THE PHENOMENA OF ELECTRON CHARGE EJECTION DURING THE HOT ELECTRON BEAM TRANSPORTATION

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The transportation of hot electron beam through the drift chamber along the magnetic field was experimentally studied. The main attention was paid to the phenomena of electron charge ejection on the drift chamber wall. Experimental results shows that self-consistent Penning-Malmberg trap occurs after the stage of non-stationary virtual cathode with the limiting of electrons current in axial direction and radial ejection of electrons on the chamber wall. PACS: 52.27.Jt

1. INTRODUCTION

Theoretical consideration of electron charge ejection phenomena was made in [1]. The results of this consideration were experimentally confirmed by V. Fedorchenko [2]. Both considered a simple diode configuration without a magnetic field.

In this work the transportation of hot electron beam through the drift chamber along the magnetic field was experimentally studied. The main attention was paid to the phenomena of electron charge ejection on the drift chamber wall.

The experimental results of charged particles ejection dynamics for a various charge density increasing rates in the space of drift are submitted.

The main differences between phenomenon described in this work and charge ejection studied in [1, 2] are:

- the presence of a longitudinal magnetic field;

- the ejection of a charge occurs in a radial direction;

- the ejection of a charge occurs at the moment of a beam current break-down.

2. EXPERIMENTAL SETUP

The scheme of experimental setup is shown on Fig.1. The main beam was generated by the electron gun. Such gun consists from indirectly heated cathode and anode metal grid. The injection of electron beam was provided by applying of positive voltage pulse (injection pulse) to the anode grid. The form of anode grid was chosen specially for obtaining the required form of electron beam (hollow cylinder). The main beam was injected into the drift space (a brass tube of length L = 150 cm. and diameter D = 4 cm.) at whose entrance and exit were flat metal grids. The tube was cut parallel to the generatrix into two equal halves and was made up of two sectors of angular extent 180º (π - electrodes). Both sectors were attached to the leads and used for diagnostic purposes. The thickness of injected beam was Δ = 1…2 mm. and its diameter was d = 2 cm. The beam energy was 20…80 eV. The constant longitudinal magnetic field had a strength of H = 100…2000 Oe. The magnetic field varied over the length of the drift tube by less than 5% so we assumed it to be uniform inside the drift tube. It is also necessary to note that injector is located near the entrance to the drift tube at the area of non-uniform magnetic field. The range of working pressures was $10^{-4}…10^{-7}$ Torr.

Diagnostic measurements of axial distribution of electrostatic potential were made by high-frequency Langmuir probe. The probe was placed on the mobile carriage together with a multigrid electrostatic analyzer. The occurrence and evolution of diocotron oscillations was detected by π − electrodes. In this experiments we generated diocotron modes with the azimuthal wave number l = 1. In this case the oscillations of current induced on each of the π − electrodes are in opposite phases. The flat grids located at the entrance and exit of the drift tube were used for measuring of current input and output.
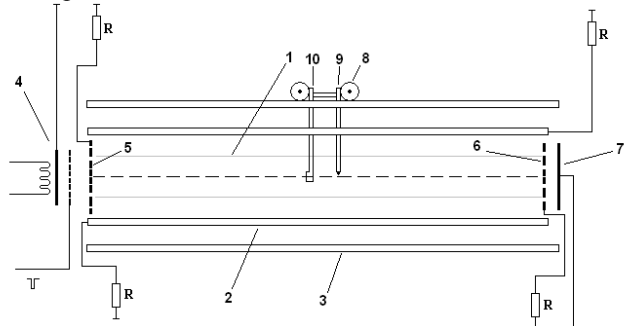

Fig.1. Schematic of the experimental setup:
1) electron beam; 2) drift tube; 3) vacuum chamber;
4) electron gun; 5) entrance grid; 6) exit grid; 7) collector;
8) carriage; 9) high-frequency Langmuir probe;
10) electrostatic analyzer

3. EXPERIMENTAL RESULTS

3.1. DYNAMICS OF PARTICLES EJECTION DEVELOPMENT

The Ejection charged particles across the magnetic field was observed during the transportation of cylindrical electron beam through the space of drift. Such beam had a strong dispersion in velocities.

