Pseudospark-sourced Micro-sized Electron Beams for High Frequency klystron Applications

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Abstract: Electron beams of micro sizes have been recently extracted from a pseudospark discharge. A three cavity pseudospark-driven 94 GHz klystron has been designed and simulated using the particle-in-cell (PiC) code MAGIC-2D and modeled with CST Microwave Studio. The simulation results to date look promising.

Keywords: Klystron, Pseudospark discharge

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1. INTRODUCTION

In recent years radiation sources in the terahertz region (0.1-10*THz*) have received much interest because of the demand in the fields of plasma diagnosis, radiotherapy and advanced communication, etc. All these applications require compact and inexpensive radiation sources. The klystron is an excellent choice for high frequency generation, due to its high gain, high efficiency and robustness as well as the fact that it may be scaled in size in order to achieve higher frequency operation [1]. Due to the decrease in size as the frequency is increased, there is a need for the electron beam current density to increase in order to achieve reasonable output powers. A pseudospark discharge is a viable possibility in this respect, due to the emitted linear beam's characteristic properties such as high current density and high brightness as well as being self-focusing during its propagation [2, 3]. A pseudospark driven microklystron will be a compact and simple device as no external magnetic guiding field is required. Experimental results of the production of pseudospark-sourced electron beams of diameter in the submillimeter range and 94 *GHz* klystron simulation results will be presented.

2. PSEUDOSPARK MICRO BEAM EXPERIMENTS

Pseudospark (PS) discharge has been studied at Strathclyde University for a number of years with regard to its underlying physics and potential applications [4-9]. Because of its scalability accompanied with its ability to produce a high quality beam, it is an ideal electron beam source for high frequency radiation sources extending from Ka (26.5*GHz* to 40*GHz*) band, W (75*GHz* to 110*GHz*) band to the terahertz region. The propagation of a PS electron beam is aided by an ion channel formed by the front of the beam resulting in no need for a guide magnetic field, which brings great simplicity and feasibility. Most recently, beams of 200, 100, and 70 microns respectively have been extracted from a single-gap PS discharge. As shown in Figure 1, a single-gap PS discharge chamber is constructed with a 3mm aperture through the anode and cathode, an 8*mm* insulation disc and a 0.5*mm* thick collimating disc of 200, 100 and 70 microns apertures each attached to the anode respectively. Corresponding to the beam sizes, the beam currents after the collimating disc are measured in the range of 1A to 300 *mA* at a beam voltage of 8 *kV*. This shows the possibility to use the PS beams to drive klystrons for millimetre wave to terahertz radiation generation. At a pressure of 100mTorr, a typical output current was measured as shown in Figure 2 with a collimating disc of 70 micron aperture attached to the anode. It demonstrates an output current of various stages with current from 260*mA* to 6*A* corresponding to voltage from 12 *kV* to 5 *kV*. This beam is very promising for driving a microklystron.

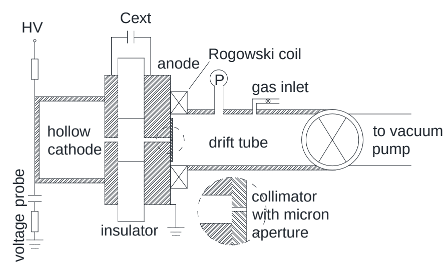

Fig. 1 Schematic of PS micro beam experiment

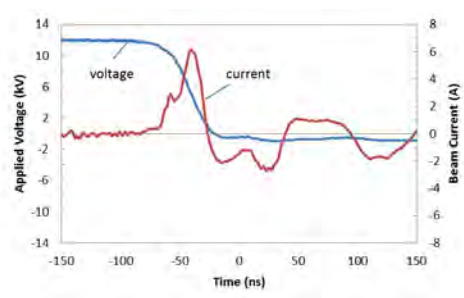

Fig. 2 Typical current and voltage traces of 70 micron PS beam

3. MICROKLYSTRON SIMULATIONS

Based on the 200 micron diameter PS–sourced electron beam, a three cavity 94 *GHz* klystron has been designed and simulated using the Particle-In-Cell code MAGIC and modeled by CST Microwave Studio. This 94 *GHz* klystron is driven by an 8*kV* electron beam of 80μm radius and 15*mA* current focused by a 0.6*T* magnetic field in the simulation, as shown in Fig. 3. MAGIC-2D results revealed a strong amplification signal with a peak power output of 20*W*, a gain of 20*dB* and an efficiency of 16.7% when the Q-factors were 880 for the input cavity and 1800 for the other two cavities, as shown in Fig. 4. Simulations were also performed using a modified current and voltage pulse in an attempt to better model device performance with a realistic pseudospark pulse. Voltage was stepped down to an average of 8 *kV* for 15ns before dropping to zero, whilst a current pulse of peak current 15 *mA* was timed to coincide with the voltage step, as shown in Fig. 5.

