Seminar

===

Institute for Plasma Research

===

Title: Effect of plasma-driven magnetohydrodynamic activity and pulsed gas-injection on edge plasma turbulence in ADITYA-U tokamak

Speaker: Mr. Kaushlender Singh
Institute for Plasma Research, Gandhinagar

Date: 08th January 2026 (Thursday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

Abstract

In tokamak plasmas, the understanding, and the controlling capability of turbulence in the plasma edge and scrape-off layer (SOL) regions are crucial for the development of magnetic confinement fusion reactors. In these regions, the free energy associated with the gradients in mean temperature, density, and potential (∇T_e, ∇n_e, and ∇V_p) induce several instabilities leading to fluctuations in these quantities which display turbulent and intermittent characteristics. The turbulence in the edge region significantly impacts the radial transport of particles and heat across the LCFS whereas the SOL turbulence significantly influences the heat and particle fluxes to the material boundaries (limiter/divertor) of tokamak.

In this thesis work, the edge/SOL region of limiter discharges of ADITYA-U tokamak is characterized by means of specially designed Langmuir probes with fixed and reciprocating drives. Systematic and exhaustive measurements in the edge/SOL region of typical discharges of ADITYA-U tokamak, revealed a turbulent nature of the density and potential fluctuations in edge region whereas the SOL region demonstrates an intermittent behaviour. To investigate the role of neutral atoms on turbulence and intermittency in the edge/SOL region of tokamaks, fuel gas neutrals are injected in form of short pulses in the SOL/edge region of ADITYA-U. It has been observed that the gas-injection leads to flattening of radial profiles of mean density and potential in the edge region, resulting in reduction in their fluctuation amplitudes. Interestingly, although the intermittency increases in the edge region following gas-injection, the overall confinement increases. Further investigation discovered that the neutral gas injection modifies the edge/SOL transport primarily through changes in electric fields rather than the blob characteristics alone, providing a mechanism to regulate turbulence-driven transport.

The magnetic perturbations are also known to modify the edge turbulence. In this thesis, an effect of magnetic perturbation generated by plasma-driven (internal) magnetohydrodynamic (MHD) activity on edge turbulence is explored and impact of internal MHD activity on edge turbulence is experimentally demonstrated. It has been observed that the MHD modes, mainly the m/n = 2/1, beyond an amplitude threshold value of $\tilde{B}_\theta / B_\theta \sim 0.3 - 0.4$ %, excite coherent oscillations in the density and potential having the same frequency as the MHD mode. Interestingly, the mode investigation of the excited mode reveals that the coherent mode in edge potential fluctuation has a mode number of m / n = 2 / 1 whereas the edge density fluctuation has a mode number of m / n = 1 / 1. The coupling of even harmonics of potential to the odd harmonics of pressure is due to 1/R dependence of the toroidal magnetic field. Furthermore, the MHD induced coherent modes result in a reduction in edge turbulence and associated transport. This is contrary to the expectation of a detrimental effect on confinement due to enhanced MHD modes and indicates towards self-healing of discharges.

In summary, this thesis work demonstrates that neutral gas injection modifies edge turbulence and transport primarily through changes in electric fields, leading to reduced radial blob transport despite increased intermittency. Furthermore, internal resistive MHD modes above a threshold amplitude drive coherent oscillations with GAM-like properties, which suppress broadband turbulence and decrease cross-field particle flux.
