Experimental Investigation of Pseudospark generated electron beam

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Experimental Investigation of Pseudospark generated electron beam

Niraj Kumar, D K Verma, J Prajapati, M Kumar, B L Meena, M S Tyagi, V Srivastava and U N Pal

Microwave Tubes Area, Central Electronics Engineering Research Institute (CEERI) (Council of Scientific and Industrial Research (CSIR)), Pilani, Rajasthan-333031, India

E-mail: niraj.kr@rediffmail.com

Abstract The pseudospark (PS) discharge is, however, more recently recognized as a different type of discharge which is capable of generating electron beams with the highest combined current density and brightness of any known type of electron source. PS discharge is a specific type of gas discharge, which operates on the left-hand side of the hollow cathode analogy to the Paschen curve with axially symmetric parallel electrodes and central holes on the electrodes. The PS discharge generated electron beam has tremendous applications in plasma filled microwave sources where normal material cathode cannot be used. Analysis of the electron beam profile has been carried out experimentally for different applied voltages. The investigation has been done at different axial and radial location inside the drift tube in argon atmosphere. This paper represents experimentally derived axial and radial variation of the beam current inside the plasma filled drift tube of PS discharge based plasma cathode electron (PCE) gun. With the help of current density estimation the focusing and defocusing point of electron beam in axial direction can be analyzed. It has been further confirmed the successful propagation of electron beam in confined manner without any assistance of external magnetic field.

1. Introduction

The Pseudospark discharge can produce the electron beam of high current density (>10^4A cm^{-2}), high brightness (up to 10^{12}Am^{-2}rad^{-2}) and narrow beam diameter. Interest in this high-quality, high-current electron beams has proved their potential applications in diverse areas such as electron-beam lithography and plasma processing techniques [1]. One of the major advantages for this type of gun is elimination of back-ion bombardment problem. It would add great advantage for high-power microwave tube community. Furthermore it can enhance the overall efficiency of microwave tubes.
Investigation has been done on the effect of seed electrons and physical dimension of hollow cathode on Pseudospark discharge [2,3]. Plasma electron gun is electron beam source where the extraction of electron is based on gas discharge. This kind of e-gun has been described in detail elsewhere [4,5]. To create the plasma one needs a discharge, such as, for example that used in ion sources. Thus there are two main components of the plasma cathode electron gun: a plasma generator based on hollow cathode pseudospark discharge and a beam extraction system. The discharge system for plasma cathode electron (PCE) guns does not have a hot filament or similar kind of thermionic solid cathode, and so it is ''filament less'' or ''cold cathode'' which is a primary distinction between a plasma

cathode e-gun and a thermionic e-gun. Due to the absence of a hot electrode, the plasma cathode system is basically more reliable, with a longer lifetime, and can generate electron beams at much higher background gas pressure, even in the fore-vacuum pressure range. A characteristic feature of this type of discharge is the generation of distinctive electron beams, before and at the time of voltage collapse [6]. H.Yin and colleague [6] had developed Pseudospark plasma electron gun with a single hole channel for microwave applications. However, little work has been done on the analysis of electron beam profile inside the drift space in gaseous atmosphere. Our focus is to develop high energy, intense electron beams for high power microwave applications. In this paper, we present some results for analysis of electron beam profile generated by Pseudospark experiment using a single hole channel.

2. Experimental set-up

The initial study of electron beam production has been carried out on a single-gap Pseudospark system for a wide range of parameters, including applied voltage and gas pressures. The experiments has been performed for the single-gap Pseudospark sourced PCE-gun for electron beam generation. Figure 1 shows the schematic view of the experimental setup. The hollow cathode geometry has been used to design PCE gun. The hollow cathode is cylindrical in shape having a total height of 59.7 mm. The inner and outer diameter is 59.4 mm and 65.4 mm respectively. The thickness of the cylinder and the aperture size 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. A Circular disc (copper) of dia 30mm is kept at ground. With the help of current transformers (Model 110, Pearson Current Monitor) beam current at collector can be measured. The hollow cathode is connected to the dc power supply 25 kV, 1 mA through a 5 MΩ charging resistor. The anode is kept at ground. The PCE Gun has been evacuated using TMP (Varian Turvo V-301) and then refilled with argon gas in a controlled manner using mass flow meter (Matheson:8272-0453). There was no external guiding magnetic field applied to the drift space. The charging voltage was measured using a voltage probe (Tektronix P6015A). Measurements of the beam current were realized using circular rings where each ring are connected to wire which are passing through current transformer and further these transformers are connected to the digital oscilloscope (Tektronix DPO 4054) which synchronously displays the voltage and current waveform. The actual developed PCE gun is shown in Fig. 2.

