7. PROJECT 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 joint research bilaterally 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 in FY2022 are the following seven key-topics; (1) magnetic configuration control for energy confinement, (2) Confinement improvement by hydrogen pellet injection, (3) relation between structure formation and plasma fluctuations in the core and peripheral region, (4) physics mechanism of hydrogen pellet ablation, (5) optimization of particle supply and heating scenario, (6) development of new technology in experiment and analysis.

Two results from this collaboration research in FY2022 are shortly reported below. The annual report for all the collaboration subjects in this program will be published by NIFS.

Magnetic configuration control for energy confinement: The energy confinement dependence on rotational conversion in Heliotron J shows a negative trend, which is inconsistent with the ISS04 scaling. As an indicator of neoclassical transport, the stored energy is studied against the effective helical ripple ε_{eff}. Although a negative dependence on ε_{eff} appears, such a dependence may be determined by a result at the lowest ε_{eff} configuration. If we exclude this configuration result, we obtain a weak regression with a evaluation coefficient of R^2~0.2, which means that the data for most of the configurations cannot be explained by ε_{eff}. The contribution of turbulent transport is under evaluation.

Control of the rotational transformation can change the position and width of magnetic islands produced at the rational surface. The period of the magnetic island structure (m/n=7/4, 8/4, 9/4) can also be controlled by the rotational transform. When the magnetic island is shifted from the periphery to the core region, the confinement degradation is clearly visible in a certain range. A ultra-high-resolution ECE measured with a recently introduced ultra-fast oscilloscope in the GHz band enable us to observe the response to modulated ECH in the magnetic island configuration. Probe measurements of the fluctuations at the magnetic island and electric field measurements using a Doppler reflectometer are also in progress.

In the magnetic configuration control experiments, a principal component analysis has been applied to study the relation among the parameters that characterize the confinement. The bumpiness scan experiment can be summarized as follows: the first component (PC1) is the plasma volume, the second one (PC2) is the rotational transform, and the third one (PC3) is a parameter related to bumpiness. This means that the rotational transform scan experiments can be controlled independently of the bumpiness and aspect ratio. This method will be a useful tool for analyzing the results of configuration control experiments in which many configuration parameters are interdependent.

Physics mechanism during hydrogen pellet ablation: The density of pellet ablation cloud can be measured from the Stark broadening of the emission lines of the Balmer series, which is the emission of hydrogen. In the near-infrared region, the Zeeman effect on the Doppler broadening and the Stark broadening are relatively large compared to the visible region, and this can be a particularly useful tool for medium-sized devices such as Heliotron J. The polarization separation measurement of helium atoms by Zeeman spectroscopy has been proved to be a useful tool. For Stark broadening, in addition to the conventional emission of H_β lines in the visible region, the Pa-α lines of the Paschen series in the near-infrared region have been used. The Stark broadening of the emission from the dissolved cloud passing through the line of sight has been measured using a small, simple near-infrared spectrometer, and is found to be slightly above the lower limit of the spectrometer ($< 4\times10^{21}$ m^{-3}), which is about two orders of magnitude smaller than a reported value ($\sim10^{23}$ m^{-3}) in LHD. This means that measurements using multiple bandpass filters with different transparent bands are not applicable, suggesting the need for a different approach. Currently, we are developing i) a fast spectroscopy system to spatially track the density of the dissolved cloud through fast spectroscopy of the Stark broadening of the visible H_β line with increased resolution and using a high-speed camera, ii) a high-dispersion near-infrared spectroscopic diagnostic to simultaneously determine the Zeeman splitting, Stark broadening, and Doppler broadening, and iii) a near-infrared emission line intensity ratios to estimate the electron temperature of the ablation cloud.