Modelling of trapped high density electron clouds relevant to gyrotrons

G. Le Bars[1], J.-P. Hogge[1], J. Loizu[1], S. Alberti[1], A. Cerfon[2]

[1] *EPFL, Swiss Plasma Center, CH-1015 Lausanne, Switzerland*

[2] *New York University, Courant institue of mathematical sciences, NY-10012 New York, USA*

Nonneutral plasmas are of broad interest for antimatter physics, particle accelerators and high power microwave sources such as gyrotrons. Indeed, the study of charged particle confinement is crucial for developing long-term antimatter storage (Penning traps) or to avoid arcing and improve efficiency of particle accelerators and microwave sources. In gyrotrons specifically, operation has been sometimes compromised by the presence of localized trapped electrons (i.e. not belonging to the main electron beam) in the gyrotron gun region [1]. Such trapped electrons can lead to arcing and, in some cases, prevent the electron gun from operating at nominal electron acceleration voltage [2]. The trapping of particles is the consequence of the presence of crossed electric and magnetic fields and has some analogies to a Penning trap.

We present a parametric study that characterizes trapped electron clouds in a magnetron injection gun with electrodes of different shapes and external bias. The electron cloud shape and maximum density, as well as the evolution of the self-consistent electron trapping well are obtained by using a 2D axisymmetric electrostatic particle-in-cell code with Dirichlet boundary conditions on elliptic boundaries, where realistic electron gun geometries and their non-trivial electromagnetic field topologies can be simulated. The boundary ellipticity is here implemented by means of weighted extended b-splines [3]. In a second step, using the steady state density profiles obtained with the particle-in-cell code, an eigen-value equation [4] is solved numerically to determine, a posteriori, the linear stability of the axisymmetric equilibrium to diocotron modes. This paves the way to a better understanding of the type of instabilities that could cause the breakdowns observed in gyrotrons gun assemblies.

References

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