Experimental Study of Post-Acceleration and Transport of a Pseudospark-Produced Electron Beam*

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Abstract

Preliminary results of post-acceleration and transport experiment of a pseudospark-produced electron beam are presented. The electron beam propagating in a low-pressure gas is accelerated by a simple induction linac system. The beam transport characteristic in the gas filled drift tube is determined and the beam appears to be in the ion-focusing regime. The brightness of the post-accelerated beam is found to be $\sim 2\times 10^{10}$ A/(m rad)^2.

I. INTRODUCTION

Recently, high-brightness electron beam produced by a simple pseudospark device has been reported.[1] Such high-brightness beam sources would find immediate application in high-current accelerators[2] and in rf sources such as free-electron lasers.[3],[4] In this work, preliminary experimental results of post- acceleration and transport of a triggered pseudospark produced electron beam are reported. The electron beam, produced and propagated in the same low-pressure background gas, is accelerated by a simple induction linac system. The current, emittance and time-resolved energy spectrum of the electron beam are measured in conjunction with the study of the post- acceleration and transport of the beam.

II. EXPERIMENTS

A. Experimental Setup

The experimental setup is shown in Fig. 1. The discharge chamber consists of a planar cathode with a hollow cavity, two sets of intermediate electrodes and insulators, and a planar anode. The hollow cavity is a 2.54-cm diam 4-cm long cylindrical cavity in which a trigger electrode made of 6.35-mm diam semirigid coaxial cable is inserted. All the electrodes are made of brass and the insulators are of plexiglas. A 3.2-mm diam center hole is present through the entire electrode system. The storage capacitor used in this experiment is a 2.7 nF low- inductance type door knob capacitor. A homemade compensated resistive divider is used to monitor the cathode voltage. A Rogowski coil is built into the downstream side of the anode flange to monitor the electron beam current extracted through the anode hole. A diagnostic chamber, which is placed below the linac module, can accommodate various diagnostics such as a movable Faraday cup, a movable emittance meter and a time-resolved energy spectrometer.

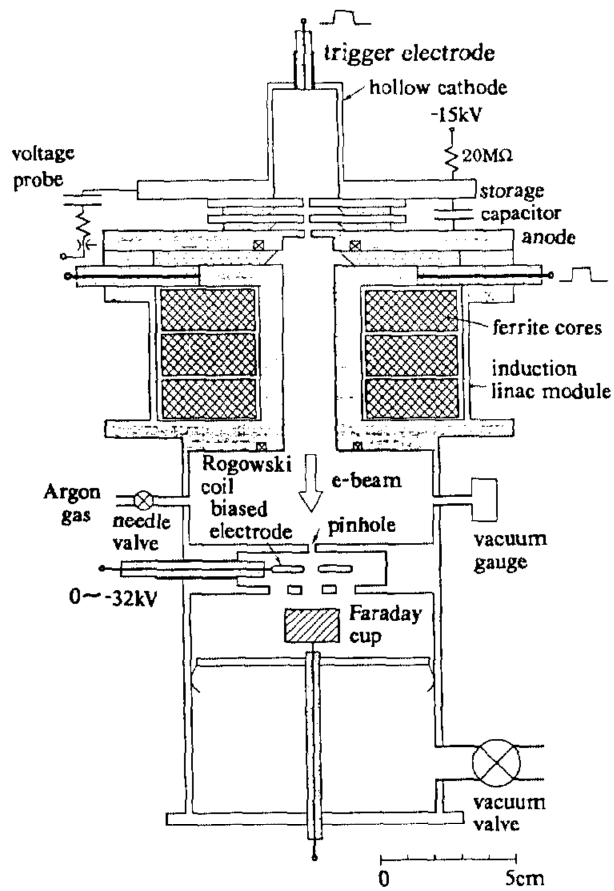

FIG. 1 Experimental setup.

