Seminar

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Institute for Plasma Research

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Title: Studies on intrinsic plasma disruptions, plasma detachment and confined runaway electrons in Aditya-U Tokamak

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Date: 12th December 2025 (Friday)

Time: 02:30 PM

Venue: Seminar Hall, IPR

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Abstract

Tokamak plasma disruptions, detachment and the dynamics of runaway electrons remain as major challenges towards realizing a successful tokamak-based fusion reactor. Sawtooth instability, an internal disruption, leading to a sudden degradation of core-plasma confinement, needs to be controlled for various reasons related to heat-transport and impurity accumulations. In this thesis work, a novel mechanism for controlling the sawtooth period in ADITYA-U has been demonstrated by applying short fuel-gas pulses at the plasma edge. The short bursts of gas-injection effectively stabilizes sawteeth, with the degree of stabilization controlled by the amount of injected gas. This method for controlling sawtooth period provides a simple and cost-effective tool to understand the sawtooth crash mechanism, particularly in small and mid-sized tokamaks. Furthermore, this control mechanism manifested that the sawtooth crash mechanism in ADITYA-U is caused by formation of a critical temperature gradient near the q = 1 surface, a marked departure from the conventional paradigm.

In addition to the internal disruptions (sawtooth), the cause of major disruptions occurring during the plasma-current ramp-up phase has been identified. After analyzing hundreds of discharges, it has been established that the disruption during the current ramp-up phase is triggered when the rate of rise of plasma current crosses a threshold value. To prove further, avoidance of these disruptions are experimentally demonstrated by controlling the plasma current rise-rate in real time using gas-injection through a DSP-controller-based hardware system.

It is quite well know that to protect the plasma facing components, plasma boundary should be kept in detached state. However, detached plasmas are prone to disruptions due to their inherent production mechanisms using density ramp-up or current ramp-down and/or gas-injection etc. This thesis work demonstrates that detached plasmas without disruption can be achieved if periodic short detached states are produced instead of a continuous detached state. In ADITYA-U, periodic short detached plasma states are obtained using periodic fuel gas injection in short bursts. These periodic detached states are thoroughly characterized using extensive experimentation with several standard and especially developed diagnostics. Thorough analysis revealed that modification of radial electric field is the most plausible cause of attaining a detached state instead of momentum loss or recombination at the edge due to gas-injection. To further verify and establish the role of radial electric field in producing detached plasma state, the radial electric

field in the edge region of ADITYA-U is modified using a biased electrode. The detached states are obtained with modifying the radial electric field which unambiguously corroborates the role of radial electric field in attaining the detached plasma states in tokamaks.

Any disruption study remains incomplete without assessing the behavior of runaway electrons as internal, minor, or major disruptions are always known to produce runaway electrons. A dedicated hard x-ray monitoring system has been developed to detect thin-target bremsstrahlung emission from ADITYA-U and the dynamics of confined runaway electrons particularly those correlated with sawtooth crashes are investigated and studied.