**Progress on the charge breeding ECR ion source**

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The Charge Breeding ECR Ion Source (CBECR) is a key part in the Upgrade Project for the future re-acceleration of radioactive ion beams [1]. In the last year, the effort was concentrated to commission the CBECR and also to gain experience in tuning the injection beam line to the K500 cyclotron. The charge breeding is a complex process and theoretical works are not feasible to simulate and to describe in detail the process, so extensive experimental work is needed in order to achieve the final goal.

The ions to be charge breed, $1^+$ charge state, were delivered by an ion gun from Heat Wave Labs [2] loaded initially with rubidium and afterwards, with cesium. The ion gun construction details can be found on the manufacturer website. Special attention was paid to the injection assembly from the ion gun into the CBECR. Downstream of the ion gun (see Fig. 1), an electrostatic steerer was installed in order to correct the ion gun misalignment and also a Faraday Cup Array was installed to measure the injected $1^+$ ions current. There is no electrons suppression on this Faraday Cup, so no breeding efficiency can be inferred with reasonable uncertainty.

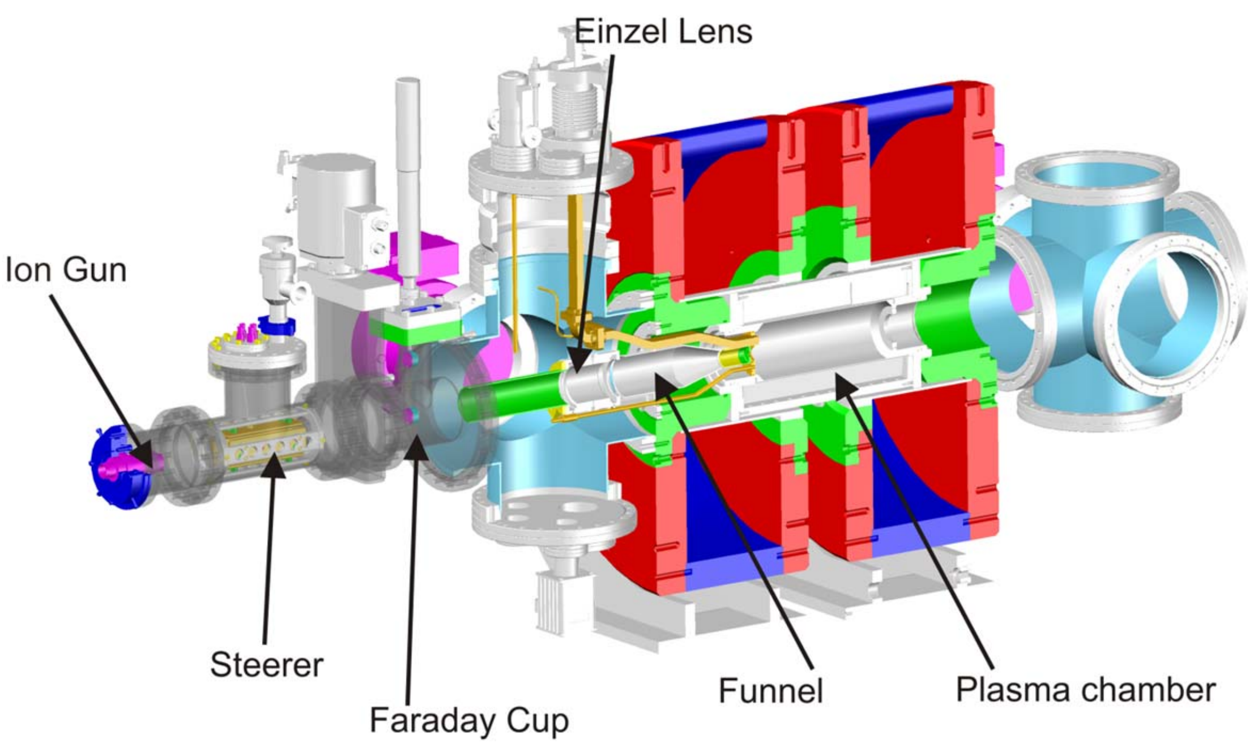


**FIG. 1.** Engineering drawing of the Charge Breeding ECR including the ion gun and the injection assembly.

The $1^+$ ions from the ion gun have to overcome the ECRIS plasma potential in order to be trapped, thermalized and further ionized to achieve a higher charge state. Careful tuning of the injection elements is crucial and most of the effort was directed towards understanding and finding good settings to transport the $1^+$ ions into the plasma chamber. Different charge state spectra were taken in various conditions: changing the microwave power transmitted, support gas load and injection settings. Initially, a computer program that monitors the analyzed current was used to follow variations of a specific charge state peak. Later, after finding robust signs of the breeding process, the usual charge state spectrum with the ion gun turned on and off was used to determine the strength of the process. Fig. 2 shows such a spectrum with the ion gun loaded with rubidium.

