DRIFT OSCILLATIONS SUPPRESSION DURING THE ELECTRON PLASMA DECAY

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The drift waves were excited in non-neutral electron plasma created by injection of a hot electron beam into the drift chamber of the experimental device. The main attention is paid to the regime in which the injected electrons are captured and confined in the central area of the drift chamber in a metastable state. The duration of such confinement was anomalously long. Earlier such state was explained by the presence of coherent drift oscillations in the plasma of the confined particles. But a set of experiments with the drift oscillation suppression have shown that the metastable state of confined plasma exists without a drift oscillations generation. An effective method of the drift wave suppression was found.

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INTRODUCTION

The main properties and modes of damped drift oscillations of charged particles in the decaying electron flow plasmas in the longitudinal magnetic field were studied recently [1]. These so-called "residual oscillations" exist in both the linear and non-linear damping regimes. The presence of non-linear damping allowed us to assume that the damping process observed in the decaying plasma was partially collisionless. Special attention was paid to the fact of the wave regeneration. It was observed after complete damping of the drift wave as a response on the auxiliary beam injection. The existence of such type of phenomena confirmed the assumption on a collisionless nature of the drift wave damping. Besides, the response detected after the auxiliary beam injection may be considered as an indication of the residual charged particles presence in the space of drift. Such a long confinement of the beam particles after the injection breakdown was explained in [2] by formation of a self-consistent electron trap during the "hot" beam transport through the drift tube. Thus the particles with the lowest longitudinal velocities have been confined in the space of drift for a long time after the beam injection termination.

The confinement time was first supposed to be explained by the wave damping time T_{DAMP}. However after numerous experiments in which the wave regeneration was observed the confinement time was decided to be connected to the maximal response detection time t_{REG}. Actually t_{REG} represented a maximal time delay of the auxiliary beam injection at which the response was observed.

In this work we present the results of in-depth study of the residual electron plasma in the regimes with the residual wave amplitude suppression. A number of the studies dedicated to suppression of such type of waves were published earlier in which various methods of the wave amplitude reduction were used. For hollow cylindrical electron flows the central electrode with an appropriative potential on it [3] was used. To perform the wave amplitude suppression in the flows with continuous radial density profile the magnetic field shear was arranged [4]. In our case a simple and accessible method was used. The oscillations were reduced by introducing the Langmuir probe into the excitation zone. This allowed to separate a moment of complete damping of the drift oscillations from the temporal threshold of the regeneration observation.

EXPERIMENTAL DESIGN AND SETUP

The scheme of the experimental setup is shown in Fig.1. The main beam was generated by the electron gun. The gun consisted of an indirectly heated cathode and a metal grid anode. The injection of the electron beam was achieved by applying a negative voltage pulse (injection pulse) to the cathode. The shape of the anode grid was chosen to match the required cylindrical shape of the electron beam. The main beam was injected into the drift space, a brass tube of length L = 150 cm and diameter D = 4 cm, with flat grids at the entrance and the exit. The tube had been cut in parallel to the generatrix into two equal halves and thus was made up of two sectors of angular extent of 180º (π-electrodes).

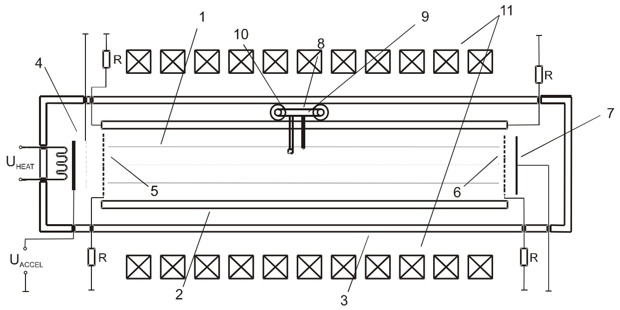

Fig.1. Schematic of the experimental setup: 1 - electron beam, 2 - drift tube, 3 - vacuum chamber, 4 - electron gun, 5 - entrance grid, 6 - exit grid, 7 - collector, 8- carriage, 9 - Langmuir probe, 10 - electrostatic analyzer, 11 – magnetic field coils

