ECRH Breakdown of gases in a stellarator

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The breakdown by the 2nd electron cyclotron harmonic microwaves in a stellarator is re-examined theoretically. The collisionless electron dynamics inside a vacuum vessel (VV) under the microwave field action has proved to be a fundamental part of the theory. In a stellarator-like magnetic configuration, this dynamics may be of the four different types. We have established which of the types is presented non-negligibly in VV and can provide an average energy increase at a fast enough rate under the electron-neutral collisions. The electrons of this type, located near the magnetic axis, give rise to an electron avalanche evolving at a timescale ~1 ms, provided that the magnetic field at the axis differs from the resonant value by no more than 5%. Far from the magnetic axis, the breakdown is mainly attributed to the ionization of neutrals excited to metastable electronic states near the axis and freely migrating then across the magnetic field; the electrons of all types can support such a subthreshold impact ionization. We have suggested quite a simple analytical estimate for the breakdown delay time, which seems to be in a good agreement [1] with the experimental results from the L-2M stellarator.

The study performed allows the following conclusions to be drawn. In a classic stellarator like L‑2M the electron avalanche evolves (i) near the magnetic axis, and (ii) all along its circumference, that is not only in the region of VV exposed to the microwave beam. The avalanche evolves due to a non-negligible population of the group consisting of electrons that are in resonance with the microwaves just when they pass through the local minima or maxima of the ambient magnetic field. The ‘nonlinear’ type of electron dynamics [2] is of no importance for the breakdown in similar devices. The same physical considerations can be applied as well to various fusion devices, although the final estimates may differ depending on both the geometry of VV and the magnetic configuration.

References

1. Shchepetov S.V., Tereshchenko M.A., Vasilkov D.G., Kholnov Yu.V. Plasma Phys. Control. Fusion 2018 Vol. 60 125003.
2. Seol J., Hegna C.C., Callen J.D. Phys. Plasmas 2009 Vol. 16 052512.