6. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

NIFS Bilateral Collaboration Research Program on Heliotron J

Since FY2004, the Heliotron J group at IAE, Kyoto University has joined the Bilateral Collaboration Research Program by National Institute for Fusion Science (NIFS), an Inter-University Research Institute. This unique collaboration program promotes joint researches bilaterally between NIFS and research institutes or research centers of universities that have unique 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 advanced helical-field, and to improve the plasma performance through advanced helical-field control in Heliotron J. Picked up in FY2020 are the following seven key-topics; (1) transport study concerning field configuration control and relating plasma structure formation control, (2) control of plasma profile, plasma flows, plasma current for confinement improvement, (3) investigation of structure formation of plasma fluctuations in core and peripheral region, (4) understanding of MHD instabilities of energetic particle modes and its control, (5) enhancement of operation region of high density plasmas, (6) optimization of particle supply and heating scenario, (7) development of new technology in experiment and analysis.

Two results from this collaboration research in FY2020 are shortly reported below. Annual report for all the collaboration subjects in this program will be published by NIFS.

Magnetic configuration dependence of energy confinement properties and profile structure formation: The Heliotron J device has a feature of high freedom of magnetic confinement configuration compared to other stellarator/heliotron devices. We so far clarified the effect of the toroidal mirror component in the magnetic field spectrum, so called, the bumpiness, on neoclassical transport, MHD and confinement of energetic ions. Recently we have installed plasma diagnostics for profile measurement in Heliotron J, which makes it possible to analyze the physical mechanism of the configuration dependence. In this fiscal year, we have extended the configuration control parameters, and have conducted experiments of the bumpiness control and the rotational transform control.

In the magnetic configuration control experiment, we have extended the bumpiness parameter from conventional low, medium and high bumpiness to higher bumpiness, that is, ultra-high bumpiness. We have measured electron density and temperature profiles with a Nd:YAG Thomson scattering diagnostic with the launching angle of electron cyclotron heating and the magnetic field strength are adjusted for on-axis heating. The line-averaged electron density is kept constant, $n_e = 1 - 1.2 \times 10^{19}$ m^{-3}. We have observed that the stored energy measured with a diamagnetic loop is maximal at the standard (medium bumpiness) configuration.

The hollow density profile may be related to trapped electrons. According to the TRAVIS code calculation, the population of the trapped electrons is higher as the bumpiness is higher, related to the magnetic ripple structure. The transport of the trapped electrons may be reduced, resulting that the electron density profiles is flatter. We need to perform neoclassical analysis and turbulence simulation analysis to clarify the relationship between the profile shape and the magnetic configuration.

Formation of electron internal transport barrier (e-ITB) in NBI only plasmas: e-ITB was observed in helical plasmas typically in ECH plasmas. On-axis ECH heating forms a positive radial electric field determined by the neoclassical transport, forming aa large electron temperature gradient with reduced thermal transport coefficient. This phenomenon has been observed in many helical devices including Heliotron J. On the other hand, in NBI plasmas, ion ITB has been observed, but no e-ITB has been never observed. In this experimental campaign, we have observed an e-ITB in NBI-only plasmas in Heliotron J for the first time. The NBI is injected in co and/or counter direction. When a high intense gas puffing (HIGP) is applied to an NBI plasma without ECH, the electron density and the stored energy increases, and the increasing rate is changed a little 20 msec after the HIGP. In this timing, the electron temperature gradient changes at $r/a < 0.3$, and the central electron temperature rises up to 0.6 keV. The electron density profile is not flat but centrally peaked. A multi-channel AXUV measurement shows that the intensity at the core region increases with the edge intensity kept low. In conventional gas puffing, on the other hand, no increase in electron temperature is observed, and the electron temperature is as low as 200 eV. We will study the physical mechanism of the e-ITB formation in NBI-only plasmas by controlling the external parameters such as magnetic configuration and HIGP intensity.