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An LCIF diagnostic to test fusion relevant atomic data in RAID

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Collisional cross sections and collisional-radiative (CR) models are of upmost importance for plasma diagnostics in the entire community, from low-temperature athmospheric pressure plasmas and fusion applications to astrophysical studies. Large efforts have been undertaken to provide collisional data by experiments, simulations, and analytic calculations. However, the validation of collisional data and CR models is very challenging and requires high-quality spectroscopic measurements and complex data analysis methods [1-2]. Here, we present our effort to validate collisional data relevant for fusion applications by modeling the results of fast spectroscopic diagnostics in a highly reproducible plasma experiment.
The Resonant Antenna Ion Device (RAID) [3], operated at EPFL, Switzerland, is a linear plasma device that produces a steady-state Helicon discharge, sustaining electron densities ne of few 10^{17} to 10^{19} m^{-3} and temperatures Te of 1 to 10 eV in hydrogen (deuterium), helium, and argon. The plasma is highly reproducible and well diagnosed by means of Langmuir (LP) and B-dot probes, as well as optical emission specttroscopy (OES), Thomson scattering (TS), laser induced fluorescence (LIF), and two photon absorption LIF (TaLIF).
A Laser Collisional Induced Fluorescence (LCIF) diagnostic in helium plasmas [4] that enables simultaneous monitoring of various (> 10) optical transitions (n = 3 and 4 $\rightarrow$ n = 2), was recently developed at RAID [5]. The local pumping of the 1s3s 1D level hereby minimizes the effect of integration along the line of sight. In the future, we suggest to utilize a tunable ps-laser pulse (28 ps, 193 nm to 2300 nm) which will allow us to pump different He levels with high temporal resolution. An absolute calibration of the detection system can directly yield the (combined direct and cascade) apparent population rate of the probed levels (except 1P) resulting from the pumping process, while the measurement of the fluorescence life time enables quantitative inference about the opacity of the plasma and the (collisional) quenching in various plasma conditions. Comparison of the experimental results with predictions from a CR model allows understanding the role of complex (de)population processes like opacity. Ultimately, we intend to develop a method that allows simultaneous fitting of the experimental spectra

obtained from different pumping schemes, while varying the reaction rates for the dominant collision processes by using a probabilistic approach based on Bayesian data analysis, similar to [1-2]. With the extensive spectral data sets provided by the LCIF diagnostics and the independently obtained plasma parameters from TS and LIF, we will push this analysis to a level that will enable us to put experimental constraints on the collisional cross sections for helium to improve present-day plasma diagnostics in the fusion community.

References

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