Beam Cooling of High-Intensity ISOL Beams

G. Bollen[1], S. Schwarz[1], F. Herfurth[2]

[1]National Superconducting Cyclotron Laboratory, Michigan State University
South Shaw Lane, East Lansing, MI 48824, USA
[2]CERN, 1211 Geneva 23, Switzerland

Beam cooling based on the use of radiofrequency ion guides filled with a light buffer gas at low pressure has successfully been applied to low-energy beams of rare isotopes and serves to improve the performance of various experiments (see [1,2] for example). Most of the present systems are operated at beam intensities of less than a few nanoamperes and space charge effects are not observed or small. In the case of RIA, orders of magnitude higher maximum intensities are expected for the ISOL beams and space charge effects must be considered. We propose to design and build a high-current beam cooler and to study its properties and its applicability to RIA ISOL beams.

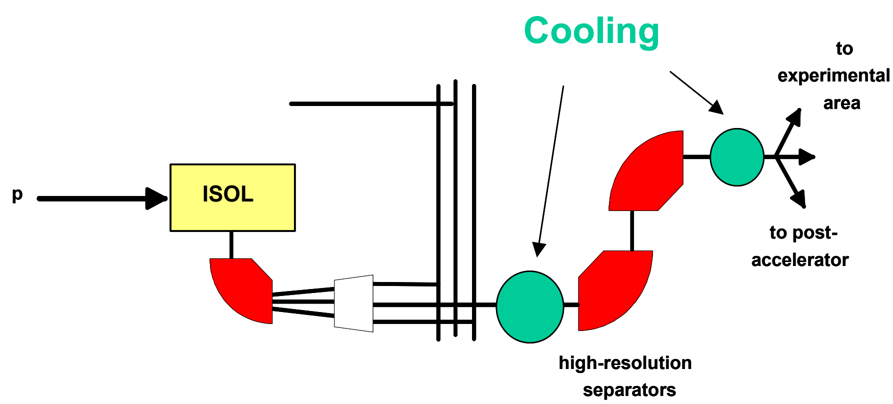

Fig. 1: The preferable location for the cooling of ISOL beams at RIA is in front of the high-resolution separators.

At RIA, beam cooling of the ISOL beams would have many benefits, in particular if the cooling was performed between the pre-separators and the high-resolution separators. Design studies [3] of the high-resolution separator suggest very large dipole magnets with superb field quality. Beam cooling would allow size and cost of these separators to be reduced and isobar separation with good neighbor-mass suppression would be less difficult to achieve. A reduced beam emittance has also positive consequences for the beam transport. The ion beam has lost its history after passing a beam cooler, which makes beam tuning largely independent of the ISOL target/ion source system and of the beam transport to the cooler. Furthermore, cooled beams experience fewer losses in the beam lines and allow smaller-sized ion optical elements to be used. Beam injection into charge state boosters and into the post-accelerator becomes easier and in particular those experiments that employ the ISOL beams directly can benefit from a higher beam quality.

We propose to design and build a beam cooler optimized for high intensity beams. A system is envisioned which allows studying space-charge effects up to several microamperes beam intensities. In order to keep the beam emittance small the radiofrequency ion guide will be designed to provide a transverse focusing much stronger than that presently realized in low-intensity coolers. At the NSCL, we recently constructed a beam cooler system for low-intensity rare isotope beams (Fig. 2) for the Low-Energy Beam and Ion Trap (LEBIT)[1] project at the NSCL. Novel features realized in this 2nd – generation system is for example cryogenic operation for achieving very low emittance beams. Cryogenic operation will also be useful for the high-intensity system, not necessarily for minimizing the beam emittance but for in-situ gas purification.

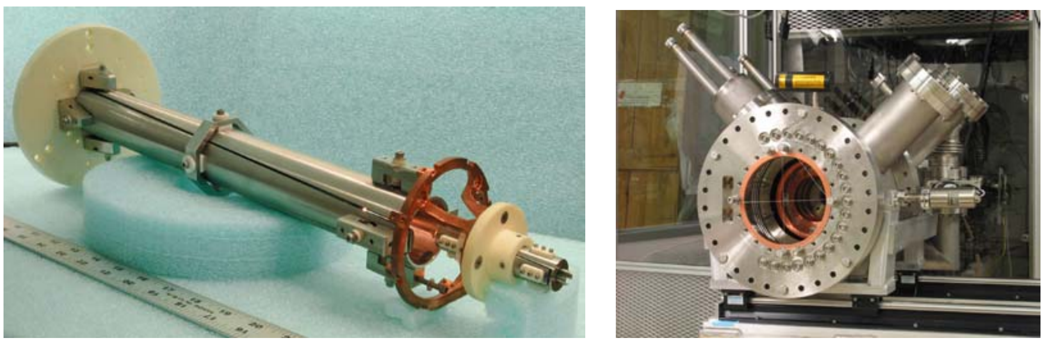

Fig. 2: Beam cooler for the LEBIT project at the NSCL. Left: Electrode structure of the RFQ ion guide; an advanced electrode configuration is used. Right: Vacuum chamber with incorporated liquid N_2 cooling shields; this allows beams to be cooled to temperatures as low as 80 K. Tests of the system have started.

A key to a successful design of a high-intensity cooler for RIA is a detailed numerical simulation of its properties. Efficient codes for the realistic simulation of buffergas cooling in ion guides and ion traps have already been developed at the NSCL. These codes have been successfully used not only for the design of the NSCL cooler and buncher discussed above, but also by other groups for the design of beam coolers and ion traps.

We are extending these codes to be able to handle space charge. First calculations have been performed and the preliminary results show very good agreement with experimental data at low intensities. They also indicate that cooling of beams with microampere intensities and probably above may be possible.

[1] F. Herfurth et al., Nucl. Instr. Meth. A469 (2001) 254
[2] A. Nieminen at al., Nucl. Instr. Meth. A469 (2001) 244
[3] M. Portillo et al., Proc. Particle Accelerator Conference, Chicago, 2001, p 3015
[4] S. Schwarz et al., Nucl. Instr. Meth. B204 (2003) 474

[1] Funded by MSU