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Development of HECRAL-C: A Cryogen-Free Hybrid Superconducting ECR Ion Source for Milliampere-Level C^{4+} Ion Beam Production

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A novel hybrid superconducting Electron Cyclotron Resonance (ECR) ion source named HECRAL-C has been developed to produce milliampere-level C^{4+} ion beams. It features a conduction-cooled superconducting axial magnet for 18 GHz operation and a Halbach-array radial hexapole made of high-coercivity and high- remanence NdFeB magnets. The development of HECRAL-C builds on the previous HECRAL ion source with a liquid-helium bath-cooled axial superconducting magnet designed for 24 GHz operation. HECRAL-C has been successfully commissioned and stably producing over 1 emA of C^{4+} beams. Integrated with a newly designed Low Energy Beam Transport line (LEBT), it delivers a 1.2 emA C^{4+} beam to the Radio Frequency Quadrupole (RFQ) accelerator with a normalized transverse emittance of 0.23 π·mm·mrad. This paper details the design and performance of HECRAL-C and the LEBT system.

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