LANSCE H^+ RFQ STATUS*

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Abstract

The LANSCE linear accelerator at Los Alamos National Laboratory provides H^- and H^+ beams to several user facilities that support Isotope Production, NNSA Stockpile Stewardship, and Basic Energy Science programs. These beams are initially accelerated to 750 keV using Cockcroft-Walton (CW) based injectors that have been in operation for over 37 years. To reduce long-term operational risks and to realize future beam performance goals for LANSCE we are completing fabrication of a 4-rod Radio-Frequency Quadrupole (RFQ) and design of an associated beam transport line that together will eventually become the modern injector replacement for the existing obsolete H^+ injector system. A similar H^- system is also planned for future implementation. An update on the status and progress of the project will be presented.

INTRODUCTION

The present dual-beam CW-based injector scheme for the LANSCE linac is shown in Fig. 1. The two beam species are merged into a common beam transport line and bunched before injection into the drift-tube linac (DTL). The proton beam (H^+) is presently accelerated to 100 MeV for isotope production. The H^--ion beam is accelerated to 800 MeV and used to produce neutrons for a wide variety of applications. Assessment of failure modes of our CW injectors revealed the potential for significant disruption of beam operations at LANSCE [1], primarily due to catastrophic failure of major components and unavailability of spare parts.

Our strategy to reduce operational risks associated with the current CW-based injector systems involves the eventual replacement of these systems with modern radio-frequency quadrupole (RFQ) based injectors. This approach is expected to improve reliability due to reduced overall complexity of the systems and by modernization. RFQ accelerators are employed worldwide and have demonstrated stable and reliable operation.

To meet both present and future, anticipated beam-delivery requirements, implementation of several RFQ-based injectors will be required at LANSCE [2]. Due to funding constraints and to minimize facility and operational impacts, this will be done in a phased manner with development of the H^+ RFQ having highest priority due to its impact on our near-term high-power performance goals [3, 4].

The RFQ is required to operate at a high duty factor of up to 15% and must meet strict beam performance requirements. Complementary simulations using the TRACE 2-D/3-D, PARMTEQM and PARMILA codes [5], Beampath [6], the CST Studio suite of codes [7] including Particle Studio, and the ANSYS [8] code were used to validate the design results prior to fabrication.

To ensure mechanical and operational robustness of the RFQ, several technical evaluations were completed prior to acceptance of the design [9]. These included: addressing potential structure cooling issues, evaluation of tuning range, impact of stem spacing on frequency and field flatness, impact of vane cross-section and stem geometry on dipole fields, and investigation of end-region field effects on emittance growth and final output energy.

The final physics design of the 4-rod RFQ was completed and verified through a joint effort between the Institute of Applied Physics (IAP) at Goethe University, Frankfurt, Germany, and Los Alamos in 2011[10]. A final mechanical design review was held in April 2013. Fabrication of the RFQ began in April 2014 in Germany by our project partner Kress, GmbH and was completed in December 2014.

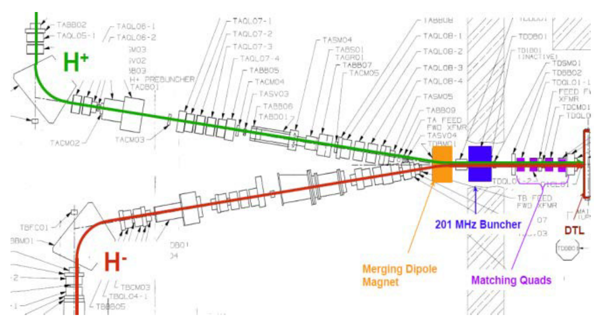

Figure 1: Present H^+/H^- CW injector layout.

The H^+ RFQ and planned beam-transport layout will replace the existing H^+ CW injector and beam line, requiring no changes beyond the merging dipole upstream of the common H^+/H^- beam transport section (See Fig.1). This enables early implementation of the new H^+ system, independent of the longer-term plans to implement multiple RFQ injectors. It is still our current plan to operate and commission the RFQ/beam transport system on a separate test stand prior to integration at the front end of the LANSCE linac. Figure 2 shows a preliminary layout of the new RFQ/ beam line configuration.

