§2. Studies of Particle Control and Mitigation of Heat Load by Closed Divertor and Detachment

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The main aims of the group "(1) the divertor and edge plasma physics" was "to understand the particle balance for a high performance plasma by the control of neutral particles using a closed helical divertor systems with in-vessel cryosorption pumps" and "to evaluate the energy balance at the mitigation of heat load by detachment plasmas in LHD". Here we review the dedicated experiments of our group in the 17th experimental campaign as follows:

i) Characteristics of the closed divertor pumping

In the 17th experimental campaign, four sections of cryosorption pumps in the closed divertor systems were activated. At present, the obvious effect of the divertor pumping on the plasma is not obtained because the pumping speed is still below the target. However, the local particle balance analysis in the divertor has been undertaken carefully, with the result that about 12% of the neutral pressure in the divertor is reduced with the divertor pumping at the moment. A lot of effort of the improvement of the divertor pumping is being devoted toward the next campaign.

ii) Mitigation of heat load by detachment

In LHD, three kinds of a radiation enhancement have been established. One is an impurity seeding gas assist. Second is a resonant magnetic perturbation (RMP) assist. Third is a complete detachment by electron cyclotron heating (ECH), which was demonstrated for the first time in this campaign. Here we describe the brief summary with respect to each subject. The detail will be described elsewhere.

a) Impurity gas seeding

- As an impurity seeding gas, N_2, Ne and Ar have been utilized in LHD. Kr, which is a high-Z impurity, was seeded as one of the main seeding gas for the radiation enhancement in the 17th experimental campaign. The emission location was estimated by the soft X-ray multichannel spectrometer (SOXMOS), suggesting that high-Z ion is emitted in the core plasma.
- The dependence of the increase of the radiation power by Ne seeding gas on the magnetic configuration and the background electron density was investigated. Moreover, the radiation enhancement was sustained successfully for the long discharge of 3.5 sec. by the intermittent Ne puffing.
- The different toroidal axisymmetry of the divertor flux at the detachment was observed in various impurity seeding gases.

b) RMP assist

Various diagnostics such as an imaging bolometer, a divertor spectroscopy and Langmuir probe array were further developed in the 17th experimental campaign in order to identify the physical mechanism in the divertor detached plasmas. The location and temporal evolution of the radiation, and toroidal axisymmetry of the divertor flux at the RMP assist detachment were investigated.

c) Complete detachment by ECH

Complete detachment with strongly peaked electron temperature profiles called e-ITB (electron internal transport barrier) has been demonstrated for the first time in LHD. These results show the possibility of simultaneous achievement of improved confinement and divertor heat load reduction in future helical-type fusion reactors.

It should be noting that the transport code for SOL/divertor plasma and neutrals have been highly developed by the collaboration with the theoretical study.