Confinement of a toroidal non-neutral plasma in magnetic dipole

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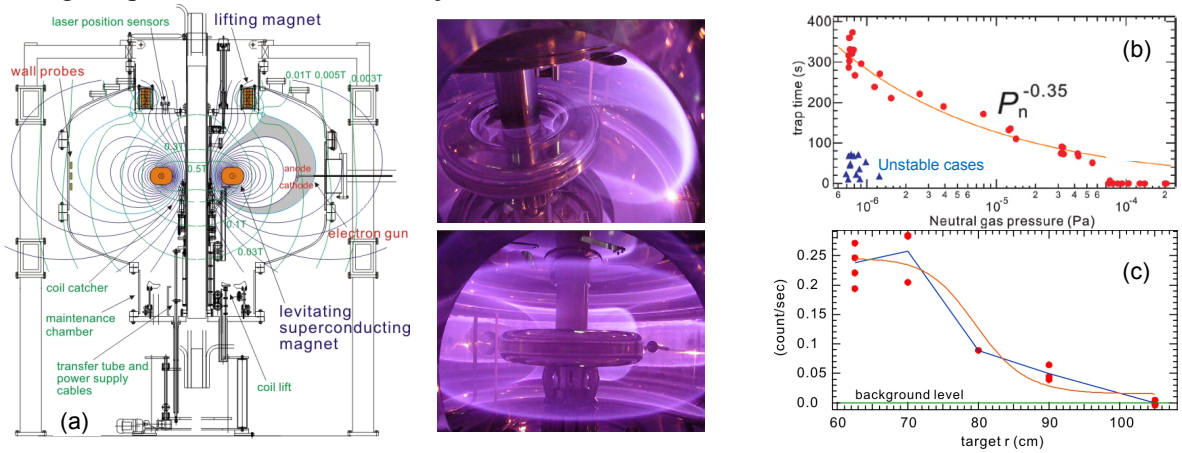
Aiming for the stable confinement of toroidal non-neutral plasmas, we have conducted electron plasma experiment in the Ring Trap 1 (RT-1) device [1]. RT-1 is a laboratory magnetosphere, a dipole field configuration generated by a levitating superconducting magnet. In an axially symmetric dipole field, the canonical angular momentum of a trapped charged particle is conserved, and particle motions are localized on magnetic surfaces. By magnetically levitating the dipole field magnet without using mechanical support structures [2], one can produce axisymmetric, closed, and unperturbed magnetic surfaces. Thus excellent confinement of non-neutral plasmas is expected in the dipole field configuration. Another important issue for the formation of toroidal non-neutral plasmas is particle injection method. Although particles may be stably trapped inside the closed magnetic surfaces, they must be injected from outside of the confinement region prior to the trapping phase. In RT-1, we have demonstrated effective inward particle diffusion and stable confinement of a pure electron plasma for more than 300s [1,3]. When the plasma is in turbulent state during beam injection, plasma flow has a shear, which activates the diocotron (Kelvin-Helmholtz) instability. The canonical angular momentum of the particle is not conserved in this phase, realizing the radial diffusion of charged particles across closed magnetic surfaces. In the stable confinement phase, spontaneous formation of a rigid-rotor equilibrium state was observed. As well as the understanding of fundamental relaxation processes of charged particles, the dipole configuration may be applied to antimatter physics [4]. In contrast to linear configurations, toroidal traps can confine multiple-component plasmas, even with opposite-sign charges. Simultaneous confinement of electrons and positrons enables experiments on pair plasmas, and in the future, it can potentially be used for very interesting topics, laboratory studies of electron-positron plasma in space phenomena. We have started positron injection experiment in RT-1 with a small (1MBq) Na-22 source. Preliminary experiment showed that energetic positrons have closed trajectories in RT-1.



(a) Cross section of RT-1 and visualized magnetic surfaces. (b) Confinement time of electron plasma and (c) spatial profile of 511keV γ-ray count rate when Na-22 source was at r=80cm.

[1] Z. Yoshida *et al.*, Phys. Rev. Lett. **104**, 235004 (2010).
[2] Y. Yano *et al.*, Fusion Eng. Design **85**, 641 (2010).
[3] H. Saitoh *et al.*, Phys. Plasmas **17**, 112111 (2010).
[4] Z. Yoshida *et al.*, in *Non-neutral Plasma Physics III* (AIP Conf. Proc. **498**), 397 (1999).