The Trapped Electron Experiment (T-REX): Commissioning and First Results

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Gyrotrons are the only sources used for electron cyclotron resonance heating (ECRH), and are considered as the primary ones for heating and current drive systems of fusion reactors, making their efficient operation crucial for the advancement of fusion energy. Past gyrotron experiments have highlighted some instability issues, leading to restricted operating ranges. One major cause is the presence of trapped electrons within the gyrotron's magnetron injection gun (MIG) region, resulting in undesired currents and subsequent operational failures. To avoid such issues, the current approach is mostly based on tight manufacturing tolerances for the MIG geometry[1]. We present initial experimental findings of the TRapped Electrons eXperiment (T-REX), a novel and unique plasma experiment constructed at the Swiss Plasma Center that aims to understand the underlying physics of formation and evolution of electron clouds in gyrotron MIG designs. Their comprehensive understanding could serve to help relaxing some of the current gyrotron's tight manufacturing tolerances. The T-REX experiment replicates typical MIG geometries, electric and magnetic fields, and is supported by kinetic simulations via the 2D Particle-in-Cell (PIC) code FENNECS[2,3]. The experimental set-up is characterized by two coaxial electrodes placed in a vacuum chamber mounted on top of a superconducting magnet. The central electrode is biased to negative DC voltages, while the outer one is at ground. This leads to an applied external radial electric field (1 to $100\,\mathrm{MV/m}$), and an axial magnetic field ($B < 0.4\,\mathrm{T}$) that induce azimuthal drifts and confining electron energies between 0.1 to $1\,\mathrm{keV}$. Such experimental setup bears resemblances to Penning traps. The geometry of the electrodes, electric and magnetic field configurations, as well as composition and pressure of the background gas, can be adjusted to replicate typical MIG parameters. We present experimental findings on the current distribution and electron cloud dimension based on imaging, for a set of applied voltages and magnetic fields, and compare those with simulation results performed with the FENNECS code. The planned diagnostics include also optical emission spectroscopy, a phosphor screen system, Streak camera imaging, and, potentially, electric field distribution via the Stark effect. Furthermore, T-REX is also designed to be capable of detecting potential growth of diocotron modes, via the aforementioned diagnostics in combination with a segmented outer electrode. Finally, we aim to gain valuable insights into the trapping and dynamics of electrons within MIG regions, paving the way for improved gyrotron performance and reliability in fusion energy systems.

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