The space of drift was limited axially by two π-electrodes and radially by two measuring grids. Fig.2. represents the oscillograms of signals obtained from π-electrodes. This oscillograms displays the dynamics of particles ejection process and diocoron instability absence thereof instability. Asymmetrical pulses were development. Fig.2(1) displays the signals obtained in the

drift chamber. The occurrence of diocotron oscillations was always preceded by the ejection process. Such process arises initially at the end of the injection pulse as a small pulse of voltage. In case of beam current increasing the ejection pulse moves towards the first front injection pulse. During such movement the pulse of ejection becomes shortened (Fig.2(2)-2(6)).
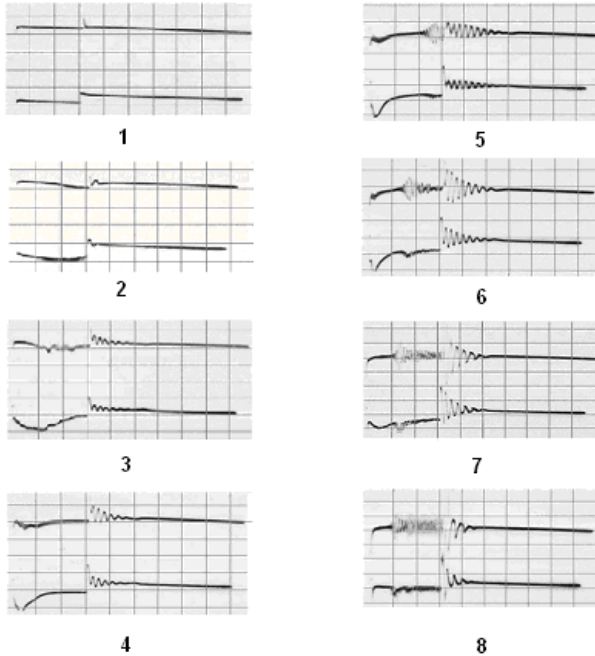

Fig.2. Oscillograms of signals from π-electrodes. Sensitivity - 0.05 V/div; broach - 0.2 ms/div; H=1 κOe. Amplitudes of injection impulses: U_1=20 V, U_2=21 V, U_3=23.5 V, U_4=25 V, U_5=27.5 V, U_6=30 V, U_7=32.5 V, U_8=35 V

It is also necessary to note that the diocotron oscillations were not only observed during the pulse of injection. So called "tails" of damped diocotron oscillations were formed after the pulse of injection (Fig.2(2)). In case of beam current or energy increasing the duration of such tails grows together with the injection pulse amplitude. Finally "tail" duration may exceed the length injection pulse. Further growth of the injection pulse amplitude reduces to transition of the diocotron oscillations into a noise mode (Fig.2(7)-2(8)).

3.2. THE DYNAMICS OF LONGITUDINAL AND CROSS CURRENTS

There is a strong connection between variations of longitudinal and cross currents during the injection pulse energy changing. The oscillograms of such currents are presented on Fig.3. Here the top traces represent the signal from π-electrodes while the bottom traces represent the signal from the measuring grid. It is easy to notice from given oscillograms (Fig. 3(1)) that the ejection pulse is followed by the stage of longitudinal output current growth. Fig.3(2), 3(3) displays the time shortening of signals observed on π-electrodes. From Fig.3(4) one can conclude that the longitudinal output current growth stage is followed by satiation stage. After the electrons cross-ejection the amplitude of π-electrode signal is also established on the certain level which does not change during the pulse of

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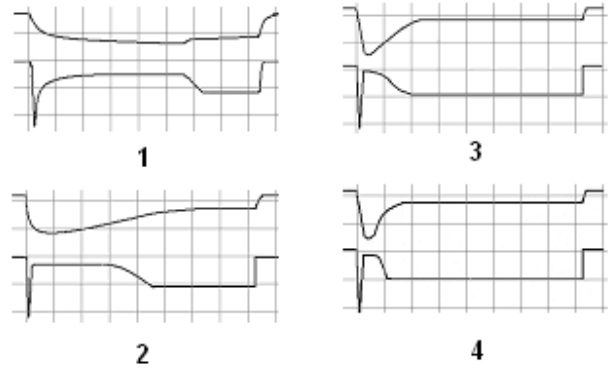injection. Fig.3. gives a rough idea about dynamics of longitudinal and cross currents in considered system.

Fig.3. Signals obtained from π-electrode and measuring grid. Sensitivity of the top trace - 0.5 V/div; sensitivity of the bottom trace - 2 V/div; broach - 0.1 ms/div; H = 1 κOe

