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Two-Dimensional Particle-in-Cell Simulation of Ion Extraction Process with an M-Type Electrode Configuration

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Research on evolutional processes of low-pressure bounded decaying plasmas plays an important role in various plasma applications and fundamental studies, e.g., the ion extraction process of laser-induced plasmas, which is one of the key parts in atomic vapor laser isotope separation (AVLIS). The efficiency of ion extraction is a key factor for practical implementation. Thus, in the past few decades, substantial efforts have been devoted to studies on the ion extraction mechanisms, and proposals of various methods to speed up this process. Since the electric field is unable to penetrate the plasma bulk region due to the shielding effect, modifications of the electrode configuration have been studied and the feasibility was proved by experimental results [1-3]. One of the modified version is the so-called M-type electrode configuration by adding a vertical grounded electrode as an anode from the upper center of the ion extraction region.

Compared with experiments, theoretical analysis and numerical simulation could provide more details about the evolution of the plasma parameters for a deeper understanding to the physical mechanisms during the decaying process. In this paper, firstly, the physical processes involved during the whole plasma decaying process are analyzed based on the one-dimensional (1-D) analytical model as presented in Ref. [4]. And then, the two-dimensional (2-D) numerical simulations are conducted using the 2d3v particle-in-cell (PIC) code (EDIPIC-2D) for the ion extraction process under different geometrical configurations of the electrodes. The calculation domain is shown Figure 1(a). And the Spatiotemporal evolutions of the ion number density during decaying of the plasmas are presented in Figure 1(b) for a typical case. It is seen clearly that, on the one hand, three different stages exist during the whole ion extraction process, which is consistent with the 1-D case with a parallel electrode configuration, i.e., the electron oscillations, sheath expansion and ion rarefaction wave (IRW) propagation, and the plasma collapse [4,5]; while on the other hand, there also exists obvious difference from the 1-D case with propagation of IRW in both vertical and horizontal directions with inserting the anode between the parallel electrodes. In addition, the effects of geometrical parameters of the anode on the ion extraction characteristics are also studied numerically. This research provides a deeper understanding to the ion extraction process with an M-type electrode configuration, and may provide a theoretical guidance for actual applications.

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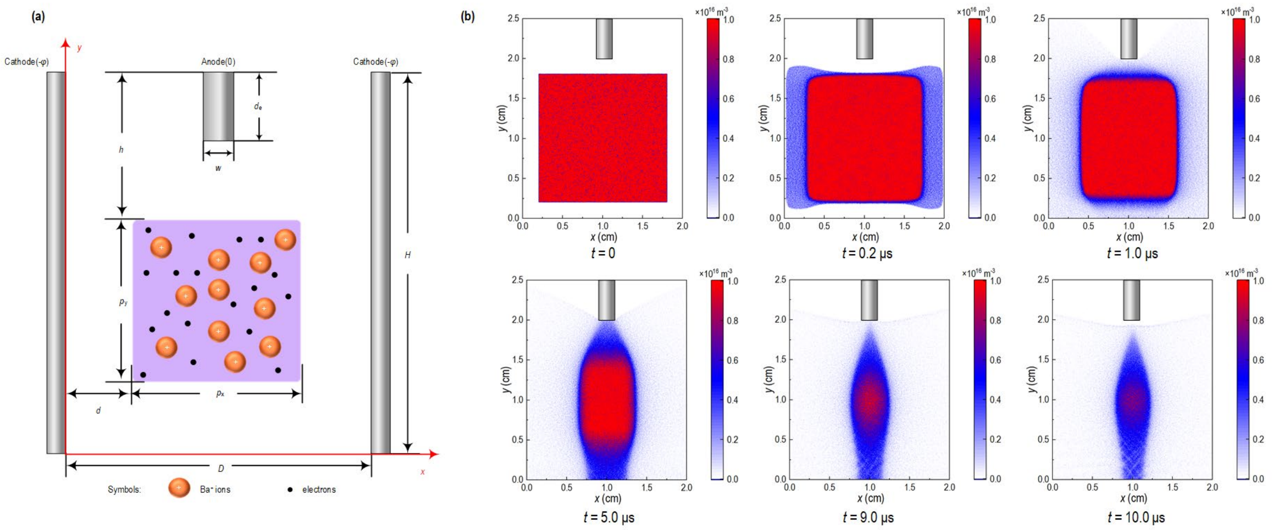

Figure 1. Schematic of the 2-D calculation domain with an M-type electrode configuration (a), and the spatiotemporal evolutions of the ion number density during the plasma decaying process (b).