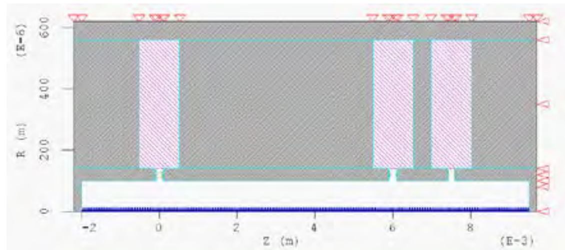

Fig. 3 The schematic diagram of the 94 GHz klystron

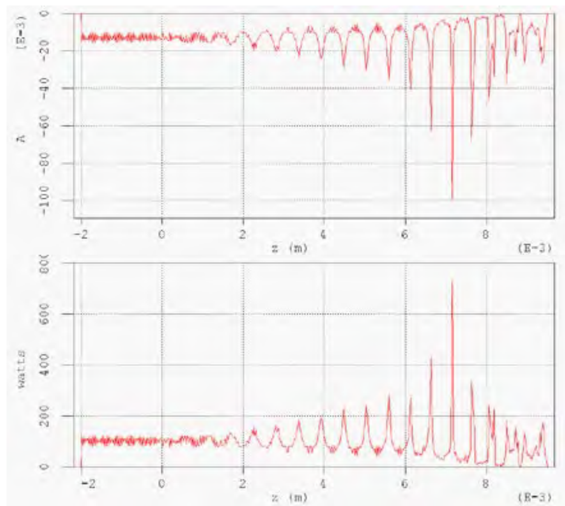

Fig. 4 Strong amplification in the klystron simulation

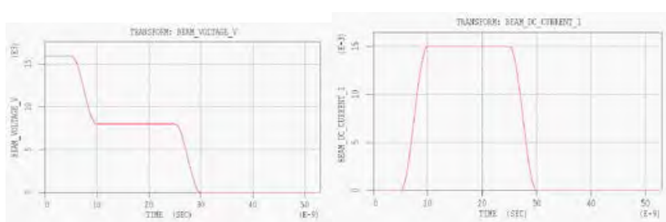

Fig. 5 Pulsed current and voltage traces, 15 ns duration.

4. MICROKLYSTRON DESIGN WITH COUPLER

Owing to the precise dimensions involved with high-frequency klystron design and manufacture, coupling was an issue due to the cavities possessing dimensions significantly smaller than waveguide of corresponding frequencies. A solution has been proposed via coupling the input and output cavities to a tapered length of waveguide, gradually increasing to standard waveguide dimensions. In order to compensate for the difference in cut off frequency, the taper is lined with a dielectric material, thus altering the effective cut off frequency along the length of the coupler. The proposed structure was then modeled in CST Microwave Studio. The coupling arm itself shows an expected forward transmission of ~98%, whilst transmission via a modified klystron cavity gives a forward transmission of ~80%. Steps are currently underway to construct and test the coupler and device.

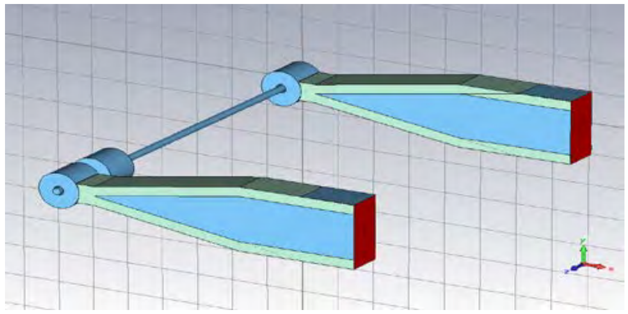

Fig. 6 CST Microwave Studio modeled 3-cavity klystron.

5. SUMMARY AND ONGOING WORK

A three-cavity klystron which operates at a frequency of 94 *GHz*, using a pseudospark discharge as a beam source, is currently under investigation. Through the use of the EM modeling packages MAGIC-2D and CST Microwave Studio, it has been possible to construct a realistic model of device performance. Manufacturing and experimental measurements shall begin soon on the 94 *GHz* klystron, as well as testing of the coupling system.

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