3.3. THE CASE OF SINUSOIDAL INJECTION PULSE

The experimental study of charged particles cross ejection was also provided for various durations of the injection pulse fronts. With this purpose we applied a sinusoidal injection pulse on the anode grid of the electron gun. Different durations of the injection pulse were obtained by varying the frequency of applied sinusoidal voltage. Fig.4(1) represents the oscillograms of input and output longitudinal currents obtained from entrance and exit grids respectively. The top trace displays a signal from the exit measuring grid and the bottom with the entrance. The exit grid oscillogram observed two jumps of longitudinal current. First of them is caused by the virtual cathode formation process that takes place in the chamber of drift. Second jump corresponds to a longitudinal ejection of electrons. Fig.4(2) displays the oscillogram of signal obtained from π-electrode. The formation of virtual cathode is followed by the particles cross ejection. After such ejection the occurrence of diocotron oscillations was observed. It is also necessary to note that after the second jump of longitudinal current (the restoration of longitudinal current) the "tail" of damping diocotron oscillations was observed.
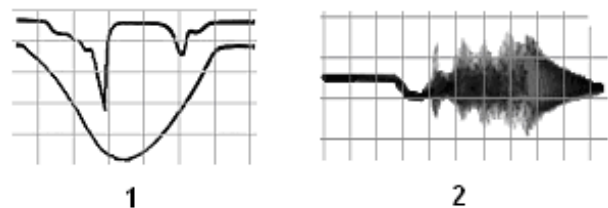

Fig.4. The excitation of diocotron oscillations during and after the sinusoidal injection pulse.
1- Sensitivity of the top trace -0.1 V/div; sensitivity of the bottom trace–5V/div; broach-0.1ms/div;H = 2κOe; 2- Sensitivity – 0.05 V/div, broach – 0.05 ms/div

3.4. HYSTERETIC DEPENDENCES OF LONGITUDINAL CURRENT

The dependences of output longitudinal current on its input value are expressed graphically on Fig.5. This dependence has a hysteretic character. By comparison

with Fig.4. one can conclude that during the reverse motion by the hysteresis curve there is a current after the moment of virtual cathode disappearance. This jump of longitudinal current can be explained as result of charged particles longitudinal ejection. Such ejection was described by V.Rutkevich and A. Paschenko [2].
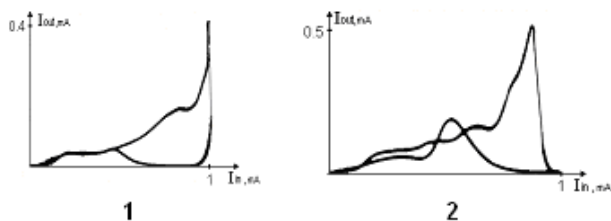

Fig.5. The dependences of output longitudinal current on its input value. H_1=1 кОе; H_2=2 кОе

4. CONCLUSIONS

In the presented work the phenomenon of charged particles (electrons) ejection across the magnetic field is considered. Such phenomenon arises during the injection of cylindrical electron beam with a strong dispersion in velocities into the drift tube placed in longitudinal magnetic field.

Such ejection is followed by the process of non-stationary virtual cathode formation. This formation occurs as result of longitudinal current limiting provided by the spatial charge of injected beam.

It was noticed, that studied phenomenon always precedes the formation of potential double sagging followed by the coherent diocotron oscillations excitation in the space of drift.

Also it is shown, that diocotron instability arises not only in tubular beams, but also in the continuous beams of electrons strongly washed away on the speeds.

REFERENCES

1. A.V. Paschenko, B.N. Rutkevich // *Radiotechnics and Electronics.* 1979, v. 24, p.152 (in Russian).
2. A.V. Paschenko, B.N. Rutkevich, V.D. Fedorchenko, Y.P. Mazalov // *Jornal of Technical Physics.* 1983, v.53, N1 (in Russian).

ЯВЛЕНИЕ СБРОСА ЭЛЕКТРОННОГО ЗАРЯДА ПРИ ТРАНСПОРТИРОВКЕ ГОРЯЧЕГО ПУЧКА ЭЛЕКТРОНОВ

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Произведено экспериментальное исследование транспорта горячего пучка электронов в камере дрейфа в продольном магнитном поле. Основное внимание уделялось явлению сброса электронного заряда на стенку камеры дрейфа. Результаты экспериментов показывают, что формирование самосогласованной ловушки Пеннинга-Малмберга наблюдается после стадии формирования виртуального катода с сопутствующим ограничением аксиального тока электронов и выбросом их на стенку камеры.

ЯВИЩЕ СКИДУ ЕЛЕКТРОННОГО ЗАРЯДУ ПРИ ТРАНСПОРТУВАННІ ГАРЯЧОГО ПУЧКА ЕЛЕКТРОНІВ

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Проведено експериментальне дослідження транспорту гарячого пучка електронів крізь камеру дрейфу у повздовжньому магнітному полі. Багато уваги приділено явищу скиду електронного заряду на стінку камери дрейфу. Результати експериментів показують, що формування самоузгодженої пастки Пеннінга-Малмберга спостерігається після стадії формування віртуального катоду з супутнім обмеженням аксіального току електронів та викидом їх на стінку камери.