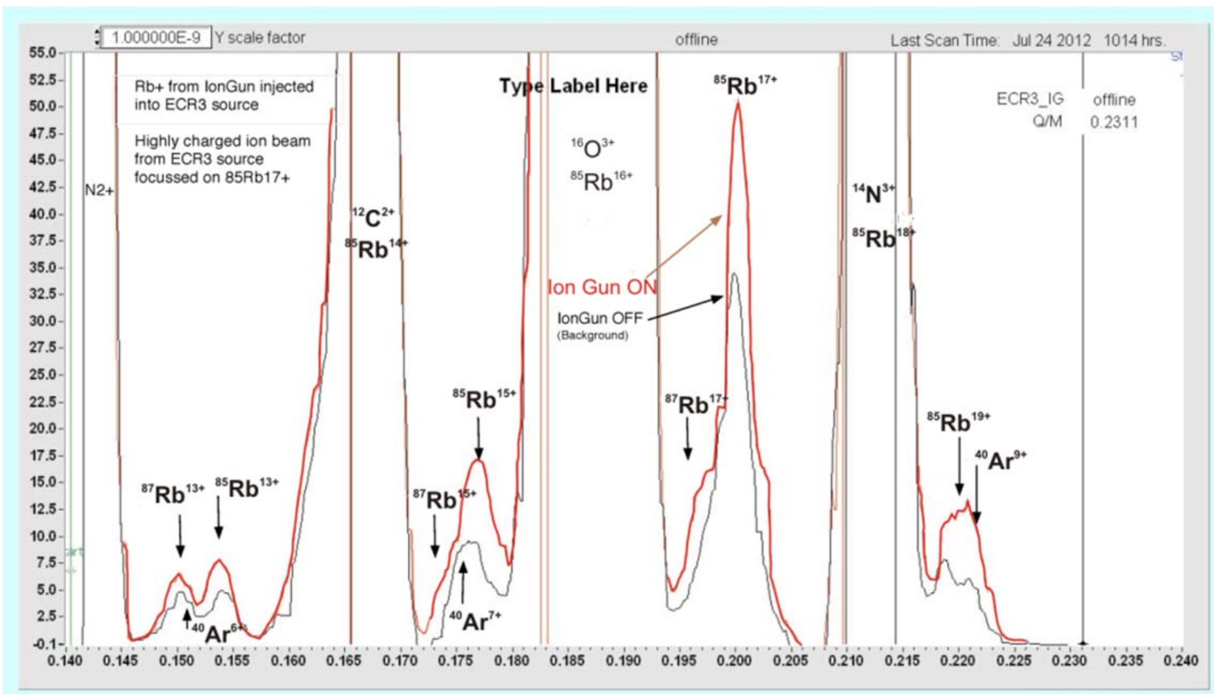


**FIG. 2.** Screenshot of the charge states spectrum showing the intensity variation of the $^{85}Rb^{17+}$ charge state when the ion gun was turned on or off.

When ion gun was loaded with cesium, and similar tests were performed showing a richer analyzed spectrum, and also a more efficient charge breeding process. Figure 3 represents a screenshot of the analyzed charge state spectrum with cesium used as the $1^+$ ion source. It is noticed a multitude of higher charge states of cesium peaking at $24^+$. These results are in agreement with the observation made by Vondrasek *et al.* [3].

The injected $1^+$ ion current was not measured properly; consequently we cannot provide an efficiency figure for the charge breeding. Our tentative of efficiency measurements shows big discrepancy between rubidium and cesium breeding efficiency: from 0.5% for $^{85}Rb^{17+}$ charge state to 13.2% for $^{133}Cs^{24+}$ respectively.

