Negative Ion Beam Cooling Using a Collisional RF Quadrupole Ion Guide

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The Holifield Radioactive Ion Beam Facility (HRIBF) uses the Isotope Separator On-Line (ISOL) technique to provide accelerated radioactive ion beams (RIBs) for nuclear structure physics and nuclear astrophysics research. The radioactive ion beams produced are often mixed with isobaric contaminants that compromise experimental results. At the HRIBF, a magnetic mass separator with a nominal mass resolving power of M/ΔM ~20,000 is provided for isobaric purification. However, in order to achieve this high resolving power in practice, a very high quality beam (one with a very small emittance and energy spread) is required. The tandem accelerator at the HRIBF requires negatively charged ions as input. Negative-ion beams are most often generated in Cs-sputter sources or by means of charge conversion of positive-ion beams. In both cases, the resulting negative-ion beams have inherently large emittances due to the large energy spreads associated with the energetic sputtering or charge transfer processes. Thus, the degree of isobaric purification that otherwise could be obtained is limited by the rather poor qualities of negative beams from these sources.

We have investigated the feasibility of cooling negative ion beams by injecting them into a gas-filled RF quadrupole ion guide where their energies are dissipated in collisions with a buffer gas. After reaching thermal energy distributions with the buffer gas, the ions can be re-accelerated to form beams with the qualities required for effective mass resolution of contaminant and beams of interest. The objective of the present studies was to develop a system and evaluate its feasibility for cooling negative RIBs to achieve beam qualities required for eliminating contaminant isobars through magnetic analysis without sacrificing intensity. To this end, we have constructed an ion cooler, consisting of a deceleration stage, a gas-filled RF quadrupole, and a re-acceleration stage, and used it to cool negative-ion beams with initial energy distributions >10 eV to energy spreads ~2 eV with an overall transmission efficiency of ~17% for F^- beams. A detailed description of the collisional cooler and results derived from cooling experiments with both negative- and positive-ion beams will be presented.

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