HIGH-FREQUENCY GENERATION DURING THE ELECTRON FLOW DECELERATION AND REFLECTION BY THE ELECTROSTATIC POTENTIAL

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In this work we present the results of experimental study of generation of the RF-oscillations in a classic flat triode configuration for both presence and absence of the reflected particles flow. The amplitude and frequency characteristics are studied. The behavior of main characteristic parameters for both cases was analyzed and compared.

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INTRODUCTION

In this work we study the main features of RF-power generation in the flat triode system in which electron flow is accelerated in the space between the indirectly heated cathode and grid electrode and is decelerated when passing towards the anode.

The study of RF – radiation was carried out in two different modes with negative and positive anode potential respectively. The first one represents a well-known Barkhausen-Kurtz generation while the positive anode potential mode was not previously studied in a proper way. It was experimentally observed by V.I. Kalinin [1] but was never considered as a separate mode.

EXPERIMENTAL SETUP

The electron beam instability was found and investigated experimentally in the devices, which simulated the conditions of the instability. The electron flow was investigated in a planar triode electrode geometry. The experimental setup is presented in Fig.1.

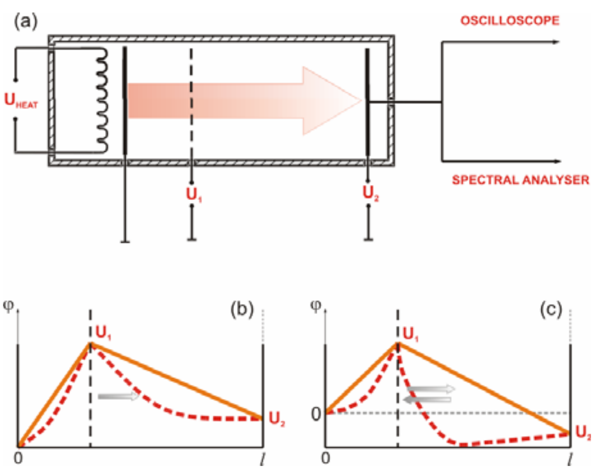

Fig. 1. The schematic experimental setup (a) and the distributions of longitudinal potential (b, c)

The electron flow produced by indirectly heated cathode propagated towards anode and grid. The linear dimensions of the electrodes (grid, anode) substantially exceeded the spacing between electrodes (l = 0.35 cm). The cathode-grid and grid-anode separation distances are in the ratio of 1:5. In the experiments, we measured the anode and grid voltages (U_2 and U_1), the emission current density, and the oscillations spectrum. The amplitude of oscillations was also measured, and the increments were estimated. The vacuum chamber, in which the experiments were performed, was pumped down to a residual pressure of $2\cdot10^{-6}$ Torr. In the second case, the residual pressure was estimated to be about 10^{-7} Torr. In both cases, the cathode was grounded.

EXPERIMENTAL RESULTS

Generation of high-frequency oscillations was observed when the potential of the metal grid was significantly higher than the anode potential. That means that the phenomenon takes place when the flow of electrons is decelerated. In the case of negative anode potential, most of the flow particles were reflected. Thus a "reversed flow" occurs. Otherwise, if the anode potential is positive, the "reversed flow" is not clearly detected.

It was shown that increasing U_1 (the grid voltage) leads to the anode current growth. At the same time the increase of negative anode potential cause the flow current damping (Fig. 2), what may be considered as particles reflection. Thus, the experiment carried out at the negative anode potential deals with both forward and reversed flows.

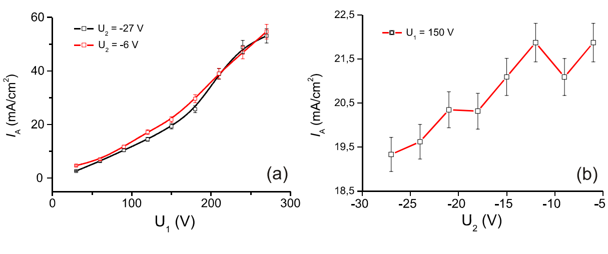

Fig. 2. The case of negative anode potential: volt-ampere characteristics

The oscillations frequency exhibited a strong growth (from 90 to 180 MHz) during the grid voltage increase (U_1 = 30…300 V), Fig. 3,a,b. Increasing the reflecting anode potential (U_2) at the relatively high values of grid voltage (U_1 > 150 V) results in noticeable frequency growth. The frequency spectrum was not clearly linear. For low anode potentials U_2 = - (9…21) V the frequency band width is maximal for small accelerating grid voltages.

