Challenges in PIC Modeling: Electromagnetic Description and Resonance Phenomena

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This contribution provides an overview over applications of low-temperature plasmas for which new aspects of PIC modeling have to be taken into account. These new aspects come with a number of numerical as well as conceptual challenges, three of which are electromagnetic effects, resonance resonance effects, and plasma chemistry at high pressure.

Boltzmann's equation is certainly the most fundamental description of low-temperature plasmas. It is in fact imperative to take it seriously when particle systems are not in thermal equilibrium. [1] This holds in particular for low-pressure plasmas. It has been also recently shown that kinetic effects even occur in atmospheric pressure plasmas. Under certain conditions electrons show strong non-Maxwellian behavior. [2] The energetic behavior of electrons is of course directly related to the ongoing plasma chemistry which makes low-temperature plasmas so useful. [3] Whenever accurate information about the energy distribution of particles in a non-equilibrium plasma is needed, e.g., to calculate the fundamental transport properties of particles or the rates for elementary collision processes, a kinetic approach is mandatory.

A number of different kinetic approaches for directly solving Boltzmann's equation have been developed and used. One of these methods is particle-in-cell (PIC) coupled to Monte-Carlo collisions. [4 - 7] In this method super-particles in a Lagrangian frame – each of which represents millions of real physical particles – are followed in continuous phase space whereas particle densities and current as velocity moments of the distribution functions are calculated on Eulerian grid points. The basic PIC method itself is intuitive and quite simple to implement. It consists of just four fundamental procedures: i) integration of the Newton's equations of motion for the particles, ii) assignment of charges and currents to the numerical field grid, iii) calculation of the fields on the grid points, and iv) interpolation of the fields from the grid to the particle positions. This straightforward and conceptually simple approach is probably one reason for its popularity, particularly in the low-temperature plasma simulation community.

Although the PIC approach is more than 60 years old and quite straightforward – as briefly described above –, its development has not been completed. With the today's amazing applications of plasmas, new challenges in the context of numerical plasma simulation using PIC pop up. This contribution is intended provides an overview over a limited number of applications of low-temperature plasmas for which new aspects of PIC modeling have to be taken into account. These new aspects come with numerical as well as conceptual challenges, three of which are electromagnetic effects, resonance effects, and plasma chemistry at atmospheric pressure [8 - 10].

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