§8. Stable Detachment of IDB Plasmas with a Large *m*/*n* = 1/1 Magnetic Island Cooled by Supersonic Gas Puff

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Stable detachment of high-density internal diffusion barrier (IDB) plasmas with m/n = 1/1 resonant magnetic perturbation (RMP), where m and n denote poloidal and toroidal mode numbers, respectively, has been performed. This method is based on the idea in Ref. 1, where experimental results of stable detachment of gas-fueled plasmas with flat density profiles using RMP are reported. This new method has two remarkable merits; one is the stability of detachment and another is the energy confinement in the core region. In the last experimental campaign, this method was applied to IDB plasmas with strongly peaked density profiles. With RMP, a large m/n = 1/1 magnetic island was formed in the edge region with the core plasma being unaffected, and in some cases, the plasma transiently detached after pellet injection. To keep the detachment phase longer, supersonic gas puffing (SSGP) of hydrogen was applied. In the case with both of RMP and SSGP, detachment was successfully maintained.

Typical waveforms in IDB discharges without RMP (#93948), with RMP (#94017), and with both of RMP and SSGP (#94021) are compared in Fig. 1. In the cases with RMP, the m/n = 1/1 RMP was applied throughout the discharge, and the plasma stored energy (Fig. 1(a)) was decreased due to a large m/n = 1/1 magnetic island formed in the edge region. The magnetic island can be recognized by the local flattening at R ~ 3.1 m and 4.6 m in the temperature profiles shown in Fig. 2. Detachment took place after intense pellet injection (t ~ 2 s) in the cases with RMP and the divertor flux was significantly reduced (Fig. 1(e), where the ion saturation current, I_{sat}, measured on a divertor tile is shown). However, the plasma automatically reattached in the case with RMP alone (#94017), when the mantle density decreased to ~6×10^{19} m^{-3} (Fig. 1(d)). A short pulse of SSGP was applied at t ~ 2.2 s in #94021. Then, the mantle density was increased above 6×10^{19} m^{-3}. In this case, detachment was sustained longer. Detachment was kept even when the mantle density decreased to < 6×10^{19} m^{-3} (t > 3s) in #94021. This might presumably be due to the reduction of the heating power (Fig. 1(b)) at that time. Complete detachment in LHD, such as the Serpens mode, has been observed when the edge density exceeds the Sudo density limit, n_c^{Sudo} [2]. However, the edge density in detached plasmas with RMP is smaller than n_c^{Sudo}, even with SSGP, as shown in Fig. 2. The core confinement property was not influenced by RMP alone. However, it was deteriorated in the case with both of RMP and SSGP. The increased island width and/or the shallow penetration of the heating beams due to the higher mantle density are the possible causes of this deterioration.

1) Kobayashi, M. et al.: Phys. Plasmas **17** (2010) 056111
2) Miyazawa, J. et al. : Nucl. Fusion **48** (2008) 015003

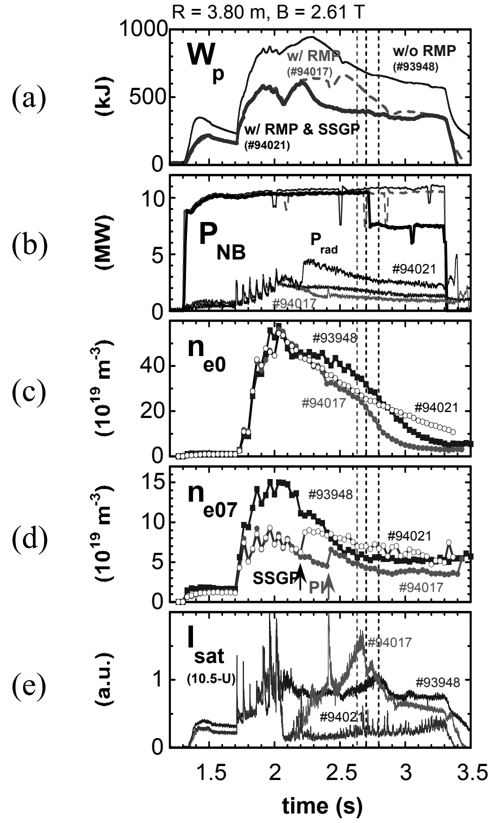

Fig. 1. Typical waveforms in IDB discharges without RMP (#93948), with RMP (#94017), and with both of RMP and SSGP (#94021), where (a) the diamagnetic plasma stored energy, (b) the total heating power, (c) the central electron density, (d) the mantle electron density at ρ = 0.7, and (e) the ion saturation current measured on a divertor tile are shown from top to bottom.

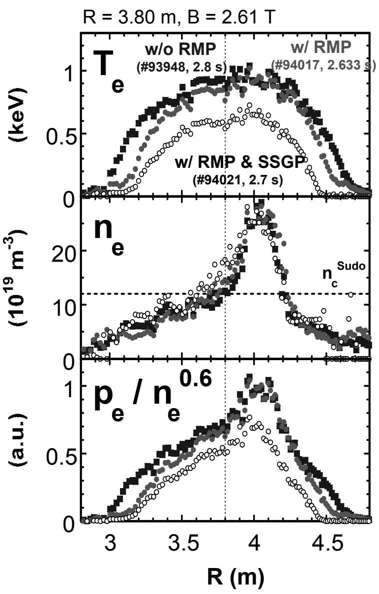

Fig. 2. Radial profiles of (a) the electron temperature, (b) the electron density, and (c) the electron pressure normalized by the gyro-Bohm type density dependence, in the three discharges shown in Fig. 1.