§14. Study of Effective Ion Charge (Z_{eff}) in LHD

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Values of Z_{eff} have been studied with the radial profiles in LHD using visible bremsstrahlung continuum. The vertical profiles are measured at horizontally elongated plasma cross section. The Z_{eff} profiles are successfully obtained, but the discharges possible to the measurement was limited to a few configurations of $R_{ax}\leq 3.60$m or high-density pellet discharges, because nonuniform visible bremsstrahlung emission in the ergodic layer disturbed the radial profile observation from the core plasma. Results obtained in the limited conditions are presented.

The Z_{eff} profile is analyzed for high-density plasmas maintained by six H_2 pellets. The line-averaged density increases up to $2.1\text{x}10^{14}\text{cm}^{-3}$ with relatively high plasma pressure of β=1.44%, as shown in Fig.1 (left). The density profile is peaked, whereas the temperature profile is fairly flat, in particular at $\rho\leq 0.8$. The bremsstrahlung emissivity profile is further peaked, since the emission is proportional to the square of density if Z_{eff} is constant. The Z_{eff} analyzed shows an entirely flat profile with values closed to unity.

On the other hand, the density profile is much different for the single carbon pellet injection because of the outer ablation. It is clear from the density profile that the carbon pellet is ablated at $\rho\sim 0.7$. According to this the emissivity profile of the visible bremsstrahlung becomes extremely hollow. However, the Z_{eff} analyzed also shows a flat profile, not depending on the density profile. The values are closed to 7 which suggest the existence of another impurity such as helium.

The Z_{eff} profiles are also studied for different density profiles produced with H_2 gas puffing instead of the pellet. Results are shown in Fig.2. The hollow density profile has the peak value at ρ=0.9 with a little higher density compared to the flat density profile. Although the two density profiles are considerably different, the resultant Z_{eff} profile becomes flat. Through all the analyses we understand the Z_{eff} profiles are flat in most of discharges in LHD. The experimental results on the present Z_{eff} study indicate that the impurity partial pressure is radially constant to the electron (or ion) pressure.

Behavior of the Z_{eff} values is investigated in both of the gas-puff ($n_e\leq 10\text{x}10^{13}$ cm^{-3}) and H_2 pellet ($10\leq n_e\leq 30\text{x}10^{13}$ cm^{-3}) discharges. The line-averaged Z_{eff} is used for the analysis to avoid large errors in the Abel inversion process. The line-averaged Z_{eff} quickly decreases from 3.8 to 1.4 as the line-averaged density increases from 3 to $9\text{x}10^{13}\text{cm}^{-3}$ for $R_{ax}\leq 3.6$m configurations (see Fig.3). The Z_{eff} values usually tend to increase at relatively low-density range for such inwardly shifted plasma axis configurations. In contrast to it, the Z_{eff} values are close to unity in the H_2 pellet injection discharges for R_{ax}=3.85m, suggesting a better impurity screening effect. Carbon densities are also analyzed from the Z_{eff} values. The ratios of total number of carbon ions to total number of electrons widely distribute in range of 0.1 to 10%..

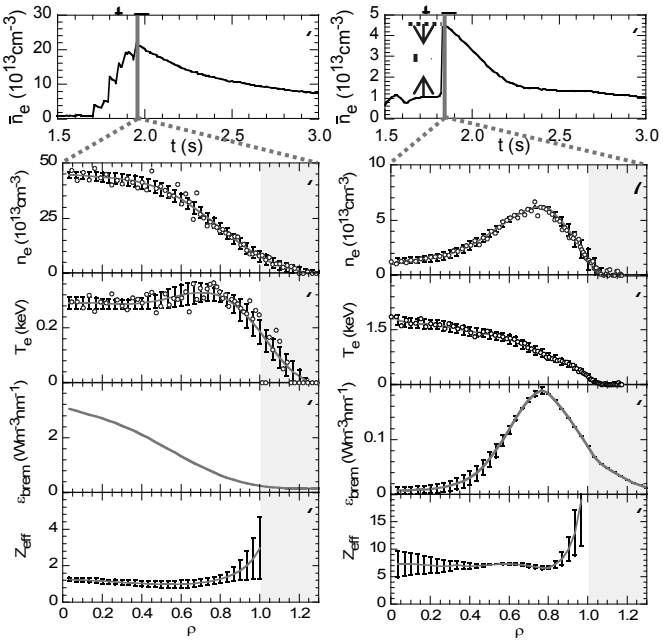

Fig.1 Radial profiles of Z_{eff} in NBI discharges with solid H2 multi-pellet (left) and single carbon pellet (right).

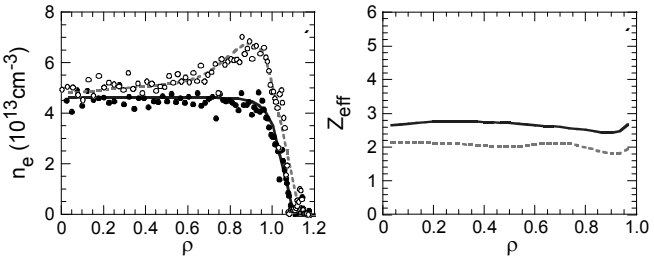

Fig.2 Radial profiles of Z_{eff} for flat (solid line) and peaked (dashed line) density profiles.

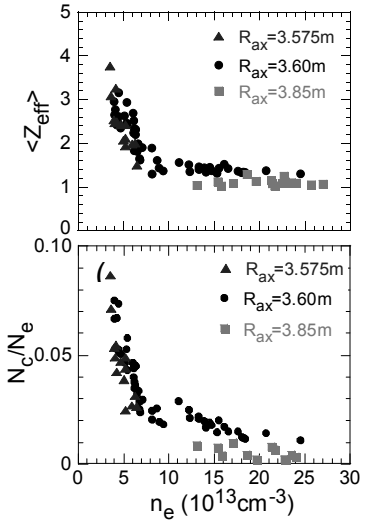

Fig.3 Line-averaged Z_{eff} (left) and ratio of total number of carbon ions to total number of electrons (right).

1) H.Y.Zhou, S.Morita et al., RSI **79** (2008) 10F536.
2) H.Y.Zhou, S.Morita et al., PFR **5** (2010) S1021.
3) H.Y.Zhou, S.Morita et al., J.Appl.Phys 107 (2010) 053306.