# §13. Study of Confinement Improvement in Helical Devices

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Besides to expand our knowledge on the torus plasma physics, it is an urgent issue to find a path to improved plasma confinement in the helical system. In this collaboration, we are searching for effective scenarios to improve LHD plasma confinement through workshops for understanding the experimental and theoretical results from small heliotron devices (CHS (NIFS) and Heliotron DR (Kanazawa Inst. Tech.)) and a large device LHD. The results from advanced helical systems such as TU-Heliac (Tohoku Univ.), Heliotron J (Kyoto Univ.) and CHS-qa (NIFS) are also investigated.

In PY1999, in addition to discussions at 12th International Stellarator Conference (Madison, USA), 10th International Toki Conference (Toki) and other meetings, we had a joint symposium on "Prospect for Improvement of Plasma Confinement in Helical Devices" with Institute of Advanced Energy, Kyoto University at Uji from March 7 to March 8. (The program of this symposium is shown in Appendix)

ICRF heating experiments have been successfully performed in LHD. It seems the ion cyclotron damping is dominant to heat bulk ions in the central region. In ICRF heating, increase of radiation power is observed in many other devices. However, the radiation power is kept low level during ICRH phase in LHD. This might give us a hint to resolve impurity source problem during ICRF heating.

With good progress of the LHD experiment, it becomes interesting and important to discuss similarities and differences in plasma behavior between LHD and other small devices. From this point of view, the transition phenomena from (to) the ion-root to (from) the electron-root in NBI plasmas were discussed and concluded that the radial electric field can be explained by the neo-classical theory. This suggests that the observed anomalous transport should be ambipolar. The re-heat mode is observed also in LHD. This suggests strong dependence of the core plasma performance on the edge plasma condition.

As a common problem in magnetic confinement system, the role of the electric field and the advantages and disadvantages of perturbation magnetic fields were discussed including the results from tokamaks and mirrors. These lead us to re-recognize the importance of self-organization by plasma against external electric or magnetic fields.

The first plasma experiment in Heliotron J was performed in December 1999. Current-less plasmas have been produced successfully by 53.2 GHz ECH at B ~ 1.0 T ($P_{ECH} \leq 300$ kW, $\Delta t \leq 50$ ms). Scanning experiment of the confine field strength shows that the plasma production is possible at two magnetic field regimes. This may be related to the location of the resonant layer for the 2nd harmonic X-mode since the magnetic field strength along the magnetic axis has two maxima par a field period, which is different from that in conventional planar axis heliotrons.

The recent theoretical works show the possibility of configuration optimization by adjusting the Fourier components of the confinement field. Kyoto group will experimentally investigate the dependence of plasma confinement properties on the field configuration in Heliotron J. Tohoku group is also planning to study the effects of the bumpy field on plasmas in a heliac configuration. These devices can control the field configuration in a wide range. To study the configuration effect on the particle transport in helical systems, the simulation experiment by using electron beams is another interesting way. One of the key technologies of this kind of experiment is to control the pitch angle of the emitted electrons. Efforts to improve the pitch angle controllability are performed by Tohoku group.

**[Appendix: Symposium Program]**

"Prospect for Improvement of Plasma Confinement in Helical Devices",
IAE, Kyoto Univ., March 7-8, 2000

Session 1. Resent Results in Helical Devices
- 1-1 "ICRF Heating on LHD", T. Mutoh (NIFS)
- 1-2 "Reheat mode in LHD and comparison with CHS", S. Morita (NIFS),
- 1-3 "Transition from ion root to electron root in LHD", K. Ida (NIFS),
- 1-4 "Pitch angle distribution measurement of an electron mesh gun for an electron transport experiment in TU-Heliac", S. Kitajima (Tohoku Univ.),
- 1-5 "Effects of perturbing magnetic fields on the transport of charged particle and plasmas in Heliotron DR", S. Morimoto (Kanazawa Inst. Tech.),
- 1-6 "MHD behavior in heliotron configurations", T. Nakajima (NIFS),

Session 2. Improved Confinement in Tokamaks and Mirrors
- 2-1 "Ripple Reduction Experiment with Ferritic Insertion on JFT-2M", H. Kimura (JAERI),
- 2-2 "Improvement of confinement in the GAMMAIO tandem mirror", Y. Nakashima (Univ. of Tsukuba),
- 2-3 "Basic study on the interaction of rotating helical field with tokamak plasma", M. Kobayashi (Nagoya Univ.),

Session 3. New Helical Concepts
- 3-1 "Physics design of CHS-qa", S. Okamura (NIFS),
- 3-2 "Initial Experiments in Heliotron J", T. Mizuuchi (Kyoto Univ.),
- 3-3 "Collision-less particle confinement improvement by utilizing the bumpy field in helical-axis heliotron", M. Yokoyama (NIFS),

Session 4. Special Lecture
"Prospect for helical Fusion Reactors"
- 4-1 "Progress of the LHD Experiment", O. Motojima (NIFS),
- 4-2 "Present Status and future prospects of fusion engineering A & D", A. Kohyama (Kyoto Univ.),
- 4-3 "Present Status of TJ-II Helical axis Stellarator", J. Guasp (CIEMAT),
- 4-4 "Historical Review of Heliotron Research", A.Iiyoshi (Chuo Univ.)