2003-230-N0 -- DEMONSTRATE THE TWO-CHARGE STATE INJECTOR CONCEPT FOR THE RIA DRIVER LINAC

Principal Investigators:

P. N. Ostroumov, Physics
V. N. Aseev, Physics
R. Pardo, Physics
J. Nolen, Physics
R. Vondrasek, Physics
B. Rusthoven, Technology Development
A. Barcikowski, Technology Development
S. Sharma, Accelerator Systems

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Purpose: The present-day performance of electron cyclotron resonance (ECR) ion sources, and considerations based on fundamental limiting processes in the formation of high-charge state uranium ions in such sources, indicate that uranium beam intensities as high as 7 pμA in a single charge state of 28+ or 29+ are unlikely to be obtained in the near future. Such a high current is required in order to produce the Rare Isotope Accelerator (RIA) driver linac design goal of a 400 kW uranium beam, even if we assume multiple charge state beam acceleration following the strippers. A solution to this limitation is an acceleration of two-charge-state heavy ion beams in the front end of the RIA driver linac. The purpose of this project is to develop and test design concepts for a major component of the injector system of the RIA driver linac, namely a two-charge state operation of the low energy beam transport (LEBT) and 57.5 MHz continuous wave (cw) radio frequency cavity (RFQ). The injector system is a key component of the new technique to obtain high intensity heavy ion beams.

Approach: The concept of two-charge state beam acceleration in the injector system is new but based on existing technical components. The extraction and separation of a dual charge state beam will be done on the base of the achromatic bending system downstream of the ECR which is placed on the high voltage (HV) platform. The best beam quality in longitudinal phase space can be obtained with the help of a multi-harmonic buncher followed by a cw RFQ. We have developed a simulation code and applied it for the design of the injector system for the RIA driver linac. The mechanical layout of the 2q-LEBT has been developed. It is proposed to set-up the test model LEBT in the experimental areas of the Dynamitron facility of the Physics Division. Detailed experimental investigations of the cold model of the 57.5 MHz RFQ has been carried out by postdoctoral researcher Nickolai Vinogradov.

Technical Progress and Results: Design of the beam optics in the 2q-LEBT was performed. The first order design of the LEBT has been carried out using TRACE-2D and -3D codes. Higher order optimization has been done using the code GIOS. Further optimization of the LEBT has been based on simulations of multi-component heavy-ion beam dynamics using multi-particle code TRACK. The code TRACK has been especially developed for the RIA driver design and allows us to perform end-to-end simulations beginning from the ECR ion source. The baseline design of the RIA driver linac calls for a 100 kW uranium beam that requires a total of ~2 pμA in charge states 28+ and 29+. The estimated total beam current extracted from the ECR will be ~3 mA. The space charge of this multi-component ion beam affects the uranium beam parameters. To compensate the linear component of the space charge forces, an electrostatic triplet between the ECR and bending magnet is used. A schematic layout of the 2q-LEBT is shown in Figure 1. The LEBT can be tuned to accept any two-charge-state ions with masses A≥180 by satisfying two conditions: 1) provide the design velocity at the RFQ entrance for the average charge state; 2) provide the same time difference between the two charge states over the distance L, between the multi-harmonic buncher (MHB) and velocity equlizer (VE). Use of electrostatic quadruples is planned for beam focusing in the LEBT.

