THE STABILITY OF MAGNETIZED NON-NEUTRAL PLASMA FLOW WITH A BROAD VELOCITY DISTRIBUTION

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The stability of the magnetized non-neutral plasma cylindrical flow was studied experimentally. The flow is injected into the drift tube and spreads along its axis. The radial motion of the charged particles is limited by longitudinal magnetic field. During the experimental study the influence of such factors as the magnetic field strength and the average flow velocity on stability of the flow fluctuations was investigated.

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INTRODUCTION

The stability of low-frequency electrostatic fluctuations in cylindrical non-neutral plasma flow with relatively broad distribution of the particle velocities injected into a longitudinal magnetic field represents an attractive subject for both theoretical and experimental study. The results of such studies are not only important for physics of charged particle beams but also may be exploited in the field of plasma physics and controlled fusion.

Studied fluctuations are observed in cylindrical flow of non-neutral (electron) plasma. They have a pronounced azimuthal component. Thus under certain conditions they may interact with the flow particles which are drifting azimuthally (ExB - drift) with the velocities $V_{dr} \approx V_{ph}$. Such particles are usually called 'resonant'. Depending on the resonant particles distribution by velocities the fluctuations amplitude may be stimulated or damped. In the first case the fluctuations become unstable. This may cause the distortion of the flow profile and forming of the density bunches which are shifted from the symmetry axis of the system (diocotron instability). The bunches are moving azimuthally with the wave phase velocity.

In most cases, the wave-particle interaction for such type of fluctuations provides damping of the oscillations [1,2]. The reason of this lies in decreasing electron density profile which is characteristic for the most of cylindrical electron beams. In this case the waves with the azimuthal wave number l = 1 are observed. Such waves are usually excited due to interaction of the flow fluctuations with the drift tube walls or with the resonant ions.

In this work we study the influence of such parameters as the longitudinal magnetic field strength and the acceleration voltage on dynamics of the diocotron instability. Special attention is paid to the effect of the probe insertion into the flow which is really noticeable under certain experimental conditions.

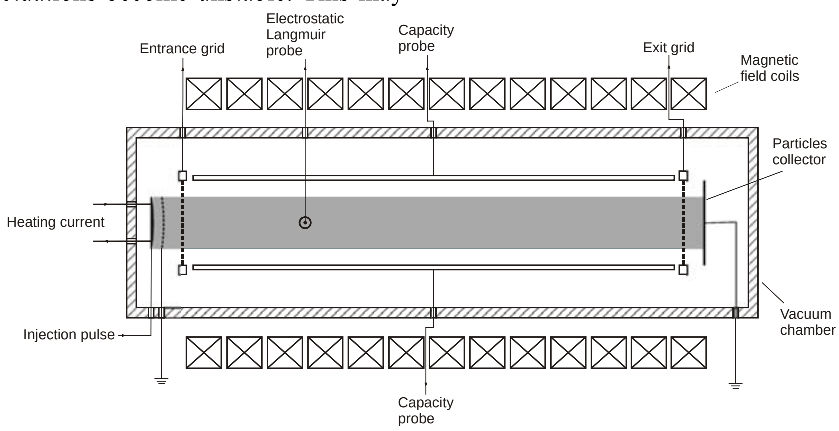

Fig.1. Schematic of the experimental device

EXPERIMENTAL SETUP

The experimental device (Fig. 1) represented a brass drift tube (L = 150 cm, R = 2 cm) placed into vacuum chamber (p = 5×10^{-7} Torr) at longitudinal magnetic field (H = 920…2100 Oe). The charged electrons flow was formed using the particles injector consisted of indirectly heated cathode and grounded anode grid. The injection of the flow was performed by applying of a negative potential pulse to the cathode. In the framework of the experimental study the pulse amplitude (U_{ACCEL}) did not exceeded a value of 30 V. The flow density at the drift tube entrance was $n_e = 2\times10^7$ cm^{-3}. The flow radius was r_{fl} = 1 cm. The width of the flow particles distribution by velocities was 20 eV.

