§19. Spectroscopic Measurement of Cold Electron Temperature and Density in the Magnetospheric Device RT-1

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A magnetospheric plasma experiment has been conducted in the ring trap 1 (RT-1) device. The levitated superconducting magnet demonstrates a stable high β plasma confinement together with intriguing astrophysical phenomena provoked by inward diffusion, such as a peaked density and a particle acceleration. The plasma in RT-1 consists of ions ($\sim 10\,\text{eV}$), cold electrons ($\sim 50\,\text{eV}$), and hot electrons ($\sim 10\,\text{keV}$). In typical high β plasma, the hot electrons occupy about the half of the total electrons. The hot electrons contribute to the significant part of the β, and the cold electrons determine the energy balance on ions (the hot electrons are decoupled from the ions because of the long equipartition time). Whereas hot electron density and temperature are measured via interferometry and X-ray spectroscopy, we had not measured the cold component in a confinement region on high β operation.

In this study, we estimated cold electron temperature (T_e^{cold}) and density (n_e^{cold}) by a helium line ratio method [1] with ADAS program [2]. T_e^{cold} may be estimated by commonly used He I line ratio 728.3/706.5 nm. However, the other commonly used He I line ratio 667.9/728.3 nm is not available for estimating n_e^{cold} since the typical plasma density in RT-1 is less than $10^{18}\ \text{m}^{-3}$ for which 667.9/728.3 nm ratio loses the sensitivity to n_e^{cold}. We investigated several He I line pairs and figured out that 501.8/471.3 nm ratio gives a plausible n_e^{cold}.

Figure 1 shows two dimensional spatial profiles of T_e^{cold} and n_e^{cold} estimated by 504.8/492.2 nm and 501.8/471.3 nm ratios respectively. The profiles are reconstructed assuming that T_e^{cold} and n_e^{cold} are functions of a magnetic flux and a magnetic field strength [3]. The results show that T_e^{cold} has nearly flat spatial profile and n_e^{cold} has vertically thin and radially elongated profile. n_e^{cold} profile is consistent with that reconstructed from the interferometry.

Figure 2 illustrates a dependence of T_e^{cold} on a local maximum β which is estimated by a diamagnetic current measured by flux loops and MHD equilibrium calculated by Grad–Shafranov solver [4]. T_e^{cold} is a linear function of β. When the superconducting magnet is levitated, T_e^{cold} shows a weak dependence on β whereas T_e^{cold} strongly depends on β for a mechanically supported operation. This interprets that coupling between hot and cold electrons are weak for the levitated operation and strong for the supported operation.

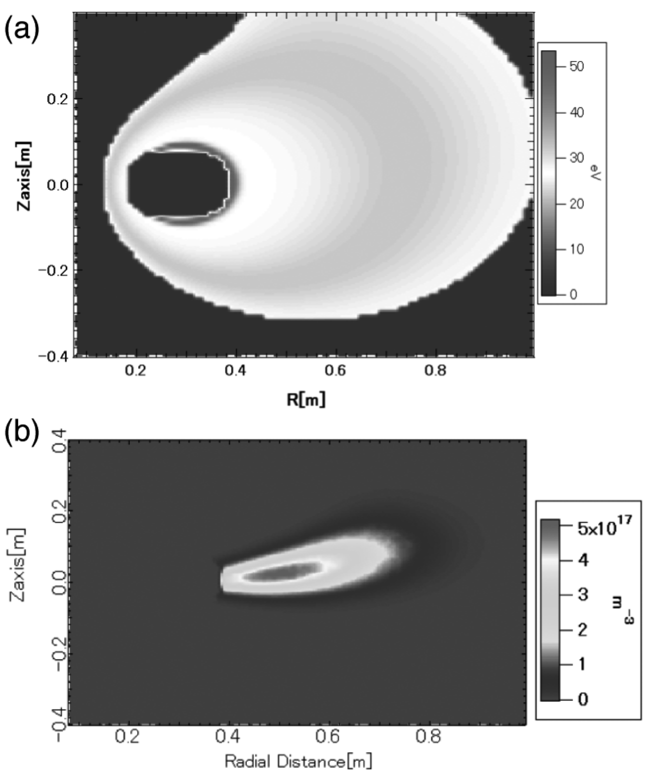

Fig. 1: Two dimensional spatial profiles of (a) T_e^{cold} estimated by 504.8/492.2 nm ratio and (b) n_e^{cold} estimated by 501.8/471.3 nm ratio.

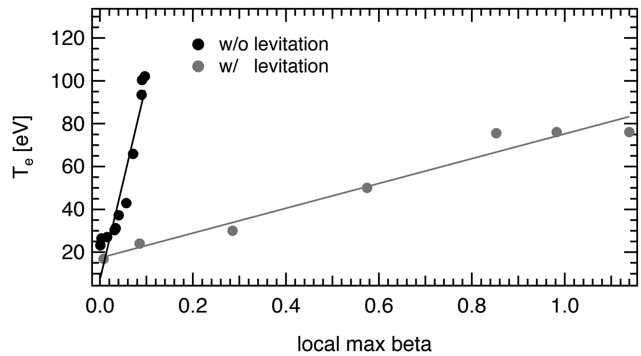

Fig. 2: Dependence of T_e^{cold} on local maximum β with and without levitation of the superconducting magnet.

1) Schweer, B. *et al.*: J. Nucl. Mater. **196-198** (1992) 174.

2) Summers, H. P.: The ADAS User Manual, version 2.6, http://www.adas.ac.uk (2004).

3) Saitoh, H. *et al.*: Phys. Plasmas **22** (2015) 024503.

4) Furukawa, M.: Phys. Plasmas **21** (2014) 012511.