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Investigation of electron beam parameters inside the drift region of plasma cathode electron gun

Deepak K. Verma*, U. N. Pal, N. Kumar, J. Prajapati, M. Kumar, Ram Prakash and V. Srivastava
Microwave Tubes Division, CSIR-Central Electronics Engineering Research Institute (CSIR-CEERI), Pilani, Rajasthan-333031, India.

E-mail:deepakverma31@gmail.com

Abstract. This paper presents experimental studies for the production and propagation of an electron beam from a single gap pseudospark discharge based plasma cathode electron (PCE) gun. The generated electron beam has been successfully propagated for more than 25 cm in a gaseous environment without application of external guiding magnetic field at different operating conditions. The electron beam losses due to recombination with ions and collision with walls of drift space have been estimated. The electron beam profile has also been analyzed in the drift region of the gun.

1. Introduction

The pseudospark (PS) discharge is recognized as unique type of discharge [1] which is capable of producing electron beams with highest combined current density and brightness of any known type of electron source [2-7]. The PS discharge based plasma cathode electron (PCE) gun has potential applications in microwave generation, electron beam melting, welding, surface treatment, plasma chemistry, radiation technologies, laser pumping, where material cathode cannot be used [8,9]. This type of gun has longer life as compared to that of material cathode. The PS discharge operates in hollow cathode geometry on the left-hand side of the Paschen curve with axially symmetric parallel electrodes and central holes on the electrodes [10]. The discharge system for PCE-guns does not have hot filament or similar kind of thermionic solid cathode, and so it is ‘‘filament less’’ and known as ‘‘cold cathode’’. This is primary difference between a plasma cathode electron-gun and a thermionic electron-gun. Due to the absence of hot electrode, the plasma cathode system is basically more reliable, with a longer lifetime, and can generate electron beams at much higher background gas pressures, even in the fore-vacuum pressure ranges. In this paper experiments has been performed to investigate the electron beam propagation inside the drift region at different operating conditions. Variation in the electron beam current and discharge current at different location of drift region has been analyzed to understand the electron beam behavior in the drift space. This study is essentially required for the development of plasma assisted backward wave oscillator (BWO) [11].

* To whom any correspondence should be addressed.

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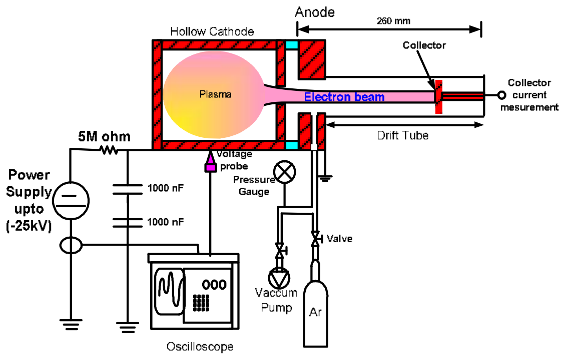
2. Experimental Set up

The single-gap pseudospark based plasma cathode electron gun experiments have been performed at different operating conditions. The schematic view of the experimental setup and the fabricated PCE-gun are shown in Figure 1 (a, b).The hollow cathode has been connected to the dc power Supply (-25 kV, 1 mA) through a 5 MΩ current limiting resistor while the anode is grounded. There was no external applied guiding magnetic field for the focusing of electron beam. The hollow cathode and anode geometries have been used to design and fabricate the PCE-gun. The hollow cathode is cylindrical in shape having height 59.7 mm. The inner and outer diameters are 59.4 mm and 65.4 mm respectively. The thickness of the cylinder and the diameter of the aperture is 3 mm each. The anode dimensions are same as that of the cathode. The anode and cathode are assembled in a ceramic casing with 3 mm gap between them. The anode and cathode are assembled in a ceramic casing with 3 mm gap between them. A circular ring arrangement has been developed for beam current diagnostics in radial as well as in axial directions. The charging voltage has been measured using a capacitive voltage probe (Tektronix P6015A). The measurements of the beam current were realized using Rogowski belts, one located at the anode to measure the beam current while another current transformer was connected to the discharge circuit to measure the discharge current. These transformers are connected to the digital oscilloscope (Tektronix DPO 4054) which synchronously displays the voltage and current waveform. The discharge takes place in the region between hollow cathode and anode when the field reaches to the breakdown level of the gap. The beam current has been measured at different location of the drift space.

