§6. Stable Sustainment of Divertor Detachment in High Beta Plasma Using Resonant Magnetic Perturbation Field in LHD

Kobayashi, M., Narushima, Y., LHD Experiment Group

Realization of high performance core plasma with mitigated divertor heat load is the one most important issue for future reactor. In LHD, it has been found that the application of the resonant magnetic perturbation (RMP) field with mode number of m/n=1/1 that creates edge remnant island in the edge stochastic region, has a stabilizing effect on the detached plasma through capturing of the radiation belt at the island structure as well as the decoupling of the edge recycling/impurity transport from the confinement region [1)]. The operation domain of the stabilized detachment, however, has been limited to the relatively low beta plasma, β~0.2%. In this experiment, the stable sustainment of divertor detachment with RMP application in the high beta plasma has been attempted.

The magnetic configuration has been selected as an inward shifted configuration with the magnetic axis (R_{ax}) is at 3.75 m with reduced toroidal field strength (B_t) of 0.75 T, which realizes high beta plasma of ~ 1% together with the resonant surface for m/n=1/1 RMP marginally outside the confinement region that is considered to be necessary condition to obtain decoupling between the confinement and the edge recycling region, as mentioned above. (cf. the RMP assisted detachment has been obtained so far with Rax=3.85 or 3.90 m, B_t ~ 2.5 T, and RMP coil current (I_{RMP}) ~ 3000A.)

Figure 1 shows the temporal evolution of various plasma parameters of the RMP assisted detached plasma with the high beta operation together with the case without RMP application. It is shown that in the case with RMP, the detachment transition, that is defined as the reduction of divertor particle flux as shown in Fig.1 (c), occurs at t~3.50 sec accompanied by the enhanced radiation, and it is sustained successfully until the end of discharge terminated by stop of the NBI. The divertor particle flux shows different behavior between the tiles 6I-R and 6I-L, which are situated at the inboard side midplane of the same toroidal section but connected to different divertor legs. That is, the particle flux at 6I-R starts to decrease earlier than at 6I-L. This is considered due to the mode structure imposed to the edge plasma by m/n=1/1 RMP, that is indeed reflected on the edge radiation structure as well as the divertor particle flux distribution after the detachment transition with mode structure of m/n=1/1. Without the RMP application, otherwise, the discharge goes to radiation collapse with increasing density. In the present experiments, the RMP coil current was set to 1920A, which is relatively higher than in the case with the previous low beta plasma, in terms of I_{RMP}/B_t, i.e. I_{RMP}/B_t, = for the present case and = for the previous case. It is also found that there is a clear decrease in the density after detachment transition even with the continuous fueling by gas puff. This is different behavior than the previous low beta detachment case, where the plasma density increased even with reduced gas puff, indicating better fueling efficiency after detachment transition. The plasma response against RMP field, which is plotted in Fig.1 (f), shows that after detachment transition the plasma response becomes in phase with the external RMP, i.e. plasma enlarges the magnetic island, while before the detachment the plasma prone to screen the RMP.

The present experiments have clearly demonstrated that the stable sustainment of the divertor detachment with RMP application is compatible with the high confinement plasma as high as b~1 %. The operation domain of this kind of detached plasma will be explored further in the high beta plasma by changing the RMP amplitude and magnetic configuration.

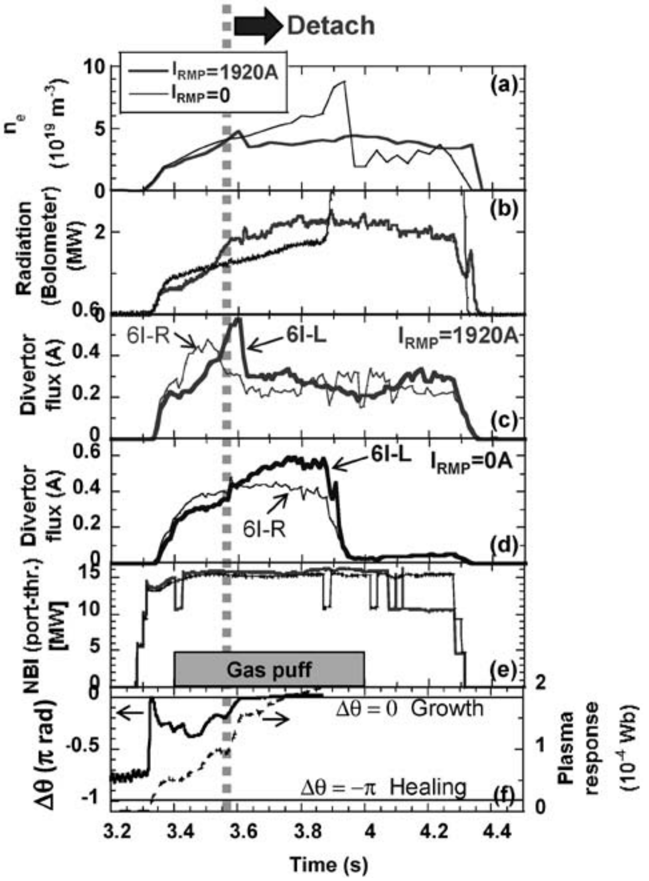

Fig. 1. Temporal evolution of (a) Line averaged density, (b) Radiated power obtained by bolometer, (c) divertor particle flux with I_{RMP}=1920A of the left and right divertor legs at the inboard side of the toroidal section 6I, (d) Divertor particle flux at the same location as (c) but with I_{RMP}=0A, (e) NBI port through power and gas puff timing, (f) Plasma response. The phase relative to the external RMP with solid line (left axis), the amplitude with dashed line (right axis). For (a), (b) and (e), thick lines：I_{RMP}=1920A、thin lines：I_{RMP}=0A.

1) Kobayashi, M. et al.: Nucl. Fusion **53** (2013) 093032.