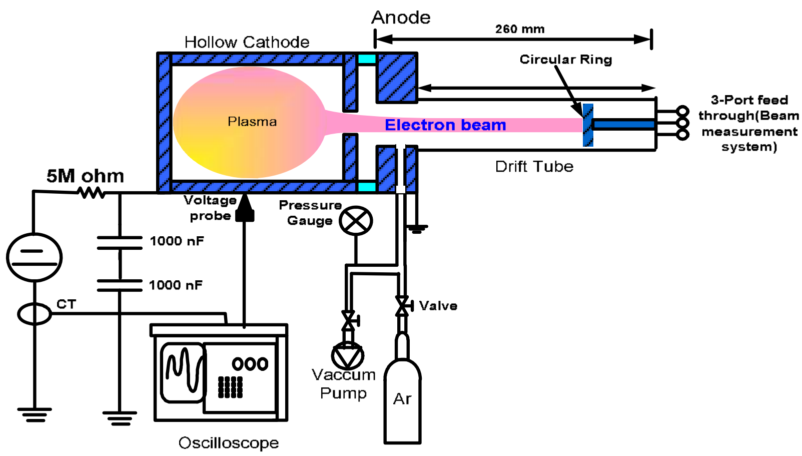

Fig. 1. Schematic view of Experimental set-up

Fig. 2. Developed single gap PCE Gun

3. Results and discussions

Experiments have been performed for the analysis of beam current distribution inside the drift space of 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. The high voltage applied across the pseudospark chamber was then increased slowly until breakdown occurred. All the discharge took place nearly around 10^{-1}mbar. A graph has been plotted between different breakdown voltages and pressure which is shown in Fig. 3 at fixed gap between anode and cathode of 3mm. This curve further confirms the pseudospark nature of discharge. Real time waveform for beam current and discharge current has been plotted for 16kV in Fig. 4 which clearly demonstrate the pseudospark characteristics. A typical experimental trace for different breakdown voltages vs. beam current &discharge current has been reported in Fig. 5 at fixed location z=14.5cm inside the drift tube. Beam current and discharge current is found to be increasing with respect to applied voltage. Figure 6 represents the variation of beam current inside the drift space at two distinct locations which are start and end of drift space which is 15cm long. During propagation of beam inside the drift space, there is beam loss mainly due to recombination with ions, collision with walls etc. Analysis for axial and radial variation of electron beam profile has been carried out. The electron Beam is found to be focused inside the drift space [7]. Radial variation of beam current density at two different distinct axial locations (z=0 & 107 mm) for 20kV applied voltage is shown in Fig. 7. Due to the beam loss during propagation, reduction in current density has been observed.

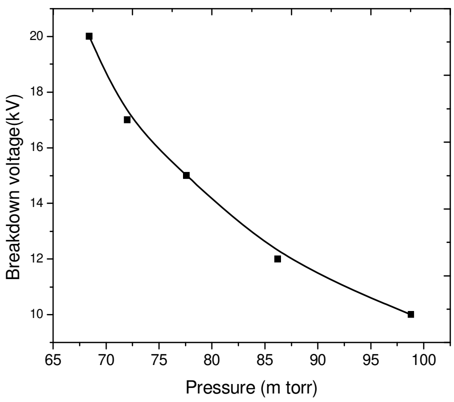

Fig. 3. Experimentally deduced breakdown voltage vs. applied pressure at (gap=3 mm, cathode aperture=3 mm) *Ref.* [7]