3.Result and discussion

Experiments have been performed for the analysis of beam current propagation inside the drift space of the PCE-gun. Initially the PCE-gun has been evacuated up to ~10^{-6} mbar. Then argon gas is filled inside the pseudospark chamber in a controlled manner.



(a)

(b)

Figure 1. (a) Schematic view of experimental set-up, (b) developed single gap PCE gun

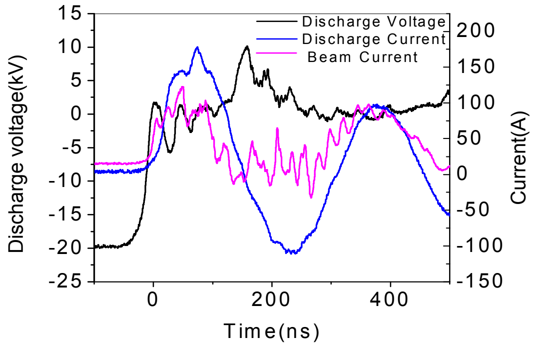


Figure 2. Experimental result showing hollow cathode voltage and discharge current and beam current.

The high voltage applied across the pseudospark chamber was then increased slowly until the breakdown occurred. It has been observed that the discharge took place around 80 Pa of working pressure and this has been repeated at different voltages. Figure 2 shows a typical trace of the experimental values of discharge voltage, discharge current and beam current which clearly demonstrate the pseudospark discharge characteristics at different times [10,12].When the electron beam is propagated in the pseudospark gaseous environment, it ionizes the gas and a plasma channel is formed in the beam path. The beam electrons would repeal the electrons of the plasma and an ion channel will be formed around the electron beam. These ions will attract the beam electrons and counteract the defocusing space charge forces of the electron beam. Therefore, there occurs a self-pinching of the pseudospark electron beam. This is due to the fact that the electron beam is propagating in the ion focusing regime [13]. The Figure 3 shows that at the fixed applied voltage, the percentage of the beam current with respect to the discharge current reduces from anode region to the collector region. It has also been seen that the maximum beam current is near anode region (z=0 mm) and the minimum beam current is near to the collector region (107 mm).

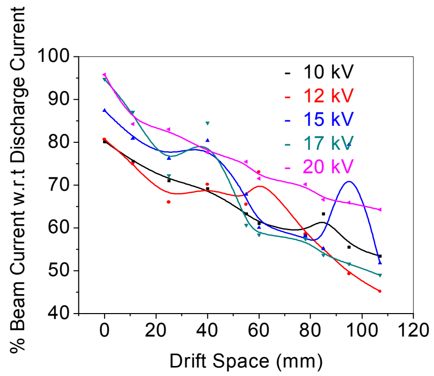


Figure 3. Experimental values of percentage of beam current measurements at different location of the drift space and at different anode voltages.

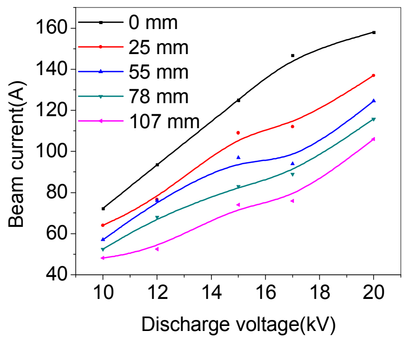


Figure 4. Experimental results of beam current variation with applied voltage at different location of the drift space.

The Figure 4 shows the beam current variation with applied voltage at different location of the drift space. It is observed that when applied voltage is 10 kV the obtained beam current is up to 70A. Furthermore, the beam current increases with applied voltage. The observed beam current reaches up to 150A at 20 kV applied voltage.

4. Conclusion

A pseudospark based PCE-gun has been designed and developed for the generation of electron beam useful for plasma assisted microwave sources and surface applications. The analysis of the electron beam profile inside the drift space has been carried out at different operating conditions. The generated electron beam has been successfully propagated for more than 25 cm in a gaseous environment without application of external guiding magnetic field. The beam current has been measured at different locations of the drift space which decreases with the distance. The electron beam losses due to the recombination with ions and collision with the walls of the drift space have been estimated.

5. Acknowledgement

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