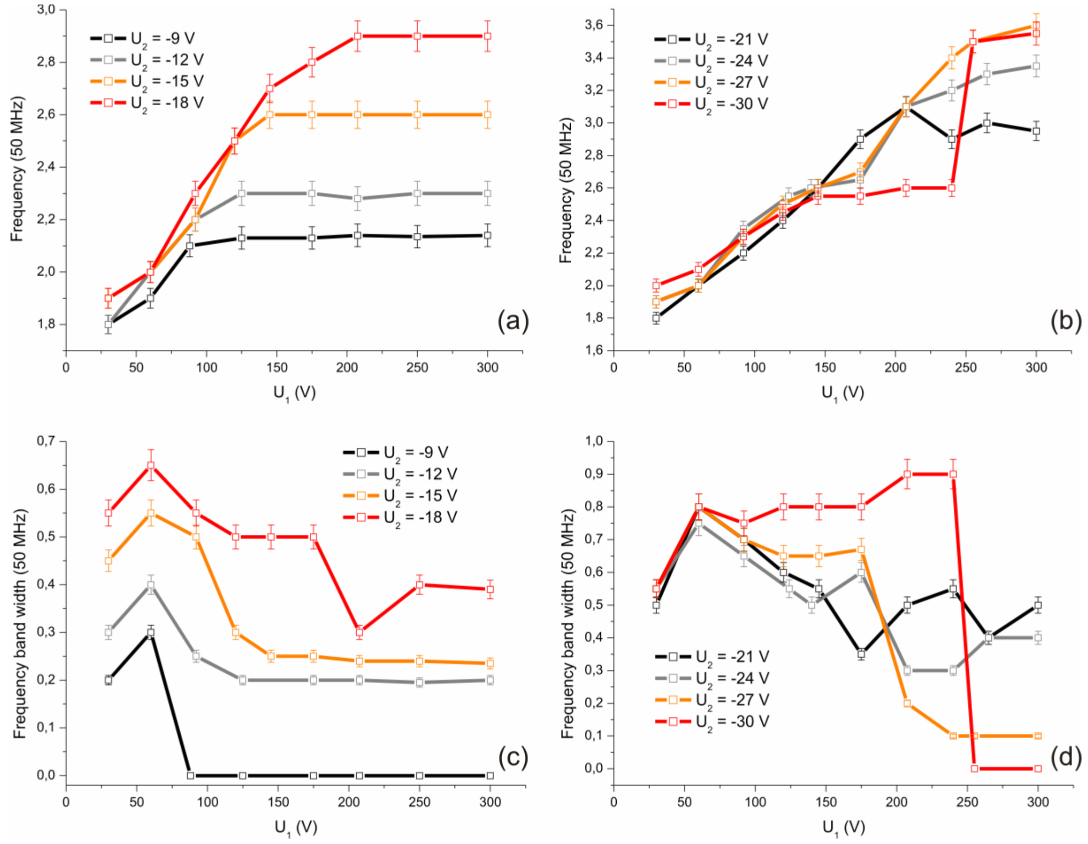

Fig. 3. The case of negative anode potential: RF – generation averaged frequency value (a,b) and band width (c,d) for different anode and grid potentials

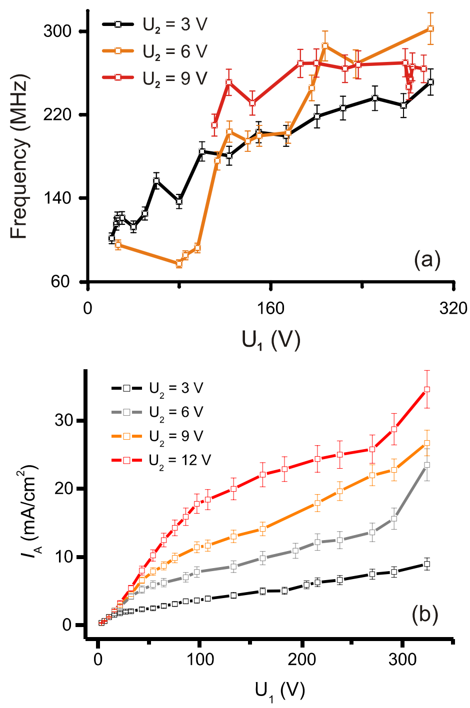

Fig. 4. The case of positive anode potential: generation parameters (a) and volt-ampere characteristics (b)

When U_2 = - (24…30) V the maximum shifts to higher values of U_1, Fig.3,c,d.

