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TRAPPED PARTICLES INFLUENCE ON THE ELECTRON PRODUCTION WITH ANOMALOUSLY HIGH ENERGY

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Introduction

Diocotron instability may be considered as growing electrostatic wave that propagates across the magnetic field. Radial widening of this wave and further capture of azimuthally drifting electrons are usually explained to be caused by nonlinear saturation of the wave. The diocotronic instability in the system of hollow annular electron cord, with the central electrode situated along the axis, is studied in [1]. The central electrode made it possible to control the radial electric field. The variations of frequency and density of electron plasma on the nonlinear stage of the diocotronic oscillations in an annular electron cord are examined in [2]. Nonlinear diocotronic mode is studied theoretically by the method of perturbations of endless electron plasma cord [3].

Electrons of anomalously high energy with periodical diocotron oscillations impulses are observed during examination of the instability of overmagnetted electrons in high-voltage discharge of low pressure inmagnetic field [4].

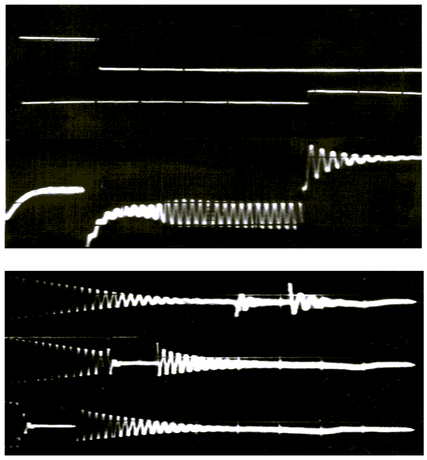
The capture of particles into the field of electrostatic wave is investigated in [5], where also the wave profile dynamics is studied experimentally and theoretically.

In the foregoing work of the authors [6] it is shown that, during the diocotron instability evolution, the spatial redistribution takes place in the beam's cross-section, which is connected, probably, with drift of electrons in longitudinal magnetic field, radial, and azimuthal electric fields of the diocotrone wave.

Experimental results

A detiled describtion of the experimental setup is given in [6].

Stimulation and suppression of the diocotron oscillations were performed with the axial electrode. The effect was produced by short impulses, the duration of the impulse being less than semi period of the diocotron oscillations, as well as impulses with the duration comparable with the time of existence of the oscillations. It's necessary to note that the impulses being short, stimulation or suppression of the diocotron oscillations wasn't strongly pronounced. The amplitude could vary in the range of 10-20% of its maximum. Even when series of the short impulses were applied, the frequency of the impulses being equal to that of the diocotron oscillations, no swinging or damping of the oscillations was observed. When the durable impulses were applied an intensive stimulation or suppression of the diocotron oscillations was observed, in accordance to the polarity of the impulse applied.



a

b

Fig.1. Stimulation of the diocotron oscillation: a) axial electrode (τ=10μs); b) additional beam (τ=100μs)

The oscillogrammes of the diocotron oscillations, which demonstrate the incentive effect of the negative polarity impulses, applied to the axial electrode relatively to the drift tube, are presented on Fig.1a. In this case, the diocotron oscillations were observed on one of the π-electrodes. In further experiments on stimulation and suppression of the diocotron oscillations an additional beam was used, which was injected with the same radius as the basic one but with different duration and intensity. The additional impulse was injected after the termination of the basic impulse. The incentive effect of such additional beam can be seen on Fig 1 b. The beam was overlayed on the oscillations that existed after the termination of the injection impulse and as a result the amplitude and the time of existence of the oscillations increased. The electric charge brought by the beam into the drift space created an additional transversal electric field that stimulated the rise of the diocotron oscillations.

