§5. Comparison of 3D Edge Radiation Structure between Experiments and Numerical Simulation in RMP Assisted Radiative Divertor Operation in LHD

Kobayashi, M., Masuzaki, S., Yamada, I., Narushima, Y., Suzuki, C., Tamura, N., Peterson, B.J., Morita, S., Dong, C.F., Ohno, N. (Nagoya Univ.), Yoshimura, S., Feng, Y. (Max-Planck-Inst.), Goto, M., Sato, K., Akiyama, T., Tanaka, K.

It is found that resonant magnetic perturbation (RMP) fields have a stabilizing effect on the radiating edge plasma, realizing stable sustainment of radiative divertor (RD) operation in the Large Helical Device (LHD). Without RMP, thermal instability leads to radiative collapse 1). Divertor power load is reduced by a factor of 3~10 during the RMP assisted RD phase, while maintaining relatively good core plasma confinement with confinement enhancement factor $\tau_E^{\exp} / f_{ren} \tau_E^{ISS04}$ ~ 0.96. Although the mechanism of the RD stabilization with RMP is under investigation, the modification of the 3D edge radiation structure with RMP is considered responsible for the stabilization effect.

3D structure of radiation distribution has been analysed using the 3D edge transport code EMC3-EIRENE. Fig. 1(a) and Fig.2(a) show carbon radiation distribution in poloidal cross section at toroidal angle (ϕ) = 93 degrees without and with RMP, respectively. The plots correspond to the cases with radiation fractions by the carbon of 40 (without RMP) to 60 (with RMP) % of P_{SOL} (~8MW). In the case without RMP, it is found that the peaked radiation is located at the inboard side as shown in Fig.1 (a). Further increase of density leads to inward penetration of the peaked radiation and the radiated power fraction reaches 100% with significant reduction of divertor particle flux, indicating collapse of plasma. In the case with RMP, the peaked radiation region moves to the bottom of plasma as shown in Fig.2 (a), where X-point of m/n=1/1 island is located. The results suggest selective cooling around the X-point of the island. This is considered due to isolation of flux tubes around the X-point because of the singularity of field line geometry. Namely, the most of heat flux has to be delivered to the X-point thorough only perpendicular transport, which is much smaller than parallel transport. The situation leads to reduction of temperature at the X-point compared to other poloidal locations and thus the reduced temperature leads to increased radiation with carbon at high density range.

Comparison of the radiation structure between the experiments and the modelling has been carried out. Fig.1 (b) and Fig.2 (b) show vertical profiles of line integrated radiation obtained from the experiments and the modelling. The line of sight (LOS) of the measurements are indicated with white lines in Fig.1 (a) (also in Fig.2 (a)), which has 16 channels starting from the bottom. Without RMP (Fig.1 (b)), because of the enhanced radiation localized at the inboard side, the line integrated profile has a peak around ch.10 in the modelling, while the measurements shows a peaked radiation around ch.8, which is slightly downward shifted compared to the modelling. In the case of modelling, there appears also strong peak at ch.1-2, which comes from the poloidally elongated radiating flux tubes at the right bottom, that is almost tangential to the LOS of ch.1-2, as seen in Fig.1 (a). In the experiments, however, such peaked profile has not been observed. In the case with RMP (Fig.2 (b)), the peak of the radiation moves to lower channel numbers, i.e. ch.5, due to the enhanced radiation around the X-point as predicted by the modelling. This is also observed in the experiments, where the peak is located at ch.3, slightly downward shifted compared to the modelling by 2 channels.

As shown above, there is slight deviation of the behaviour in the radiation profiles between experiments and modelling, such as downward shift of the peak locations and the absence of fine structure in the experiments, which needs further investigations into the transport model used in the present analysis, as well as alignment of measurement system. However, at least the global change, i.e. peak shift from middle channels to lower ones, agrees well each other, indicating the selective cooling around X-point of m/n=1/1 island with RMP application.

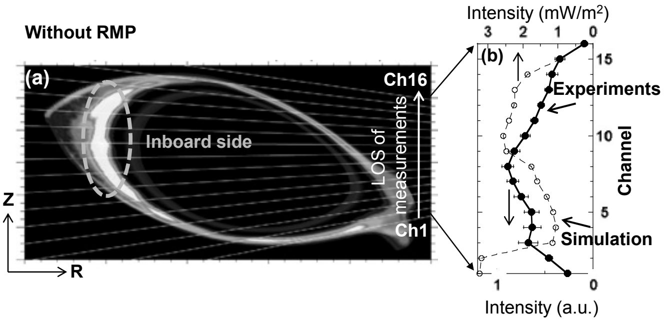

Fig.1. Radiation distributions without RMP. (a) Carbon radiation distribution in poloidal cross section obtained by EMC3-EIRENE simulation. (b) Line integrated radiation profiles obtained by experiments (●) and simulations (○).

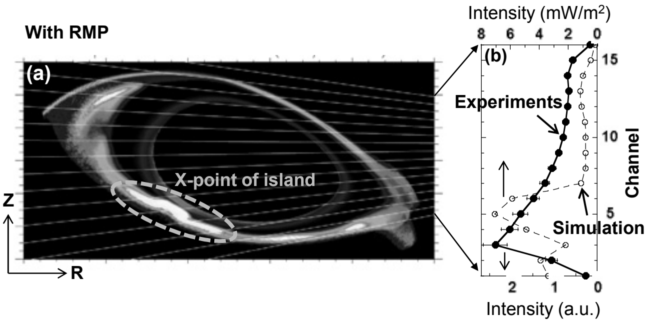

Fig.2. Same as Fig.1 but for the case with RMP.

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