The drift tube consisted of two azimuthal segments. Such construction allows carrying out the measurements of the fluctuations azimuthal dynamics. The measurements of longitudinal distribution of potential were performed by a moveable Langmuir probe.

EXPERIMENTAL RESULTS

Variation of the magnetic field intensity and the acceleration voltage

The fluctuations dynamics was investigated without the Langmuir probe insertion into the flow.

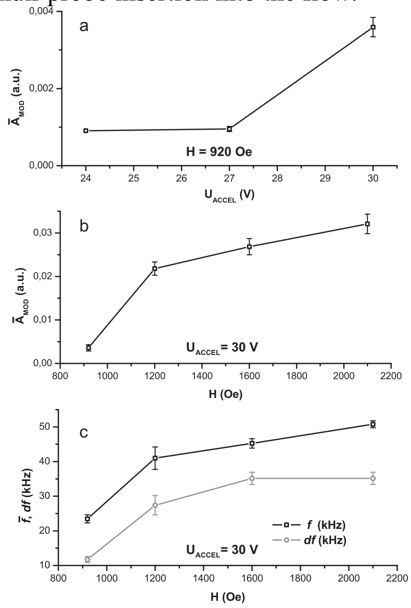

Fig.2. The averaged depth of the amplitude modulation (a and b), the averaged frequency and the width of the frequency band (c) depending on U_{ACCEL} and H

The main attention was paid to the current fluctuations detected in the drift chamber walls. The behavior of such fluctuations usually displays the azimuthal dynamics of the flow fluctuations. In the framework of the experimental study the analysis of nonlinear effects observed in the fluctuations dynamics was carried out. In particular, the averaged depth of the amplitude modulation ($\overline{A}_{MOD}$) was measured for different experimental conditions.

It was shown that $\overline{A}_{MOD}$ grows (Fig.2) together with increase of the magnetic field intensity (*H*) or the acceleration voltage (U_{ACCEL}). In the first case $\overline{A}_{MOD}$ grows intensively while H is increasing from 920 to 1200 Oe. Further increase of H results in $\overline{A}_{MOD}$ growth with smaller rates.

The dependence of the frequency characteristics (averaged frequency - $\bar{f}$ and frequency band width - *df*) on H correlates with those of $\overline{A}_{MOD}$

Increase of the acceleration voltage gives a pronounced $\overline{A}_{MOD}$ growth in the range of U_{ACCEL}=27…30V. At lower values of U_{ACCEL} the amplitude modulation is much weaker and the frequency band width is negligibly small.

Probe measurements

The measurements of the longitudinal potential distribution (Fig. 3,c,d) have shown the presence of a pronounced potential maximum at z = 20...70 cm. (the coordinate of the maximum point depended on the experimental parameters). In our configuration such phenomena may be explained by influence of spatial charge of the electron flow.

One of the most interesting results of the probe measurements consisted in a noticeable influence of the probe insertion into the flow on the electrostatic fluctuations behavior. In particular the most intensive reaction of $\overline{A}_{MOD}$, $\bar{f}$ and *df* on the probe introduction was observed at increased values of H and U_{ACCEL} (Fig. 3,a,b).