Both sectors were attached to the leads and used for diagnostic purposes. The diameter of the injected beam was d = 2 cm. The beam energy was 20 - 80 eV. The constant longitudinal magnetic field had a strength of H = 100 – 2200 Oe. The magnetic field varied over the length of the drift tube by less than 5%, so we consider it as uniform inside the drift tube. The injector was located near the entrance to the drift tube, in the area of non-uniform magnetic field. The range of working pressures was $10^{-4} - 10^{-7}$ Torr. Diagnostic measurements and the drift wave suppression were made by the Langmuir probe. The probe was placed on the mobile carriage together with a multigrid electrostatic analyzer. The occurrence and evolution of drift oscillations was detected by π–electrodes. We observed the generation of drift modes with the azimuthal wave number $l = 1$. In this case, the oscillations of current induced on each of the π–electrodes were in opposite phases. The flat grids at the entrance and the exit of the drift tube were used for measuring the current input and output.

Early experiments had shown the existence of drift oscillations, during the pulse of injection. As it was predicted, we had detected the wave with $l = 1$.

EXPERIMENTAL RESULTS

We have monitored the behavior of damped and regenerated waves at different magnetic field values and probe positions. The main temporal parameters of the wave damping (T_{DAMP}) and regeneration (t_{REG}) were measured under different experimental conditions. First we have measured T_{DAMP} and t_{REG} while the Langmuir probe was located in the central region of the drift tube. A number of values were obtained for different magnetic field values. Then the probe was moved to the drift tube edge and the measurements were repeated.

In the first case t_{REG} was growing together with H while it was varying from 1800 to 2040 Oe. T_{DAMP} grows until the magnetic field reaches 1900 Oe. After that, it reduces and then keeps on a constant level (Fig.2).

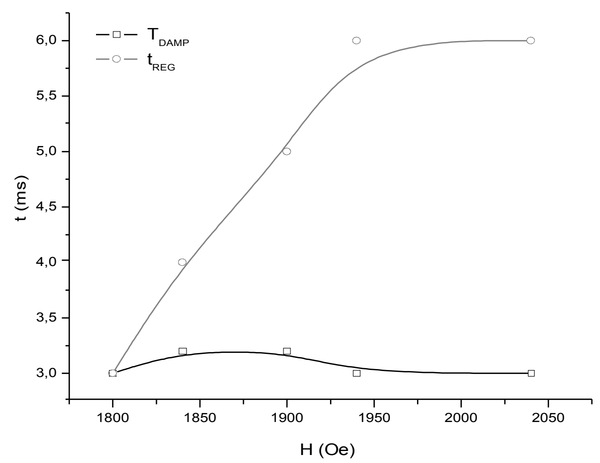

Fig.2. Behavior of the damping time and the maximal regeneration time delay in dependence on the magnetic field intensity with the probe introduced into the excitation zone

The second case exhibited a stable growth of both temporal delays while H was growing from 1800 to 2040 Oe (Fig.3).

The results mentioned above allow us to conclude that the presence of an electrostatic Langmuir probe in the region of the wave excitation reduces the wave damping time and increases the maximal regeneration time delay.

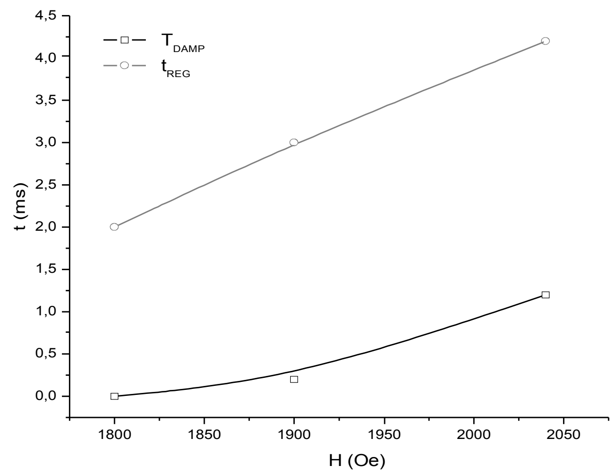

Fig.3. Behavior of the damping time and the maximal regeneration time delay in dependence on the magnetic field intensity without the probe introduced into the excitation zone

