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Commissioning of the ion beam buncher and cooler for LEBIT

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Abstract. A radiofrequency-quadrupole ion accumulator and buncher has been set-up for the low-energy-beam and ion-trap (LEBIT) facility, which is in its final commissioning phase at the NSCL/MSU. The buncher is a cryogenic system with separated cooling and accumulation stages, optimized for excellent beam quality and high performance. The completed set-up of the LEBIT ion buncher is presented as well as first experimental results on pulse forming and beam properties.

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1 Introduction

The goal of the low-energy-beam and ion-trap (LEBIT) project is to convert the high-energy exotic beams produced at NSCL/MSU into low-energy low-emittance pulsed beams for ISOL-type high-precision experiments. The necessary beam manipulation is done in two steps. First a high-pressure gas stopping cell reduces the beam energy from ≈ 100–$150\,\mathrm{MeV}/u$ to about $5\,\mathrm{keV}$. A radiofrequency quadrupole (RFQ) ion buncher then accumulates and cools the beam before it ejects the ions as pulses. These pulses are then sent to a $9.4\,\mathrm{T}$ Penning trap mass spectrometer for high-precision mass determination. Details on the LEBIT project, its status and the gas stopping cell can be found in separate contributions to this conference [1,2].

2 Concept of the LEBIT ion beam buncher

The ion accumulator and buncher in the LEBIT project is a linear Paul trap system that accepts the $5\,\mathrm{keV}$ DC beam from the gas cell and converts it into low-energy low-emittance pulsed beams. The cooler and buncher has been designed as a two-stage system in order to separately optimize the cooling and extraction processes: A high-pressure part allows for fast cooling whereas in a low-pressure trapping region ion bunches with low energy-spread are formed. The two sections are separated by a miniature RFQ providing sufficient differential pumping. Both the cooler and the trap section have been built as cryogenic devices and can be cooled with LN_2. This measure is to increase the acceptance of the system, to decrease the cooling time and to significantly reduce the emittance of the resulting pulse compared to an operation at room temperature. A third feature distinguishing the LEBIT buncher from RFQ ion bunchers used at ISOL facilities elsewhere is the novel electrode design which allows the electric force in the cooling section to be created without the need for segmented rods. Figure 1 shows the fully assembled sections before insertion into their cryogenic chambers. More details of the design of the buncher system can be found in [3].

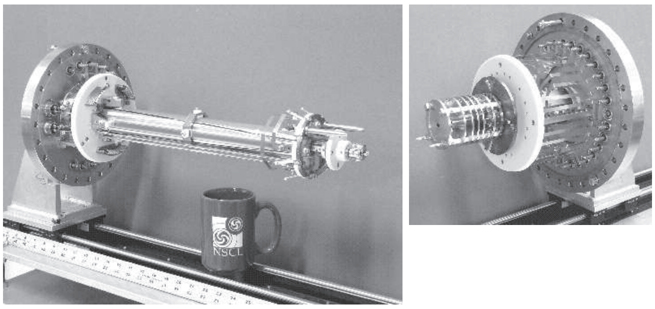

Fig. 1. Photographs of the cooler section (left) and the trap section (right).

3 Experimental results

A series of systematic investigations has been launched to characterize the performance of the buncher, some exemplary results are presented here.

In order to illustrate the damping of the axial ion motion in the buncher, short ion pulses have been injected into the buncher. The DC voltages of the buncher

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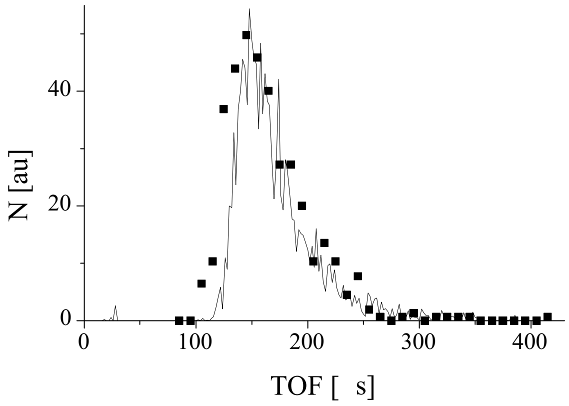

Fig. 2. Temporal shape of an ion pulse produced by a 3 μs beam gate after passing through the buncher. The experimental result (solid curve) is compared with that of corresponding simulations (square dots).

