Seminar

Institute for Plasma Research

Title: Collisional–Radiative Modeling of Low-Temperature Hydrogen Plasmas for Negative Ion Sources

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Venue: Seminar Hall, IPR

Abstract

Negative ion sources play a vital role in fusion research and accelerator applications by providing high-intensity beams for plasma heating and diagnostics. The ROBIN (RF-Based Negative Ion) source serves as an important experimental platform for investigating hydrogen negative ion production under controlled plasma conditions. A detailed understanding of the population kinetics of excited hydrogen states is essential for optimizing negative ion formation and interpreting spectroscopic measurements.

In this work, we present a multi-level collisional–radiative (CR) model for atomic hydrogen, developed specifically for plasma conditions relevant to the ROBIN negative ion source. The model incorporates key atomic and molecular processes, with rate coefficients obtained from cross-section data averaged over Maxwellian electron energy distributions. Steady-state rate equations are solved to determine excited-state populations for principal quantum numbers $n = 2–6$ over a range of electron densities. Using these populations, Balmer line intensities corresponding to Hα (3→2), Hβ (4→2), Hγ (5→2), and Hδ (6→2) transitions are calculated, normalized, and quantitatively compared with experimental optical emission spectroscopy (OES) measurements through a non-linear deviation metric δ based on normalized line ratios.

The dependence of normalized line intensities and δ on electron density reveals clear trends in excitation kinetics in low-pressure hydrogen plasmas, including the suppression of higher excited states at lower densities due to dominant electron-impact excitation and radiative decay processes. The minimum in δ identifies the electron density at which the calculated spectra best reproduce experimental observations, enabling a precise, spectroscopy-based determination of plasma parameters. The close agreement between modeled and measured line ratios validates the developed CR framework and highlights the role of molecular channels, establishing a robust diagnostic approach for ion-source-relevant plasmas and providing a foundation for future extensions to higher-density regimes.