§7. Numerical Analysis on Divertor Detachment Stability in the Stochastic Magnetic Boundary of LHD

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Understanding of mechanism of divertor detachment and its stability is the most important and interesting issue in terms of control of excessive divertor power load in magnetically confined fusion devices, as well as of plasma transport (particle, energy) physics including the magnetic geometry effect. The energy balance of the detached plasma at the low temperature range (below 10 eV) with the strong impurity radiation might be very complex: the system is strongly nonlinear due to the temperature dependence of parallel (possibly perpendicular too) energy transport coefficients, of impurity radiation intensity, of impurity transport terms, of neutral ionization rate coefficient. The magnetic field geometry also affects the stability through coupling between parallel and perpendicular transport. In tokamaks, it is often observed that the detachment leads to localized radiation at the X-point of separatrix (X-point MARFE) and the plasma performance is degraded. The mechanism of this phenomenon is not yet fully understood. The recent experiments in LHD have shown that the n/m=1/1 remnant island structure created in the stochastic region has stabilizing effect on the radiating plasma realizing stably sustained divertor detachment operation with the core plasma being unaffected[1)]. The results provide us a clue to the understanding of the detachment stability.

The edge plasma transport is analyzed taking into account the detailed three dimensional magnetic field structure using EMC3-EIRENE, which solves the Braginskii type fluid equation with a Monte Carlo scheme, including interaction with divertor recycling neutrals. In order to simulate the magnetic field configuration with the n/m=1/1 islands, the computation domain covers the edge region outside of LCFS and the half torus in toroidal direction, while the another half is covered assuming stellarator symmetry. The volume is discretized with radial x poloidal x toroidal = 104 x 601 x 191 mesh surfaces. The grid points are aligned with the magnetic field lines when they are traced in toroidal direction. In this way the code can realize clean separation between the parallel and perpendicular transport which significantly differ each other in the magnitude by several orders. The computation has been conducted in Plasma Simulator SR16000 L2 powered by HITACHI Ltd. With the half torus model, the code consumes about 13 GB memory per processor and 5 hours of CPU time for one set of iteration of mass, momentum and energy transport equations together with neutral transport.

Fig.1(c) shows the radiation distribution obtained by the code for the cases with and without the n/m=1/1 island. In the sustained detachment case (with island, right), it is seen that the radiation peak located around the X-point of the island, where the plasma is selectively cooled down. The measurements of the radiation profile shown in the Fig.1(a) indicates strong peak at the line of sight passing through the X-point (ch.4) for the case with the island, being consistent with the computation. Fig.2 shows the impurity radiation, divertor particle flux and energy loss with neutrals. In the attached case with lower density, the computation converges after about 30 iterations. In the detachment case, on the other hand, the computation starts to oscillate, which is also observed in the experiments. The cause of the oscillation is under investigation.

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

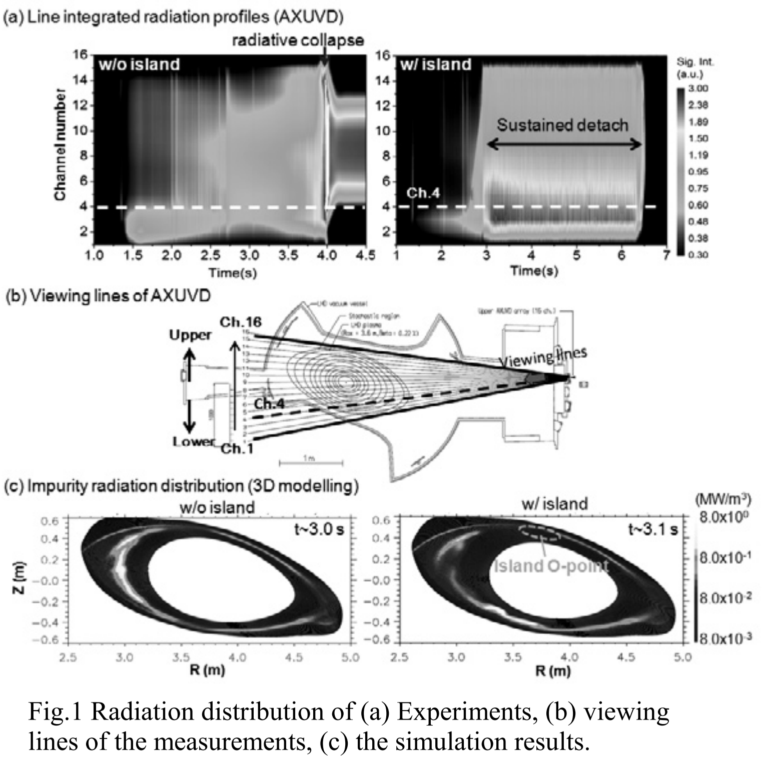

Fig.1 Radiation distribution of (a) Experiments, (b) viewing lines of the measurements, (c) the simulation results.

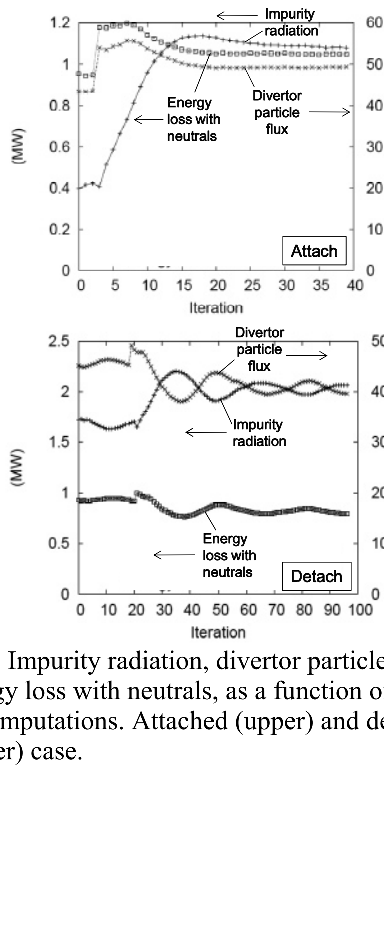

Fig.2 Impurity radiation, divertor particle flux, energy loss with neutrals, as a function of iteration of computations. Attached (upper) and detached (lower) case.