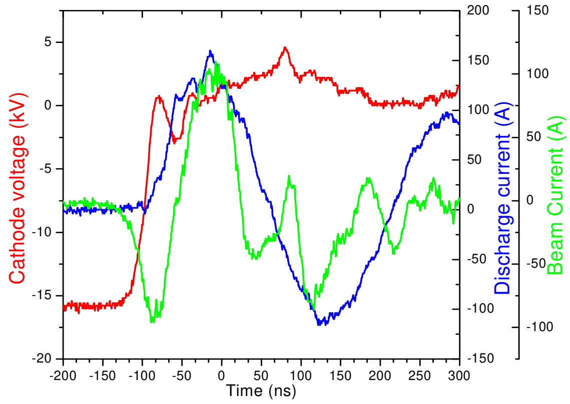

Fig. 4. Typical trace for beam current and discharge current @ 16kV

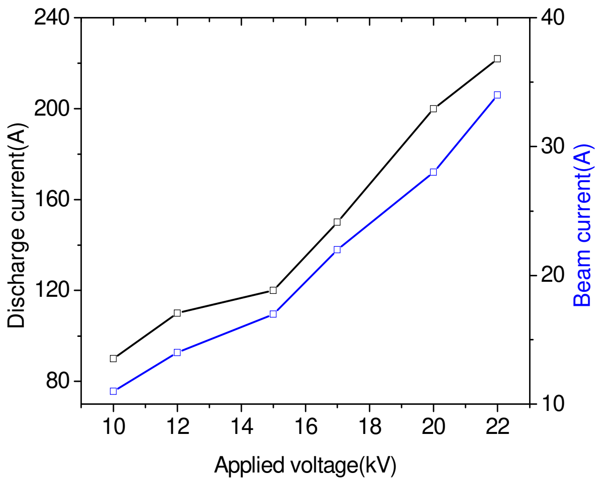

Fig. 5. Beam current and discharge current variation vs. applied voltage at z=14.5cm

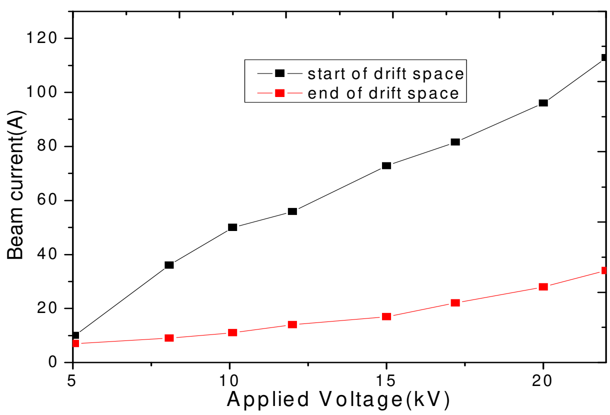

Fig. 6. Beam current vs. applied voltage

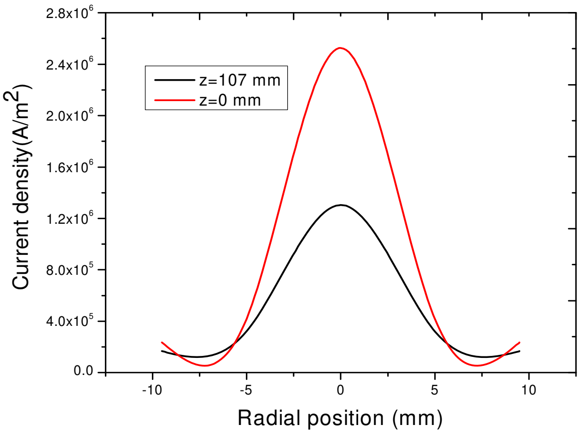

Fig. 7. Radial beam current density at 20kV

4. Conclusion

We have successfully designed and developed pseudospark based electron gun. The pseudospark discharge has been found to be a promising source of high brightness and high intensity electron beam pulses. The experimental investigation has been carried out for axial and radial variation of the beam current inside the drift space of PCE-gun. Analysis of the electron beam profile has been done experimentally for different applied voltages. It has been proved the successful propagation of electron beam in confined manner without any assistance of external magnetic field.

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