The charge breeding ECR ion source at the Cyclotron Institute

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The goal of the Upgrade Project of the Cyclotron Institute is to reaccelerate beams of radioactive ions for the exploration of the vast area of experimental nuclear physics using unstable nuclei. Ion guide techniques stop fast collision products in helium. These products are removed from the production target by helium flow and are subsequently formed into radioactive ion beams (RIB) of low charge state. Reacceleration to energies higher than 3 – 5 AMeV requires much higher charge states. These can be achieved using the charge-breeding process predicted in the late '90s for modified ECR ion sources. The PIAFE project [1] first proved this experimentally.

Charge breeding is defined as the process where low charge state ions, 1^+ or 2^+, are trapped by the plasma of an ECR ion source and subsequentlly further ionized before being extracted. The process is complex and very difficult to approach from a theoretical point of view; extensive experimental work needs to be performed in order to achieve the goal of charge-breeding.

One of the key components of the Upgrade Project is the commissioning of the Charge Breeder ECR Ion Source designed, fabricated and delivered by Scientific Solutions, San Diego, California [2]. The injection of the 1^+ ions into the plasma chamber is critical in that the energy of the incoming beam must match the extraction potential of the ECR ion source plus the plasma potential (a few tens of volts)

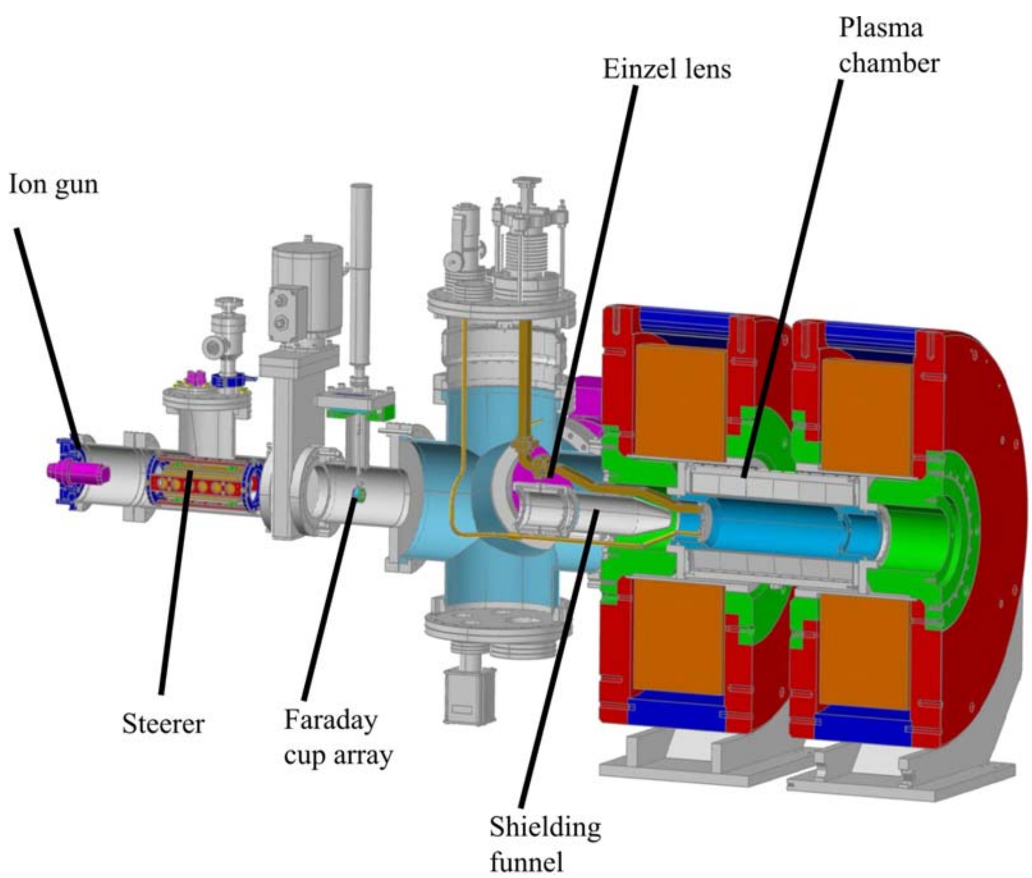

FIG. 1. Engineering drawing of the CBECR depicting the injection system.

in order for the ions to be trapped. Fig. 1 illustrates our testing scheme. The initial 1^+ ions (alkali metals) are produced using the HeatWave Labs ion gun and an electrostatic steerer corrects for any misalignment of the optical axis. The injection system of our Charge Breeder ECR consists of an einzel lens, a funnel, shielding the 1^+ ions from the microwave guide held at the same potential as the plasma chamber, and a tube placed at the entrance of the plasma chamber. This end tube can be biased or grounded via an external high voltage feedthrough.

