AP1

1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

The MPM model for the Simulation of ECR Ion Source

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Electron cyclotron resonance (ECR) ion source is considered to be the most efficient facility for generating highly charged ions beams, because of its board ion variety, high charge-state and beam stability, repeat-ability, etc[1-4]. Through more than 30 years of development, ECR ion source has been evolved from a sizeable, energy-intensive and complicated prototype to the one with compact structure, high efficiency and user-friendly operations[5,6]. However, compared with experiments, the study on theories and simulations of ECR ion source is more rare and immature, on account of its complicated physical phenomena during discharge, which will lead to a magnificent increase of computational cost. With the rapid development of high-speed, high-capacity and high-performance computers, it is feasible and essential to make an in-depth study on the theories and numerical simulations.

Up to now, there are three models on the simulation of ECR ion sources proposed by researchers[7], which are the particle model, the fluid model and the hybrid model. Compared with the other two, the particle model can describe the actual physical process more precisely.

In this paper, we present the newly developed MAGY/PIC/MCC (MPM) model for simulations of ECR ion sources. We choose the MAGY theoretical model[8,9] to describe the time-varying electromagnetic fields, the PIC method to deal with the interaction between the charged particles and fields, and the MCC method to simulate the collisions among particles. The electromagnetic model is applied to accord better with physical facts.

The MAGY theoretical model is based on the waveguide model expansion method. To describe the electromagnetic fields as a superposition of transverse electric and transverse magnetic eigenmodes of the waveguide, we then need not to have a full solution of Maxwell's equations but instead a set of coupled partial differential equations of amplitudes of the modes, which can have a significant saving of computation. After this, the fields can be computed as a superposition of the eigenfunctions with the calculated amplitudes.

As for the motion part, we take advantages of the PIC method in collective motions and the MCC method in collision motions[10]. In the PIC simulation part, relativistic equations of motion are solved by the explicit leapfrog scheme using Boris's method. In the MCC simulation part, the elastic, excitation, ionizing electron-neutral collisions and the elastic, charge exchange ion-neutral collisions are taken into account. For a snapshot, random number R_1 is generated and a collision is assumed to have occurred if $R_1 < P_{c,e}$, where $P_{c,e}$ is the electron-neutral collision probability, then random number R_2 is chosen to determine the collision type said above.

So far we have built a self-consistent description of the interaction between the charged particles and the electromagnetic wave. Furthermore, a whole situation circular flow including convergence judgments and diagnostics has been established. In this way, we can build a numerical simulation of time domain which is able to give us the plasma properties during time including the magnetic confinement, ECR heating and highly-charged ionization.

Acknowledgements

This work is supported by the Fundamental Research Funds for the Central Universities (Grant Nos. ZYGX2016J065 and ZYGX2016J065).

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