Fig.2 presents the dynamics of beam electrons' distribution function by the velocity that has been averaged on a large number of impulses with different beam parameters in the regime of the effects observed. The curves of the velocity distribution were taken in the drift space of electron beam in three cross-sections: in the initial part of the drift tube, in the middle part and in

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the terminal part of the drift gap. The distributions were taken for the direct, the inverse and the azimuthal electron flows. The dynamics of the distribution functions for the direct flows reflects the fact that there existed a group of high-energy particles in the middle part of the drift space, because the maximum of the distribution had a 10 eV shift in its middle region to the hand of high energies, while the distribution taken in the terminal part of the drift space had no shift. On the other hand the shift existing only in the central part of the tube, the fast particles could escape from the drift space or could live only in a finite part of it, independently from the major flow of the particles.

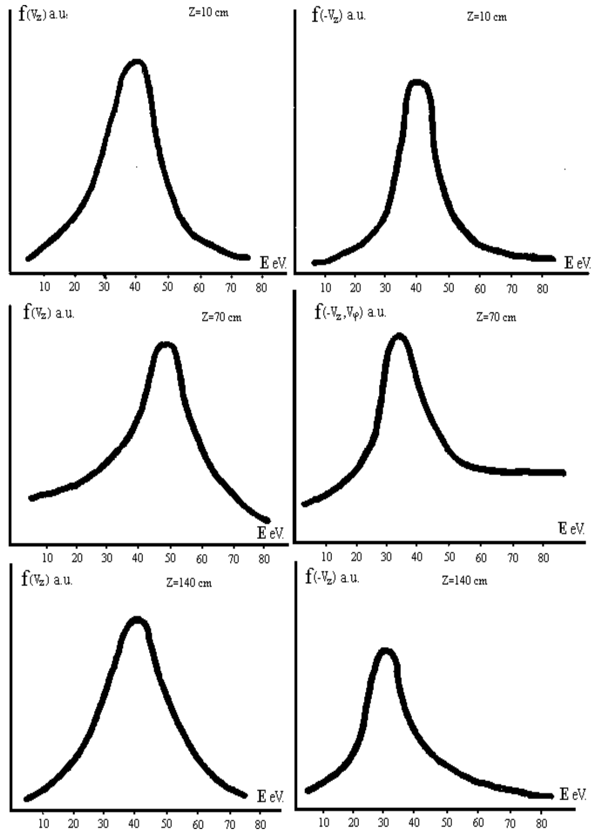

Fig.2. Dynamics of beam electrons distribution function by the velocity in three cross-sections, for the direct, the inverse and the asimuthal electron flows

A group of slow particles also appeared during the drift of electrons in the direct course. This phenomenon is brightly manifested in the middle part of the drift space and not in the same street in the initial and the terminal parts. Thus, the slow particles showed the same behavior as the fast ones. According to the dynamics of the distribution functions we could assume the shift of the distributions in the middle part was caused by particles captured into the field of electrostatic trap, which was formed by the movement of particles along the drift space.

A side from the velocity distribution functions of the direct electron flow the distributions of the inverse particle flows as well as the azimuthal flows were taken. These functions are presented on Fig.2 b. They differ from the distribution of the direct flows in the middle part of the drift space by a plateau-like increase of a number of high-energy particles and by 10 eV shift of maximum to the hand of lower velocities.

Fig.3 demonstrates the oscillogrammes of the diocotron oscillations in the case when the π-electrodes were used as a probes. The form of the diocotrone oscillations in dependence of their amplitude may be sinusoidal or nonsinusoidal with the highest harmonics.

