Technological Advancement in Plasma Assisted Microwave Source at CSIR-CEERI

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Abstract

A pseudospark discharge is a viable possibility for plasma assisted microwave source development due to the emitted linear beam characteristics, such as, high current density and high brightness as well as self-focusing during its propagation. The pseudospark discharge based single gap plasma cathode electron (PCE) gun, multi-gap PCE-Gun and sheet beam PCE-Gun have already been developed. The X-band slow wave structure (SWS) for beam-wave interaction has been designed, developed and characterized which operates in the range of 8.5 -9.7 GHz. The conical horn antenna has been designed and characterized for spent beam collection. The assembly of the SWS with conical horn antenna for generation of microwave signal has also been developed. The design parameters have been optimized accordingly for efficient microwave generation. The design and technology establishment would lead to test an integrated plasma assisted microwave source at CSIR-CEERI.

Keywords

Pseudospark, Electron Beam, Microwave, Plasma.

I. Introduction

For high power microwave generation, a small size, light weight source is a plasma-assisted slow-wave oscillator called 'PASOTRON', which has drawn considerable attention of the researchers for the last couple of decades [1-2]. The plasma-assisted devices can be especially attractive for systems and applications where size and weight reductions are important. The research work done in the past showed that the presence of controlled amount of ionized gas (plasma) inside the microwave tubes had improved their characteristics beyond what is currently available in vacuum devices [2]. The presence of plasma increases the beam current transport and can relax the required magnetic field in microwave tubes, and significantly improve their performance with respect to RF power, bandwidth, efficiency, compactness, and long-pulse as well as high pulse repetition frequency (PRF) operation capability, etc. Recently research work on plasma assisted microwave sources has been started at CSIR-CEERI and significant progress has been made.

The plasma assisted microwave source mainly consists of plasma cathode electron gun (PCE-Gun) as an intense electron beam source, periodic slow wave structure (SWS) for beam-wave interaction and antenna for radiating the microwave signal. A 3 mm hollow cathode- anode aperture, 5-20kV/50-160A PCE-Gun has already been developed based on Pseudospark discharge [3-6]. Particle-in-cell (PIC) simulations have also been performed to analyze the discharge characteristics of PCE-Gun [5].

A sheet-beam plasma cathode electron gun has also been developed and demonstrated [7]. The maximum current density ~1kA/cm2 with propagation length of sheet beam ~ 200 mm has been achieved. The X-band SWS for beam-wave interaction has been designed, developed and characterized for its operation in the range of 8.5 GHz -9.7 GHz. The SWS and conical horn antenna alongwith PCE-Gun has been coupled for the beam wave interaction analysis and radiation study. This paper reports the earlier efforts and development in this area.

II. Experimental set-up

The schematic view of the experimental setup is shown in Fig. 1. The hollow cathode geometry with a central aperture facing a planar anode has been used to design the PCE-Gun. The hollow cathode has been taken cylindrical in shape with inner and outer diameters 50 mm and 56 mm, respectively along with length 50 mm. The thickness of the cylinder and the cathode-anode aperture has been kept 3 mm in size. The anode dimension has been taken same as that of the cathode. The anode and cathode are assembled in a ceramic casing with 3 mm gap between them. The hollow cathode has been connected to a negative DC power supply 20 kV, 1 mA through a 5 MΩ charging resistor while anode has been grounded. The electron beam originating out from the cathode-anode aperture during PS discharge which has been exerted in the drift space region. A copper circular disc of different dimensions has been used in the drift space region to collect the electron beam. The beam current at the collector has been measured with the help of current transformers (Model 110, Pearson Current Monitor).

The PCE-Gun has been evacuated up to 10-6 mbar using TMP (Varian Turbo V-301) and then refilled with argon gas in a controlled manner using Mass Flow Controller (Matheson:8272-0453). The high voltage applied across the PS chamber has been increased slowly until breakdown occurred. There was no external guiding magnetic field applied to the drift space. The charging voltage has been measured using a voltage probe (Tektronix P6015A, attenuation: 1kX) connected to the digital oscilloscope (Tektronix DPO 4054) which synchronously displays the voltage and current waveforms.

III. Results and Discussion

The typical trace for the discharge current and gas gap voltage profile for the PCE-gun has been obtained for different operating conditions. A sample waveform of gas gap voltage 15 kV is shown in Fig.2 which depicts the beam current measured at z=107 mm. The energetic component of the beam is formed during the pre-breakdown phase whereas the low energy beam component is formed when the applied voltage gets collapsed due to conductive path formation between the hollow cathode and anode. Due to this behaviour of PS discharge, distinct phases have been observed in the beam generation. In the hollow cathode cavity the plasma is a copious source of electrons, which has been used to generate the high current density electron beam. The discharge in the PCE-gun is an axially symmetric self-sustained transient low pressure gas discharge. Furthermore, together with the delayed voltage breakdown and a fast current rise we have achieved an intense electron beam. The beam current has been measured at different axial positions inside the drift space using different collectors. The beam current and the discharge current have been experimentally deduced for different applied gap voltages and different axial locations inside the drift space.

