§16. Impurity Behavior in Long Pulse Discharges with High NBI Heating Power in LHD

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Impurity behavior has been mainly investigated so far in long pulse discharges with low NBI heating power (< 3 MW). The upgrade of NBI heating systems (P_{nbi} ~ 10 MW, t_d ~ 5 s) enables us to maintain high performance plasmas for long time. Now we can study impurity behavior in long pulse discharges with high temperature plasma. In these discharges, we observed no peaked radiation profile as seen in the discharges with low NBI heating power. Here, we report the experimental results in long pulse discharges with high NBI heating power (P_{nbi} = 3~10 MW).

Figure 1 shows a typical long pulse discharge with high NBI heating power. In the early stage of this discharge, the total heating power is about 10 MW and the heating power steps down to 6 MW at around 6 s. The average plasma density is kept constant (~ 4 x 10^{19} m^{-3}) in the first half period of discharge and the density is increased gradually by the step down of heating power. The plasma temperature also decreases with the step down of power. The line averaged radiation intensity (AXUVD signal) and the intrinsic impurity line intensity (Fe XXIII) at the central chord of plasma increase gradually and seem to be saturated. The step down of heating power brings out a discontinuous rise of the radiation and the impurity line intensity. The measurements of local radiation power with bolometer arrays show a hollow profile in the high power phase and a peaked profile in the low power phase, as shown in Fig. 2. The time trace of the radiation power is indicated at the last column of Fig. 1 and the peaking of radiation power rapidly starts with the power step down. The peaked radiation profile also appears in a quasi-steady state discharge with 6 MW. As found in the previous study, there is an impurity accumulation window in the operational regime of hydrogen discharges on LHD and the plasma parameters in these discharges corresponds to those in the accumulation window. However, no peaked radiation profile is observed in the high power discharge with 10 MW. Another important feature is to enhance the radiation in the edge plasma region.

According to neoclassical theory of impurity transport in helical plasma, the convection term depends on radial electric field (positive: outward, negative: inward) and normalized temperature gradient (outward). In these discharges, the radial electric fields are negative and almost the same. For hydrogen discharges with various heating power (3~10 MW), we measured radiation profiles in the range of accumulation window. Figure 3 shows the dependence of radiation peaking factor on the normalized electron temperature gradient. Although the temperature gradient depends on the heating power, the normalized temperature does not change largely. However, no peaking of radiation is observed in the discharges with high heating power (10 MW). Such a drastic change suggests that there is a new type of outward convection (due to plasma turbulence etc.) in the core region for high power heating. This may be related to impurity hole observed in high T_i mode in LHD. Further investigation will be needed to understand the physical mechanism.

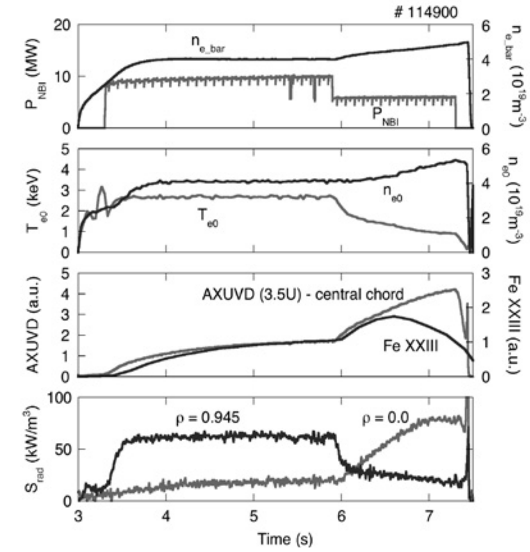

Fig. 1. NBI discharge with 6 MW and 10 MW

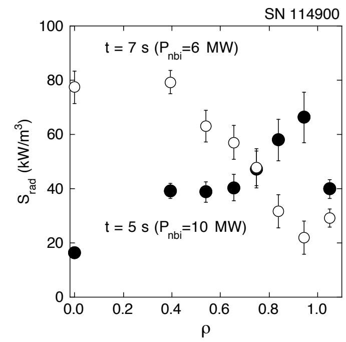

Fig. 2. Radiation profiles in 6 MW and 10 MW heating

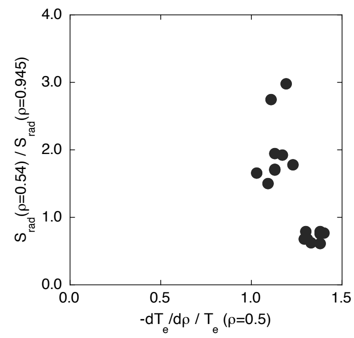

Fig. 3. Dependence of radiation peaking factor on normalized T_e gradient