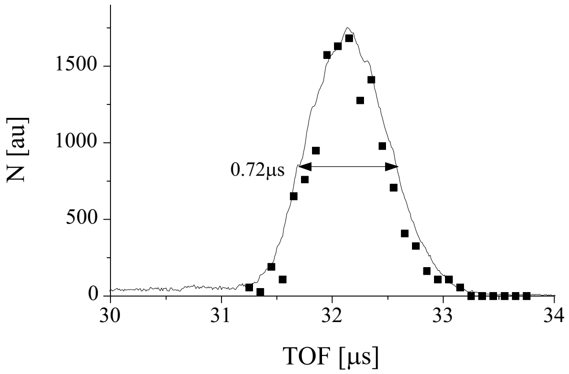

Fig. 3. Time-of-flight distribution of ions accumulated in the buncher and extracted as pulses measured with an MCP detector. The experimental result (solid curve) is compared with that of corresponding simulations (square dots). The latter is corrected for a 0.4 μs electronic time delay.

section were permanently set to ejection mode, so that the ions were directly accelerated to a micro-channel plate (MCP) detector after a single passage through the system. Figure 2 shows the temporal shape of an ion pulse produced by a 3 μs beam gate after passing through the cooler/buncher for a buffer gas pressure of $p = 5 \cdot 10^{-3}$ mbar. The ion pulse is delayed and considerably broadened compared to its initial width of 3 μs. The results of corresponding microscopic ion-trajectory calculations (also shown in fig. 2) reproduce the temporal profile nicely ascribing it to multiple scattering of the ions with the He buffer gas molecules.

Proper timing is essential for the efficient transfer of ion pulses from the buncher to the subsequent Penning trap. For this reason time-of-flight distributions are routinely measured with an MCP detector downstream the buncher. Figure 3 shows such a distribution of Ar ions accumulated in the buncher and extracted as pulses together with the result of accompanying ion-trajectory calculations. The calculations reproduce the shape of the distribution well except for a shift of about 0.4 μs, which can be assigned to electronic effects.

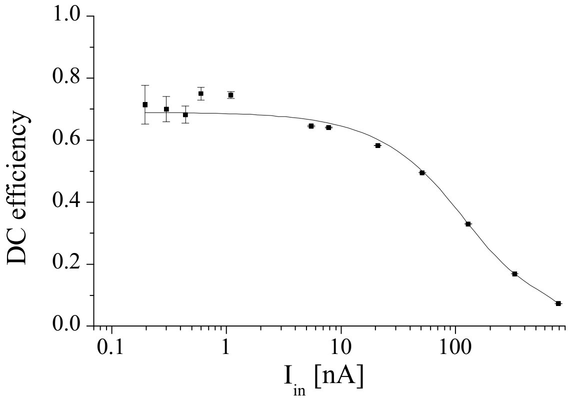

Fig. 4. Transmission efficiency for continuous beam as a function of the incoming beam current. The solid line is to guide the eye.

After having found initial good operation parameters the efficiency of the system was determined. The ingoing current was recorded at a Faraday cup located before the buncher, where a movable phosphorus screen was used to confirm that all of the ingoing beam entered the Faraday cup. To check the efficiency of the buncher as a DC beam cooler the DC voltages of the buncher section were again set to ejection mode and the beam coming out of the buncher was detected with another Faraday cup. Figure 4 shows the transmission efficiency for continuous beam as a function of the incoming beam current. The efficiency is about 70% for currents up to 10 nA. This range covers well typical beam intensities at current rare-isotope facilities. The efficiency then drops to about 10% for 500 nA of ingoing beam. Preliminary simulations indicate that this drop occurs at the space-charge limit of the miniature RFQ. First attempts to cool the cooler with LN$_2$ resulted in an efficiency increase to $\approx$ 80% for low beam current, however due to temporary technical reasons, the temperature could only be lowered to about $T \leq 234$ K.

In pulsed-mode the efficiency for the buncher and Penning trap combination was measured to be $\geq$ 10–15% for incoming beams currents of a few pA.

4 Summary

An RFQ ion accumulator and buncher has been commissioned as part of NSCL's effort to provide exotic nuclei produced in fragmentation reactions as a low-energy low-emittance ion beam for high-precision experiments. Initial tests of the buncher show good pulse-forming capability and high efficiency for both continuous and pulsed beam extraction.

References

1. P. Schury *et al.*, *Precision experiments with rare isotopes with LEBIT at MSU*, these proceedings.
2. R. Ringle *et al.*, *The LEBIT 9.4 T Penning trap system*, these proceedings.
3. S. Schwarz *et al.*, Nucl. Instrum. Methods B **204**, 474 (2003).