Canard and mixed mode oscillations in an excitable glow discharge plasma in the presence of inhomogeneous magnetic field

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It is well known that a change in the control parameter or external perturbation of an excitable system near the threshold produces various nonlinear phenomena such as noise induced resonances, canard oscillations and mixed mode oscillations [1, 2]. In this paper, we report on the experimental observation of canard orbit and mixed mode oscillations (MMOs) in an excitable glow discharge plasma [3] induced by an external magnetic field perturbation using a bar magnet. At small value of magnetic field, small amplitude quasiperiodic oscillation are excited, and with the increase in the magnetic field large amplitude oscillations were excited. Analyzing the experimental results it seems that the magnetic field is triggering and controlling the intrinsic noise of the system which may be responsible for the observation of such nonlinear phenomena. It is observed that the noise level increases with the increase in magnetic field strength. Internal plasma noise triggers quasiperiodic small amplitude oscillation. When the internal noise strength increases, the dynamics of the system goes from the small amplitude quasiperiodic oscillations to small-amplitude oscillations with sporadic single spikes, then to irregular MMOs. Regular MMO has been also observed for the higher magnetic field strength. The magnetization effect of ions is playing a role in the transition from irregular MMO to regular MMO. Since ions were magnetized for higher magnetic field wheras for lower magnetic field ions were unmagnetized. So, the observation of regular MMO might be due to the dominance of ion cyclotron mode, which is triggered by the magnetization of ions, over internal plasma noise. Hence, the irregular MMOs are probably dominated by the stochastic process, whereas the regular MMOs are probably dominated by the ion cyclotron mode. We also explored the main characteristics, typical frequencies, and evolution of inter-oscillations interval to understand the dynamics of the system.

The experimental results have been corroborated by a numerical simulation using a FitzHugh-Nagumo (FHN) like macroscopic model [4] derived from the basic plasma equations and phenomenology, where the noise has been included to represent the internal plasma noise. This macroscopic model shows MMO in the vicinity of the canard point when external noise is added. The results of the numerical simulation are in good agrement with that of experimental.

Beyond the interest of the study of these nonlinear phenomena from experimental and dynamic point of view, their characterization is also very important for experiments involving real application in glow discharge plasma. Such study may be useful for various application of discharge plasma like plasma coating, plasma sputtering and other plasma application.

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