§6. Detachment Stabilization with n/m=1/1 Resonant Magnetic Perturbation Field Applied to the Stochastic Magnetic Boundary of the Large Helical Device

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Divertor detachment is a scheme to mitigate the excessive power load onto material surface by increasing impurity radiation at divertor region. Control of the radiating plasma, however, still remains a challenging issue. It is often observed that as soon as the plasma detaches from the divertor plates, the radiation region moves to the X-point of the divertor configuration and degrades the core plasma performance.

The recent experiments in LHD have shown that the application of n/m=1/1 resonant magnetic perturbation field has stabilizing effect on the detached plasmas[1]. Fig.1 shows the calculated magnetic field structure of LHD indicated by connection length with and without the perturbation field. The white region at the outboard side represents an O-point of the remnant island in the stochastic region created by the perturbation field. Fig.2 shows the time traces of line averaged density, radiation intensity, divertor particle flux, gas puff rate for the case with and without the n/m=1/1 perturbation field. Without the perturbation field, the increase of the density gives rise to saturation of divertor flux around t=2.5 sec. The fact that the density continues to increase in spite of the saturation of divertor recycling (divertor flux) indicates improved particle confinement time. One of the reasons for this is considered due to upstream shift of ionization front because of the significantly lowered edge temperature, which hardly can ionize the neutrals so that they can penetrates deeper. The impurity radiation gradually increases from t=3.0 sec and leads to radiative collapse at t=4.0 sec, where reduction of gas puff rate can not stop the increase of the density and of the radiation intensity.

The radiative collapse is avoided in the case with the perturbation field as shown in the thin lines in Fig.2, where the plasma goes to detachment phase at t=3.0 sec with increased radiation. The detachment phase is sustained until the end of discharge terminated by stop of NBI (neutral beam injection) heating. The ratio of H_γ/H_β increases after the detachment transition, indicating presence of volume recombination. The radiation increases by a factor of 3, while the divertor power load estimated by Langmuir probe decreases by factor of 2 to 10 with scatter of experimental data. It is found that the radiation intensity, divertor flux and neutral pressure exhibit intermittent oscillation during the detachment phase with 50 to 70 Hz. The plasma performance does not degrade after the detachment transition, which is confirmed with the diamagnetism as well as the estimated plasma pressure (electron density multiplied by electron density) profiles obtained by Thomson scattering system. The vacuum ultra violet spectroscopy measurements confirmed no heavy (iron) impurity accumulation during the detachment phase. 3D edge plasma transport simulation has been performed using EMC3-EIRENE, which shows increase of radiation intensity around the X-point of the n/m=1/1/ island with formation of dense and cold plasma. The line integrated radiation profile measurements are consistent with the simulation results, which shows intense peak at the line of sight passing through the X-point. The mechanism of the stabilizing effect of the island structure in the stochastic region on the radiating plasma is under investigation.

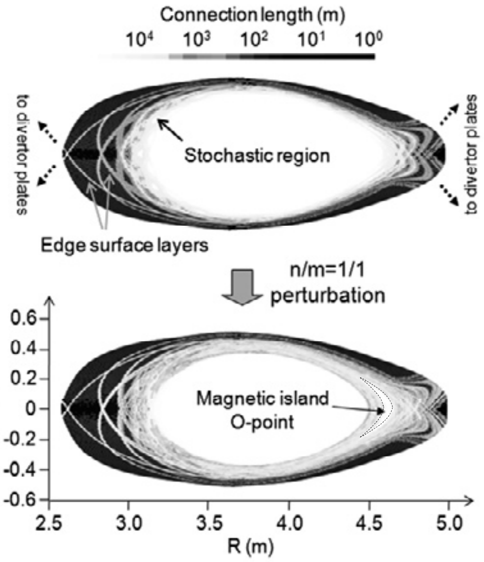

Fig.1 Connection length distribution in LHD with (lower picture) and without (upper picture) the n/m=1/1 resonant magnetic perturbation field. The white region indicated at the outboard side in the lower picture represents the O-point of remnant island.

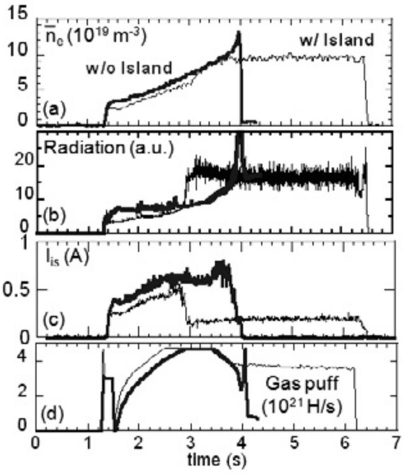

Fig.2 Time traces of (a) line averaged density, (b) radiation intensity, (c) divertor particle flux and (d) gas puff rate, for with (thin lines) and without (thick lines) the n/m=1/1 perturbation field (island).

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