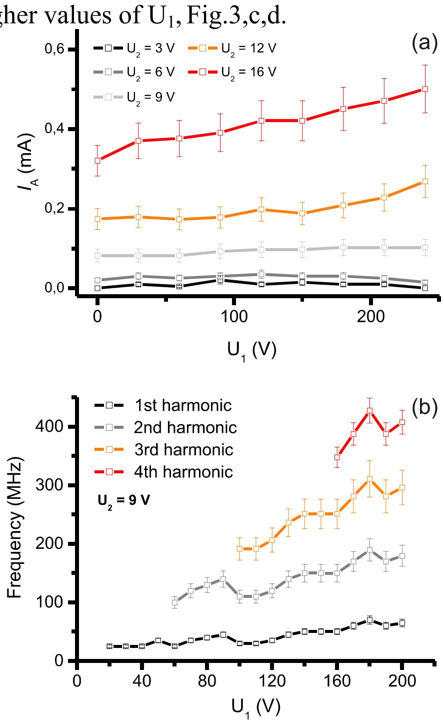

Fig. 5. The case of positive anode potential: volt-ampere characteristics (a) and generation parameters (b) increased system size (l = 3 cm)

In case of the positive anode potential there is no noticeable "reversed flow". The frequency of oscillations similarly grows during the grid voltage increase but the generation range is much narrower and the frequency dependences are more volatile.

The frequency values are also slightly lower than in the negative anode case.

For example, if U_2 changes from 30 to 300 V the oscillations frequency grows from 45 to 160 MHz (Fig. 4).

The experiments provided in similar system with significantly bigger longitudinal size show the frequency decrease. At the same time the generation spectrum was enriched by a number of additional harmonics. For the first harmonic the frequency varied between 25 and 60 MHz. For higher harmonics the frequency exceeded 400 MHz.

The results mentioned above were obtained at U_2 = 9 V. This regime corresponded to the flow deceleration without a noticeable reverse flow formation (Fig. 5).

CONCLUSIONS

A comparative analysis of two generation modes demonstrates sufficient difference in the flow dynamics. Application of negative electrostatic potential to the anode of the system creates a 'reversed flow' which passes through the metal grid electrode towards the cathode. Most particles then become reflected by the cathode potential and move towards the grid electrode. Finally the flow particles oscillate around the grid electrode. This process causes the RF-oscillations in the anode current.

The value of anode potential in this mode affected strongly the RF – generation dynamics.

If the anode potential is positive the 'reversed flow' is usually not detected. The RF – oscillations are therefore localized in the space between the metal grid and anode. The mechanism of such generation is based on the process of energy exchange between the flow particles and the oscilations caused by the system own capacity ant inductivity.

The frequency of oscillations in this mode is less sensitive to the value of anode potential. The frequency magnitudes are slightly smaller than those for the flow reflection modes.

The increase of the system size leads to reduction of RF-oscillation frequency. At the same time it is much easier to observe a higher harmonics of the main generation frequency in such higher-scale devices.

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ВЧ-ГЕНЕРАЦИЯ ПРИ ТОРМОЖЕНИИ И ОТРАЖЕНИИ ЭЛЕКТРОННОГО ПОТОКА ЭЛЕКТРОСТАТИЧЕСКИМ ПОТЕНЦИАЛОМ

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Представлены результаты экспериментального исследования ВЧ-генерации в триоде в режимах с наличием и отсутствием отраженного потока. Исследуются амплитудные и частотные параметры. Проводится сравнительный анализ.

ВЧ-ГЕНЕРАЦІЯ ПРИ ГАЛЬМУВАННІ ТА ВІДБИТТІ ЕЛЕКТРОННОГО ПОТОКУ ЕЛЕКТРОСТАТИЧНИМ ПОТЕНЦІАЛОМ

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Представлено результати експериментального дослідження ВЧ-генерації в тріоді в режимах з відсутнім та наявним потоком відбитих електронів. Досліджуються амплітудні та частотні характеристики. Проведено порівняльний аналіз.