7. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

NIFS Bilateral Collaboration Research Program on Heliotron J

The Heliotron J group at IAE, Kyoto University has joined the Bilateral Collaboration Research Program managed by National Institute for Fusion Science (NIFS) since FY2004. This unique collaboration program promotes bilateral research between NIFS and research institutes or research centers of universities that have facilities for nuclear fusion research. Under this collaboration scheme, the facilities operated in the different universities are open to all fusion researchers just as joint-use facilities of NIFS.

The main objective of the research in our Heliotron J group under this joint research program is to investigate experimentally/theoretically the transport and stability of fusion plasma in the advanced helical magnetic field and to improve the plasma performance through advanced helical-field control in Heliotron J. Picked up are the following seven key-topics; (1) magnetic configuration control for energy confinement, (2) production and confinement of high-density NBI plasmas and high-beta plasmas with novel fuelling methods, (3) electron thermal turbulent transport with self-criticality, (4) control of MHD and its physical mechanism, (5) edge plasmas in advanced helical systems, (6) production of energetic (MeV) electrons by non-resonant microwaves, and (7) development of new plasma diagnostics and analysis methods.

Two results from this collaboration research in FY2024 are shortly reported below. The annual report for all the collaboration subjects in this program will be published by NIFS.

Formation of internal transport barrier in NBI plasmas: Controlling heat transport is important to achieve high performance in magnetic confinement fusion plasmas. In stellarator/heliotron plasmas, a high electron temperature plasma with a steep electron temperature gradient (electron temperature transport barrier; e-ITB) formation in the plasma center has been observed at electron cyclotron heating (ECH). This is called CERC (Core Electron-Root Confinement) because a strong positive radial electric field (electron root) is formed near the core. Under such conditions, it is known that a characteristic strong positive radial electric field (Er) is formed.

In this study, we found that the heat transport was improved in the inner region by applying high intensity gas puffing (HIGP) to neutral beam injection (NBI) heating. We have measured the temperature profile with a Thomson scattering system and a charge exchange spectroscopy and evaluated the radial electric field by simulation. The plasma is heated with balanced NBI at an injection power of 280-290 kW. The gas puffing is abruptly switched off by applying a high-intensity gas puffing (HIGP) for a short period of 10 ms. After the HIGP injection, the Te profile shrinks and becomes more peaked. It then recovers to form an e-ITB structure with core Te of 370 eV. The difference is remarkable compared to the usual gas puff (GP) experiment. On the other hand, the ion temperature profile also sharpens with a similar time variation, but to a small degree.

The radial electric field calculated using the DKES PENTA code shows (i) a negative sign and (ii) no difference in the radial electric field compared to the normal gas puffing experiment, even in the peaked profile, suggesting that confinement is improved by a physical process different from that of CERC. We are currently investigating the relationship with lower-order rational surfaces.

L-H transition experiment: The H-mode transition, which improves plasma confinement performance in fusion plasmas, has been studied extensively. During the L-H transition, an increase in ExB shear flow and a decrease in turbulence amplitude have been observed in stellarator/heliotrons as well as in tokamaks. On the other hand, it has been frequently observed that the pedestal density gradient increases during the H-mode transition, but the temperature gradient remains unchanged. The lack of a temperature transport barrier suggests weak correlation between heat and particle transport in stellarator/heliotrons. The situation is similar to I-modes in tokamaks.

In this study, electron density and electron temperature fluctuations during the L-H transition of heliotron J have been measured simultaneously with a Doppler reflectometer and an electron cyclotron emission (ECE). The L-H transition occurs in high-density plasmas ($n_e > 1.5\times10^{19}$ m^{-3}) and is characterized by a change in the radial electric field, a decrease in the turbulence amplitude, and an increase in the pedestal density gradient only. The same characteristics as in previous studies have been observed: a change in radial electric field, a decrease in turbulence amplitude, and an increase only in the pedestal density gradient. Electron temperature fluctuation is observed at the frequency of about 15 kHz before the L-H transition. The density fluctuation amplitude measured with the reflectometer also oscillates at the same frequency, suggesting that this mode is nonlinearly coupled with the background turbulence. This mode also has a radial correlation length over the region, $0.2 < \rho < 1.0$. After the L-H transition, the amplitude of the density fluctuation decreases while the electron temperature fluctuation remains unchanged.