§1. Effect of Active Control on Plasma Performance in Magnetically Confined Toroidal Plasmas

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In high-beta toroidal plasmas such as Spheromak (SP), Field Reversed Configuration (FRC), Spherical Tokamak (ST), and Reversed Field Pinch (RFP), various methods for active control have been applied to realize improvement of plasma performance or to control plasma dynamics during MHD relaxation. We can list up the methods such as magnetic helicity injection for current profile control, neutral beam injection for heating or density profile control, inductive current drive for current density profile control, magnetic boundary control for MHD stability manipulation, Compact Torus (CT) plasma injection for helicity injection, and so on. Each method for the control is intended to control plasma dynamics during the MHD relaxation and/or self-organization process which characterize the high-beta toroidal plasmas.

In this program, collaborative experiments will be conducted among HIST (SP) at Univ. of Hyogo, NUCTE (FRC) at Nihon U., TS-3 and 4 (SP, FRC, ST) and UTST (ST) at Univ. of Tokyo, and RELAX (RFP) at KIT, LHD at NIFS, with research topics related to active control. We also intend to enhance strong collaboration with theorists in the fields of dynamics of high-beta plasmas. Theoretical activities on particle simulation at Gunma Univ., 3-D MHD simulation at NIFS, two-fluid MHD equilibrium and stability at JCGA are included in this collaboration.
For the FY 2011, we performed some review trips for mutual understanding and discussion on the specific topics to be focused in our collaborative experiments, as well as to encourage young students to participate in this collaboration.

There follows a list of topics discussed in this year:
- JCGA - U-Hyogo: current drive mechanism by multi-helicity injection, two-fluid MHD equilibrium
- NIFS - KIT: 3-D MHD simulation for low-A RFP plasmas, relacation process to helical RFP
- Gunma-U – U-Hyogo: modeling of generation of high-speed neutral gas flow using CT acceleration technique
- Gunma-U – Nihon U – U-Tokyo: stability of FRC plasmas, NBI heating in FRC
- U-Tokyo – KIT: measurement of poloidal flow in helical RFP, momentum injection to RFP with NBI, SXR imaging for magnetic reconnection process
- U-Tokyo – U-Hyogo: physics of wave excitation process associated with magnetic reconnection, spectroscopic studies on relaxation process
- U-Tokyo – Nihon-U: NBI to ST, rotating magnetic field for steady state operation, RMF application, spectroscopic studies of spontaneously rotating FRC
- KIT – Nihon-U: imaging diagnostic for FRC plasmas
- U-Hyogo – Nihon-U: helicity injection to FRC using coaxial magnetized plasma gun
- U-Hyogo – KIT: CT injector design for momentum input

Figure 1 shows an example of the output from present collaboration. We have estimated fraction of the ionized particles in a hydrogen beam which is assumed to be injected horizontally into the RELAX plasma. The beam energy was assumed to be 5-kev, 10-keV, and 15-keV. The ionization fraction is plotted as a function of central electron density (parabolic density profile is also assumed). The figure shows that the ionization fraction of about 60% is expected when we inject 15-keV beam into RELAX plasma with central density of $2\times10^{19}\mathrm{m}^{-3}$. The fast ion orbit calculation has also been carried out to show that almost all the produced 15-keV ions can be trapped in RELAX plasma. Since the slowing-down time of the fast ions is about 0.4 ms for the assumed plasma parameters, we can expect some plasma response to NBI in RELAX plasmas. Since the line-averaged electron density is 0.1-$2.0\times10^{19}\mathrm{m}^{-3}$ with central electron temperature of ~100 eV (from Thomson scattering) in RELAX, we have started design study for low-energy (10-20 keV) NBI system for low-A RFP.

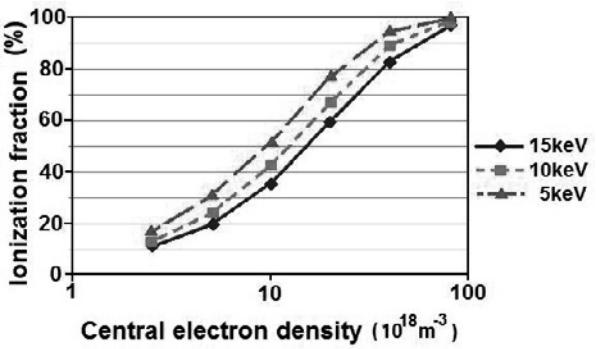

Fig.1 Dependence on density of ionization fraction of horizontally injected NBI particles in RELAX plasma.