The Art of Measuring Electric Fields in Plasmas

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Detection of atoms and molecules in partially ionized plasmas has always been at the core of laser-aided plasma diagnostics. The motivation for their measurement is usually closely related to the plasma chemistry or, in case of metastable or generally long living excited states, to their impact on ionization or creation of high enthalpy gases. However, excited states of atoms or molecules can serve also as sensitive probes for the detection of electric fields in the plasma. Arguably, electric fields in plasmas are one of the most important parameters. Macroscopic fields (on scales much longer than the Debye length) connect to charge and current densities and micro fields (on scales shorter than the Debye length) to the plasma density. This allows diagnostics on fluctuations, waves, sheath structures and oscillations etc.. An example for derivation of charge densities in a discharge by first principles from measured electric field structures is shown in Fig. 1. While electric fields cannot be detected directly by laser spectroscopy, they change the wave functions and the energy states of the bounded electrons in the excited states of atoms or molecules. This leads to a surprising variety of diagnostic techniques. The talk will review the development of the various techniques and their applications over the past decades. Indeed, the LAPD symposium has played a major role in communicating and discussing developments in the field throughout. Since the author has been part of this development, the review will have to some extend a personal perspective but will not be limited to it.

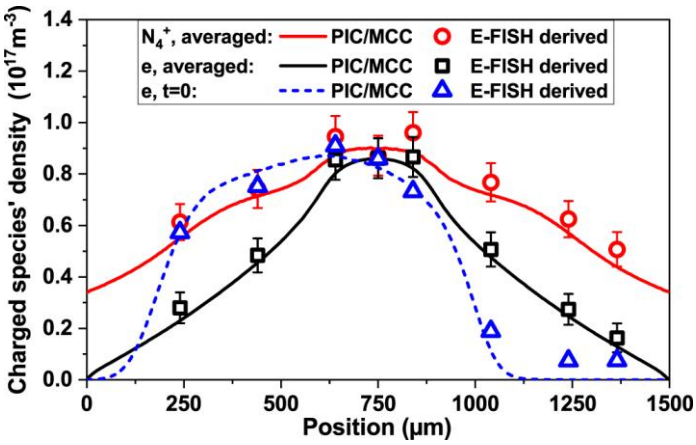

Figure 1. The static main ion, N_4^+, density, the period averaged electron density, and the electron density at $t = 0$ in an atmospheric pressure RF (13.56 MHz) micro discharge in He/N_2 (atmospheric pressure plasma jet). The position is measured from the powered electrode. The measured quantities (symbols) are derived by first principles from the measured electric fields (using the EFISH technique) in the discharge. The lines are representing an ab-inito PIC/MCC simulation (from [1]).

[1] Inna Orel et al 2025 Plasma Sources Sci. Technol. 34 06LT02.

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