§8. Structure of Resonant Magnetic Perturbation in LHD Detached Plasma

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Reduction of the heat load on a divertor is an urgent issue for realizing the magnetically confined fusion reactors. To maintain the detached plasma, externally controlled methods such as gas puffing in the divertor region have been studied. In the LHD experiments, a resonant magnetic perturbation (RMP) is utilized to establish the detached plasmas [1, 2], and it was reported in Ref. [3] that the finite plasma response field (PRF) was detected and shows a significant critical value of the phase difference, $\Delta\theta_{pl}$ (defined as the phase difference between the RMP and the PRF), to establish the detached state. The behavior of $\Delta\theta_{pl}$ was discussed in detail in Ref. [3], but the amplitude of PRF ($\Delta\Phi_{pl}$) was not dealt with. In the recent study, it is found that the waveforms of the $\Delta\Phi_{pl}$ show the different behaviors before the transition to the detached state depending on the phase of the RMP as shown in fig. 1. Under the RMP of "6-O" case, the $\Delta\Phi_{pl}$ decreases from t = 4.4 s to transition after the increase in $\Delta\Phi_{pl}$ until t = 4.4 s (fig. 1 (b)), whereas the $\Delta\Phi_{pl}$ continues to increase by the transition (fig. 1 (g)) under the RMP of "7-O" case (fig. 1 (g)). The critical values of $\Delta\theta_{pl}$ indicate different value in each case (fig. 1 (c) (h)). These differences are thought to be originated from the existence of the intrinsic error field and the exact perturbed field should be a superposition of the RMP and the error field. To determine the exact island structure, the effective perturbed field (EPF), obtained by superposing of the RMP, intrinsic error field and the PRF, is adopted. The structure of EPF with the amplitude ($\Delta\Phi_{eff}$) and phase ($\Delta\theta_{eff}$) reflects the exact structure of the perturbed field. Investigating the EPF, it is found that the $\Delta\Phi_{eff}$ increases before the plasma enters into the detached state in both RMP cases (fig. 1(d) (i)) maintaining the $\Delta\theta_{eff}$ around 0 (fig. 1(e) (j)). Observed in both RMP cases is the common behavior that the width of the magnetic island made by the effective perturbed field is smaller than the vacuum island width before the transition, and it becomes larger than that after the transition without the phase shift. This experimental observation means that the detached state is accompanied by the amplification of the exact structure of the perturbed field. The change of the PRF contributes to establish the detached state via the modification of the amplitude of RMP.

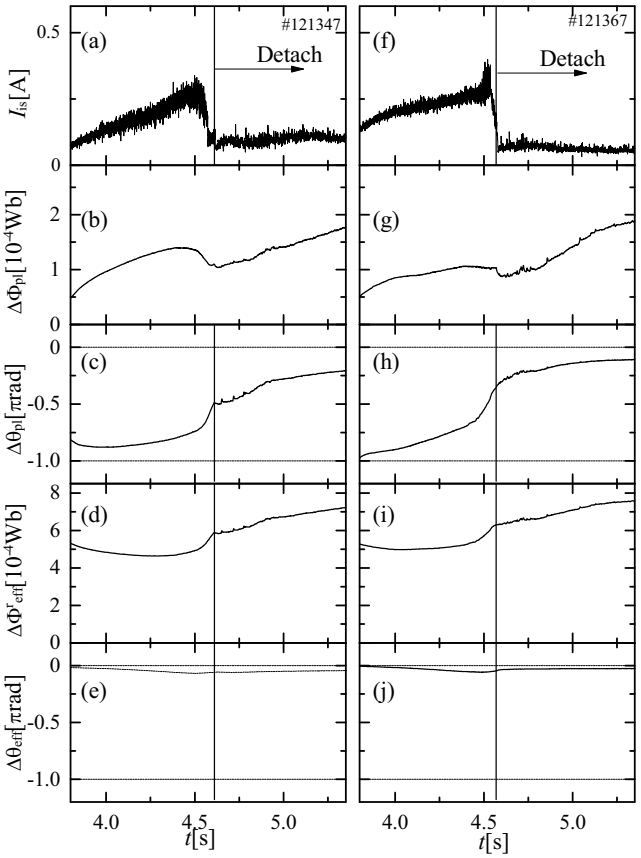

Fig.1 Waveform of (a, f) ion-saturated current on divertor, (b, g) amplitude of plasma response field (PRF), (c, h) phase of PRF, (d, i) amplitude of effective perturbed field (EPF), (e, j) phase of EPF. Phases of RMP are 6-O (left) and 7-O (right) respectively.

[1] M. Kobayashi et al., Nuclear Fusion **53**, (2013) 093032
[2] H. Tanaka, et al., Joint 19th ISHW and 16th RFP workshop, 2013, Padova, Italy, Poster C4
[3] Y. Narushima, et al., Plasma Fus. Res. **8**, (2013) 1402058