Seminar

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Institute for Plasma Research

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Title: Study of the Dynamics of Cross-Field Diffusion and Turbulence in a Magnetically Screened High-Beta Plasma

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Date: 11th September 2025 (Thursday)

Time: 03:30 PM

Venue: Seminar Hall, IPR

Abstract

Pressure-gradient-driven Electromagnetic (EM) drift-wave fluctuations were observed in the target plasma of the Large Volume Plasma Device–Upgrade (LVPD-U). While drift-wave turbulence modes are conventionally regarded as electrostatic, our measurements demonstrate a strong electromagnetic character. With increasing plasma beta, density fluctuation levels decrease whereas magnetic fluctuation amplitudes increase, and cross-correlation coefficients between density fluctuations ($\tilde{n}_e$) and magnetic fluctuations (δB) reach values ~ 0.8, confirming magnetic behavior. The fluctuations shows a frequency range of $\sim 6 - 13$ kHz with typical perpendicular wave numbers $k_\perp \approx 0.13\ cm^{-1}$, propagating in the electron diamagnetic drift direction with phase velocity $v_{ph} \sim 3.3 \times 10^3$m/s. These observations identify the modes as pressure-gradient-driven electromagnetic drift turbulence. In conclusion, we predict that these modes may be coupled with other low-frequency branches such as lower-hybrid, Alfvén, or magneto-sonic modes, consistent with theoretical expectations and previous studies of drift−EM coupling in high-β plasmas.

Systematic investigations of time-dependent density diffusion in LVPD-U reveal distinct behaviours: decay of plasma density in the core and simultaneous buildup in the edge region, both regulated by the transverse Electron Energy Filter (EEF) field. To quantify the underlying transport, two-dimensional Mach probes were employed to measure plasma flow vectors in axial and radial directions. The results show that cross-field diffusion dominated by radial gradients and fluctuations, exceed parallel diffusion by several orders, establishing perpendicular transport as the primary mechanism inside the EEF.

The temporal decay of ion saturation current was modelled with a nonlinear time-dependent density function,$T = T_0\left[1 + \left(\frac{T_0 t}{\tau}\right)\right]^{-\alpha}$, where τ is the decay constant and α is an empirical exponent. Experimental fitting demonstrates that α increases with the transverse magnetic field B_X, reflecting nonlinear scaling in the diffusion process. Consequently, the effective diffusion coefficient is expressed as $D_\perp^{exp} \approx \frac{\alpha L_n^2}{\tau_d} \approx 1.6 \times 10^5 cm^2/s$, and is typically two orders of magnitude larger than the classical prediction $D_\perp^{classical} \sim \frac{\nu_{ei}\rho_e^2}{1+\frac{\omega_{ce}^2}{\nu_{ei}^2}} \approx 7 \times 10^3 cm^2/s$. These findings highlight that turbulence-driven and nonlinear processes govern the anomalous, time-dependent density diffusion in the target plasma of LVPD-U.

References:

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[8] J. D. Huba, *NRL Plasma Formulary* (Naval Research Laboratory, latest ed.) -- lower-hybrid, Alfvén, and magnetosonic wave parameters.