Eur. Phys. J. A **25**, s01, 739–741 (2005)
DOI: 10.1140/epjad/i2005-06-150-9

EPJ A direct
electronic only

Recent developments of the radioactive beam preparation at REX-ISOLDE

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Received: 16 November 2004 /
Published online: 11 August 2005 –

Abstract. This year, three main topics of research and development have been pursued at the REX-ISOLDE facility low-energy stage, complementary to the energy upgrade of the postaccelerator. These concern the ion cooling method tests, the charge exchange process study in the buffer gas of the Penning trap REXTRAP, and the molecular beam injection into the trap and REXEBIS ion source. We report here on some progress in these different investigations.

PACS. 29.27.-a Beams in particle accelerators – 41.75.-i Charged-particle beams – 52.55.-s Magnetic confinement and equilibrium – 34.70.+e Charge transfer – 29.25.Rm Sources of radioactive nuclei

1 Introduction

The low-energy stage of REX-ISOLDE [1] consists of a Penning trap (REXTRAP) for radioactive ions bunching and cooling, and an electron beam ion source (REXEBIS) for the charge breeding. It allows an efficient acceleration of the radioactive beams produced at ISOLDE in a compact LINAC. Complementary to the last energy upgrade [2], research and development are pursued to improve the beam preparation.

2 Buffer gas cooling tests

The charge breeding efficiency within REXEBIS depends strongly on the quality of the incoming cooled beam, *i.e.* longitudinal and transversal emittances from the trap. For high intensities, the space charge of the trapped ion cloud prevents an efficient cooling in REXTRAP with the presently adopted method, the so-called sideband cooling [3]. Eventually this results in a decreased efficiency of the trapping process. A new cooling method has been introduced and was first tested 2 years ago, the so-called rotating wall cooling. It is inspired by an existing technique used to compress the cloud of a non-neutral plasma along the axis of Penning traps, see *e.g.* [4]. It uses a combination of a rotating multipole excitation in the transverse plane of the trap with a buffer gas damping the ions motion [5].

During the latest tests this method was directly compared to sideband cooling. Both quadrupolar and dipolar excitations were applied at the (2,1) plasma mode eigenfrequency [5]. The measured efficiencies of the different cooling methods for $^{39}K^+$ ion numbers above 10^7 are showed in fig. 1. The experimental conditions were identical to those described in [5] except the excitation amplitude V_{pp} = 30 V. The excitation frequency was optimized for each measurement as it is slightly varying according to the number of injected ions. Clearly the rotating wall dipolar excitation and sideband cooling excitation efficiencies show a quite similar behaviour. The rotating wall quadrupolar excitation is slightly less efficient. A saturation effect appears for every method above 10^9 ions per bunch.

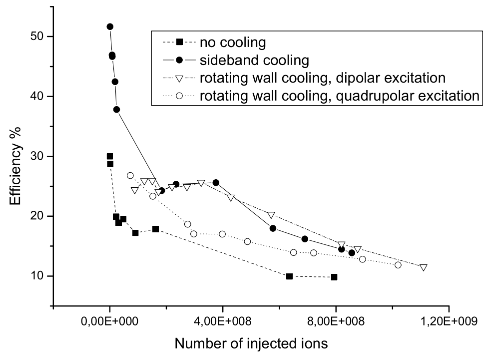

Fig. 1. Cooling efficiencies. See comments in the text.

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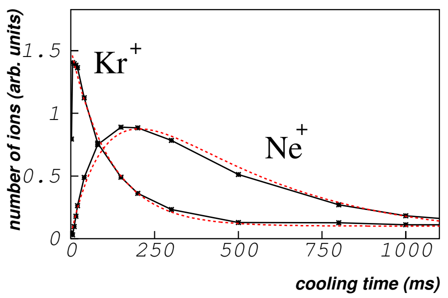

Fig. 2. Evolution of $^{78}Kr^{+}$ and $^{20}Ne^{+}$ ion numbers as a function of the cooling time. These were recorded and identified by time of flight on a MCP detector. See comments in the text.

