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DESIGN OF THE H- BEAMLINE FOR THE LANL RFQ TEST STAND*

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Abstract

The Los Alamos Neutron Science Center (LANSCE) accelerator produces high intensity H^+ and H^- beams for multiple experiments in fundamental and national security science. The proposed LANSCE Modernization Project (LAMP) is evaluating necessary upgrades to enable continuous LANSCE operations in years to come. LAMP seeks to upgrade the H^+ and H^- 750-kV Cockcroft-Walton (CW) generators with a dual-beam, 3-MeV Radiofrequency Quadrupole (RFQ). For technology maturation and expertise associated with this concept, an RFQ test stand with LAMP-like layout is being set-up to demonstrate dual-beam operation in an RFQ with all beam patterns required by the facility. The RFQ test stand will have 35-keV H^+ and H^- beamlines that simultaneously inject into a 750-keV RFQ. Assembly and initial characterization of the H^+ beam is under way. The LANSCE H^- beam has stringent timing requirements and the test stand will also demonstrate systems like a beam chopper and a low frequency buncher to produce required beam patterns. We describe the design of the H^- beamline based on accelerator codes Warp and Impact.

INTRODUCTION

The LANSCE accelerator facility at the Los Alamos National Laboratory (LANL) represents a unique capability by delivering high-intensity beams for multiple nuclear and neutron experiments: H^+ beam is delivered to the Isotope Production Facility (IPF), H^- beams with different timing structures are delivered to the Lujan Center, the Weapons Neutron Research (WNR), proton-Radiography (p-RAD) and Ultracold Neutron (UCN).

To keep this facility producing intense beams in years to come, a possible upgrade, encompassed in the LAMP, is being investigated [1]. Among the identified critical upgrades required are:

- Double the H^+ and H^- sources output current to enable up to 35 mA beam current generation.
- Replace the two 750-keV Cockroft Walton generators with a new dual-beam Radiofrequency Quadrupole.
- Install a new 100-MeV Drift Tube Linac (DTL).

These upgrades require a complete re-design of the existing accelerator front-end (sources to end of the DTL). An RFQ Test Stand is being developed to help mitigate the identified LAMP technology risks. The RFQ Test Stand incorporates two 35-keV H^+ [2] and H^- beamlines that inject both beams into a 750-keV RFQ [3]. Figure 1 shows the planned layout of the RFQ Test Stand beamlines and RFQ. The H^+ source-to-RFQ beamline is currently being characterized [4] and the RFQ is being conditioned [5] at high radiofrequency (rf) power. This paper will describe the status of the H^- beamline design.

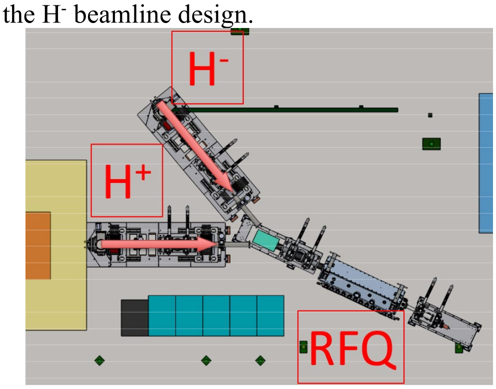

Figure 1: Floorplan of the RFQ Test Stand at LANL. 35-keV H^+ and H^- beamlines merge at 25° into the RFQ.

The H^- beamline requirements are driven by the beam-time structures to be demonstrated together with the RFQ. These are the equivalent to LANSCE beam timing as delivered to the Lujan and the WNR facilities. The Lujan beam is injected and accumulated in the Proton Storage Ring (PSR), it is formed from trains of bunches separated by 5 ns for a duration of 270 ns, and a gap of no beam for 90 ns. This pattern repeats itself for the duration of a full 625-µs macro-pulse, The PSR effectively compresses a full macro-pulse into a single, high-intensity beam pulse delivered to the Lujan Center target. The WNR beam is formed from a sequence of single high-peak-current bunches separated at 1.8 µs over a 625 µs macro-pulse. This inter-bunch separation enables time-of-flight neutron studies, and care is taken to minimize beam dark current present in these gaps between bunches.

The next section will describe the main elements included in the beamline, followed by preliminary simulations.