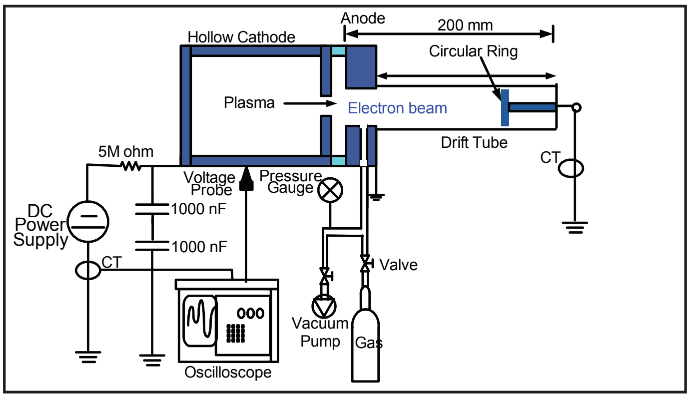

Fig. 1: Schematic view of experimental set-up

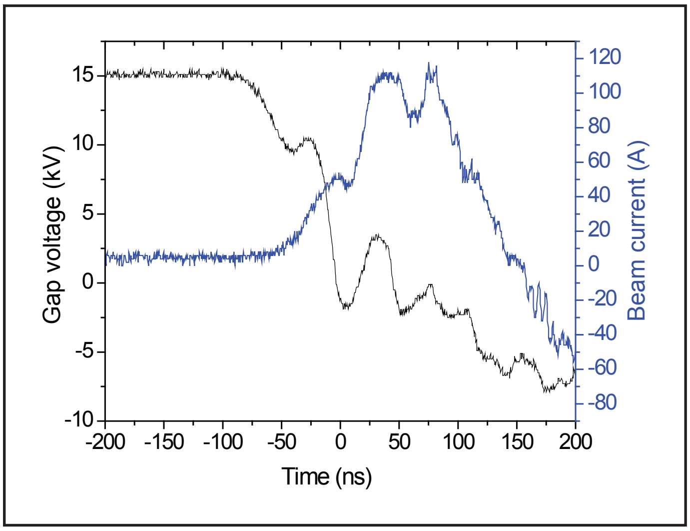

Fig. 2: V-I characteristics for developed-PCE Gun (Argon gas at 10 Pa)

A waveform for the beam current and discharge current for different applied gap voltages at z = 53 mm inside the drift space is shown in fig. 3.

At the higher applied voltages, the positive accelerating field penetrates to the larger extent inside the hollow cathode region and creates more ionization. This leads to increase in beam current as well as discharge current. Similar behaviour has been observed in the developed PCE-Guns.

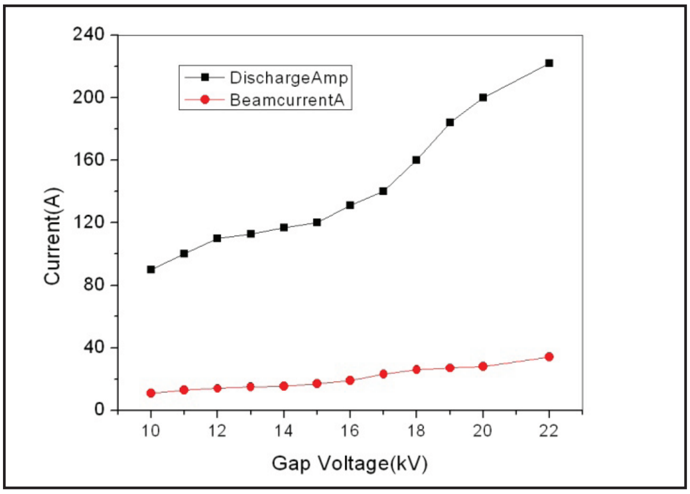

Fig. 3: Beam current and discharge current at different applied voltages

IV. Conclusion

A single gap pseudospark discharge based PCE-Gun has been successfully designed and developed for the generation of short pulse electron beam for its application in plasma filled microwave source. The PCE-Gun is capable of producing intense electron beam which has been propagated more than 200 mm in the drift space region without application of external magnetic field in drift space. Recent developments have been made for beam wave interaction analysis as well as microwave generation in the X-band at CSIR-CEERI.

V. Acknowledgement

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