CHARGE BREEDING EXPLORATION WITH THE MAXEBIS*

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Abstract

The demand for high charge states of exotic ions prior to their injection into an accelerator has driven the development of the charge breeding method. Existing facilities like REX-ISOLDE or ISAC at TRIUMF are already using a charge state booster for the post acceleration of radioactive ions. Planned facilities like MAFF, SPES, SPIRAL II and EURISOL have identified the need of a breeding system because of the demand for highly charged ions for low energy experiments and because of the available budget and space. Therefore the exploration and optimization of existing charge state breeders is mandatory and is supported by the I3-EURONS and the EURISOL-DS. The Frankfurt MAXEBIS (MAX electron beam ion source) setup has been modified within the past years towards a charge state breeder including external injection of alkaline ions by a surface ionisation source. The electron gun, the inner electrode structure and the collector of the MAXEBIS have been modified. The charge breeding experiments will be done at GSI. The new setup and first experimental results will be presented.

INTRODUCTION

The MAXEBIS [1] has at present two tasks. In one of the tasks the MAXEBIS is used as a test injector for the HITRAP cooler Trap (HITRAP => Highly Charged Ion Trap; RETRAP [2]), which is an essential part of the HITRAP project [3]. In addition the complete low energy part of HITRAP will be tested. The whole beam line is built up outside GSI at the Heckhalle (fig.1). After the test period the MAXEBIS will move to GSI, and will be included in the HITRAP beam line as a test injector during GSI accelerator shutdowns or for commissioning purpose.

The second task are investigations of charge breeding for EURONS und EURISOL-DS (European Isotope Separation On-Line Radioactive Ion Beam Facility). Here the goal is to apply known ion source techniques in order to improve the critical charge breeding issues, like efficiency, beam quality and purity. The Frankfurt MAXEBIS is an essential tool of the advanced charge breeding collaboration. Since this device is working in ultrahigh vacuum without any support gas, the total extracted current of unwanted ions is low. By virtue of the small emittance even very small amounts of the rare radioactive ions can be separated easily with a mass separator of moderate resolving power. For most isotopes, a mass-to-charge-ratio within the acceptance of the accelerator can be found without background from ionized residual gas. Secondly the charge breeding process within an EBIS with a high electron beam current density can be made very fast and can even be manipulated due to the well adjustable electron beam energy.

The goals of the advanced charge breeding experiments related to the MAXEBIS charge state breeder are: 1) To decrease the width of the charge state distribution by manipulation methods to obtain the highest efficiency in a single charge state. 2) Optimization of the transverse and longitudinal emittances of the extracted beams, using cooling techniques. 3) Raising the injection efficiency by using the ions of a partially neutralized electron beam to increase the capture ratio of externally injected ions. 4) Improvement of the charge breeding times for heavier isotopes and improvement of the maximum ion throughput concerning available EBIS breeder.

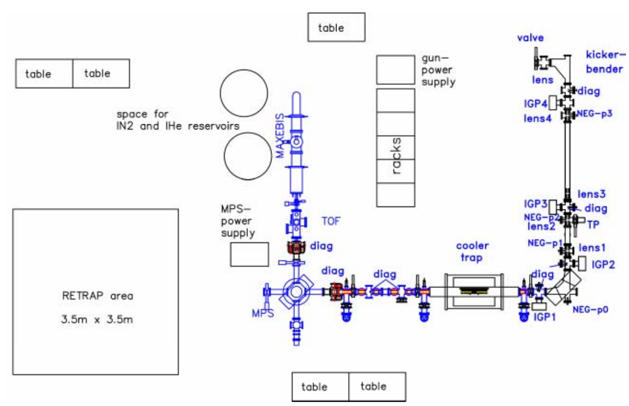

Figure 1: Setup of the test injector beam line for the HITRAP cooler trap vertical beam line and RETRAP and for charge breeding experiments, built up outside GSI at the Heckhalle.

MAXEBIS

The central part of the test injector and charge breeder beam line is the MAXEBIS. The MAXEBIS was developed and used at IAP (Institut für Angewandte Physik) Frankfurt by R. Becker and M. Kleinod. The electron gun, the inner electrode structure and the collector of the MAXEBIS have been modified during the past years. The MAXEBIS is using a solenoid with a cold bore. The superconducting magnet can reach up to 5 T

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magnetic field strength. The high current electron gun is based on a 2 mm IrCe cathode which can be driven to a maximum emission current density of about 95 A/cm^2. The position of the cathode can be modified by a manipulator system (see fig.2). Thus the magnetic field at the cathode surface and hence the electron beam compression can be changed.