H- BEAMLINE

The RFQ test stand beamlines transport the beam from the ion sources to the RFQ, while providing space for diagnostics and time-pattern generator devices, including chopper and low frequency buncher. The transverse focusing is done with solenoid magnets, assumed to be the same design as in the H^+ magnets. Quadrupoles are required to match the beam into the RFQ after the 25° bending magnet

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used to merge the H^+ and H^- beams. At 35 keV, a significant challenge to be addressed is managing the space charge forces present, this is especially the case for single, high-current bunches such as those in the WNR-like beam, where no space charge compensation can be expected.

H^- Ion Source

The H^- source is based on the established SNS design [6]. It is scaled for 35 keV beam extraction and it is expected to output up to 35 mA beam current; roughly double what the current LANSCE sources provide. The model of the source includes a dipole field required to deflect the co-produced electron beam into the electron dump electrode. Electron current is in the order of ten times the ion current [6], and at 35-keV, it generates X-rays. Figure 2 shows a Warp simulation of the H^- source electrodes with both H^- (red) and electrons (green) being extracted; the electrons are dumped on the e-dump electrode.

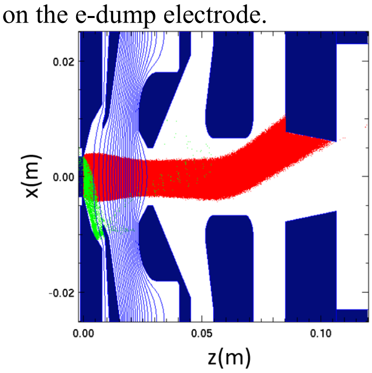

Figure 2: Warp simulation showing 35-keV H^- ion (red) and electron (green) beam extraction. Electrodes are solid blue. From left to right: Pierce, e-dump, extractor, chopper, and chopper dump.

Beam Chopper

A fast beam chopper is required to generate the timing patterns of the Lujan and WNR beams. The chopper needs to be short to provide the required rise and fall times of under 10 ns; a single electrode is suitable rather than a travelling wave-type structure. Short rise / fall times are required to help minimize the WNR dark current, maximizing the signal-to-noise ratio for time-of-flight experiments. A beam dump for the chopped beam is also part of the design and should absorb the beam power safely. Figure 2 also illustrates the beam chopper deflecting the beam into the chopper dump.

Low Frequency Buncher

A low frequency buncher is routinely used in LANSCE at 750 keV for the WNR beam. The structure consists of two gaps separated by $\beta\lambda/2$, with β the beam velocity and λ the rf wavelength. The center pipe is actively driven by an rf circuit. The low frequency buncher introduces energy modulation in the beam, resulting in longitudinal focusing downstream.

For the RFQTS, an existing 10.06 MHz low-frequency buncher used at the former LANSCE polarized beamline is being repurposed for use at 35-keV. Figure 3 shows the longitudinal electric field along the centerline of the 35-keV low-frequency buncher, calculated with TRAK [7].

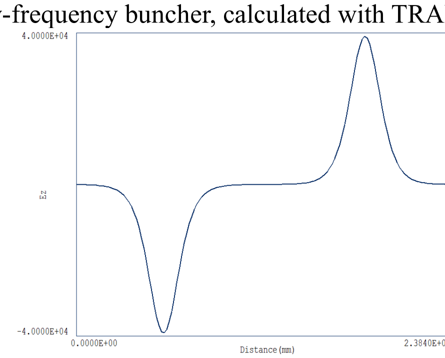

Figure 3: Longitudinal electric field along the 35-keV low-frequency buncher.

Bending magnet

The bending magnet is designed to merge the H^+ and H^- beams, prior to injection into the RFQ. The beam of each species is bent by 25°. This design is based on the LANSCE TDBM01 magnet, which serves a similar function. The aperture measures 5.12 in, or 130 mm, which is sufficient to house beam pipes with an outer diameter of 4 in. Each pole uses 20 turns of water-cooled wire that operates with a current of 83 A, producing a uniform bending field of 320 G. Figure 4 shows a CST simulation of the merge.

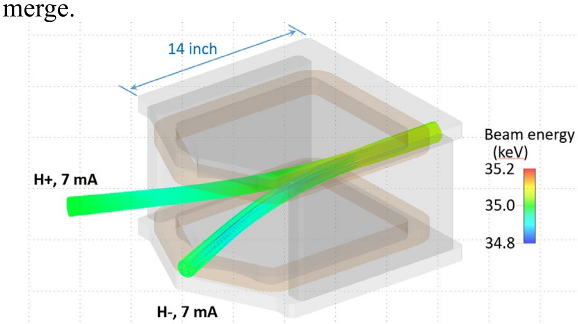

Figure 4: CST Simulation of the 25° bending magnet showing transport of both beams.

