Seminar

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Institute for Plasma Research

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Title: Study of electron dynamics in tokamak plasma through Electron Cyclotron (EC) emission using Radiometer

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Date: 14th November 2024 (Thursday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

Abstract

The study of both thermal and non-thermal electron dynamics is essential for characterizing tokamak plasma. One key parameter, the thermal electron temperature, is critical for achieving and sustaining controlled fusion, influencing particle confinement, collisional transport, and energy transport. Recent advances in instrumentation, particularly Electron Cyclotron Emission (ECE) techniques such as the Michelson Interferometer and Radiometers, have been widely used to measure this parameter. Radiometers are known for providing localized temperature measurements with high spatial (≤1 cm) and temporal (≤10 μs) resolutions, using microwave sensors that operate at room temperature. These features make radiometers well-suited for localized plasma electron temperature measurement.

A significant challenge in ECE diagnostics arises from the dependence of cyclotron frequencies on toroidal magnetic fields (B_T), which vary across different experimental scenarios. Existing solutions like wideband and sweep sources, though effective, are costly and complex, highlighting the need for innovative, cost-effective diagnostic techniques that can operate across a range of (B_T) values. This research introduces a simple yet uncommon design consisting of an integrated high-frequency RF (radio frequency) unit and a fixed low-frequency IF (intermediate frequency) unit. By varying the RF unit while keeping the IF unit fixed, this design enables precise ECE measurements across diverse toroidal magnetic field ranges, offering a simpler and more adaptable approach to ECE diagnostics [1]. Using the newly developed ECE radiometer, spatially and temporally resolved plasma electron temperature measurements can be obtained.

Using this system, the effects of kinetic instabilities on ECE signal from runaway electrons (REs) were investigated in low-density ($n_e \leq 1x10^{19}$ m^{-3}) plasma discharges at ADITYA-U tokamak. The 16-channel broadband ECE radiometer detected single &/or multiple step-like increase of 20-40% in signal amplitude within microseconds, along with occasional step modulations, observed for the first time at ADITYA-U tokamak. Pitch Angle Scattering (PAS) of REs, triggered by kinetic instabilities, is a likely cause of this sharp rise in ECE signatures [2]. PAS can increase synchrotron radiation, lowering the radiative energy limit of REs by transferring parallel momentum ($P_{\|}$) to perpendicular momentum ($P_{\perp}$), and thereby enhancing ECE radiated power. This makes the ECE radiometer useful for studying PAS events, which may possibly limit on-axis runaway electron energy depending upon plasma parameters, offering a potential method for runaway mitigation.

Preliminary ECE radiometer data indicates that gas puffing, often used to increase plasma density; significantly affects PAS events, potentially altering their timing or even preventing them. The PREDICT code (Production of Runaway electrons and Energy Dynamics in Tokamaks), based on the relativistic test particle model, simulates these observations for the first time. Experimental support for the observations is obtained from $LaBr_3$ (Ce) Hard-X-ray spectrometer. A database of PAS events has been compiled, investigating discharge parameters to predict and pre-estimate their occurrence. The trigger conditions identified in this database have been used as input to the PREDICT code, yielding results consistent with ECE observations [3]. This study could pave the way for novel methods of runaway electron mitigation using PAS.

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*1***. *Varsha Siju*** et al Journal of Instrumentation **16** P10020, (2021).
2. ***Varsha Siju*** et al Rev. Sci. Instrum. **93** 113529, (2022).
3. ***Varsha Siju***, et.al. Plasma Science and Technology, **26** 115101, (2024).