Charge Breeding with the SPARC-EBIT

A. Thorn*[1], A. Sokolov[2], G. Vorobyev[2], F. Herfurth[2], O. Kester[3], W. Quint[2], F. Ullmann[4], and G. Zschornack[1]

[1]Institut für Angewandte Physik, Technische Universität Dresden, Germany; [2]GSI, Darmstadt, Germany; [3]NSCL/MSU, East Lansing, USA; [4]Dreebit GmbH, Dresden, Germany

Highly charged ions (HCIs) are an important tool in various fields of basic and applied physical research. However, in many cases the species of interest cannot be produced directly by a primary ion source. Therefore, charge breeding, i.e. the conversion of singly charged ions to highly charged ions, is an essential part of projects such as nuclear or astrophysical experiments with post accelerated beams of radioactive ions [1] or precise nuclear mass measurements with ions stored in penning traps [2].

At GSI's HITRAP facility [3] HCIs up to U^{92+} can be provided using an accelerator complex to strip electrons off the initially low charged ions at high velocities. In case the beam from the accelerator structure is not available, tests can be run using a compact room-temperature electron beam ion trap, the SPARC-EBIT [4], which was designed to produce HCIs from gaseous materials injected through a needle valve. To broaden the range of particles which can be fed to the source we have investigated its abilities as a charge breeder.

The setup for the charge breeding experiments includes a surface ion source for the creation of the singly charged alkali metal ions. The measurements presented in this paper were performed using potassium. These primary ions are guided straight towards the SPARC-EBIT where the charge breeding process takes place. It can be divided into three phases: K^{1+} injection, breeding, and re-extraction of a pulse of highly charged ions from the EBIT. During the re-extraction phase a quadrupole bender mounted in between the two ion sources is switched from ground to high voltage to bend the ion trajectories by 90 degrees and send the pulse towards the multi passage spectrometer (MPS) where it can then be analyzed by magnetic A/q separation.

A typical A/q spectrum of charge bred potassium measured with the MPS is presented in figure 1. The source parameters given in the picture were found to be optimal for continuous potassium ion injection. After a breeding time of $t_{\mathrm{breed}} = 3$ s the charge state distribution has reached its equilibrium. Since the electron beam energy of the EBIT was set close to the ionization energy of the K-shell, helium-like potassium shows the highest relative abundance in the spectrum. Bare potassium ions have been detected, though only in small amounts. Further on, it was discovered that an injection time of $t_{\mathrm{inj}} = 20$ ms at the beginning of the breeding time, t_{breed}, is sufficient to achieve the maximum ion output for high charge states. The capture efficiency during the measurement resulted in $\approx 2 \cdot 10^{-4}$. Breeding efficiencies for different charge states are presented in table 1.

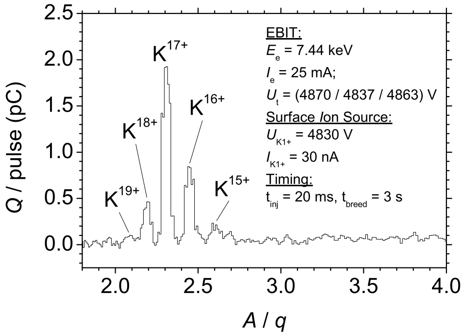

Figure 1: Charge state distribution after $t_{\mathrm{inj}} = 20$ ms and $t_{\mathrm{breed}} = 3$ s. The experimental parameters given in the picture are the electron beam energy, E_{e}, as well as the electron current, I_{e}, of the EBIT, the drift tube voltages, U_{t}, the K^{1+} ion acceleration potential, U_{K1+}, and finally the K^{1+} current, $I_{\mathrm{K1+}}$, measured on a Faraday cup in front of the EBIT entrance.

The activities will be continued with studies of advanced charge breeding techniques [5] using high-Z elements.

Table 1: Charge breeding parameters for various potassium ion charge states q including the breeding time at which q represents the maximum of the charge state distribution, t_{breed}, the maximum number of K^{q+} ions per pulse, $N_{\mathrm{K}^{q+}}$, the relative abundance of the charge state q, $N_{\mathrm{K}^{q+}}/N_{\mathrm{K}}$, and the breeding efficiencies, $\varepsilon_1 \rightarrow q$.

q	t_{breed}(ms)	$N_{\mathrm{K}^{q+}}(10^5)$	$\frac{N_{\mathrm{K}^{q+}}}{N_{\mathrm{K}}}$	$\varepsilon_{1 \rightarrow q}(10^{-5})$
9	50	2.4 ± 0.5	29 %	6.3 ± 1.6
14	300	2.7 ± 0.5	32 %	7.2 ± 1.8
17	1000	5.6 ± 1.1	45 %	15.3 ± 3.8

References

[1] D. Habs et al.: Hyperfine Interactions 129 (2000) 43–66

[2] J. Dilling et al.: Int. J. Mass Spectrom. 251 (2006) 198

[3] F. Herfurth et al.: Int. J. Mass Spectrom. 251 (2006) 266

[4] B.E. O'Rourke et al.: J. Phys. Conf. Ser. 163 (2009) 012103

[5] O. Kester et al.: J. Phys. Conf. Ser. 2 (2004) 107

---

[*] a.thorn@fzd.de