TAMUTRAP as an isotopic separator

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The TAMUTRAP facility consists of two main components: a radio frequency quadrupole (RFQ) Paul trap used to cool and bunch ions, and a cylindrical 180-mm diameter Penning trap [1,2]. This differs from several other trap facilities in that it has only one Penning trap designed for decay studies; other facilities have a purification Penning trap for isobaric and isotopic beam purification prior to a measurement trap dedicated to perform mass measurements. We have demonstrated that one can use a single trap to purify the beam and perform mass measurements.

A purification Penning trap is filled with helium buffer gas [3], usually $1x10^{-3}$ – $1x10^{-5}$ mbar, using a special gas-feeding system. The TAMUTRAP Penning trap does not have such a system, however helium gas used in RFQ cooler/buncher diffuses throughout the beamline, including into the Penning trap. A normal operating pressure for the RFQ is around $7x10^{-3}$ mbar leading to a vacuum of 3.7×10^{-7} mbar in the trap. However, if we increase the RFQ helium flow and operate it at $2.5x10^{-2}$ mbar, the gas pressure in the trap area increases reaching $1.3x10^{-6}$ mbar just before the superconducting solenoid housing the Penning trap, down to and $4.8x10^{-8}$ at the exit of the solenoid. The pressure at the centre of the trap can be then estimated to be an average of those two pressures.

We have carried out tests with natural rubidium released from an offline ion source located before the RFQ cooler/buncher. Natural rubidium consists of two main stable isotopes: ^{85}Rb and ^{87}Rb with natural abundances of 72.17% and 27.83%, respectively.

A bunched beam of ^{85,87}Rb ejected from the RFQ was captured in-flight into the Penning trap in the usual manner: the potential of the injection side of the trap was lowered to the level of the trap bottom (150 V) allowing them to enter. With the ejection side closed (300 V) ions are reflected back; trapping is accomplished by closing the injection side before the bunch beam escapes.

After capturing, the ions were allowed to collide with the buffer-gas atoms. Cooling occurs as energy is transferred to the lighter-mass helium atoms, and neutralization does not proceed due to the high ionization potential of helium. After cooling (in our case for 350 ms), the ions collected in the trap centre at the minimum of the axial electric potential well.

Fig. 1 show the timing pattern of our purification scheme, and Table I lists the other setting used. The first step in our one-trap purification scheme was to move all the trapped ions into a larger orbit than the 4-mm exit hole of the trap by applying a dipole excitation at the magnetron frequency (155 Hz, 20 V). This excitation is mass-independent and affects all ions confined in the trap, *i.e.* both $^{85}Rb^{+}$ and $^{87}Rb^{+}$. Next a quadrupole excitation at the cyclotron frequency of a particular ion species, $f_C=1/(2\pi)qB/m$, selectivity re-centres ions of a particular mass m. Due to the lower pressure compared to typical purification traps, we needed to apply a relatively long (200 ms) and strong (20 V) quadrupole excitation in order to re-centre ions in our trap. After the purification process, a normal time-of-flight ion cyclotron resonance excitation [4] was applied for 200 ms to create frequency scans shown in Fig. 2.