The RFQ has been delivered to Los Alamos. High-power RF testing is planned next. The ion source and high-voltage platform are being assembled in preparation for full assembly of an RFQ Test Stand that will include the ion source, low-energy beam transport (LEBT) to

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match the H^+ beam into the RFQ, the RFQ, and a medium-energy beam transport (MEBT) section for final matching in to the LANSCE DTL. Details are discussed in the following sections below.

RFQ FABRICATION & TESTING

Mechanical design and fabrication of the RFQ have been the joint responsibility of the IAP and Kress. The RFQ is a 4-rod design using several innovations including improved cooling, a rectangular vacuum vessel that can be easily opened for access to the tuning plates, improved end-cell geometry, and variable cell spacing to improve overall field flatness of the RFQ [11].

Tuning and low-power testing were done in Germany with Los Alamos participation in December 2014. Figure 3 shows the RFQ just prior to tuning at IAP. Figure 4 shows a close-up, interior view of the RFQ. Tuning of the RFQ to set the resonant frequency and field flatness is done iteratively and primarily using empirical methods, however, recent progress is being made to improve analytical and computational models to expedite this process and to improve accuracy [12].

High-power testing will be done at Los Alamos and is expected to use the High Power Test Facility at LANSCE [13]. The RFQ will be tested at full peak power and the full 15% duty factor (120 Hz, 1250 μs RF pulse length) using the 201.25-MHz Thales TH781 Intermediate Power Amplifier and associated low-level RF controls capability of the test facility. The estimated full peak power required for the test is 90-100 kW.

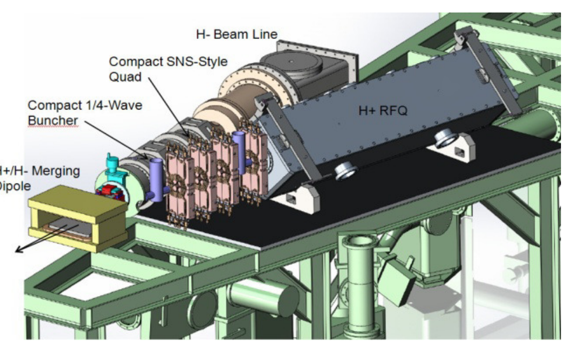

Figure 2: Shown is a preliminary engineering layout of the new H^+ RFQ injector, compact quads, and compact bunchers on the existing LANSCE beam transport line.

ION SOURCE/ INJECTOR

The extraction geometry of our present H^+ duoplasmatron ion source has been redesigned to produce a 35-mA beam with a transverse emittance of < 0.02 π-cm-mrad, normalized [14]. Modifications to an existing source are planned soon, followed by testing to verify the new design. Figure 5 shows a cutaway view of the source and new extraction-electrode geometry.

A 2-solenoid magnetic LEBT has been designed to match the beam from the ion source into the RFQ (see Fig. 6). This LEBT has been optimized to transport beams over a wide range of space-charge neutralization and transverse emittance, while allowing sufficient space for diagnostics and a beam deflector [14]. The design layout minimizes the beam size in the LEBT and potential emittance growth due to solenoid aberrations. The major components for the LEBT (solenoids, power supplies, and vacuum pumps) have been procured and are ready for installation.

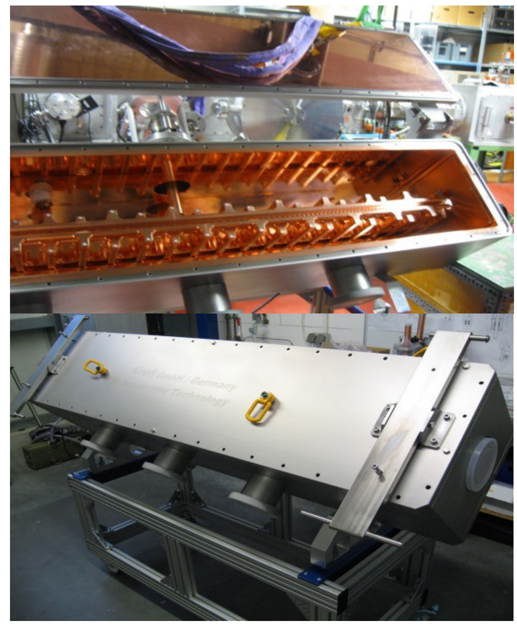

Figure 3: Shown is the 4-rod RFQ at IAP during tuning with the vacuum vessel open (top) exposing the vanes and closed (bottom).

