained by the integration for the wavelengths around 653nm corresponding to the energy of ~15keV(in simple LOS geometry). In this situation, high temporal resolution signal of FICX component is clearly observed when the NBI#4 as a probe beam injected. In the discharge, no clear indication of AE related signal is observed in the fast-FICXS signal because of the large background level. Further improvements to reduce the background level is necessary.

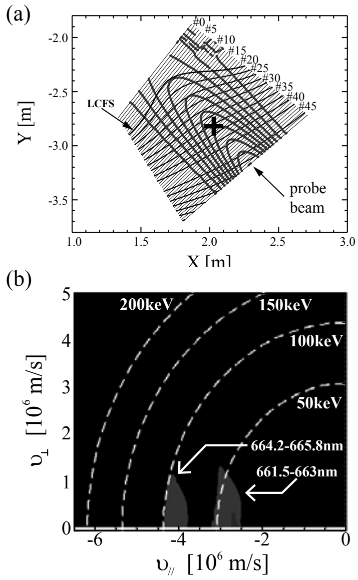

Fig. 1 (a) (a)Midplane views of a magnetic flux surfaces, an attenuation profile of probe beam and the tangential LOS. (b) Typical sensitivities on velocity space for the tangential FICXS measurement at the specific location indicated by the bold cross in Fig.1(a).

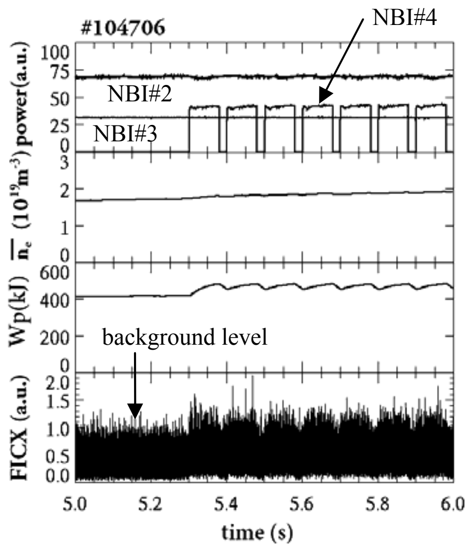

Fig. 2 Waveforms of NBI power, line-averaged electron density, stored energy and FICX signal.

[1] Heidbrink, W.W., et al.: Plasma Phys. Control. Fusion **46** (2004) 1855.
[2] Osakabe, M., et al.: Rev. Sci. Instrum. **79** (2008) 10E519.
[3] Ito, T., et al.: Rev. Sci. Instrum. **81** (2010) 10D327.
[4] Podestà, M., et al.: Rev. Sci. Instrum. **79** (2008) 10E521.