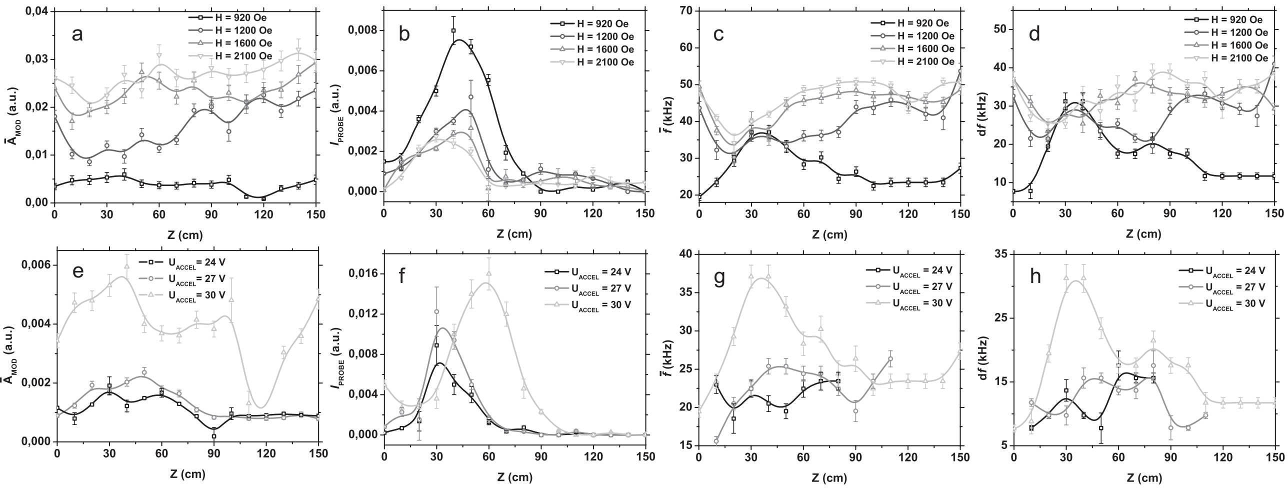

Fig.3. The amplitude modulation depth (a – for different H values, e – for different U_{ACCEL} values), the probe current (b – for different H values, f – for different U_{ACCEL} values), the average frequency (c– for different H values, g – for different U_{ACCEL} values) and the frequency band width (d – for different H values, h – for different U_{ACCEL} values) dependencies on the probe longitudinal coordinate

As one could see from the experimental data the current level in the probe circuit reduces together with increasing of H. At the same time, the most pronounced reaction on the probe introduction was observed at higher values of H. Thus the effect of the probe immersion is not proportional to the rate of interaction between the probe and the flow particles. However, the probe insertion may distort the distribution of the resonant electrons (or ions) by their velocities and so it may cause noticeable changes in the fluctuations dynamics. It is useful to note that the injector is placed outside the magnetic field coil. So the flow is injected into spatially inhomogeneous magnetic field at the coil edge. Thus the magnetic field intensity variation affects strongly on the flow radius. In particular, the increasing of H should lead to the flow radius decreasing. This suggestion allows to conclude that the instability is much more sensitive to the probe immersion if the probe is inserted into the edge of the flow.

CONCLUSIONS

It was shown experimentally that the increase of the magnetic field strength leads to intensification of the unstable processes. This fact contradicts with the classic pattern of diocotron instability development in pure electron plasma. It was also estimated that the acceleration voltage rising leads to more intensive development of the instability which also leads to the question about the influence of ionization processes on the system stability [3,4]. The dynamics of the frequency characteristics has shown a good correlation with that of the average depth of the amplitude modulation.

The probe measurements have shown that the resonant particles may be concentrated at the flow edge.

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УСТОЙЧИВОСТЬ ПОТОКА ЗАМАГНИЧЕННОЙ ЗАРЯЖЕННОЙ ПЛАЗМЫ С ШИРОКИМ РАСПРЕДЕЛЕНИЕМ ЧАСТИЦ ПО СКОРОСТЯМ

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Экспериментально исследована устойчивость замагниченного цилиндрического потока заряженной плазмы. Поток инжектировался в трубку дрейфа и распространялся вдоль ее оси. Радиальный дрейф частиц потока ограничивался продольным магнитным полем. Исследовалось влияние на устойчивость системы таких факторов как напряженность магнитного поля и средняя скорость частиц потока.

СТІЙКІСТЬ ПОТОКУ ЗАМАГНІЧЕНОЇ ЗАРЯДЖЕНОЇ ПЛАЗМИ ІЗ ШИРОКИМ РОЗПОДІЛОМ ЧАСТОК ПО ШВИДКОСТЯХ

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Експериментально досліджено стійкість замагніченого потоку зарядженої плазми. Потік інжектувался до трубки дрейфу та поширювався вздовж її вісі. Радіальний дрейф частинок потоку обмежувався повздовжнім магнітним полем. Досліджувався вплив на стійкість системи таких факторів як напруженість магнітного поля та середня швидкість частинок потоку.