The work effort was concentrated in creating a remote control configuration of the ion source together with the ion gun and the electrostatic steerer. All the power supplies were moved out from the vicinity of the source, and they are completely remote controlled, making troubleshooting and monitoring much easier. A Faraday cup array (FCA) was developed together with the control software. The FCA consistsof 35 pins embedded inside an insulator (ceramic) structure and covered by a copper mask. Current hitting each pin is measured using a low-current scanner card (model 7158) installed inside a programmable switch unit (model 7002) from Keithley Instruments. LabView based software was designed to read the digital picoammeter and to provide an image of the beam (see Fig. 2). A slight steering effect was observed when either the ion gun extractor or lens is tuned, an effect which was canceled by adjusting the voltage on the horizontal or vertical plates of the electrostatic steerer. The image also provided us with an estimated beam spot size of about 7 mm at the FCA's location, approximately 400 mm from the exit aperture of the ion gun.

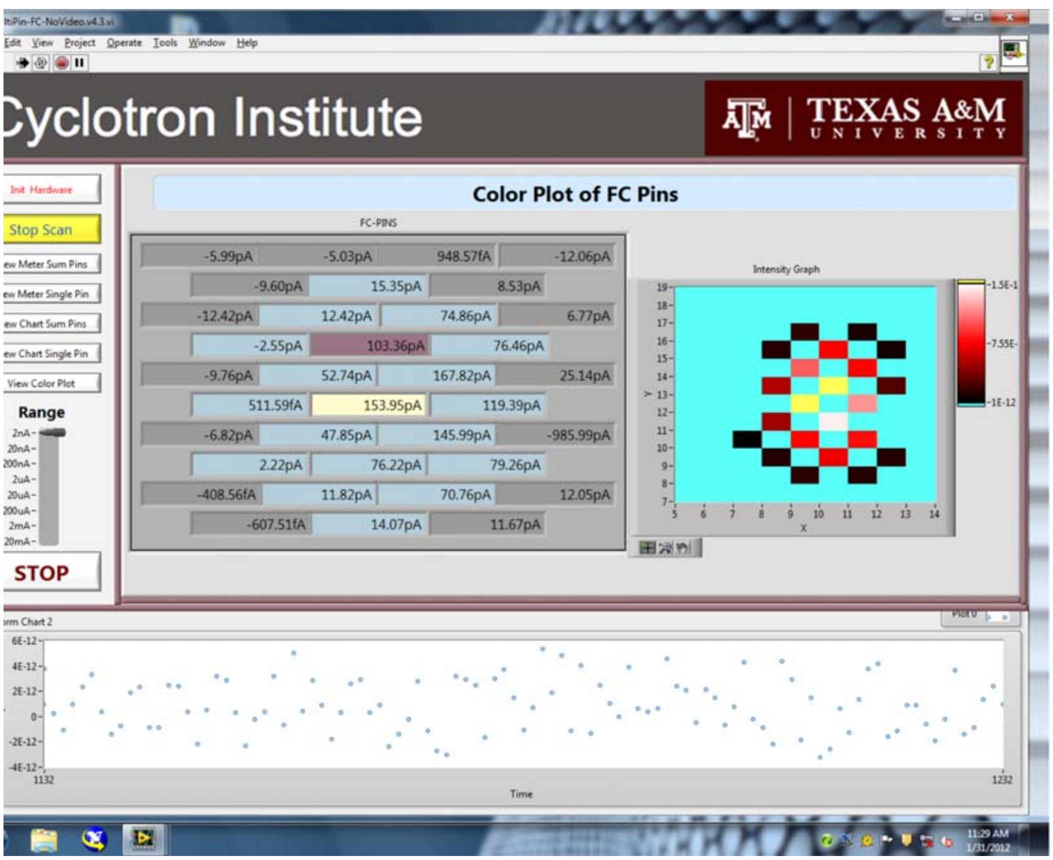

FIG. 2. Screenshot of the controlling software for the Faraday Cup Array. The circle diameter represents approximately 7 mm.

SIMION calculations were performed for various conditions, taking into account the solenoidal magnetic field of the two coils. Calculations show the ions are slowing down at the entrance of the plasma chamber and move inside the plasma chamber following a spiral trajectory. Depending on their velocity, the ions are captured by the plasma and suffer multiple ionizations changing their charge state.

Future tests will be focused on finding the right parameters for transporting the 1^+ ions into the chamber and search for sign of higher charge states, respectively charge breeding.

[1] J.L. Belmont *et al.*, Proceedings of the 13th International Workshop on ECR Ion Sources, Texas A&M University, College Station, Texas, February 1997.

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