B. Time-Resolved Energy Spectrum

Experimental setup as shown in Fig. 1 is used in this experiment. The cathode is charged to -15 kV with respect to the grounded anode through a 20 MΩ charging resistor. The entire chamber is initially evacuated by an oil diffusion pump typically down to 10^{-5} Torr. A time-resolved energy spectrometer system,[5] which consists of a 0.5-mm diam pinhole, a biased electrode, and a Faraday cup, is placed downstream of the anode. Argon gas is then slowly filled at a slow flow rate through a needle valve in the upper chamber while the pinhole allows the gas leak into the downstream chamber maintaing a constant differential pressure in the upper chamber and vacuum in the downstream chamber. The pressures used in this experiment are 55 and 75 mTorr, which are measured by a capacitance-manometer type vacuum gauge. By applying +20 kV pulse to the trigger electrode, the main discharge is triggered with low

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jitter time of <1 ns. The cathode voltage during the discharge

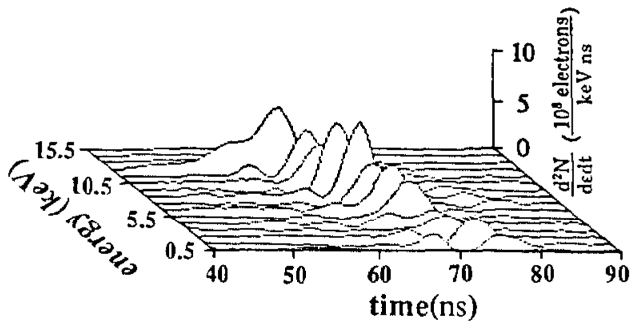

FIG. 2 The time-resolved energy spectrum of the pseudospark- produced electron beam.

is measured by the resistive probe. The electron beam generated by this discharge is sampled by the 0.5 mm diam pinhole, allowing the sampled beamlet to propagate in the vacuum cavity of the spectrometer. Only electrons of energy higher than that corresponding to a given bias voltage can pass through the center hole of the biased electrode and arrive at the Faraday cup. The bias voltages are varied from 0 to -16 kV in 1 kV increments, and the corresponding Faraday cup current signals are recorded in a digital oscilloscope. The differences between two digital waveforms of adjacent bias voltages are computed by using a personal computer. The time-resolved energy spectrum is then constructed by plotting the resultant differential waveforms as functions of energy as shown in Fig. 2.

C. Post-Acceleration

An induction linac module is attached to the downstream side of the anode as shown in Fig. 1. The linac module is terminated by a matched load 25 Ω. This is done by two 50-Ω cables (not shown in Fig. 1), one of which is conveniently used for monitoring the voltage across the accelerating gap. The electron beam generated by this discharge propagates through the induction linac. The induction linac is powered

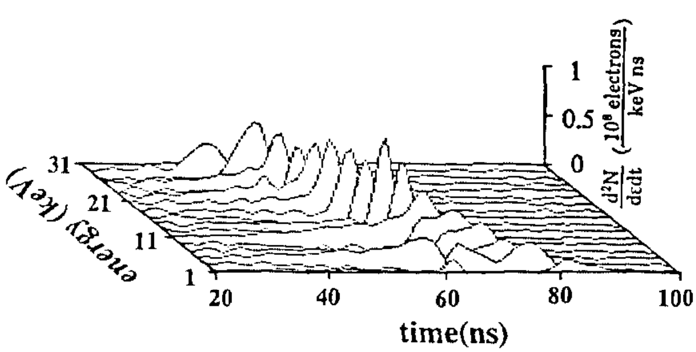

FIG. 3 The time-resolved energy spectrum of the post-accelerated pseudospark-produced electron beam.

by the Blumlein modulator that also triggers the pseudospark. Thus, the beam generation and accelerating voltage are in good synchronization. For this experiment the bias voltage is varied from zero to -32 kV in 2 kV increments and the time-resolved energy spectrum is constructed by analyzing the Faraday cup signals as described in the previous section. The resulting spectrum is plotted in Fig. 3.

It is found that the both time-resolved energy spectra shown in Figs 2 and 3 have relatively narrow spreads: instantaneous energy spreads of <1.5 keV and temporal spreads of < 2 ns. The projection of peak intensity points of each differential waveform for both cases onto the energy-time space is shown in Fig. 4. It is observed that the plots of peak intensity points for the beam before the post-acceleration follow closely the cathode voltage waveform. The plots for the post-accelerated beam are also in good agreement with a curve that is the sum of the cathode voltage waveform and the accelerating voltage waveform of the induction linac.

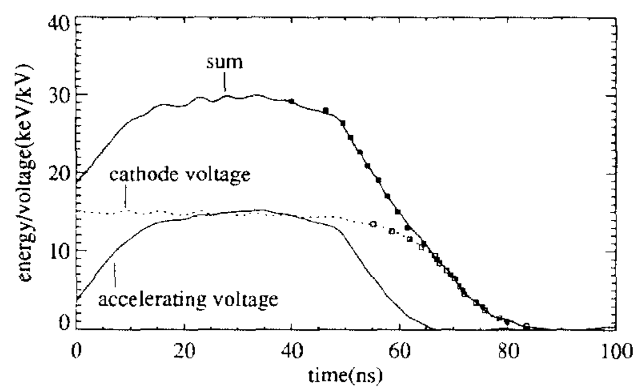

FIG. 4 Comparison of the projection of peak points of the spectra onto energy-time space with the voltage waveforms.

