§4. Development of Fast-ion Charge Exchange Spectroscopy for Fast-ion Measurement on LHD

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Confinement of fast-ions are one of the important physics issue on the Large Helical Device(LHD) since the three dimensional ripple components of magnetic field strength affect their confinement properties. To examine the properties, Fast-Ion Charge eXchange Spectroscopy (FICXS) method is under development. FICXS measurement is very simple method. It observes Doppler shifted H_{α}-lights with a proper viewing geometry, where its Line Of Sight (LOS) needs to be set to parallel the motion of fast-ions of interest as much as possible. On the other hand, we need sophisticated analysis for the evaluation of fast-ion confinement properties with the observed spectra since the velocity space integration of $\sigma_{cx}v_r$, where σ_{cx} is charge exchange cross section for H_{α} emission and v_r is the relative velocity of fast-ion with respect to neutrals, sometimes makes the direct evaluation of fast ion profile from the measurement impossible. Instead, the expected FICXS data was reconstructed from theoretically evaluated fast-ion profile and neutral density information. Then, they are compared to the experimental observation. Thus, accurate evaluation of neutral density and fast-ion simulation data are necessary.

In the evaluation of neutral density, we need to consider the Neutral Beams (NB) and Halo-neutrals on the LOS. Halo neutrals are the product of charge exchange process between bulk-ions and NB and difficult to make accurate evaluation. In the previous analysis, they were evaluated empirically[1]. This method was time consuming. Instead, we have developed a new spectrometer which is able to measure FICXS components and CXS components by Halo and NB (Halo-spectra), simultaneously. Since the FICXS component is very weak compared to the Halo-spectra, it was difficult to measure both of them, simultaneously. To overcome the difficulty, a gray notch filter was placed at the exit of the spectrometer, so that it can attenuate the Halo-spectra of around 656.2nm, significantly. Figure 1 shows a typical spectrum obtained with this spectrometer. As shown in the figure, spectral region of 656.2$\pm$1.5nm was attenuated to 1% from the original intensity. The simultaneous measurement of halo-spectra and FICXS spectra was done successfully. An investigation of Halo neutral density ratio to the NB density from the measured intensity ratio of Halo spectra to Beam Emission Spectra is now consideration.

As a theoretical approach of the development, we have estimated the change of the FICXS spectra in the C pellet injection plasma. We can discuss more in detail the simulation and experimental results comparing the results of the time development plasma. We have developed GNET-TD code[2] based on the GNET code taking into account the time development of the plasma density and temperature.

We include the experimental time development data (shot #110597, Rax=3.6m, Bax=-2.85T) of the temperature and density to GNET-TD and, also, beam ion source profiles are evaluated by HFREYA using the same time development data. The time development of the beam ion distribution is evaluated by GNET-TD. After the pellet injection we can see a clear reduction of the distribution in the high energy region at r/a=0.8 due to the enhancement of slowing down by the rapid density increase. On the other hand, at r/a = 0.2, there can be seen no clear change in the beam ion distribution. Figure 2 shows the estimated FICXS signals using the obtained beam ion distribution before and after the C pellet injection. We can see the time development of the signals due to the pellet injection.

1) Ito, T., et.al., PFR **5** (2010) S2099.
2) Yamaguchi, H., et al., PFR **8** (2013) in press.

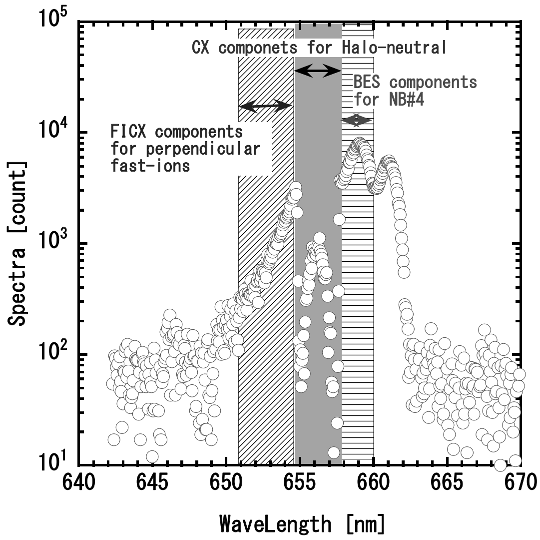

Fig.1 Typical observed spectra with a new spectrometer.

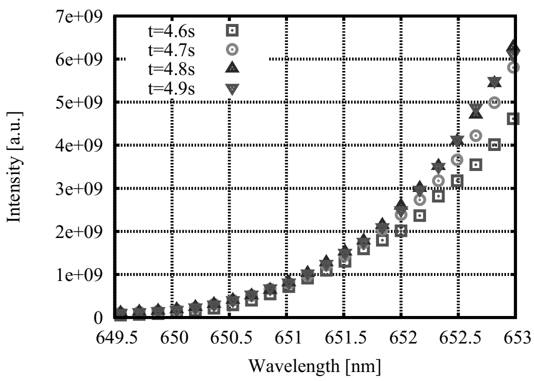

Fig.2 Estimated FICXS signals before and after the C pellet injection at r/a=0.8.