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Experimental Physics of Magnetospheric Plasma in RT-1

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The plasma experiments were performed on the Ring Trap 1 (RT-1) device, which creates a *laboratory magnetosphere* realized by a levitated superconducting ring magnet. The stable high-beta (> 1) confinement with high-temperature electrons (T_e > 10 keV) and the ion cyclotron resonance of frequency (ICRF) heating in a dipole magnetic field of the RT-1 device are successfully demonstrated [1, 2]. In recent five years, we have made major progresses in the physics of high electron beta, ion heating, and understanding of their mechanisms. These findings in the laboratory magnetospheric plasmas are described.

Naturally-made magnetospheres, as ubiquitously created in the Universe, demonstrate stable, and often high-beta confinement by 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 observe the self-organization of a high-beta plasma clump with a steep density gradient. The underlying mechanism of the self-organized plasma is explained by the topological constraint on magnetized particles [3, 4].

The operation regime of RT-1 was extended in density and beta, as shown in Fig. 1. Upgrading the injection power of the electron cyclotron (EC) heating system from 25 kW to 50 kW [1] extends the operation regime of RT-1, and thus the local electron beta exceeds more than 1 [2] by the optimization of the EC heating and filling gas pressure. The beta value is evaluated numerically by solving the Grad-Shafranov equation to obtain the magnetohydrodynamics equilibrium of magnetospheric plasmas [5].

Temperature anisotropy of trapped ions is observed in RT-1, as shown in figure 2. Through the detailed analysis, we found a spontaneous heating mechanism concomitantly occurring with the up-hill diffusion [6] caused by inhomogeneous magnetic field toward the dipole. The simulation supports the up-hill diffusion in magnetospheric plamas [4]. Excitation of coherent, chirping ion-cyclotron waves have been observed when the high-temperature electrons are dominant [7].

High ion pressure (> 0.1) is expected to generate spontaneous flow, and onsets nonlinear structures (the Bernoulli-Beltrami state). To realize this state, we developed a system for the ICRF heating, and demonstrated the increase in ion temperatures for the first time [8] as well as in flow velocities [9] by exciting the slow wave in magnetospheric configuration. The RF electric fields in plasmas are examined to understand the wave excitation, propagation, and absorption in inhomogeneous magnetic field by comparing with the simulation. The intense RF electric field outside the last closed flux surface is observed, compared with the simulation of TASK/WF2 code. The electrostatic wave might be excited near the RF antennas. Further investigation would explain the wave field formation.

References

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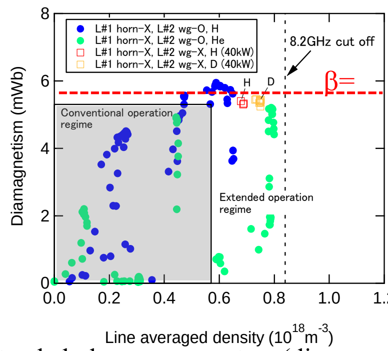

Figure 1 Extended plasma parameters (diamagnetism and line averaged density) for H, D, and He in the dipole configuration by the levitated superconducting coil of RT-1 [2]. The conventional (gray area) and extended operational regimes are plotted.

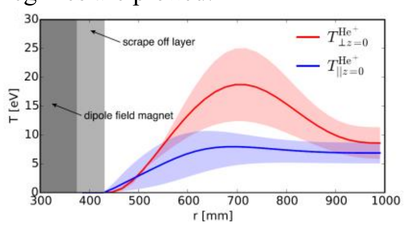

Figure 2 Temperature anisotropy of ions measured by He II line on the equatorial plane of RT-1 in helium plasma [6].