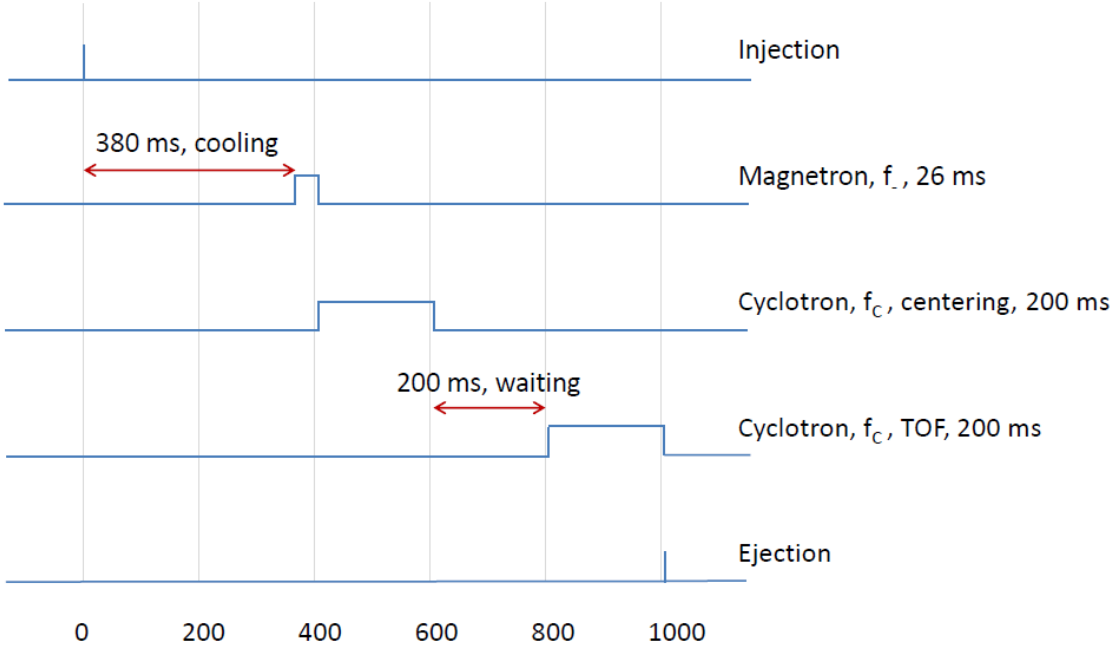

Fig. 1. Timing pattern used in the purification and subsequent TOF excitation for one-trap isotopic separation.

Table I. Summary of waveform generators used.

Generator	Motion	Amplitude	Mode	Other
Rigol DG1022	Dipole/magnetron	20 V	Burst/4	
Rigol DG1022	Quadrupole/cyclotron	20 V	Gated	centering
Tektronics AFG3022B	Quadrupole/cyclotron	adjusted	Gated, phase locking	TOF

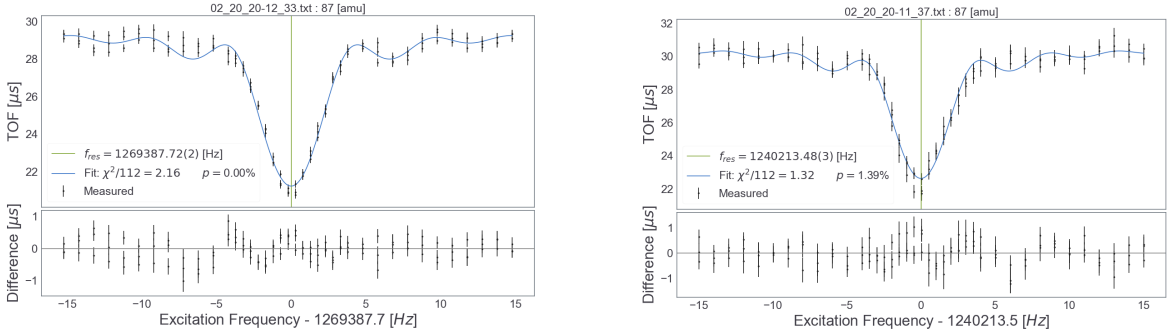

Fig. 2. Example of $^{85}Rb^{+}$ (left) and $^{87}Rb^{+}$ (right) frequency scans to determine their cyclotron frequencies.

Based on these resonance scans, we determined that our purification scheme is able to remove over 95% of the naturally abundant ^{87}Rb when cleaning for ^{85}Rb, and vice-versa.

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[2] M. Mehlman *et al.*, Nucl. Instrum. Methods Phys. Res. **A712**, 11 (2010).
[3] G. Savard *et al.*, Phys. Lett. A **158**, 247 (1991).
[4] M. Konig *et al.*, Int. J. Spectrom. **142**, 92 (1995).