Once the functioning of the CBECR was confirmed, we transported the new developed beams through the newly built injection beam line and accelerated with the K500 Cyclotron. The first accelerated beam was $^{85}Rb^{15+}$ at the energy of 10 MeV/A using 8 kV CBECR extraction voltage. The new injection beam line transport efficiency was found to be excellent, and a current of 4.0 nA was measured at the cyclotron extraction, out of 29 nA analyzed $^{85}Rb^{15+}$ CBECR current. We also have accelerated $^{85}Rb^{17+}$ at the energy of 15 MeV/A and an extracted current of 6.4 nA, out of 64 nA analyzed $^{85}Rb^{17+}$CBECR current, was measured. $^{133}Cs^{24+}$ was accelerated also at the energy of 10 MeV/A and an extracted current of 14 nA was measured out of the Cyclotron for 108 nA analyzed $^{133}Cs^{24+}$ CBECR current. The average overall transport and acceleration efficiency was approximately 12 %. This exercise of accelerating the CBECR newly developed beams helped us also to debug and solve the inherent problems that appear to any commissioning of the new beam lines.

The CBECR is one of the key parts in the Upgrade Project and now it has demonstrated its functionality. The next step will be to couple the Light Ion Guide [4] to the Charge Breeding ECR and start the necessary tests to commission the two devices coupled together.

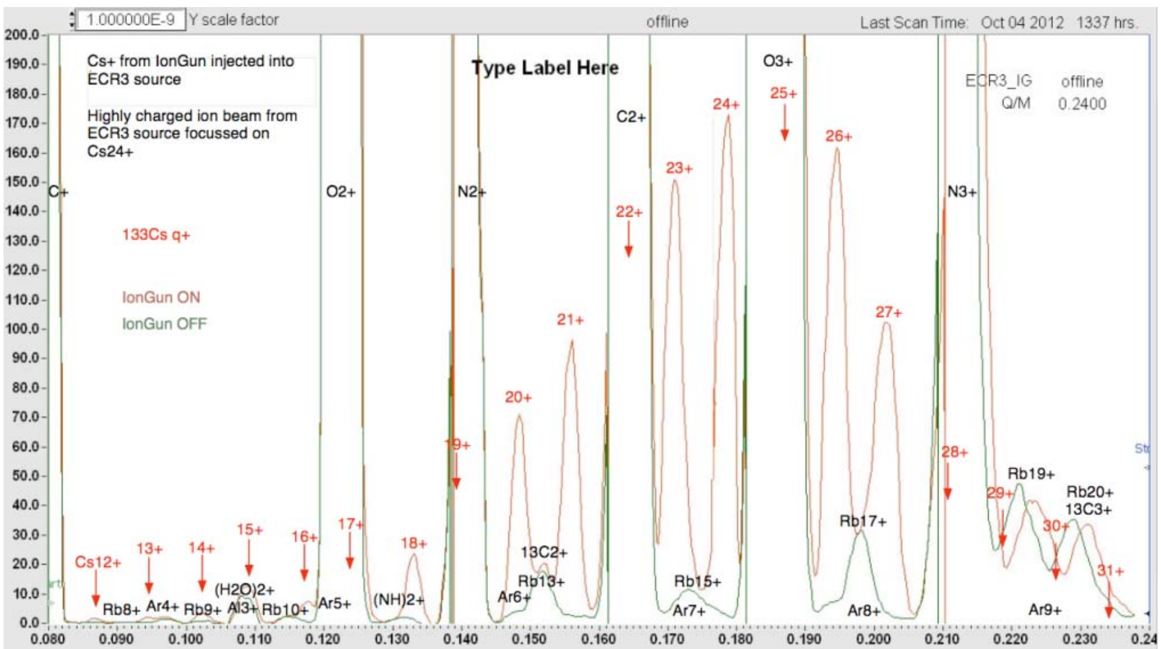


**FIG. 3.** Charge states analyzed spectrum with Cesium higher charge states pointed with red arrows.

[1] H.L. Clark *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p.V-3;http://cyclotron.tamu.edu/2012%20Progress%20Report/5%20Superconducting%20Cyclotron %20and%20Instrumentation/V_6-15_ciup.pdf

[2] Heat Wave Labs, http://www.cathode.com/pdf/TB-171.pdf

[3] R. Vondrasek *et al.*, Proceedings of ECRIS2010, The 19th International Workshop on ECR Ion Sources, Grenoble, France, 2010; http://accelconf.web.cern.ch/AccelConf/ECRIS2010/papers/wecobk02.pdf

[4] G. Tabacaru, D. P. May, and J. Ärje, Proceedings of ECRIS2010, The 19th International Workshop on ECR Ion Sources, Grenoble, France, 2010; http://accelconf.web.cern.ch/AccelConf/ECRIS2010/papers/mopot010.pdf