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Electron Behavior in Beam Diode Driven by Intense Pulsed Power Device for Warm Dense Matter State Research of Inertial Confinement Fusion

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Abstract

Electron behavior in beam diode gap was analyzed numerically based on the normalized value of intense pulsed power discharge device ETIGO-II as impedance controller for dense matter state research of inertial confinement fusion. After emission of electrons from the cathode surface, acceleration time, impedance, potential distribution and velocity varies with the function of different beam diode gap. To understand the time dependent behavior of electron and beam output current for different beam diode gap, 2-d electrostatic particle-in-cell (PIC) model was carried out. According to the numerical analysis, it was found that beam output current decreases with the increase of beam diode gap distance. The electron beam diode impedance was also observed increasing with the increase of diode gap. Numerical result reproduced experimental data and useful for the understanding of experimental result for dense matter state research of inertial confinement fusion.

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Keywords: Electron beam diode; Electron behaviour; Impedance control; Warm dense matter; Space-Charge limited emission; Pulsed-power generator

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1. Introduction

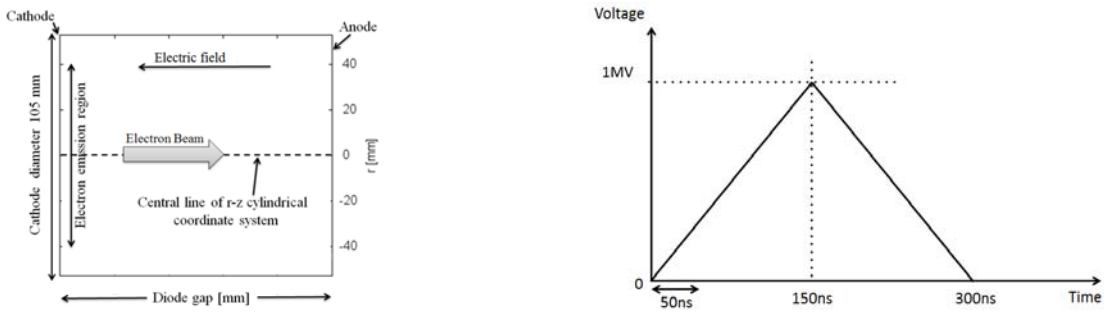
Pulsed power technologies are used in various fields and have many important applications: nuclear fusion research, particle acceleration, material processing and so on [1, 2, 3, 4, 5, 6]. In order to utilize those technologies effectively in those particular fields, physical properties of charged particle beam must be clarified in both experimentally and numerically. In the recent progress of pulsed power technology research, an intense pulsed power generator with the electron beam diode as impedance controller was proposed to investigate the warm dense matter (WDM) property as a part of nuclear fusion research, at comparable pulse duration of the inertial confinement fusion (ICF) implosion [7]. In ICF, materials of a fuel pellet pass through WDM regime during the implosion process, are so important and have a significant impact in implosion dynamics [8, 9, 10, 11]. On the other hand, intense pulsed power generator was desired to produce high electron beam current for short time scale in high energy research applications [12, 13, 14, 15, 16, 17].

Electron beam diode behaves as impedance, can control to regulate the input power and energy into the sample load. Eventually, the input power control with the electron beam diode was investigated experimentally but so long the physical behaviors of electron beam in the diode gap were not understood properly [7].

In order to understand the electron behavior and output beam current for different diode gap, numerical simulation model was implemented with the normalized value of intense pulsed power discharge device ETIGO-II. To clarify the electrostatic potential and diode gap effect on beam output current, diode impedance and potential distribution behavior in diode gap were investigated numerically. The numerical simulation based on the electrostatic PIC method was done to analyze the electron behavior in diode gap and compared with both the theoretical and experimental results, which gives the trio authenticity of experimental data. Beam diode impedance controlling technique was also analyzed to control input power and energy into the sample load, which is helpful for the study of WDM state of ICF.

2. Numerical Model and Boundary Conditions

Satisfying the space charge limited emission conditions numerical simulation of electron beam using a 2-d electrostatic PIC model was done with the deliberation of time dependent relativistic particle motion corresponding to the experimental results. In parallel diode gap external applied voltages creates uniform electrostatic potential and extracts electrons from the cathode surface and propagate through the vacuum. Here Fig. 1(a) shows the schematic diagram of numerical condition for evaluating electron beam in diode gap, which was considered cylindrically symmetric and simulation parameters were implemented based on the experimental setup of ETIGO-II [7]. The left and right boundaries were assumed as the cathode and the anode, respectively. Electric field components of numerical simulation are E_r, E_z and velocity v_r, v_z and positon r, z , which were solved using Maxwell equation and relativistic equation of motion in mesh grid system [18, 19, 20]. In this numerical simulation, external applied voltage was 1 MV maximum, which was the normal value of intense pulsed power device ETIGO-II [21]. The pulse width was 300 ns and rise and fall time was 150 ns each were shown in Fig. 1(b). Peak voltage was 1MV at 150 ns



(a) Schematic diagram of numerical simulation condition of electron beam (b) Applied voltage waveform

Fig. 1. (a) Schematic diagram of numerical simulation condition of electron beam (b) applied voltage waveform: maximum voltage is 1 MV, pulse width is 300 ns, the rise and fall time is 150 ns each