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Extended Abstract

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Theory and applications of inverted fireballs Abstract

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Inverted fireballs have been proven to be a viable tool for large area surface modifications and for a direct conversion from a DC input signal to an RF output signal. Their suitability for surface modifications in general and for deposition technologies in particular is owed to their very homogeneous plasma potential and their high charge densities. This talk will outline theoretical investigations into inverted fireballs, such as analytical models and particle-in-cell simulations and the application of these findings to technologically relevant topics. Recent findings that describe in detail how these plasma phenomena can be utilized will be shown. Furthermore, it will be demonstrated that inverted FBs exhibit a number of plasma instabilities, but they can be stabilized over a long period of time, which is necessary for their utilization in the industry. It will also be outlined in this talk where the borders of fireball research are at the moment and what needs to be done in order to gain a deeper scientific understanding in the future.

The typical phenomena of mixed mode oscillations and their associated nonlinear behaviors have been investigated in collisionless magnetized plasma oscillations in a DC glow discharge plasma system. Plasma is produced between a cylindrical mesh grid and a constricted anode. A spherical mesh grid of 80% optical transparency is kept inside a cylindrical grid to produce an inverted fireball. Three Langmuir probes are kept in the ambient plasma to measure the floating potential fluctuations at different positions of the chamber. It has been observed that under certain conditions of discharge voltages and magnetic fields, the mixed mode oscillation phenomena (MMOs) appears, and it shows a sequential alteration with the variation of the magnetic fields and probe positions. Low frequency instability has been observed consistently in various experimental conditions.

The mechanisms of the low frequency instabilities along with the origin of the MMOs have been qualitatively explained. Extensive linear and nonlinear analysis using techniques such as fast Fourier transform, recurrence quantification analysis, and the well-known statistical computing, skewness, and kurtosis are carried out to explore the complex dynamics of the MMO appearing in the plasma oscillations under various discharge conditions and external magnetic fields.

A fireball is formed inside a highly transparent spherical grid immersed in a dc discharge plasma. The ambient plasma acts as a cathode and the positively biased grid as an anode. A strong nearly current-free double layer separates the two plasmas. Electrons are accelerated into the fireball, ionize, and establish a discharge plasma with plasma potential near the grid potential. Ions are ejected from the fireball. Since electrons are lost at the same rate as ions, most electrons accelerated into the fireball just pass through it. Thus, the electron distribution contains radially counterstreaming electrons. High-frequency oscillations are excited with rf period given by the electron transit time through the fireball. Since the frequency is well below the electron plasma frequency, no eigenmodes other than a beam space-charge wave exists.

The instability is an inertial transit-time instability similar to the sheath-plasma instability or the reflex vircator instability. In contrast to vircators, there is no electron reflection from a space-charge layer but counterstreaming arises from spherical convergence and divergence of electrons. While the basic instability properties have been presented in a companion paper [R. L. Stenzel et al., Phys. Plasmas 18, 012104 (2011)], the present paper focuses on observed mode jumping and nonlinear effects. The former produce frequency jumps and different potential profiles, the latter produce harmonics associated with electron bunching at large amplitudes. In situ probe measurements are presented and interpreted.

Recently discovered inverted fireballs are non-linear plasma phenomena, which are formed in hollow grid anodes with high transparency in an existing background plasma. If a sufficiently large potential is applied, accelerated electrons from the bulk start to oscillate through the grid. Experimental investigations have shown that they produce different types of plasma instabilities. One of those oscillations is a transit time instability which originates from strong electron beams that travel through the inverted fireball. This type of instability is similar to vircator reflex oscillations and produces radio frequency waves. Hence, it is suitable to convert DC signals into signals oscillating in the MHz range. This paper analyses the dispersion relation of the transit time instability for three different plasma regimes. The regimes can be divided into a collision less regime, a regime with high collisionality and one in between those former two. It is demonstrated that the plasma properties of the surrounding background plasma have a strong influence on the behavior of the instability itself.

Bottom Note: *This work is partly presented at 5th International Conference on Theoretical and Applied Physics*