§16. Control of Detachment Onset and Sustainment with Resonant Magnetic Perturbation in Stochastic Layer of LHD

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In magnetically confined fusion reactors, the energy flux to the divertor plate caused by the direct contact of plasma with the plate surface is expected to be several tens MW/m^2, which is far beyond the engineering limit of the divertor structure. The power dispersal via volumetric energy loss such as line radiation by impurity species is, at the moment, only possible scheme to bring the divertor power load below the engineering limit. The operation of this scheme is called divertor detachment and has been investigated in various devices. The reduction of the power load has been demonstrated in many devices by increasing the radiated power fraction up to 80 ~ 90 %. AT the same time, however, it is found that once the plasma detaches from the divertor plates, the plasma tends to be thermally unstable and the control of the radiation level/location becomes very difficult. The loss of control of the detachment plasma leads to the X-point MARFE with deterioration of core plasma performance and also sometimes the discharge ceases due to plasma collapse.

In LHD, it is found that the resonant magnetic perturbation (RMP) field of n/m=1/1 mode has stabilizing effect on the strongly radiating plasma, where the detachment operation is successfully sustained without deterioration of core plasma performance up to the end of discharge [1)]. Otherwise without the RMP the plasma leads to radiative collapse. The experimental results indicate the existence of new control knob for detachment operation in addition to the conventional ones, such as density scan and impurity puff.

In the 14th experimental campaign of LHD, the possibility of detachment onset control with RMP has been demonstrated. Fig.1 shows the time trace of line averaged density, divertor particle flux and the perturbation coil current for n/m=1/1 RMP. After the initiation of the discharge at t=3 sec, the plasma density is gradually increased by gas puff and it reaches the flat top ~$8x10^{19}$ m^{-3}, while the perturbation field is also increased during the discharge as shown in the coil current. By keeping the density constant after t=5 sec, only the perturbation field increases and the plasma goes to detachment at t=6.3 sec as shown in the divertor particle flux reduction. The detachment is sustained up to the end of discharge at t=9 sec. It is seen that the detachment transition occurs at the coil current of slightly above 2000A. The timing of coil current ramp up is shifted back and forth in time while keeping the almost same density flat top to confirm the effect of RMP. It is found that the detachment onset is accordingly shifted back and forth in time. The results demonstrate the availability of the new control knob on the divertor detachment.

The compatibility of the island induced detachment with the extrinsic gas injection, which is often effective to increase the radiation fraction, has been tested. Fig.2 shows the time evolution of the line averaged density, divertor particle flux and the radiation intensity. In this case, the full RMP current is applied from the beginning of the discharge, and the island detachment occurs at t=4.5 sec. The density is still increased even after the detachment onset up to $7x10^{19}$ m^{-3} and keeps constant afterwards. The neon is puffed at t=7 sec with 50 ms pulse as indicated with the arrows in the figure. The radiation intensity increases by a factor of 1.4, while keeping the stable detachment.

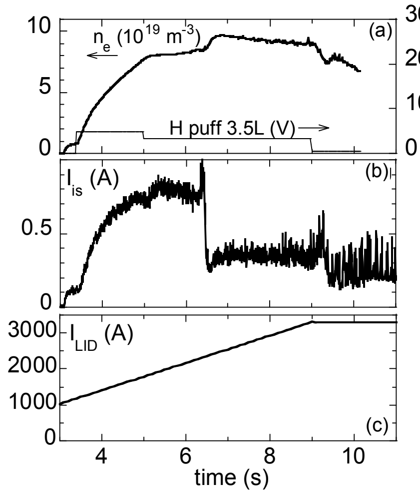

Fig. 1. Time traces of (a) line averaged density and gas puff wave form, (b) the divertor particle flux, (c) RMP coil current.

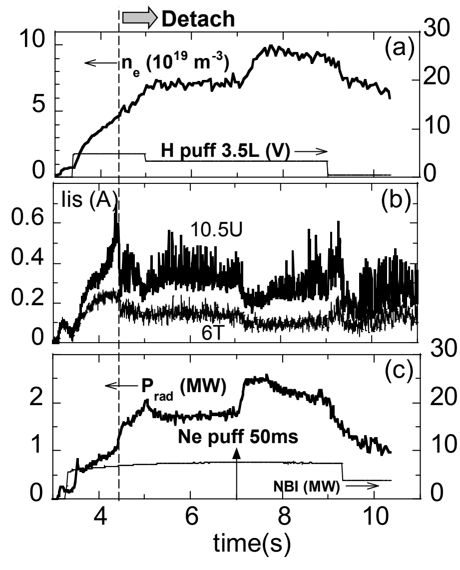

Fig. 2. Time evolution of (a) line averaged density and gas puff wave form, (b) divertor particle flux, (c) radiation intensity, NBI input power and Ne puff timing of 50 ms pulse (arrow).

1) Kobayashi, M. et al. : Physics of Plasmas **17** (2010) 056111.