§4. Comparison between Three-dimensional Transport Simulation and Impurity Radiation Measurement in RMP assisted Detached Plasma in LHD

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There appears a stochastic magnetic layer in the edge region of LHD due to overlapping between magnetic islands with different mode numbers. In this region, an impurity screening and detachment stabilization have been observed, which are considered attributed to the geometrical effects of the stochastic layer. The final goal of this research is to clarify to what extent the current transport model can reproduce and interpret the phenomena. In this report, we present comparison between three-dimensional (3D) transport simulation and impurity radiation measurement in the RMP (resonant magnetic perturbation) assisted detachment discharge in LHD [1].

In the discharge (#121351), an RMP (m/n=1/1) is applied, which acts as stabilization of edge radiation layer due to the formation of edge island in the stochastic layer [2]. The density is gradually increased by gas puffing and about 1.5 sec after the initiation of the discharge (the line averaged density ~ 6 x 10^{19} m^{-3}), the plasma goes to a detached phase, which is confirmed by a reduction of ion saturation current in the divertor probe array. The detachment is also accompanied by an increase of radiated power measured by a resistive bolometer.

The radiation distribution is measured by the infrared imaging video bolometer (IRVB) [3], which is installed at the top of the torus. The resulting temporal evolution of the radiation is shown in Fig.1, right column, where the radiation is integrated along the line of sight. The time proceeds from the top to the bottom figures, with the increasing density at the last closed flux surface (LCFS) n_{LCFS} = 4.0, 5.5, 6.0, 6.5 and 7.5 x 10^{19} m^{-3}. The detached phase starts from the third lines, as indicated in the figure. Synthetic images obtained by the 3D numerical transport simulation using EMC3-EIRENE code are also shown in Fig.1, left and middle columns, for different impurity transport coefficients, D_{imp}=1.0 and 2.0 m^2/s, respectively. The simulation code solves Braginskii-type fluid equations for mass, parallel momentum and energy of ions and electrons [4]. Impurity is treated as trace particle and carbon is used as dominant species, which originates from divertor plates. In Fig.1, trajectories of X-point of divertor legs at the top and bottom of the plasma are indicated by dashed lines, labelled as "upper HDX" and "lower HDX", respectively. The trajectory of the magnetic axis, a center of the plasma volume, is also indicated by solid lines. The top and bottom part of each figure correspond to the inboard and outboard sides of the torus, respectively.

In both experiments and simulations, the radiation is peaked at the upper part of the figure (i.e. inboard side of torus) in the attached phase (first lines of Fig.1). Especially, the radiation is formed along the trajectory of divertor leg X-point at the top of the plasma, as indicated by the dashed line, "upper HDX" in the figures. Then, with increasing density, the radiation extends towards the outboard side along the "lower HDX", as observed in the second lines. The numerical simulations reproduce the experiments qualitatively, but the radiation is more concentrated around the X-point trajectories than the experiments. It is also found that at the last phase of the discharge, the last lines of Fig.1, the radiation peak in the simulation shifts to the outboard side (bottom of the figure) completely, while the measurements shows more broad distribution from the inboard to the outboard side along the divertor leg trajectories. In the numerical simulation, the radiation distribution becomes broader with increasing D_{imp} from 1.0 to 2.0 m^2/s, as seen in Fig.1, left and middle columns. However, it is found that increasing D_{imp} more than 2.0 m^2/s does not change the distribution significantly. Thus, the current transport model predicts more peaked distribution than the experiments. As a possible reason for the difference, a drift motion of impurity due to ExB or gradient of magnetic field are considered. It is also found that the simulation overestimates intensity of the radiation compared to the experiments during the detached phase, for which a sputtering yield change due to the detachment transition might be responsible. A further analysis and improvement of the transport model are underway.

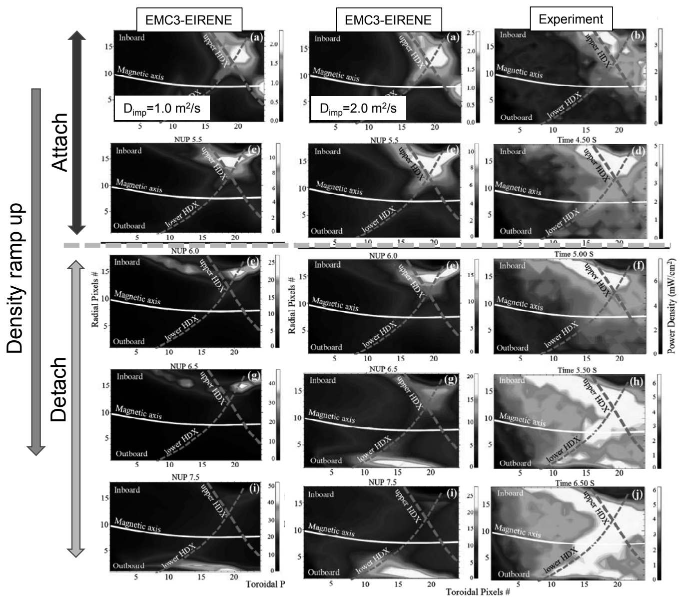

Fig. 1. Evolutions of radiation distribution at the detachment transition, as a function of density (time) in the density ramp-up discharge (#121351). Measurements with IRVB: right column, synthetic images from numerical simulations: left and middle columns for D_{imp}=1.0 and 2.0 m2/s. The density (time) increases from the top to bottom lines, as n_{LCFS} = 4.0, 5.5, 6.0, 6.5 and 7.5 x 10^{19} m^{-3}.

1) Pandya, S.N. et al., Nucl. Fusion **56** (2016) 046002.
2) Kobayashi, M., et al., Nucl. Fusion **53** (2013) 093032.
3) Peterson, B.J., Rev. Sci. Instrum. **71** (2000) 3696.
4) Feng, Y. et al., Contrib. Plasma Phys. **44** (2004) 57.