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Hybrid kinetic-liquid model of the nanosecond discharge initiated by runaway electrons

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The direct solution of Boltzmann kinetic equation is of great interest for theoretical investigations of various gas discharges. Such approach is known to be the most fundamental because it gives comprehensive information about the discharge and its evolution by providing electron and ion distribution functions for any given time point. The complete numerical solution of Boltzmann equations for multi-component gas discharge plasma is quite challenging even for one-dimensional problems due to the mathematical complexity. That is the reason why gas discharges are usually described in terms of simplified moments models with drift-diffusion approximation or particle-in-cell (PIC) models including Monte-Carlo collisions.
Here we represent novel hybrid theoretical approach for simulation of discharges. It bases on both plasma hydrodynamics and kinetics methodologies simultaneously describing the dynamics of different discharge plasma components. Particularly, we solve Boltzmann equation for electron distribution function self-consistently with ion equation of continuity coupled with electromagnetic field equations. The efficiency of the proposed approach has been shown on the example of one-dimensional coaxial relativistic gas diode. Our model accurately provides the electron power spectrum containing a group with the so-called "anomalous" energies (above the maximal applied voltage value) that were not theoretically predicted before, but do exists it various experiments. Hybrid model is also opens up the possibility to describe discharges initiated mainly by runaway electrons.

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