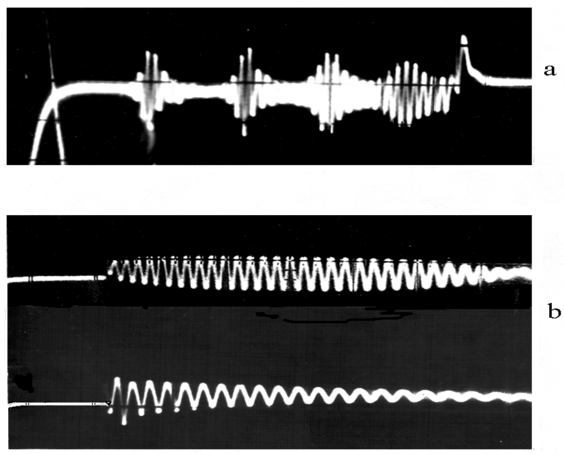

Fig.3. Oscillogrammes of the diocotron oscillation: a) during the injection; b) after the injection

A modulation of the diocotron oscillations happens when the amplitudes are high and close to saturation. As a rule the oscillations in the presence of the modulation have non-sinusoidal character. The period of the modulation is proportional to the energy and the electric current of the electron beam and may reach ~10 f_D. It is seen from the oscillogramme that the times of rise and fall of the modulative oscillations may differ in 2-3 times. It's important to note that the frequency of the diocotrone oscillations varies accordingly with the modulative impulses and decreases during the impulse. The modulative impulses may arise not only during the injection impulse but also after its termination Fig.3 b.

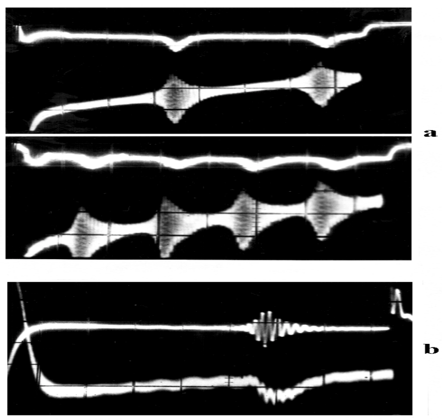

Fig.4. The output electrons across the magnetic field: a) by the electrostatic analyzer; b) by the coaxial thread

Fig.4a, b demonstrates a series of oscillogrammes relating to the cases when the diocotron oscillations were traced by the π-electrodes, while the output of the electrons across the magnetic field was traced by the electrostatic analyzer and by the coaxial thread. Either the electrostatic analyzer or the thread were situated strictly in the center of the drift space, on its axis. It can be seen from the oscillogramme that the period of the outlet of the particles across the magnetic field corresponds to the period of the modulative oscillations. Its maximum falls to the falling region. It makes it easy for us to assume that the appearance of the fast particles in the drift space may be connected with the rising and the falling of the diocotron oscillations in the form of the modulative oscillations.

It is experimentally shown that:

1) the radial electric field in the form of potential on the axial electrode or an additive negative charge in the drift space produces stimulation of the diocotron oscillations;
2) the dynamics of the velocity distribution functions of the particles demonstrates that there exists a group of particles with higher or lower, in comparison to the main part of the beam, velocities in the central part of the drift space.
3) The distribution functions of the inverse and the azimuthal flows point at the presence of the trapped particles.
4) The diocotron oscillations are modulated by amplitude in the form of exponentially rising and falling impulses with different exponent indexes, decrease of the oscillations frequency with rise of the impulse testifying to the loss of the particles during the impulse.
5) Synchronous outflow of the particles during the fall of the impulse in the transversal direction testifies to the same thesis.

Using the experimental results as a basis we may assume the presence of a group of the slow particles in the middle part of the drift space, which is resonance by the velocity for the diocotrone wave spreading in azimuthal direction. The evaluation of the phase velocity of the diocotrone wave gives:

$$V_{ph} = \pi d / T = \pi d f$$

where d - beams diameter,

T - diocotron oscillation period,

f - diocotron oscillation frequency,

The corresponding wave phase velocity for the frequency of the diocotron oscillations being 50 kHz during the injection impulse is $V_{ph} = 3*10^5$ cm/s.

After the termination of the injection impulse the diocotron frequency is ~ 10 kHz which corresponds to the phase velocity of the wave is $V_{ph} = 6*10^4$ cm/s.

These results support the conclusions made in [8] and contain new information about the mechanism of cooling and separation of the cold particles in the conditions of the experiment.

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