§15. Optimization of Helical System Concept

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The collaboration research between the Helitoron J group and other experimental groups such as the LHD and the CHS groups has been continued to understand machine-independent torus plasma confinement physics through the systematic study using the data obtained in this collaboration. The main purpose of this research is to promote experimental and theoretical studies based on the data of the improved confinement in Heliotron J and LHD/CHS for the optimization of helical confinement field aiming the control of the transport in the helical plasmas.

The five schemes for the collaboration research has been selected; (1) the database construction for plasma confinement, (2) the structure formation accompanying with the confinement transition [1, 2], (3) ECCD [3-6], EBW heating, (4) the production and confinement of high energy particles [7] and (5) the theoretical analysis of helical configuration optimization. Each group joined the plasma experiment and data analysis including the usage of fast internet for data exchange and analysis. For the collaboration of this year, we have put emphasis on the themes of the spontaneous transition in NBI plasmas, ECCD and the design of HIBP for turbulent transport study.

Spontaneous transition phenomena in NBI plasmas

Spontaneous transition like H-mode transition has been observed in ECH and/or NBI plasmas in Heliotron J. The relationship between the transition and the iota value has been observed in ECH plasmas. The delay time from the beam injection to the transition is increased with the decrease of the NB injection power, where the toroidal current is almost proportional to the injection power. However, the toroidal current at the beginning of the transition is constant and independent of the NB power for each configuration. It is because the current growth rate for the high power case is larger than that in the low power case that the threshold current is unchanged for various injection power cases. The threshold current value is 0.7 kA for the standard configuration and 1.3 kA for the high bumpy configuration. In low shear devices such as Heliotron J and W7-AS, the active control by using a non-inductive current such as an EC or a NB driven current should be important since rotational transform is changed by beta effect and bootstrap current.

Toroidal current drive

In the comparative study of second harmonic X-mode ECCD in Heliotron J and CHS, the control of the toroidal current is investigated for the various magnetic fields. A driven current depends on $N_{//}$, magnetic field strength, ripple structure and electron density. Although the field configurations are different, the resultant driven currents and its efficiencies are in the same order. The efficiency of the ECCD is considered to be controllable by the beam injection angle from the experimental results of Heliotron J, CHS and TJ-II. The efficiency of the ECCD is evaluated by $\gamma = n_e I_{EC} R / P_{EC} = 8 - 16 \times 10^{16}$ A/Wm^2, or $\zeta = 32.7 n_e I_{EC} R / P_{EC} T_e \approx 0.05$. These values are smaller than those of tokamaks, which have small field ripple. Trapped electrons may cause such results since Ohkawa effect should not negligible. In Heliotron J, a bootstrap current can be canceled by using an EC driven current since they are in the same order. Therefore, it is considered that ECCD could be used to keep the rotational transform as the vacuum condition. However, the further study is needed to keep the profile of the rotational transform from the view point of the MHD stability and local transport.

Design of the heavy ion beam probe (HIBP) in Heliotron J

The HIBP system design is performed to measure radial electric field and turbulent particle flux. Using thallium beam, whose maximum energy is 140 keV, the beam orbits which enable the detection from $\rho = 0$ to 1 are found by changing the injection point and the primary beam directions. The stray field of the detector area must be suppressed to ensure the detector performance. For this purpose, the vertical field design is changed and the analyzer is planned to be installed at the position where the distance from the exit of the vacuum chamber is 2 m. Detailed mechanical design is in progress.

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