§1. Exploration of Advanced Plasma Heating Scenarios in the Large Helical Device

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Purpose of this collaboration is to encourage the research activity of the plasma heating physics experiment group on LHD. On this group, experiments related to the optimization of reactor plasma heating scenarios and the achievement of high performance LHD plasmas were intensively conducted. During the 17th experiment cycle in LHD, the following three topics were major themes of the heating physics experiment group, i.e., physics related to (1) Electron Cyclotron Heating (ECH), (2) Ion Cyclotron Heating (ICH), and (3) Energetic Particle (EP) confinement.

1) ECH

Optimization of ECH is one of the most important issues in establishing the start-up scenarios of reactor plasmas. On LHD, the comparison of ECH efficiencies and power deposition profiles between experiments and simulations were extensively conducted, for fundamental and the 2nd harmonic ECH, and a discrepancy in the efficiency of 77GHz ECH systems are found between the experiment and simulation. It was also found that the efficiency of the ECH might be deteriorated by the coupling between Ordinary mode (O-mode) and extraordinary mode (X-mode) in the outer region from Last Closed Flux Surface (LCFS), where low density and steep magnetic shear region are existing on LHD. The optimization of the third harmonic heating was also conducted on LHD. By choosing plasmas which were sustained by radially injected Neutral Beam (NB) as target plasmas, the maximum absorption rate of 40% was achieved at the central electron density of ~1.5×10^{19}m^{-3} and the central electron temperature of ~1.5keV. This experimental result encourages us to apply the third harmonic EC heating for high-beta experiments at Bt=0.95T.

2) ICH

Optimization of ICH is also an important issue for LHD in achieving high performance plasmas since it is the major heating scheme for the steady state experiment on LHD and is also the possible second major heating scheme in high ion temperature experiments. During the 17$^{th.}$ cycle, a new ICH antenna, called FAIT, was installed and operated. The FAIT antenna was designed to have high loading resistance at the operation frequency of ~38.5MHz by using an impedance transformer installed inside the coaxial transmission line of antenna in the LHD vacuum vessel. The initial operation of FAIT antenna was quite successful. The obtained loading resistance is approximately 4Ω, which is almost the double of that of HAS antenna. The FAIT antenna also successfully reduced the heat load at the ceramic feed through which is installed at the port of LHD vacuum vessel. As a new technical approach of ICH, we have tested a Poloidail Array (PA) antenna without Faraday shield. It is generally thought that the impurity influx during the ICH is caused by the RF induced electric field which is parallel to the magnetic field. To suppress the electric field and, then, to reduce the impurity, the Faraday shield was believed to be necessary. We have conducted an experiment to evaluate the effect of Faraday shield on LHD plasmas by comparing the performance of plasmas which are sustained by ICH antenna with and without Faraday shield. No significant deterioration of plasma performance due to impurity influx was observed in the Faraday shieldless case. The achieved stored energy in the case of Faraday shield less antenna was almost comparable to that in the case of antenna with Faraday shield. This result allows us to have a simplified design for future ICH antenna by removing the Faraday shield.

3) EP confinement

Achievement of good EP confinement is an essential issue in realizing self-sustained plasmas by fusion born alpha particles. In evaluating the EP confinement, we have performed two kind of experiments. In one case, we have evaluated the EP confinement property without an influence of instabilities induced in LHD plasmas. A Si-dioded based Fast Neutral Analyzer (Si-FNA) was newly installed on tangential sightlines where radially injected Neutral Beam (NB) crosses. By using the radial-NB as an active source of neutrals, quantitative evaluation of EP became possible. The comparison of measured EP signals by Si-FNA with the EP simulations by TASK3D is now under process. In the other case, the interaction between EP and EP-induced instabilities, and the influence of the interaction on EP transport and bulk ion confinement properties were examined. On LHD, the excitation of EP induced Interchange mode was recently observed during high-Ti mode operation. It was found that the mode was excited by helically trapped EPs which were mainly produced by radially injected NBs. The radial transport of helically trapped EP was observed with the bursting mode activity. It was also found the electrostatic potential was changed drastically with the mode activity. This indicates that the radial electric field was formed by the enhanced radial transport of energetic particles. Control of an EP induced Alfven Eigen mode is also an interesting topic. The effect of ECH on AE are recently pointed out in some magnetically confined fusion devices[1]). We have also examined the effect of ECH on AE excitation on LHD and found some interesting phenomena of stabilizing and/or destabilizing EP induced instabilities with applying the ECH.

1) Van Zeeland, M. A., et al.: Nucl. Fusion 49 (2009) 065003