D. Beam Transport

The pseudospark chamber is operated at -15 kV with two different gas pressures 55 mTorr and 75 mTorr. The same gas pressure is filled in the drift tube and the accelerating gap of the induction linac. The current at downstream is measured with a movable Faraday cup at various axial positions ranging from 0.5 to 10 cm. The measurements are done for the both pressures and also with and without the post-acceleration. The typical peak current measured at anode is -1 kA. The peak values of the downstream beam current normalized to that at the anode hole are plotted as functions of the axial distance as shown in Fig. 5. The results are qualitatively in agreement with the beam propagation characteristic in the ion-focusing regime in which beam induced ionization results in self- focusing of the electron beam. The radial profile of the beam is also measured at different axial positions by using a slit plate and a radiachromic film (emittance meter). The radiachromic film is exposed to a number of consecutive beam pulses so as to produce an appropriate density profile, with the peak value of optical density not exceeding 0.5. This ensure that the measured optical density distribution is linear to the beam density. The exposed film is then scanned by an optical microdensitometer. The resultant profiles are curve fitted to Gaussian as shown in Fig. 6.

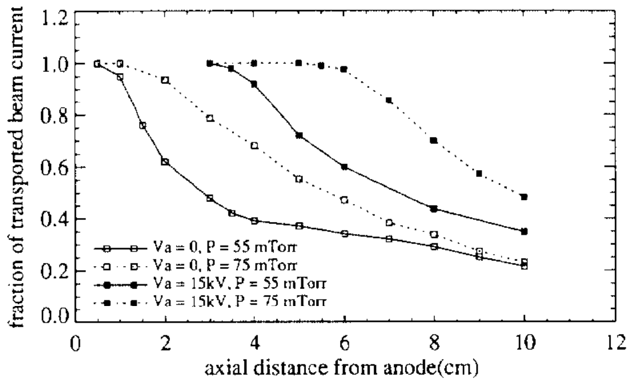

FIG. 5 Fraction of transported beam current in argon gas as a function of the axial distance.

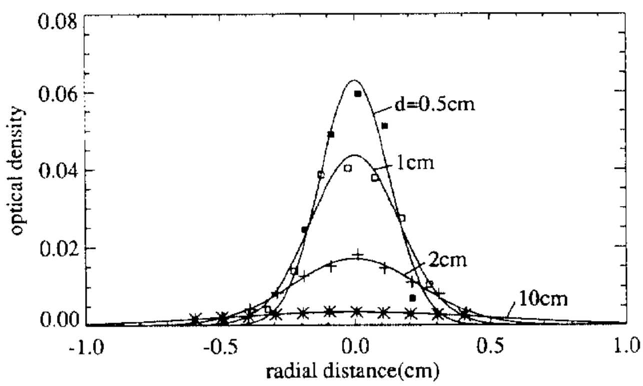

FIG. 6 The beam profiles measured at various axial positions.

E. Emittance and Brightness

The emittance of the post-accelerated beam is measured at 10 cm downstream of the anode by using the emittance meter. The procedure of the measurement and analysis are detailed in Ref.[6] The effective emittance[7] of the beam is found to be ϵ = 243 mm-mrad with the measured beam current I = 450 A. The normalized brightness[8] may be defined as $B_n = I/(\beta\gamma\pi\epsilon)^2$. Assuming an average beam energy of 25 keV, the normalized brightness is found to be $B_n = 2\times10^{10}$ A/(m rad)2.

IV. CONCLUSION

Post-acceleration and transport of the electron beam produced by a triggered pseudospark device have been experimentally studied. The electron beam that is propagating in a low-pressure gas is accelerated by a simple induction linac system. Time- resolved energy spectrum reveals that the instantaneous beam energy is equal to the sum of the cathode voltage and the accelerating voltage of the induction linac. The beam transport in a low-pressure gas is qualitatively in agreement with characteristic of beam propagation in the ion-focusing regime. The normalized brightness of the post-accelerated beam is found to be ~2×10^{10}A/(m rad)^2.

V. REFERENCES

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