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Assessment and optimization of the cavity thermal performance for the European Continuous Wave gyrotrons

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The large Ohmic load (~20 MW/m2) of the wall of the resonant cavity of high-power gyrotrons, designed for tokamaks and stellarators for EC resonance heating and current drive to deliver a microwave power of the order of MW per unit, constitutes one of the major technological limiting factors, despite the small extension of the surface on which it is deposited. Even before reaching the material strength limits, the thermal deformation of the cavity is responsible for the gyrotron frequency shift with respect to its nominal operating condition.

The proper modelling of the gyrotron cavity during long-pulse operation, including the assessment of its cooling capability, is mandatory for predicting the gyrotron performance as well as for the interpretation of experimental results. In Europe, the MUlti-physiCs tool for the integrated simulation of the CAvity (MUCCA) was developed in the last couple of years to compute the operating conditions of the gyrotron cavity accounting self-consistently for its thermal-hydraulic, thermo-mechanical and electro-dynamic behaviour. Since the validation of the numerical tool against data collected from the tests of the European 170 GHz 1 MW CW prototype gyrotron tested at KIT, which is cooled with forced-flow subcooled water passing through a porous highly-conductive copper matrix, is giving encouraging results, MUCCA is being applied to push the design of the cavity cooling to more effective solutions.

In the paper, we present and discuss first the improvement of the cooling strategy of the cavity, aiming at decreasing the bell-shaped deformation by increasing the axial length of the porous region around the cavity. This solution has been implemented in the dual frequency 84/126 GHz, 1 MW, 2 s gyrotron, built for the upgrade of the TCV tokamak at SPC, EPFL, Lausanne and ready to be commissioned in the next months. Then, the ongoing design of a new cavity equipped with mini-channels is introduced, and the trade-off between increased cooling capability and increased pressure drop will be discussed. Finally, the status of the analysis of new cooling concept for the cavity, allowed by the presence of an insert inside the resonator in the so-called "co-axial"KIT gyrotron, is presented.

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