Seminar

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Institute for Plasma Research

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Title: Study of ECR-Produced Plasma Relevant to Fusion Devices

Speaker: Mr. Tulchhi Ram
Institute for Plasma Research, Gandhinagar

Date: 24th December 2024 (Tuesday)

Time: 03:30 PM

Venue: Seminar Hall, IPR

Abstract

Electron Cyclotron Resonance[1] (ECR) plays a pivotal role in plasma generation and sustainment, especially in the context of fusion devices like tokamaks and stellarators. Through efficient wave-particle interactions, ECR enables critical processes such as pre-ionization, wall conditioning, and current drive. This thesis focuses on advancing the understanding of ECR-produced plasmas, particularly in low-aspect-ratio geometries, nonlinear wave-particle interactions, and mode conversion mechanisms.

Experimental studies were conducted in the Simple Tight Aspect Ratio Machine Assembly (STARMA[2]) device, a custom-built low-aspect-ratio plasma system designed for precision diagnostics and flexible parameter tuning. These experiments explored plasma density and temperature profiles under varying magnetic fields and wave-launching conditions. Notable findings include the high efficiency of O-X-B mode conversion[3] and its sensitivity to magnetic field gradients and density variations.

Complementing the experimental work, full-wave simulations[4] were performed using the Finite-Difference Time-Domain (FDTD) method, investigating wave propagation and absorption in magnetized plasmas. Further nonlinear wave particle intraction[5] in high power ECR beams revealed the importance of factors such as beam width, frequency mismatch, and magnetic field gradients in optimizing ECR wave absorption. The nonlinear trapping of electrons near resonance layers was identified as a key mechanism for enhancing energy transfer in low-temperature plasmas.

The integrated approach of this study combining theoretical modelling, experimental diagnostics, and numerical simulations offers a comprehensive framework for improving ECR system performance, particularly to see the feasibility of X-mode launching from the LFS or through efficient O-X model conversion. The findings provide actionable insights into optimizing ECR-assisted processes, from pre-ionization and wall conditioning to efficient plasma heating, with applications in devices such as ITER, ASDEX-U, and TCV. By bridging gaps in existing analytical models and experimental observations, this thesis contributes to the broader goal of achieving reliable and efficient plasma production and sustainment through ECR processes in fusion devices.

References:

[1] M. Bornatici, "Theory of electron cyclotron absorption of magnetized plasmas," *Plasma Physics*, vol. 24, no. 6, pp. 629–638, 1982, doi: 10.1088/0032-1028/24/6/005.
[2] T. Ram *et al.*, "Simple Tight Aspect Ratio Machine Assembly to Study ECR-Produced Magnetized Toroidal Plasma," *IEEE Transactions on Plasma Science*, vol. PP, pp. 1–10, 2024, doi: 10.1109/TPS.2024.3435375.
[3] A. K. Ram and S. D. Schultz, "Excitation, propagation, and damping of electron Bernstein waves in tokamaks," *Phys Plasmas*, vol. 7, no. 10, pp. 4084–4094, 2000, doi: 10.1063/1.1289689.
[4] A. F. Oskooi, D. Roundy, M. Ibanescu, P. Bermel, J. D. Joannopoulos, and S. G. Johnson, "Meep: A flexible free-software package for electromagnetic simulations by the FDTD method," *Comput Phys Commun*, vol. 181, no. 3, pp. 687–702, Mar. 2010, doi: 10.1016/j.cpc.2009.11.008.
[5] J. Seol, C. C. Hegna, and J. D. Callen, "Nonlinear cyclotron harmonic absorption," *Phys Plasmas*, vol. 16, no. 5, 2009, doi: 10.1063/1.3139249.