Radiofrequency Quadrupole

The RFQ is a 201.25 MHz rf structure, capable of accelerating the beam to 750 keV.

SIMULATIONS

We have identified the critical components needed for the H^- beamline and produced independent models of each device. The beam physics is being modeled in Warp [8] and Impact [9] from the H^- source to the entrance of the RFQ. Beamline devices were modelled independently as follows: the source was modeled in Warp and TRAK, the chopper was modeled in CST and Warp, the low frequency buncher was designed in Trak and implemented into the Warp model. The bending magnet was designed and modeled in CST and is being implemented in Impact. Figure 5 shows the transverse rms beam size starting from the source and through the entrance of the RFQ. The solenoids are included as field maps, and the bend is included via the bend element in Impact. The quadrupoles have not been

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designed yet, but here we assume fields similar to LANSCE quadrupoles in the 750-keV line.

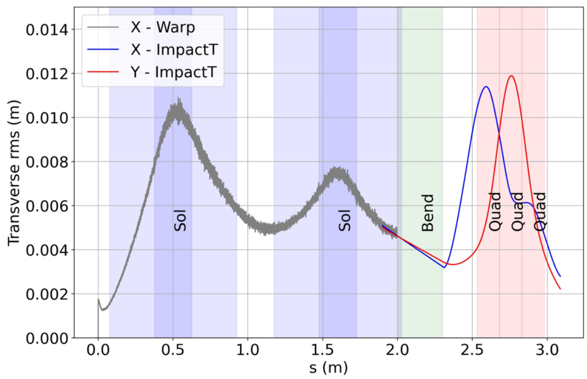

Figure 5: Transverse rms beam size calculated in Warp and Impact. Magnets are shown in color bands.

The low frequency buncher has been included in the Warp simulation. Figure 6 shows the low frequency buncher implemented in Warp, and the resulting energy modulation produced downstream.

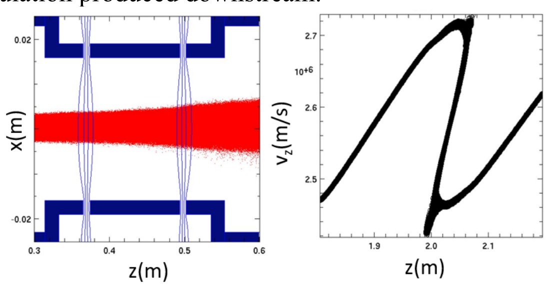

Figure 6: Warp simulation of the low frequency buncher: beam going through the device (left) and produced energy modulation (right).

Figure 7 shows a sequence of snapshots from a preliminary simulation of a 30-ns beam pulse going through the beamline with the low frequency buncher, as required for WNR-like beam.

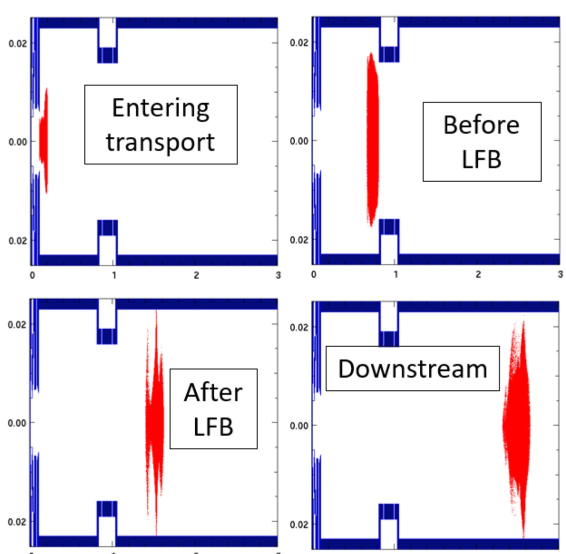

Figure 7: Snapshot sequence of a 30-ns beam pulse travelling through the beamline.

CONCLUSION

This paper summarizes the status on the design of H- beamline for the LANL RFQ test stand. Critical elements like the source, chopper, low frequency buncher, and bending magnet have been simulated independently or are being optimized. The corresponding field maps or device geometries are now being integrated into a beam physics model of the whole beamline for analysis. We were able to transport a WNR-like beam through the beamline with a compromise on the lower beam current. This is acceptable for a demonstrator experiment but will need to be addressed for LAMP-like production parameters. We are also investigating the increased emittance growth observed in going through the bending magnet and will optimize the beamline design.

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