The influence of magnetic field on the geometrical dimensions of dusty structure in striations

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Abstract. The onset of magnetic field on the glow discharge results in the redistribution of plasma flows, which in turn may cause the change of the charge of dust particles levitating in strata. Upon that dusty structure changes its geometric form and inner ordering of particles. In this work, we present the investigation of the influence of magnetic field on dusty structures formed in striation of glow discharge. We detected the variation of geometrical dimensions of structures with magnetic field, and the behavior of interparticle distance was determined. There was obtained the dependence of the concentration of dust particles in normal to vector \( B \) cross section of structure on the magnetic induction. Corresponding graph was compared to one of rotation speed, which has three characteristic diapasons. First one is characterized by negative projection of angular velocity \( \Omega \) on \( B \), two other diapasons are characterized by positive \( \Omega \) projection and the slope of \( \Omega(B) \) graph.

1. Introduction

The magnetic action on glow discharge occurs due to plasma components [1, 2]. It manifests in the decrease in transversal mobility of charge carriers. In the case of low amperage discharge and low buffer gas pressure the electrons are the most determining factor in the process of current propagation. And in the case of stratified discharge, in which the striations are the electrical traps for dusty grains, the influence of magnetic field on striation in large part determines the geometry of dusty plasmas structure.

First investigation of dusty plasma in glow discharge under magnetic field was initiated for the purpose of the form control of large dusty structure [3]. These structures often have the void space [4, 5], especially when the magnetic field affects the radial energy distribution [6–10]. So, in order to study the geometry, ordering, and interparticle distance the discharge conditions ought to be accurately selected.

During stratification of a glow discharge, dusty structures begin to rotate under the action of a magnetic field. Moreover, in various ranges of magnetic induction the mechanisms of rotation are different, and they always are the combinations of magnetic actions on the plasma components. In weak magnetic field, while electrons are weakly magnetized, ion drag dominates [11]. When the electrons become more magnetized, the mechanism of neutral gas drag due to vortex electron current comes into account [12–14]. Latter studies [15] show that the magnetic field of around 1000 G varies the geometry of standing striation. Our work shows certain facts concerning the characteristics of dusty structures under magnetic induction up to 10 000 G.
2. Experiment
Dusty structures were observed in a vertically mounted discharge tube 1.5 m long and 22 mm in diameter (figure 1). The tube was located in warm bore of cryostat of 60 mm diameter. Gas discharge was ignited in neon under 0.3 torr pressure, the discharge current was 1.5 mA. The dusty structures constructed themselves in strata from polydisperse granules of quartz with characteristic size of 6 \( \mu \)m. The dust cloud was illuminated using a semiconductor laser module and a periscope-like system with the cylindrical lens converting a laser beam into a 1 mm-thick laser sheet. The magnetic field was generated by a superconducting solenoid located in a cryostat. To force the solenoid into a superconducting state, it was cooled with liquid helium. The observation and video recording of the rotation of dust structures were carried out through the top end window of the tube, an interference filter and a turning prism. Video recording was made on a video camera with 25 fps frame rate. Next, analyzing the videos we determined the angular velocity of dust structures, as well as the concentration of dust particles in the captured cross sections.

3. Results
Figure 2 shows the dependence of the concentration of dust particles in the central cross section of the structure on magnetic induction. This dependence demonstrates the non-monotonous character. In the range up to about 375 G it increases dramatically, then, to about 1100 G, it drops sharply. Above the magnetic induction of 1100 G, including instability region of the discharge 3000–4000 G [1], the density value remains almost unchanged.

The obtained dependence can be compared with the angular velocity of the cross section under magnetic field, which is represented in figure 3. The increase in density occurs when the structure rotates with a negative projection of the angular velocity on the magnetic induction vector. Here the ion drag force is responsible for the rotation mechanism [11]. The change in the
Figure 2. The dependence of the concentration of particles $n$ in the cross section on the magnitude of the magnetic field $B$.

Figure 3. The dependence of the angular velocity of rotation $\Omega$ of the dust structure on the magnetic field $B$.

trend of dependence corresponds to the inversion of the angular velocity direction. It begins to dominate the drag of neutral gas due to the effect of the eddy current of electrons in a magnetic field [12, 13]. As the rotation speed increases, the density of the structure decreases. Above the 1100 G field, the dust trap is deformed; the geometry of the standing stratum is changed. Here, the angular velocity increases less, and the density almost remains constant, with a weak tendency to increase.
These first measurements qualitatively show the correlation between the rotational speed and the density of particles. Probably, intense ion drag, including its radial component, leads to the compression of dusty plasma. In contrast, the rapid rotation of the discharge gas leads to the decompression of the dust cross section. The presented first observations of changes in the density of dust particles in a magnetic field are interesting, first of all, for controlling the location of dust particles and creating of dusty plasma with controlled properties.

4. Conclusion
This work describes an experiment conducted with dusty structures formed in strata of a glow discharge in a magnetic field up to 10,000 G. The concentration of dust in cross sections and angular velocity were determined depending on the magnitude of the magnetic field. The dependences obtained are compared in different ranges of the magnetic field. The correlation between the change in the angular velocity of rotation and the change in the concentration of dust particles in the cross section is determined and qualitatively explained.

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