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# The Hybrid Electromagnetic Simulation of Ionization Characteristics in ECR Ion Source

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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. Compared with the intensive experiments, the study on theories and simulations of ECR ion source is more rare and immature due to its complicated physical phenomena and the huge computational cost. In this paper, an improved MAGY/PIC/MCC (MPM) model has been present for modeling ECR ion source, which can give the detailed description of ionization process in ECR discharge and save the usual computational cost by using PIC/MCC method at the same time. MPM is an hybrid electromagnetic simulation model, which includes a time-dependent description of the electromagnetic fields and a self-consistent analysis of the charged particles with collision effects. A method of the waveguide modal representation proposed by MAGY is used in the calculation of the electromagnetic fields. As the full solution of Maxwell's equations is reduced to a relatively small number of coupled partial differential equations for the amplitudes of the modes, there is a significant saving of computation time. As for the motion part, we take advantage of the PIC method in collective motions and the MCC method in collision motions. 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. So far, we have built a self-consistent description of the interaction between the charged particles and the electromagnetic field, which has passed the numerical validation by using the commercial PIC software MAGIC. In addition, a whole time-domain simulation flow including ionization process has been established, and the generation of highly charged ion with considering the magnetic confinement, ECR heating and highly charged ionization has been studied in detail.

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