§48. Charge Exchange Spectroscopy in LHD

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Radial profiles of ion temperature (T_i) and poloidal rotation velocity (v_θ) of fully ionized carbon or neon are measured with charge exchange spectroscopy (CXS) using heating neutral beam (NB) in LHD. Because of negative ion source of NB, the operating energy range of heating neutral beam is relatively high (E = 100 - 180 keV/amu). Therefore, the charge exchange cross section between fully ionized impurity and proton is much smaller than that for the charge exchange spectroscopy in most large tokamaks (40 - 60 keV/amu). The small charge exchange cross section due to the high energy beam in LHD makes the CXS measurements difficult, because

1 Number of photon of charge exchange emission is small.
2 The ratio of charge exchange emission signal to the background emission (S/B ratio) is small.

In order to solve the problem of small number of photon, large throughput Czerny-Turner spectrometer (focal length : 0.5m, F number : 4) and cooled CCD with long integration time have been developed for CXS in LHD.The background emission is mainly due to the charge exchange reaction between fully ionized impurity and thermal neutral near the plasma edge and is called cold component. It is important to measure cold component precisely at the poloidal cross section without NB especially when the S/B ratio is small (order of unity).

Four set of optical fiber array (11 fiber each) with 0.2mm core diameter and 0.25mm clad diameter have been installed to the 10.5U (with NB section upper) port,10.5L (with NB section lower) port, 7.5U (without NB upper), 7.5L (without NB lower). The charge exchange emissions are measured at 10.5U/L, while the cold components are measured at 7.5U/L to subtract the cold component from charge exchange emission. The absolute values of poloidal rotation velocity are derived from the differences of Doppler shift measured at upper and lower port.

The charge exchange line of fully ionized carbon CVI (529.05 nm Δn=8-7) is typically used for the measurements. However, the cold component of CVI sometimes is too high (S/B < 0.3) to derive ion temperature. In general, impurity with higher Z has relatively lower cold component. For example, the cold component of fully ionized neon charge exchange line NeX (524.90nm Δn=11-10) is negligible small. In order to measure ion temperature and poloidal rotation velocity more precisely, short neon gas puff (Δt = 50ms), is performed at the beginning of NB pulse when the cold component of CVI is too high.

Figure 1 shows the radial profiles of ion temperature and poloidal rotation velocity measured with CVI for LHD plasma with magnetic field of 1.5T, central electron density of $1.0\times10^{19}m^{-3}$, electron temperature 1.1 keV. Central ion temperature is 0.9 keV which is slightly lower than the central electron temperature. The magnetic axis locates at R=3.84 m due to finite beta shift.(R=3.75m for vacuum magnetic field). The plasma edge is R = 4.2m. Because the cross section between NB and line of sight of CXS is restricted only R = 3.8 - 4.2m (the center of NB does not match the center of the plasma and it is R = 4.0m at the poloidal cross section in the port 10.5L/U) , there is no measurements of ion temperature and poloidal rotation inner half of the plasma (R < 3.8m). The poloidal rotation velocity is less than few km/s for whole plasma. The poloidal rotation velocity profile shows the radial electric field is slightly negative towards the plasma edge.

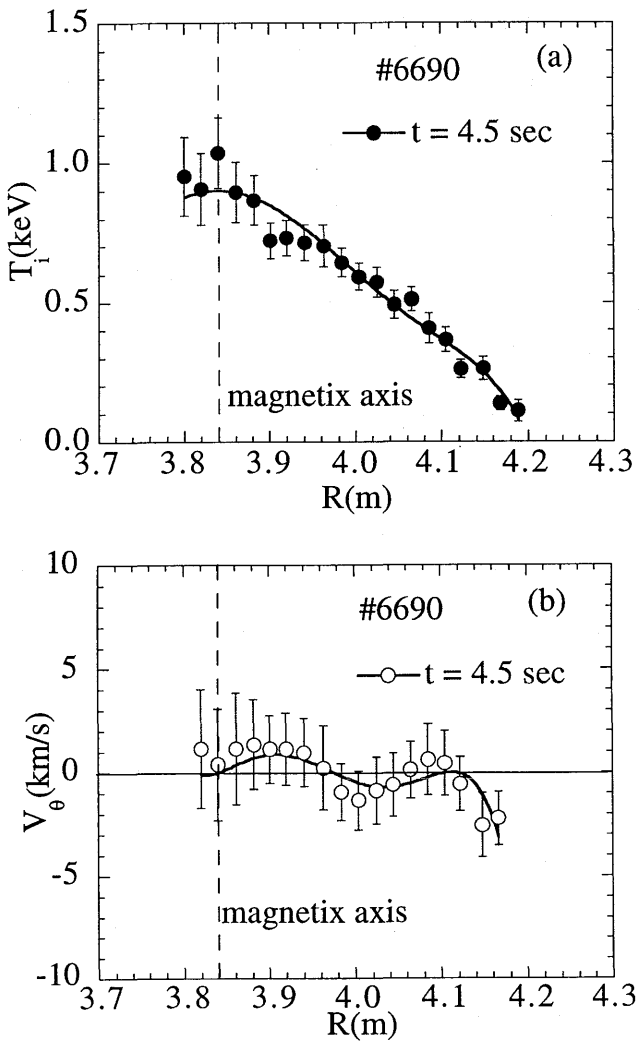

Fig.1 Radial profiles of (a) ion temperature and (b) poloidal rotation velocity measured with charge exchange spectroscopy in LHD. The positive poloidal rotation velocity stands for a plasma rotation in the ion diamagnetic direction, while negative values stand for a rotation in the electron diamagnetic direction.