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Numerical design and experimental characterization of an innovative, 3D-printed, ʻplasma-shapedʼ cavity for ECR Ion Sources

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To improve the performances of ECR In Sources, several approaches are possible. One proposed by INFN consists in the re-design of the plasma chamber and of its microwave injection system. In this work we propose innovative plasma chamber named IRIS (Innovative Resonator Ion Source), whose shape is derived from the electrons last iso-density surface as the electrons move under the influence of the confining minimum-B magnetic field. Moreover, a new microwave launching system, based on a slotted waveguide that smoothly matches the cavity wall profile, is proposed. The simultaneous adoption of these two approaches increases the source performances by: a) the excitation of electromagnetic modes with a predominance of electric field along the cavity axis, unlike the standard cylindrical plasma chambers and b) a more uniform power deposition into the plasma core due to the injection waveguide radiating slot positions.
The plasma chamber and its microwave injection system have been designed by using CST Studio Suite with the objective to maximize the waveguide-to-cavity microwave coupling for the modes excited inside the operational frequency interval. Particle-In-Cell simulations have confirmed the higher in-plasma energy deposition expected for IRIS compared to a conventional cylindrical cavity. By employing COMSOL Multiphysics, a combination of RF, thermal and structural simulations have also been carried out to assess the correct behaviour of the water cooling system.
A full-scale structure prototype has been realized in Additive Manufacturing (AM) technique via Selective Laser Melting (SLM) technology, post-processed via Plasma Electropolishing (PEP). It has been then experimentally characterized in terms of S-parameters (modal distribution) and on-axis electric field measurement for selected modes through the bead-pull technique. Experimental results are coherent with numerical simulations, confirming the correctness of the design and of the fabrication process.

Primary authors: Dr MASCALI, David (INFN - LNS); MAURO, Giorgio Sebastiano (INFN - LNS); Dr BIANCONI, Dora (INFN - LNS); Dr TORRISI, Giuseppe (INFN - LNS); LEONARDI, Ornella (INFN-LNS); GALATÀ, Alessio (INFN-Legnaro National Laboratories); Dr GALLO, Carmelo Sebastiano (INFN - LNL); PIDATELLA, Angelo (INFN - LNS); Dr MISHRA, Bharat (INFN - LNS); NASELLI, Eugenia (Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud (INFN-LNS)); Dr RUSSO, Filippo (INFN - LNS); Dr CHYHYRYNETS, Eduard (INFN - LNL); Dr PIRA, Cristian (INFN - LNL); Dr CESTER, Davide (INFN - PD); Dr SALVÒ, Leonardo (INFN - PD); Dr REBESAN, Pietro (INFN - PD); Dr PEPATO, Adriano (INFN - PD); Dr GALLO, Angelica (INFN - PD); Dr DIMA, Razvan (INFN - PD)

Presenter: MAURO, Giorgio Sebastiano (INFN - LNS)

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