Low-temperature plasma instabilities and chaotic states triggered by the nonlinear dynamics of complex space charge structures

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Plasma is a complex system that reacts and adapts to any external constraint that drive it away from thermodynamic equilibrium. One of the consequences is the self-assembling of complex space charge structures in form of fireballs or multiple double layers. The stability of these structures is assured by the equilibrium between the production of charged particles through electron-neutral impact ionizations and their loss through recombination and diffusion. When the external constraint exceeds a certain critical value, this equilibrium cannot longer be maintained and the structures pass into dynamic states, consisting of periodic disruptions and re-aggregation of the double layers exiting at their borders [1]. During the disruptions, bunches of electrons and positive ions are periodically released into plasma, triggering low-frequency instabilities that manifest as strong oscillations of the plasma parameters (plasma potential, ion and electron densities). In certain experimental conditions, such instabilities can lead to chaotic states of plasma [2].

Here, experimental results are presented on the low-temperature plasma instabilities and routes to chaos related to the nonlinear dynamics of fireballs, multiple fireballs and multiple double layers. Different geometries of electrodes were used, in different experimental conditions. The time series of the oscillations of the discharge current or of the currents collected by the electrodes were analyzed with complex methods provided by the nonlinear dynamics. Interesting phenomena are emphasized, like the self-modulation of the discharge current oscillations, intermittency, or competition of different scenarios of transition to chaos.

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