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Experimental approach for understanding self-organized plasma transport in laboratory magnetosphere RT-1

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The RT-1 device realizes a laboratory magnetosphere generated by a levitated superconducting ring magnet. We have motivated stable plasma confinement with high beta and self-organized states in a simple dipole magnetic field. The strong inhomogeneity of the magnetic field strength originates diverse phenomena, which highlight the uniqueness of the magnetospheric confinement.

We observed the self-organization of a high-beta plasma clump with a steep density gradient; a peaked density distribution was spontaneously generated through the up-hill diffusion in RT-1[1]. The electron cyclotron heating with ~ 50 kW produces the high beta plasmas. The achieved local electron beta exceeds more than 1 [2] by the optimization of the EC heating and filling gas pressure. We found out the relation between the plasma beta and the measured magnetic loop signal by solving numerically the Grad-Shafranov equation for the magnetohydrodynamics equilibrium of magnetospheric plasmas.

For high ion beta, ion cyclotron heating is demonstrated in inhomogeneous magnetic fields. A simulation code optimizes the design of the antenna for slow wave excitation. The spectroscopic measurement observes the increase in ion temperatures and flow velocities [3, 4]. The electric field sensor has been developed [5] for the detection of excited electromagnetic waves with a few MHz. The measured wave intensity is comparable to that calculated by the numerical simulation in the confinement region. The new coherence imaging spectroscopy has been developed to visualize the ion heating effect. The ion temperature increases uniformly in RT-1 plasmas. We also found that the E×B drift dominates the measured ion temperatures and flow velocities in the toroidal direction.

Temperature anisotropy of trapped ions is observed in RT-1. Through the detailed analysis, we found a spontaneous heating mechanism [6] concomitantly occurring with the up-hill diffusion caused by inhomogeneous magnetic field toward the dipole.

For understanding the internal structure of electrons and the contribution to a high beta plasma in a self-organized plasma, the x-ray radiation-detectors are implemented in RT-1 to measure the spatial profiles of the high-energy electrons. From the former study [2], the high energy electrons with ~ 50 keV were produced in the high beta plasmas of RT-1. In the case of the local electron beta (~ 0.2), the profiles of the electrons and the high-energy electrons are shown in Fig. 1. We found that the high-energy electrons with the energy of 3-15 keV forms the belt structure spontaneously in outer confinement region, which is analogous to naturally formed radiation belt in magnetospheres. Although the peak density of the high-energy electrons is ~ 4 % compared with that of the electrons, the high-energy electrons dominate the high beta in the confinement region. The electrons measured by interferometers in Fig. 1 have the temperature of a few ten eV from the helium line ratio spectroscopically. The electrons with a low energy around a few ten eV and a high energy around a few ten keV are populated with the spatial structures in magnetospheric plasmas.

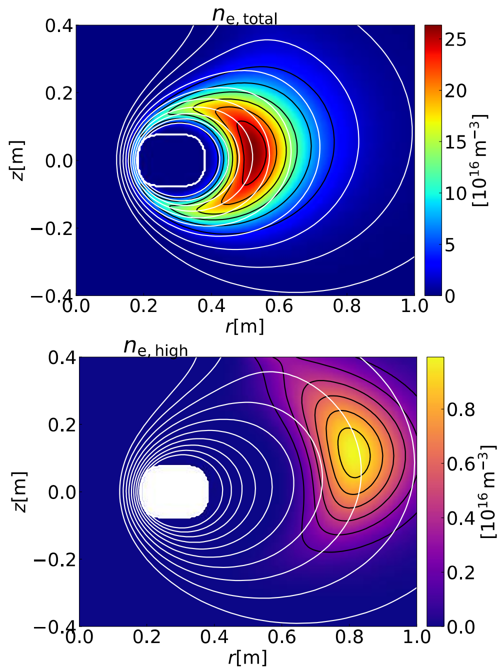

Figure 1 Profiles of electrons (upper figure) measured by the interferometers and high-energy electrons (lower one) by the x-ray detectors. The spontaneous formation of electron belt structure is observed.

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