Nonlinear Dynamics in Asymmetric and Symmetric Capacitively Coupled Radio Frequency Discharges

S. Wilczek[1], J. Trieschmann[1], J. Schulze[1,2], R. P. Brinkmann[1], Z. Donkó[3], and T. Mussenbrock[4]

[1]Ruhr University, Bochum, Germany
[2]West Virginia University, Morgantown, USA
[3]Wigner Research Centre for Physics, Budapest, Hungary
[4]Brandenburg University of Technology, Cottbus, Germany

In low-pressure capacitively coupled radio frequency (CCRF) discharges, the electron power gain and loss indicate strongly nonlinear dynamics (Fig. 1, left), which pronouncedly occur in asymmetric discharges and only for certain conditions in symmetric discharges. The alternation between electron power gain (red color) and loss (blue color) during sheath expansion at the driven (bottom) electrode correlate with the generation of multiple electron beams (Fig. 1, right) and the modulation of the density of cold bulk electrons, which are attracted back to the plasma sheath. Due to these nonlinear dynamics, harmonics in the RF current are generated. This interplay leads to the global phenomenon of a plasma series resonance and enhances the power deposition in CCRF discharges. In this work, we investigate the power gain and loss mechanisms for different discharge conditions in order to obtain a kinetic picture of the nonlinear dynamics on a nanosecond timescale.

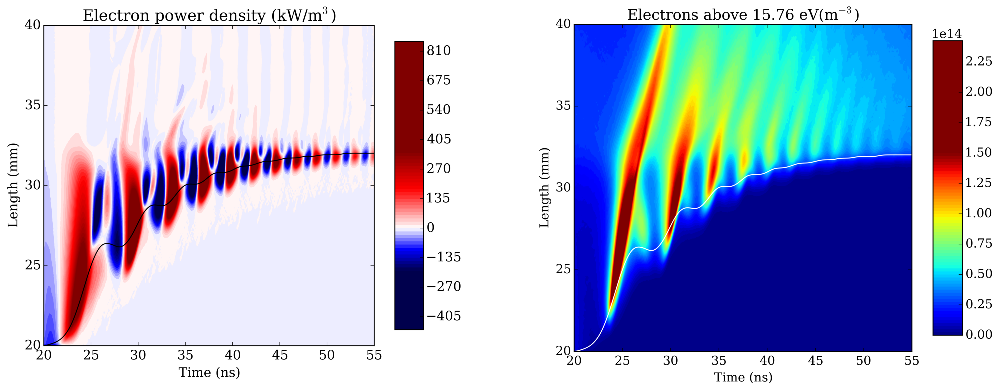

Fig. 1: Spatio-temporal distributions of the electron power density (left) and the density of electrons with energies above 15.76 eV (right) during sheath expansion near the powered electrode. The results are obtained by PIC/MCC simulations using a spherical grid. Discharge conditions: $V = 700$ V, $f_{RF} =$ 13.56 MHz, $p = 1$ Pa argon, $L_{\text{gap}} = 60$ mm, electrode area ratio $A_g/A_d = 16$ and $C_b = 0.3$ nF. The white and black line indicate the sheath edge.