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Effects of Anomalous Electron Cross-Field Transport in a Low Temperature Magnetized Plasma[1]

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The application of the magnetic field in a low pressure plasma can cause a spatial separation of low and high energy electrons. This so-called magnetic filter effect is used for many plasma applications, including ion and neutral beam sources, plasma processing of semiconductors and nanomaterials, and plasma thrusters. In spite of successful practical applications, the magnetic filter effect is not well understood. In this work, we explore this effect by characterizing the electron and ion energy distribution functions in a plasma column with crossed electric and magnetic fields. Experimental results revealed a strong dependence of spatial variations of plasma properties on the gas pressure. For xenon and argon gases, below ~ 1 mtorr, the increase of the magnetic field leads to a more uniform profile of the electron temperature. This surprising result is due to anomalously high electron cross-field transport that causes mixing of hot and cold electrons. High-speed imaging and probe measurements revealed a coherent structure rotating in E cross B direction with frequency of a few kHz. Theory and simulations describing this rotating structure has been developed and points to ionization and electrostatic instabilities as their possible cause [1,2]. Similar to spoke oscillations reported for Hall thrusters [2,3], this rotating structure conducts the large fraction of the cross-field current. The use of segmented electrodes with an electrical feedback control is shown to mitigate these oscillations [3]. Finally, a new feature of the spoke phenomenon that has been discovered, namely a sensitive dependence of the rotating oscillations on the gas pressure, can be important for many applications.

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