PIC simulations and reduced model of confined ionising electron clouds relevant to gyrotrons

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

[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 the overall efficiency of particle accelerators and microwave sources. In gyrotrons specifically, operation has been seen to be limited 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 ionise the residual neutral gas present in the vacuum vessel which can lead to arcing and preventing the electron gun from operating at nominal electron acceleration voltage [2]. The trapping of particles is the consequence of crossed electric and magnetic fields and has some analogies to a Penning trap.

We present an exhaustive numerical study that characterizes trapped electron clouds in a magnetron injection gun with different magnetic field amplitudes, electrode shapes and biases, residual gas compositions and pressures. The electron cloud shape and maximum density, as well as the evolution of the self-consistent trapping potential 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 self-consistent electron cloud build-up is simulated by considering electron-neutral collisions and the resulting ionisation using a Monte Carlo approach [3]. A reduced analytical model describing the electron cloud equilibria is then presented that explains the parametric dependences obtained from the simulations and provides insight into the control parameters that can be used to simplify the design and remove operation limitations of gyrotrons gun assemblies.

References

[1] Pagonakis I Gr, Piosczyk B, Zhang J, Illy S, Rzesnicki T, Hogge J-P, et al 2016 *Phys. Plasmas* **23** 023105.

[2] Piosczyk B, Dammertz G, Dumbrajs O, Kartikeyan M V, Thumm M K and Yang X 2004 *IEEE Trans. Plasma Sci.* **32** 853-60.

[3] Birdsall C K 1991 *IEEE Transactions on Plasma Science* **19** 65-85.