Testing the injection of ions in the CB-ECRIS* at the Cyclotron Institute

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One of the milestones in the upgrade project is the commissioning of the CB-ECRIS*. This ion source will be used to further ionize low charge-state (1^+ mainly) radioactive ions to higher charge-states (charge-breeding) for acceleration by the superconducting K500 cyclotron. The details about the CB-ECRIS can be found in the last progress report and in Ref. [1]. The frequency used to ignite the plasma was 14.5 GHz and the extraction voltage varied between 7 kV to 10 kV. The source was initially tested as a conventional ECR ion source by injecting neutral gases: oxygen and argon. After running for few weeks the source became unstable and was inoperable due to the appearance of a large and oscillating drain current. It was found that the insulator between the plasma chamber and the steel from the injection side coil had developed significant damage from a sparking track. After the insulator was removed and examined, it was replaced with one redesigned to have a longer path from high-voltage to ground. The source has since operated in a more stable fashion. Fig. 1 shows a scan for high charge-states for argon with low microwave power.

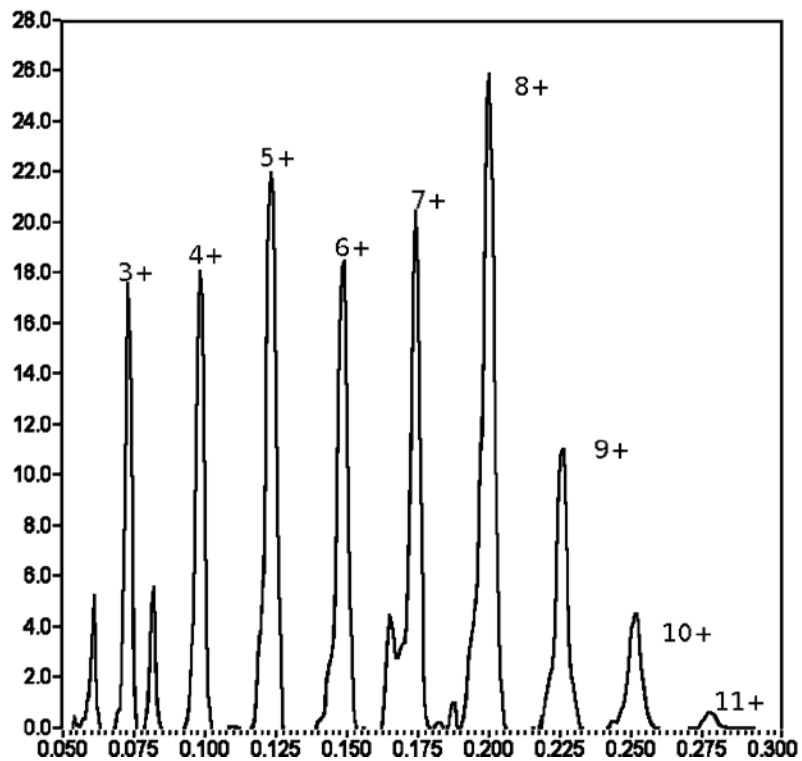

FIG. 1. Plot representing the extracted current (μA) from the CB-ECRIS with argon versus Q/M. The peaks are labeled with the corresponding charge-states.

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* Charge Breeding Electron Cyclotron Resonance Ion Source

To test the charge-breeding capability of the CB-ECRIS we chose to inject a beam of stable 1^+ ions into the plasma chamber from a commercial ion gun made by HeatWave Labs and capable of producing 1 μA of 1+ current from the alkali elements, Li, Na, K, Rb and Cs. Details of the ion gun can be found on the company website. The critical feature for high efficiency charge-breeding is the capture of the injected ions by the plasma. For this to happen the injected ions should be within a few volts of zero velocity as they encounter the plasma. Since the potential ΔV of the plasma with respect to the plasma chamber is on the order of a few volts and indeterminate, the extraction voltages V_{ext} of the ion gun and of the CB-ECRIS were tied together through a single high-voltage supply with ΔV applied to the ion gun via a low-voltage, remotely adjustable supply floating at V_{ext}. Fig. 2 illustrates the injection system. The ion gun is mounted on the left-hand flange in the figure.

