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Simulation of pseudospark discharge and the transportation of the generated electron beam

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Abstract- **This paper presents the simulation of the Pseudospark (PS) discharge process and the transportation of the generated electron beam in the ion channel using the particle-in-cell (PIC) method. The maximum beam currents that can be stably transported in different beam tunnel dimensions were simulated.**

I. Introduction

Pseudospark (PS) discharge is a low-pressure gas discharge characterized by a rapid breakdown phase with the generation of a high current density electron beam, which is over 100 times higher than a thermionic cathode. Due to the unique features of the PS-sourced beam, it has found applications in material treatment, ultraviolet light sources for lithography, high-power switches, and the generation of high-power millimeter/terahertz wave radiation [1-4].

The PS-sourced beam can also transport a long distance without the need for an external guiding magnetic field. Such features are attractive as beam sources in terahertz wave generation to produce high-power radiation. At high frequencies, the conventional vacuum electron devices suffer a quick drop in the power level due to the small cross-section of the beam tunnel and the limit of current density from a thermionic cathode.

Many experiments have been carried out to study the PS discharge process and the transportation of the generated electron beam. The challenge is the PS discharge is a fast process on a nanosecond scale, making the probe hard to capture the dynamic information with sufficient time resolution. Also the PS discharge occurs in a gas-sealed cavity and there is little space for the diagnostics circuits.

Numerical simulations can provide useful information on the dynamics of the discharge process, including the time-varying ion density and electron density. In this paper, particle-in-cell simulations were used to study the characteristics of the PS discharge process with considering the external circuit. The electron beam transportation in the ion channel was also simulated to understand the current lost at different sizes of the beam tunnel.

II. Particle-in-cell simulations

Fig. 1 is the simulation model of the PS discharge process. The dimensions are chosen from the existing experiments, and they are listed in Table 1 [5-7]. The simulations were carried out using XOOPIC [8], which is a 2D PIC simulation package including all the physical models for the gas discharge. Table I shows the major dimensions of the discharge chamber used in the simulations.

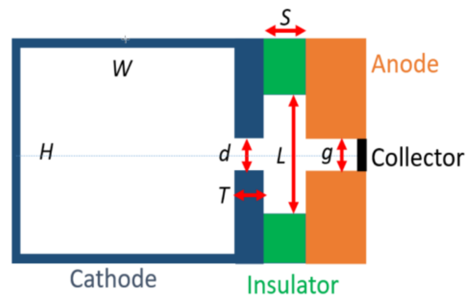

Fig. 1 Schematic drawing of the discharge chamber.

Cavity height H	50.0 mm
Cavity Width W	50.0 mm
Cavity aperture thickness T	3.0 mm
Cavity aperture size d	3.0 mm
Insulator thickness S	5.0 mm
Insulator inner diameter L	10.0 mm
Anode beam aperture g	3.0 mm

Table. 1 Dimensions of the parameters shown in Fig. 1.

The phase spaces of the electrons and ions clearly showed the different phases in the discharge process, including the Townsend discharge stage, the hollow-cathode discharge stage and the super-dense glow stage. Fig. 2 shows the densities of the electron and ion during the discharge process. It indicates the source of the electrons from the ionization of the background gas, and the secondary electrons have only a small contribution [9].

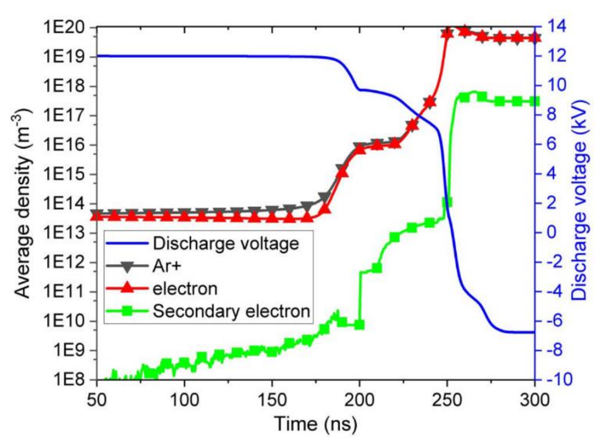

Fig. 3 The densities of the particles as the function of the discharge time.

The generated electrons will ionize the background gas. The ionized electrons have a larger velocity and will be expelled by the beam electrons, to leave an ion channel. The ion channel has a net positive charge and can focus the electron beam. In the experiments, it was found that ~20% of beam current remains after a transportation distance of 20 cm. Numerical simulations can help to obtain more information including the envelop of the electron beam during the transpotation in the ion channel. The simulated model is shown in Fig. 4 [10]. Different plasma densities and beam energies were simulated to study the conditions for stable beam transportation. The beam losses during transportation at different beam tunnel radii were also simulated to study the current limit. Simulation results showed the beam current that can transport at the same beam tunnel increases as the increment of ion density. And a larger beam

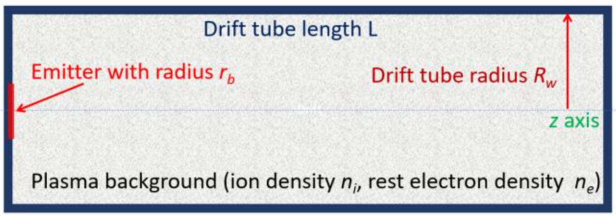

Fig. 4 simulation model of electron beam transportation.

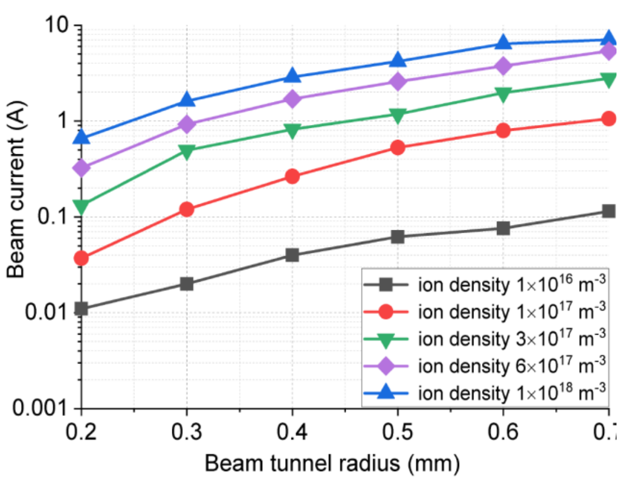

Fig. 5 Maximum beam currents at different beam tunnel radii.

tunnel supports a large current, which indicates the frequency limitation of the PS-generated beam can be used for the interaction circuit of the millimeter/THz generation.

ACKNOWLEDGMENT

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