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Influence of plasma parameters on the effectiveness of multi-cusp magnetic field confinement in negative ion sources

Cusp-shaped magnetic fields are widely used to confine plasmas in various applications. This kind of field topology is obtained by placing a set of permanent magnets with alternate orientation and regular step on the plasma chamber surfaces.

Within this magnetic field configuration, plasma loss is localised in correspondence of the permanent magnets, where the field lines are perpendicular to the walls. The width of such loss cone, usually called leak width, was found to be proportional to the geometric mean of the ion and electron Larmor radii, so that it becomes smaller for increasing magnetic field intensity.

At the same time, plasma diffusion towards the walls is reduced in the regions where the field lines are parallel to the surfaces: this leads to the formation of a Plasma Exclusion Zone (PEZ), whose characteristic dimension depends on the distance between the magnets.

Besides field intensity and geometry, plasma interaction with the cusp-shaped magnetic field –which determines the confinement effectiveness –might also be affected by plasma properties such as electron temperature, plasma potential across the sheath and collisionality. The estimation of both the leak width and the PEZ, while considering also these dependencies, is still difficult as a comprehensive tool is currently not available.

On this basis, the present contribution describes a numerical analysis of the dependence of both the PEZ size and the leak width on the main plasma parameters, performed by means of a 2D-3V Particle-In-Cell code. In negative ion sources, multi-cusp configuration is commonly applied at the source walls, but also in the beamlet extraction region, due to the presence of electron deflection magnets embedded in the extraction grid. The obtained results are finally compared with theoretical and numerical estimations from previous works.

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