8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Direct measurements of space potential and fluctuations by using a ball-pen probe in high-density helicon plasma

D. Di Matteo[1], Y. Nagashima[2,4], A. Fujisawa[2,4], T. Nishizawa[2,4], T. Yamada[3,4], and C. Moon[2,4]

[1] *Interdisciplinary Graduate School of Engineering Sciences, Kyushu University*
[2] *Research Institution for Applied Mechanics, Kyushu University*
[3] *Faculty of Arts and Science, Kyushu University*
[4] *Research Center for Plasma Turbulence, Kyushu University*
e-mail (speaker): dimatteo@riam.kyushu-u.ac.jp

In the study of plasma turbulence, being able to perform direct measurements of space potential is indispensable for the evaluation of quantities like heat and particle fluxes in magnetized plasmas. The ball-pen probe (BPP), a particular Langmuir probe (LP), has been developed and is nowadays widely used to measure the space potential ϕ_s and the electron temperature T_e in magnetized plasmas [1, 2]. Hence, we have conducted a feasibility study of a BPP installed in Plasma Assembly Non-linear Turbulence Analysis (PANTA) device, at an axial position z = 1.1 m from the helicon plasma source. The working principle of a BPP is to reduce the electron saturation current I^-_{sat} until it reaches the ion saturation current I^+_{sat} level by exploiting the difference between the Larmor radii of electrons and ions, such that the floating potential ϕ_{Bf} of the BPP equates the value of the plasma space potential ϕ_s. Furthermore, T_e can be determined by using the ϕ_f of BPP and a Langmuir probe (LP), since the relation between the ϕ_s and ϕ_f of an electrostatic probe is given by $\phi_s = \phi_f + \alpha T_e$, with $\alpha = \ln (I^-_{sat} / I^+_{sat})$. This should permit a direct measurement of ϕ_s, T_e and their relative fluctuations in the linear magnetized device PANTA.

Comparative measurements of space potential and electron temperature radial profiles were performed by the BPP, and a LP used as a reference diagnostic in the same probe array. Figure 1 demonstrates a strong correlation between the measurements of two probes in helicon plasmas. However, the probe is not properly centered relative the core, and the uncertainty of its radial position will be investigated in detail. Moreover, discrepancies arise in the closest region to the core that can be attributed to electrons entering the tube through $E \times B$ drifts strictly depending on the Hall parameter for ions $\beta_i = \omega_{ci} / \nu_i$ [3], which is the ratio between the ion cyclotron frequency and the ion collision frequency. Figure 2 illustrates that β_i is significantly less than one in the very high-density region generated by the PANTA helicon source. There, the ion dynamics is heavily influenced by collisions, creating a positive space charge inside the shielding, which generates a strong electric field at the entrance of the tube causing the electron drift [4]. The larger its diameter the larger the electric field. In fact, the probe will soon be equipped with smaller collector and tube diameters.

A preliminary spectral analysis of plasma potential turbulent fluctuations reveals notable differences between the floating potential fluctuations measured by LP and BPP at r = 6 cm. These differences are attributed to noise arising from finite temperature fluctuations.

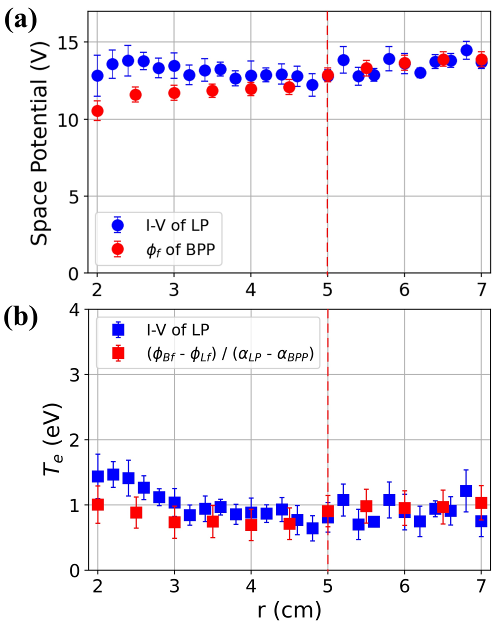

Fig. 1 Radial profiles of (a) space potential and (b) electron temperature obtained with BPP (red) and LP (blue), for B = 0.1 T, p_n = 0.36 Pa, P_{RF} = 3 kW. Dashed line is the radius of the source tube.

References

[1] J. Adámek *et al.*, Contrib. Plasma Phys. **53**, 39 (2013).
[2] F. F. Chen, Lecture notes on IEEE-ICOPS meeting (2003).
[3] G. Bousselin *et al.*, Rev. Sci. Instrum. **84**, 013505 (2013).
[4] M. Komm *et al.*, Plasma Phys. Control. Fusion **53**, 015005 (2011).

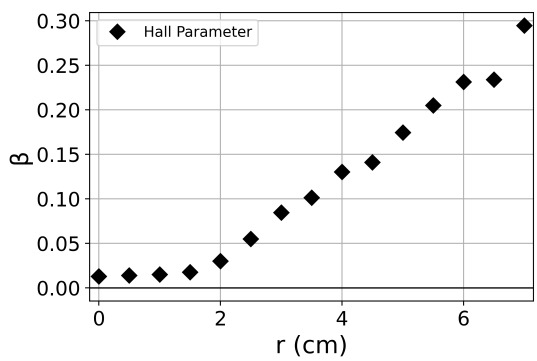

Fig. 2 Radial profile of the ion Hall parameter $\beta_i = \omega_{ci} / \nu_i$ in the PANTA plasma. Ion acoustic velocity was used to calculate the ion-ion collision frequency ν_i.