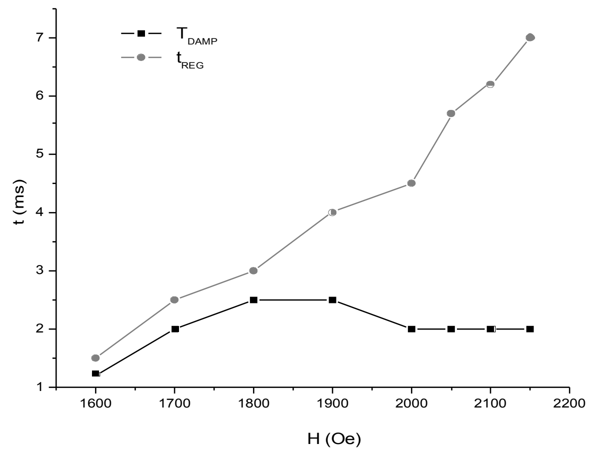

Fig.4. Behavior of the damping time and the maximal regeneration time delay in dependence on the magnetic field intensity with the probe introduced into the excitation zone (improved vacuum conditions)

To improve the results obtained we have created better vacuum conditions by reducing the residual pressure down to 10^{-7} Torr. This caused higher t_{REG} values and promoted a more effective suppression of the drift oscillations (Fig.4).

CONCLUSIONS

The introducing of an additional suppression factor into the area of the drift waves excitation results in reduction of the wave damping time (T_{DAMP}) while the magnetic field is growing. At the same time the maximal regeneration time delay (t_{REG}) exhibits a stable growth on increasing magnetic field. Thus one could conclude that the time of confinement of the beam electrons in the drift chamber after the pulse of injection termination is not closely linked with the drift oscillations damping time.

It is also remarkable that the particles are confined in the drift chamber for a sufficiently long time period.

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ПОДАВЛЕНИЕ ДРЕЙФОВЫХ КОЛЕБАНИЙ ПРИ РАСПАДЕ ЭЛЕКТРОННОЙ ПЛАЗМЫ

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Дрейфовые волны возбуждались в заряженной плазме, создаваемой в процессе инжекции пучка электронов с большим разбросом по скоростям в камеру дрейфа экспериментальной установки. Основное внимание уделялось режиму, в котором инжектированные электроны захватывались и удерживались в центральной области камеры дрейфа в метастабильном состоянии. Время такого удержания было аномально большим. Ранее такое состояние связывалось с присутствием когерентных дрейфовых осцилляций в плазме захваченных частиц. Однако, ряд экспериментов с подавлением дрейфовых осцилляций показал, что удерживаемая плазма находится в метастабильном состоянии и в отсутствии дрейфовых колебаний. В процессе исследований был также найден эффективный способ подавления дрейфовых волн.

ПРИДУШЕННЯ ДРЕЙФОВИХ КОЛИВАНЬ ПІДЧАС РОЗПАДУ ЕЛЕКТРОННОЇ ПЛАЗМИ

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Дрейфові хвилі збуджувались у зарядженій плазмі, що створювалася у процесі інжекції пучка електронів із сильним розкидом часток по швидкостям до камери дрейфу експериментальної установки. Особлива увага приділялася режиму, в якому інжектовані електрони захоплювалися й утримувалися у центральній області камери дрейфу у метастабільному стані. Час такого утримування був аномально великим. Раніше такий стан пов'язували із присутністю когерентних дрейфових коливань у плазмі захоплених часток. Однак, низка експериментів з придушенням дрейфових осциляцій показала, що утримувана плазма знаходиться у метастабільному стані навіть за відсутності дрейфових коливань. В процесі досліджень було також знайдено ефективний спосіб придушення дрейфових хвиль.