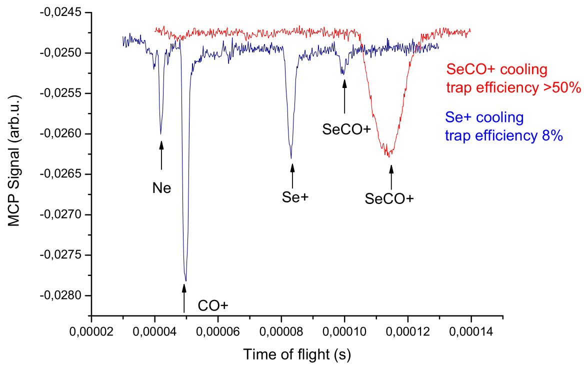

Fig. 3. Ions time-of-flight spectra after REXTRAP.

3 Charge exchange study

In REXTRAP, Ne is commonly used as a buffer gas with a pressure of about 10^{-4} mbar in the trapping area. For noble gas beams charge exchange losses have been observed. Cooled He^{+} ions are neutralized in less than 1 ms. In the case of Ar^{+} Kr^{+} and Xe^{+} ions, the direct charge exchange process with the buffer gas atoms is a closed channel, *i.e.* a channel for which the Q value is negative. Ion survival times of and above 120 ms were measured [6]. Time-of-flight spectra were recorded at the exit of the trap on a MCP detector after variable cooling times. Since the typical cooling time applied at REXTRAP is well below 100 ms it does not usually affect the overall REX efficiency. However a careful study has been undertaken as such a process might occur in a more critical manner in other buffer gas cooling devices presently in development. Numerical calculations are currently in progress to give a theoretical estimate of the contribution of the direct charge transfer. The main competitive processes are charge exchange with impurities in the buffer gas or charge exchange with the atoms of the gas mediated by a third neutral partner. In the case of Kr^{+} ions, no evidence for impurities were observed in the time-of-flight spectra. The Ne^{+} and Kr^{+} ion number evolution is shown in fig. 2. Due to the absence of any cooling excitation at the right frequency, the magnetron motion of the Ne^{+} ions increases with time and the ions are eventually lost on the wall of the trap. Dashed lines are fit to the spectra, assuming that Kr^{+} ions are only lost by charge transfer with the Ne atoms of the buffer gas. The adjusted exponential decay constants give survival times for Kr^{+} and Ne^{+} ions of 118 ms and 413 ms, respectively.

4 Molecular beam injection

According to their chemical properties, the radioactive elements can combine themselves with the impurities present in the ISOLDE target. To avoid isobaric contaminants from the ISOLDE separator it has been demonstrated this year that molecules rather than atomic ions can be efficiently injected and broken up in the low-energy stage of REX-ISOLDE [7].

During off-line tests, $SeCO^{+}$ molecules were injected into the trap. By varying the trap potentials it was possible either to cool or to break them and subsequently cool the Se^{+} ions. Figure 3 shows the time-of-flight spectra corresponding to the different trapping schemes. In the latter one, the collision induced dissociation $SeCO^{+} \rightarrow Se^{+} + CO$ was obviously less probable than $SeCO^{+} \rightarrow Se + CO^{+}$, even with optimized parameters. Due to the different trapping and ejecting voltages the size and location of ion peaks are different in both spectra. More than 50% efficiency was obtained for molecule cooling, and about 8% for molecule breakup and Se^{+} cooling. Molecule cooling and subsequent injection and breakup into the EBIS was first demonstrated during the radioactive beam time devoted to the Coulomb excitation of ^{70}Se. Preliminary analysis gives a charge breeding efficiency between 2 and 10% for $^{70}Se^{17+}$ with a breeding time of 33 ms.

5 Summary

The presented investigations address important issues for the radioactive beam developments in light of the EURISOL and RIA projects. The cooling method tests aim at an efficiency improvement for the acceleration of high intensity radioactive beams At the present stage the rotating wall cooling shows similar efficiencies as the sideband cooling. More systematic and stringent tests will be undertaken by injecting the cold beams into the EBIS. The charge exchange process study at thermal energies is of primary interest for the ongoing developments, in several different European or overseas nuclear laboratories, of buffer gas cooling cells for fission fragments —the so-called ion catchers. Lastly an efficient chemically selective method has been successfully tested this year to improve the radioactive beam purity.

This work was supported by the European Commission within the NIPNET RTD network under contract No. HPRI-CT-2001-50034.

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