Figure 4: Interior view of the RFQ. The tuning plunger can be seen in the upper-right quadrant of the picture.

MEDIUM-ENERGY BEAM TRANSPORT

A new Medium-Energy Transport (MEBT) line to match the RFQ output beam into the DTL was designed to replace the existing H^+ beam transport [15]. The MEBT must be as compact as possible to preserve the beam emittances. To accomplish this, the layout includes use of multiple compact 201.25-MHz quarter-wave buncher cavities [16] to minimize the beam phase spread and compact SNS-style MEBT quadrupoles for transverse beam focusing. Simulation studies were completed using the TRACE-3D [5] and PARMILA [5] codes to validate the multi-particle beam dynamics and linac capture (estimated to be 81% at 35-mA peak current). There is no new progress to report on the MEBT design or assembly.

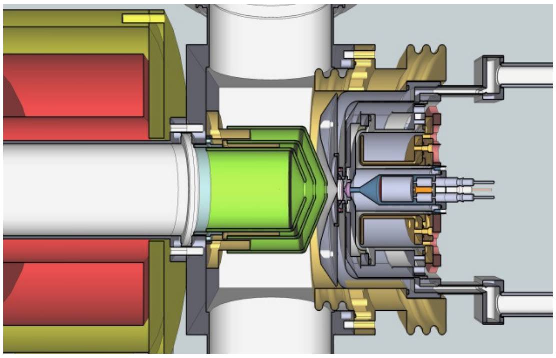

Figure 5: The Duoplasmatron source is on the right. The extraction electrodes are in the center and the 1st LEBT solenoid is on the left. Pumps are above and below the electrodes.

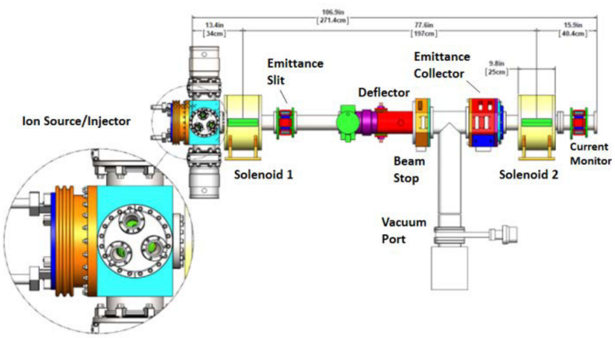

Figure 6: Magnetic LEBT layout.

RFQ TEST STAND

Our original plan was to have all necessary preparations for the test stand completed at Los Alamos by the RFQ delivery date so that high-power testing and commissioning with beam could be completed, followed by demonstration over the course of a year of stable operations prior to implementation on the LANSCE linac. However, schedule and budget constraints continue to impact implementation of the H^+ RFQ-based CW injector replacement.

In order to maintain project momentum, an intermediate-stage 35-keV ion-source test stand will be assembled, including the LEBT and sufficient diagnostics to confirm the performance and reliability of the source, the ability of the LEBT to match the beam into the RFQ and to characterize the beam into the RFQ.

Ongoing efforts to layout the full RFQ Test Stand that will include the ion source, 35-keV high-voltage system, LEBT, RFQ, RF system, MEBT, diagnostics, and controls continue. These preparations now focus on designing and building support structures and beam transport-line components; procuring RF systems and vacuum systems; as well as developing the appropriate diagnostics and controls required.

Particular emphasis of the RFQ Test Stand continues to be long-term reliability and availability of the RFQ and associated systems. Good measurements of the beam properties, including matching to the DTL, are therefore required during the testing phase of the RFQ [17]. All major components of the test stand are being designed to be compatible with implementation as a full replacement system on the LANSCE linac including, RF systems, controls, diagnostics, and all mechanical systems such as vacuum and cooling manifolds, etc.

SUMMARY

LANSCE currently supports several important user programs. Significant future programs are also planned. Both the present and future require that the LANSCE accelerator operate with high reliability and availability. Replacement of the CW-based injectors that have been in operation for over 37 years with new, modern RFQ-based injectors will contribute to improved reliability and availability by reducing long-term operational risks.

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