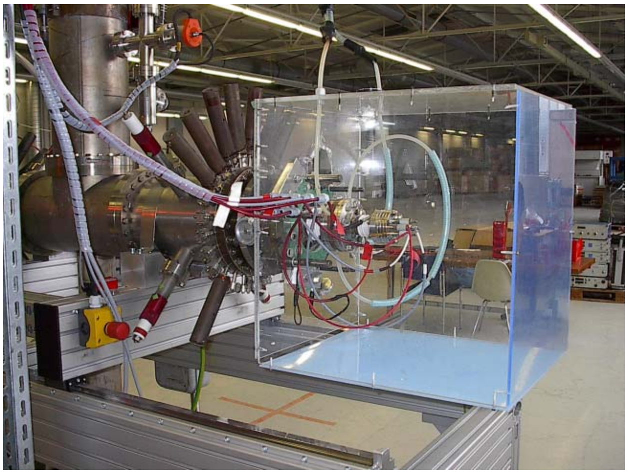

Figure 2: Electron gun of the MAXEBIS

A new collector for the electron beam has been developed and installed which can sustain 18 kW beam power. In 2005 the MAXEBIS has been moved from IAP to the GSI-Heckhalle.

TEST INJECTOR AND CHARGE BREEDER BEAM LINE AT GSI HECKHALLE

The front end of the beam line is the MAXEBIS (figure 3), which deliver the highly charged ions. For the beam diagnostics we use a TOF spectrometer (time of flight). This allows us to measure all charge states by a time of flight analysis of one single pulse of the MAXEBIS. At the end of the linear beam line the MPS (multi passage spectrometer), which is a multi directional bending magnet combined with an electrostatic double einzel lens system in every arm. The MPS bends the beam either to the HITRAP cooler trap or to the RETRAP (Rare-Element Trap), which is the second experiment to be built up in the Heckhalle. A couple of faraday cups are mounted at both ends of the MPS and directly behind the MAXEBIS.

A small surface ion source has been designed, which will provide alkaline beams for the injection of the ions into the MAXEBIS. To measure the profile of the beam we use a YAG crystal as fluorescence screen, which is included in one diagnostic box behind the MPS. A pepper pot emittance scanner has been setup in the future RETRAP beam line. This device allows us to measure the emittances of the Barium and the MAXEBIS beams. Both emittance scanners are on test for later use in the HITRAP project. The present setup is shown in fig.4.

First experiments have been performed in order to characterize the system and to get tuning parameters for beam transport and charge state separation.

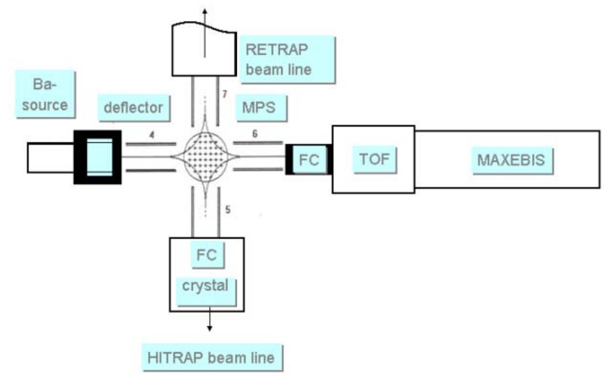

Figure 3: Front-end setup of the MAXEBIS beam line. FC= faraday cup.

Figure 4: Picture of the MAXEBIS charge breeder and test injector beam line.

EXPERIMENTAL RESULTS

In the first two runs of the MAXEBIS charge state spectra have been taken, in order to determine the electron beam current density and to get familiar with the diagnostic systems. Charge state spectra could be taken with the TOF or with the MPS magnet, using the TOF-slit as entrance slit and the slit in from of a Faraday cup as exit slit. Figure 5 shows a residual gas spectrum, measured with the TOF spectrometer. The confinement time was 25 ms. The dominant peaks are Oxygen, Carbon and Hydrogen, which correspond to the composition of the residual gas inside the up to now non baked MAXEBIS vacuum system.

Figure 6 shows a measured TOF spectrum with Xe-gas injection. The red arrows indicate different Xe-isotopes of one charge state (9+) or the next charge state (10+). The Xe-charge state with maximum abundance is 11+. Due to the present position of the cathode close to the solenoid bore a low current density was expected. In addition the charge exchange rate due to the rest gas pressure is high. After baking of the vacuum system the rate of higher charge states should be lower.

