Seminar

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Institute for Plasma Research

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Title: Comparative study of negative hydrogen ion density measurement through enhancing technical competency of various diagnostics in RF plasma

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Date: 17th April 2025 (Thursday)

Time: 03.00 PM

Venue: Seminar Hall, IPR

Abstract

The present Ph.D. work is devoted to experimental studies with an emphasis on enhancing the signal-to-noise ratio (SNR) of various negative ion diagnostics operating under noisy RF environments. These are: Cavity Ring-Down Spectroscopy (CRDS), and an inductively coupled Langmuir probe-based laser photo-detachment (LPD). The diagnostics are developed to characterize negative hydrogen ion (H^-) density in radio-frequency (RF) driven plasma sources (inductive - ROBIN and helicon - HELEN) and used in ion sources under pure “volume mode” operation (without Cs injection). The CRDS system gives line-averaged negative ion density; whereas, a Langmuir-based laser photo-detachment (LPD) technique provides local negative ion density measurement. In a high-power RF environment, the Langmuir probe always picks up RF noise. As a consequence, the LPD signal-to-noise ratio is poor (SNR ~ 1 – 1.6). To overcome this problem an RF broadband transformer is employed with a Langmuir probe to extract the LPD signal inductively from the RF noise (SNR ~ 60). A precision laser trigger mechanism is also developed for phase-synchronized measurements across the RF cycle. To correlate the negative ion density with the plasma parameters a single and a triple Langmuir probe are used to find plasma density and temperature. Diagnostic data from CRDS and LPD are cross-validated against the standard Optical Emission Spectroscopic (OES) technique confirming the enhanced accuracy and reliability of these two diagnostics.

CRDS measurement sensitivity and accuracy depend on the misalignment and reflectivity of the cavity mirrors. Long pulse operation of a negative ion source with Cs evaporation will reduce the reflectivity of the mirrors due to Cs deposition. A significant innovation in this work includes the development of an in-situ technique for measuring the effective reflectivity of high-finesse cavity mirrors by varying the gas pressure within the optical cavity. This approach, supported by a dedicated correction algorithm estimates the accurate negative ion density when reflectivity and mirror alignment are slowly but continuously degrading with time.

The present comprehensive study highlights the effectiveness of the developed diagnostics with enhanced technical competency and associated algorithms to measure accurate negative ion densities in high-power RF negative ion sources. The information provided in the thesis will be useful for characterizing a negative ion source.
