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Particle-in-Cell with Monte Carlo Collisions Gun Code Simulations of a Surface-Conversion H^- Ion Source

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Abstract. We present an extended update on the status of a particle-in-cell with Monte Carlo collisions (PIC-MCC) gun code developed at Los Alamos for the study of surface-converter H^- ion sources. The program is fully kinetic. Some of the program's features include: solution of arbitrary electrostatic and magnetostatic fields in an axisymmetric (r,z) geometry to describe the self-consistent time evolution of a plasma; simulation of a multi-species (e^-, H^+, H_2^+ , H_3^+ , H^-) plasma discharge from a neutral hydrogen gas and filament-originated seed electrons; full 2-dimensional (r,z) 3-velocity (v_r, v_z, v_ϕ) dynamics for all species; detailed collision physics between charged particles and neutrals and the ability to represent multiple smooth (not stair-stepped) electrodes of arbitrary shape and voltage whose surfaces may be secondary-particle emitters (H^- and e^-). The status of this development is discussed in terms of its physics content and current implementation details.

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Key words: Negative hydrogen ion source simulation, particle-in-cell with Monte Carlo collisions, low temperature plasma simulation.

1 Introduction

Ion source technology poses challenging problems both in experiments and simulations. These problems are substantially important as in many situations the output and quality of the produced beam determine much of the performance of complete accelerator systems. The relative complexity of ion sources usually means that *ad hoc* modeling may suffer from severe limitations. Fully kinetic representation offers the promise of studying

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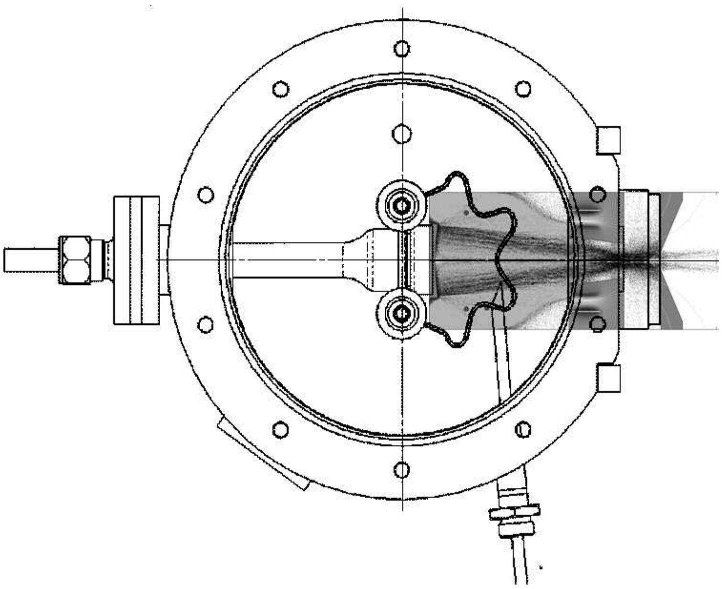

Figure 1: Composite figure showing the plasma components in the simulation region over a lateral drawing of the ion source. Shown: filaments, Cs dispenser, converter and repeller. The 3-dimensional quality of the problem has been simplified to 2 dimensions, r and z. The z coordinate is the horizontal axis of the rectangular simulation region shown, while the r coordinate is the vertical axis measured from the center of the emitting electrode. The figure shows the actual rectangular simulation region with its mirror image reflected on the z axis to suggest the cylindrical symmetry.

phenomena without full *a priori* knowledge of the myriad of effects that may affect the physics of interest. A good example of an application that can be approached this way is surface-conversion negative hydrogen ion source technology. This technology is used in diverse incarnations in major spallation neutron facilities around the world, among other applications. Both, the current output and the beam emittance of these sources impose hard limits on what can be achieved at the target end of the accelerator.

The ion source we are studying needs some description in order to provide adequate context to the reader. A blueprint of the ion source is shown in Fig. 1, with an overlay of the type of simulations described in this paper.

The ion source operates as follows: within a magnetic multicusp cylindrical chamber, a plasma discharge is initiated in a tenuous (3 to 5 mtorr) hydrogen atmosphere by incandescent tungsten filaments that are pulsed at a voltage between -100 and $-200V$. The arc produced by the filaments initiates and sustains a cascade of ionizations which form the plasma discharge. In addition to this, an external cesium oven delivers through a tube (shown in the figure) a continuous but small flow of atomic Cs.

The cesium deposits in cold surfaces all throughout the chamber. Of particular interest is the surface of a negatively biased molybdenum electrode known as the converter. This is located close to the center of the chamber, as shown in the figure. When the cesium deposits on this surface, the metal's work function is lowered and its propensity to lend electrons to adsorbed hydrogen atoms is greatly enhanced. The negative hydro-