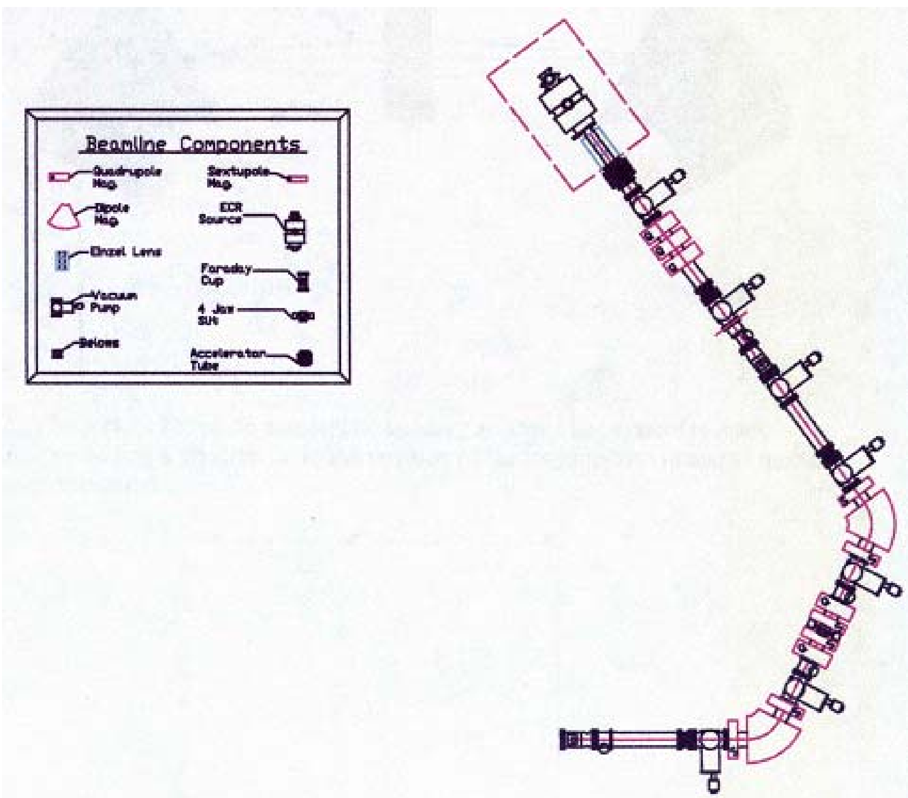

Fig. 1. 2q-LEBT beamline layout specifying major functional components of the system leading up to the first stage RFQ linac.

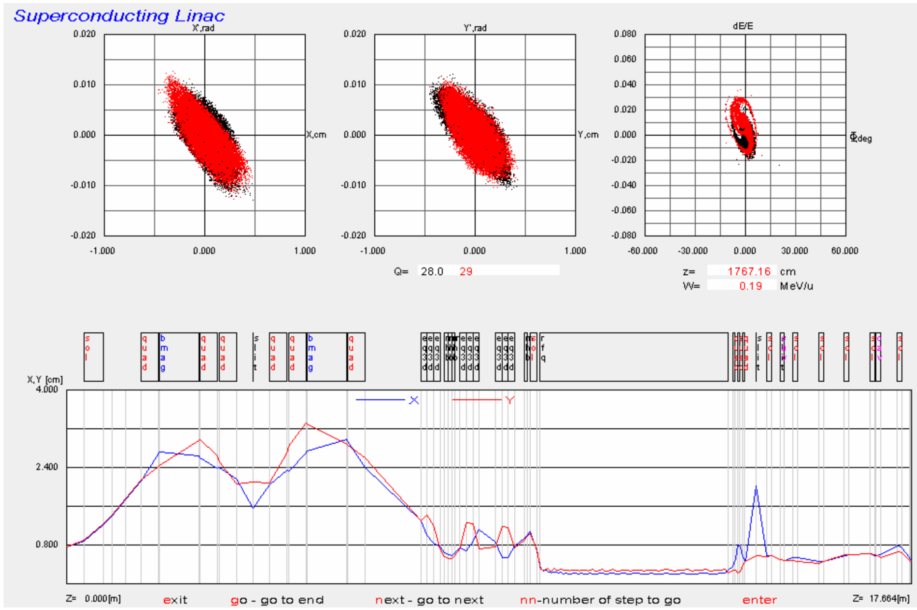

Fig. 2. Two charge state uranium beam envelopes along the LEBT-RFQ-MEBT. Transverse and longitudinal phase space plots are shown at the end of the MEBT.

Detailed beam dynamics simulations have been done to optimize the beam optics. The simulations show that rms emittance growth of a two-charge-state beam can be maintained within ~10%.

A test model of the 2q-LEBT beamline will be constructed and tested. In preparation for a detailed engineering study sufficient to develop bid packages for major components of the system, a site selection study and schematic detailed component layout of the test model 2q-LEBT was undertaken. A possible site is in the experimental areas of the Dynamitron facility of the Physics Division. This site became more appealing after we obtained a high charge-state ECR ion source and all associated equipment that was excessed by a terminating program.

The design of a more detailed engineered system including all major components such as beam diagnostic devices, vacuum system, magnetic and electrostatic elements and power supplies was also undertaken from the source to the multi-harmonic buncher. A schematic of the detailed system is shown in Figure 1.

We propose to complete detailed mechanical design of the 2q-LEBT, start the installation and test of the ECR source on the HV deck, procure the elements of the beamline, and start the fabrication of the full-power one-segment engineering test model of the 57.5 MHz RFQ.

Specific Accomplishments:

A.A. Kolomiets, V.N. Aseev, P.N. Ostroumov, and R.C. Pardo, "Front End Design of the RIA Driver Linac," PAC2003 Particle Accelerator Conference, Portland, Oregon, Abstract book, p. 186 (May 12-16, 2003)

N.E. Vinogradov, P.N. Ostroumov, E. Rotela, S. Sharamentov, S. Sharma, G.P. Zinkann, J.W. Rathke, and T.J. Schultheiss, “Development of Room Temperature Accelerating Structures for the RIA,” PAC2003 Particle Accelerator Conference, Portland, Oregon, Abstract book, p. 180 (May 12-16, 2003).

P.N. Ostroumov, V.N. Aseev, R.C. Pardo, A.A. Kolomiets, “Front End of the RIA Driver Linac,” RIA R&D Workshop, Bethesda, Maryland (August 26-28, 2003).