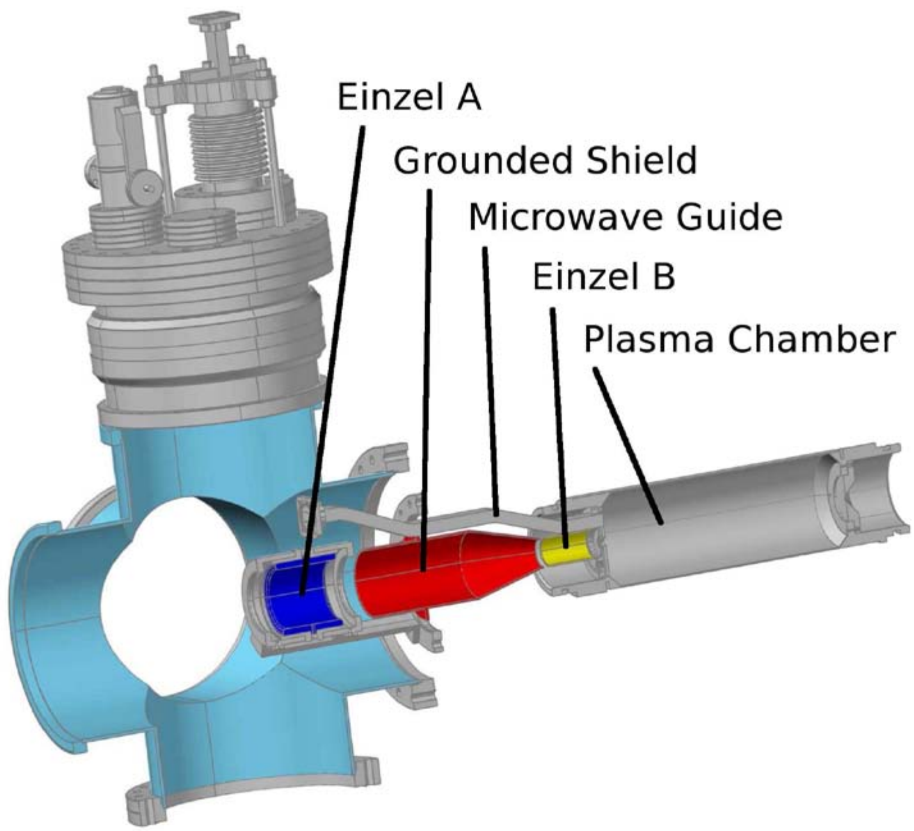

FIG. 2. The injection system of the CB-ECR. Einzel A, grounded shield, and biased tube are respectively highlighted blue, red, and yellow. The microwave guide and the plasma chamber are shown in gray.

We conducted ion transport simulations using the SIMION code, a software package designed to calculate the trajectories of ions moving through electric and magnetic fields [2]. The code was used to visualize the trajectories of the ions at the entrance in the plasma chamber as well as to estimate voltages to be applied to the Einzels A and B. The solenoid magnetic field from the injection side coil was considered during the simulations, and we could observe that it does provide extra focusing to the injected beam. In Fig. 3 we present a comparison for Rb^+ injected beam with the solenoid turned on and off. ΔV used in this simulation was 40 V.

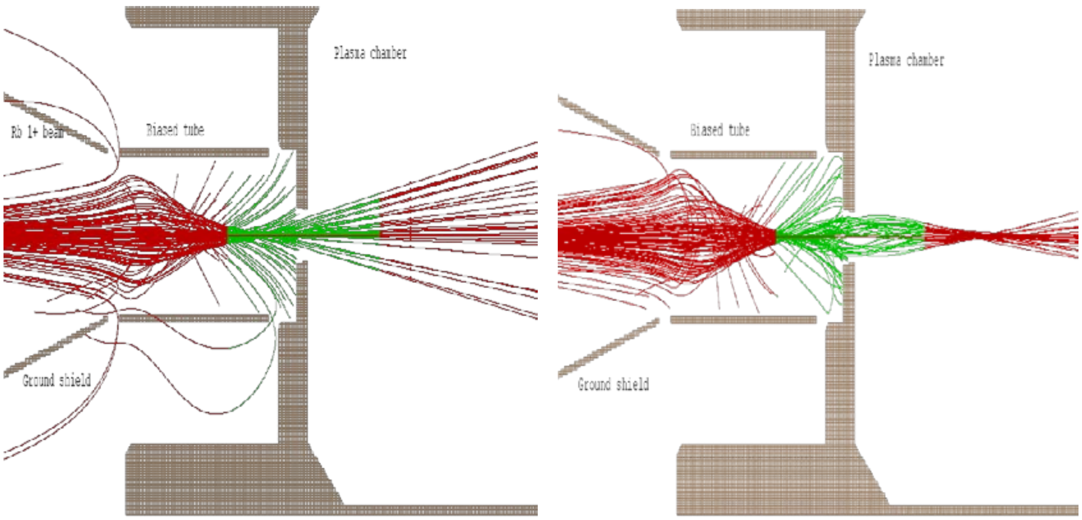

FIG. 3. SIMION simulations for the Rb^+ beam. In the left panel the magnetic field was turned off and in the right panel the magnetic field was turned on.

In tests of detecting the Rb^+ beam on the extraction side of the CB-ECRIS, without the ECR plasma ignited, it was found that the voltages used for the Einzels A and B differ from the SIMION simulations within ±10 %. Einzel A has a narrow range of voltages whereas voltages for Einzel B span a larger range for the 1^+ beam at the extraction side to still be detectable. When the microwave transmitter is turned on, the Einzel A voltage must be decreased in order to detect the Rb^+ beam again. Higher charge states of Rb have not yet been observed, and further investigations and tests are underway. For the next series of experiments we will inject a Na^+ beam, Einzel A will be eliminated from the injection scheme.

[1] W.D. Cornelius, ECRIS 2008, 18^{th} International Workshop on ECR Ion Sources, Chicago, Illinois USA; http://accelconf.web.cern.ch/AccelConf/ecris08/papers/weco-b01.pdf

[2] http://www.simion.com and references therein.