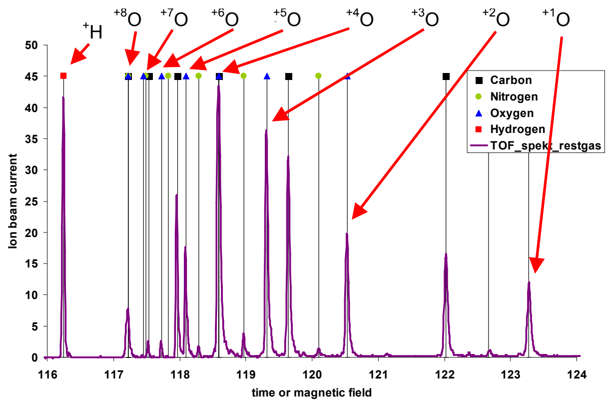

Figure 5: Residual gas TOF spectrum of the MAXEBIS

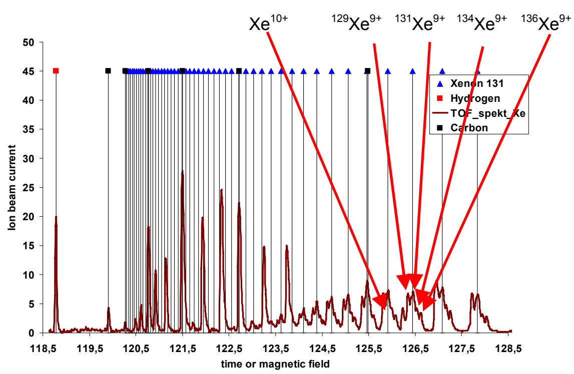

Figure 6: MAXEBIS TOF- Spectrum Xenon magnetic field 5T breeding time 25 ms, max. Xe^{11+}

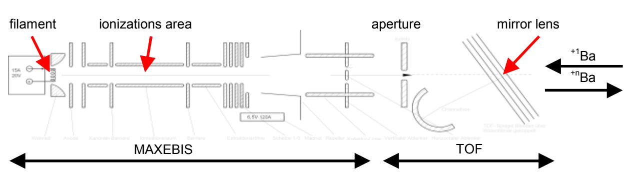

Figure 7: Inner structure of the MAXEBIS and the TOF spectrometer

One task of the charge breeding program is the external injecting of ions inside the ionisation region for charge breeding. The barium beam production take place in a small surface ion source, which is mounted in opposite direction to the MAXEBIS (figure 1, 3).

A critical point for external injection is the small acceptance of the MAXEBIS. An estimated acceptance (B=5T, q=1, m=138 (Ba), U_{ext} = 5 kV, radius beam = 0.4 mm) come to $\alpha_{xx'}$= 22 mm mrad (normalized 100% ~0.01 mm mrad) [4]. This issue ask for a proper matching of the Barium beam to the MAXEBIS, which will be optimized by the pepper pot emittance scanning.

The indication of barium ions at all parts inside the MAXEBIS up to the filament was done, as a loss current on the inner electrode, with and without magnetic filed (fig. 7). Next steps will be measurements of barium spectrums with the TOF spectrometer. But this was impossible, because we have no pulsers for the mirror lens. For that reason the barium ions are at present not able to go into the ionization area of the MAXEBIS during TOF spectra measurements.

OUTLOOK

The beam tests demonstrated that the MAXEBIS is well operating after the transport from Frankfurt to GSI. The measured TOF spectrums indicate the need of baking the vacuum system. Barium ions could be detected inside the MAXEBIS as loss current on the inner electrode. Charge state distribution measurements of metallic ions will be done after installing new high voltage pulsers, which are ordered and will be available in a few weeks.

REFERENCES

[1] O. Kester, R. Becker, M. Kleinod, H. Zimmermann, "The Frankfurt MAXEBIS Setup for Advanced Charge Breeding Experiments", Rev. Sci. Instrum. 77 (2006) 03B104

[2] L. Gruber, J. P. Holdernd, DSchneider, „Formation of Strongly Coupled Plasmas from Multi-Component Ions in a PenningTrap", Physica Scripta. Vol. 71, p 60, 2005

[3] T. Beier, L. Dahl, H.-J. Kluge, C. Kozhuharov, W. Quint, "Trapping of hydrogen-like uranium: The HITRAP project at GSI, Nucl. Instrum. and Meth. B235 (2005) 473

[4] F. Wenander, REXEBIS, "The Electron Beam Ion Source for the REX-ISOLDE Project", Design and Simulations, CERN OPEN 200-320