

A BEAM CHOPPING SCHEME CONCEPT FOR THE NEW LAMP MEBT *

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Abstract

As part of the LANSCE Accelerator Modernization Project (LAMP), the two existing 750-keV Cockcroft Waltons are planned to be replaced by a single radio-frequency quadrupole (RFQ). The new LAMP front-end needs to deliver beams with similar timing patterns to what is currently delivered to the multiple target stations. To accomplish this, the 3-MeV Medium Energy Beam Transport (MEBT) is designed with two choppers that help produce the beam timing patterns required by the experimental user facilities. The new RFQ will introduce satellite bunches around the single high-intensity bunch that is required by the users. These satellite bunches need to be removed in the MEBT. This contribution describes the design of LAMP MEBT with a beam chopping scheme and presents simulation results.

INTRODUCTION

The Los Alamos Neutron Science Center (LANSCE) accelerator facility at Los Alamos National Laboratory (LANL) delivers high-intensity beams for multiple nuclear and neutron experiments: H^+ beam is delivered to the Isotope Production Facility (IPF), two H^- beams with different timing structures are delivered to the Lujan Center and to the Weapons Neutron Research (WNR) target, single-shot trains of H^- beam are also delivered for proton radiography (pRAD) and Ultracold Neutron (UCN) experiments.

The LANSCE Accelerator Modernization Project (LAMP) is planning to upgrade the front-end of LANSCE to ensure that beams can be delivered reliably to experimental facilities in years to come [1]. A major upgrade being considered is the replacement of two 750-keV Cockcroft Walton (CW) generators for a single Radiofrequency Quadrupole (RFQ) capable of accelerating dual-species beams to 3 MeV. A MEBT will then transport and help tailor the beam before injection into a new 100 MeV Drift Tube Linac (DTL). We developed a physics model of the LAMP front-end that meets the project requirements [2]. This paper describes the current state of the MEBT design and the adopted beam chopping scheme required to remove satellite bunches in the WNR beam.

The beam to WNR is unique and challenging to produce under intense low-energy space charge effects. It consists of a high intensity rf bunch separated every 1.8 μ s over the length of a 625 μ s macro-pulse. Two major requirements are called out by the experiment; a high-intensity bunch with at least 115 pC at target, and an empty gap with beam intensity less than 10^{-5} that of the main bunch, this is

referred to as dark current at target. The MEBT chopper scheme in LAMP is designed to remove the satellite bunches produced during the high-intensity bunch formation.

Shaping of WNR Pulse in LAMP

In the LAMP conceptual design, the WNR beam is produced through beam manipulations in the Low Energy Beam Transport (LEBT) and the MEBT. High current H-beam, 35 mA, is produced at the source and propagates to the LEBT chopper. From the source to the chopper, we assume the beam to have space charge compensation of 90%. The chopper produces an initial 25-ns short pulse, and no further space charge compensation is assumed from this point. The initial pulse at the chopper is shown in Fig. 1. The chopper finite rise and fall times produce tails at the front and the back of the pulse. Here we assumed a linear ramp and a chopped pulse with 5 ns rise/fall time and 15 ns flat top.

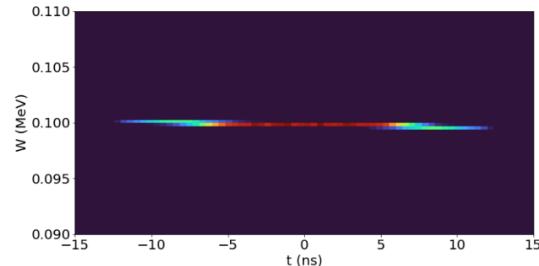


Figure 1: Beam pulse produced by LEBT chopper with 5-ns rise, 15-ns flat and 5-ns fall times.

The chopped pulse is then transported into a low frequency buncher (LFB). The LFB consists of two gaps separated by $\beta\lambda/2$ and operates at a sub-harmonic of the DTL frequency, 16.77 MHz. The electric fields across the gaps introduce velocity modulation of the beam, resulting in compression of the chopped pulse into the central 4.96-ns of the pulse, the 201.25 MHz rf period. Figure 2 shows the resulting compressed beam at the entrance of the RFQ.

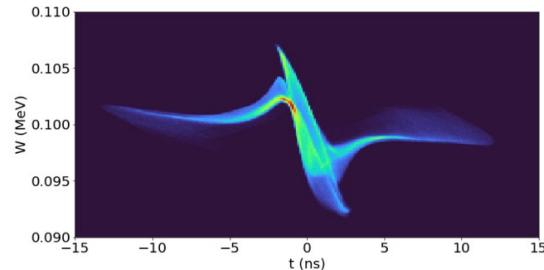


Figure 2: Beam pulse at the RFQ entrance with high charge accumulation at the center resulting from the LFB effect.

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RFQs are commonly operated with continuous input beam rather than short pulses. Our simulation studies suggest a relation between a shorter RFQ shaper and better transmission of a short pulse [3] through an RFQ. For the LAMP conceptual design, we adopted an RFQ with a shorter shaper section, characterized by the shaper energy $W_s=0.11$ MeV [4]. The RFQ shaper helps with smooth tailoring of a continuous beam into a stream of bunches. A shorter shaper section ensures the short pulse gets captured into the RFQ longitudinal acceptance faster, reducing the longitudinal expansion of the pulse. Figure 3 shows a histogram of the longitudinal distribution of particles across the pulse at the entrance and exit of the RFQ, where each bin corresponds to a 201.25 MHz rf period. The longitudinal composition of the short pulse at the RFQ entrance is reasonably well-preserved into the train of bunches leaving the RFQ.

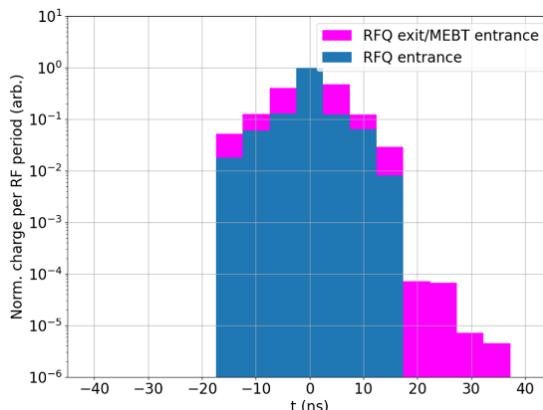


Figure 3: Histogram of longitudinal distribution of particles at RFQ entrance (blue) and exit (magenta). Each bin corresponds to a 201.25 MHz period.

The beam now moves into the MEBT, where a fast chopper system is implemented to remove the leading and trailing satellites.

MEBT Chopper Scheme

The MEBT transports the beams from the RFQ to the DTL with a set of quadrupole magnets and re-buncher cavities [5], providing enough space for the beam choppers [6]. A layout of the MEBT is shown on Fig. 4. The present chopping scheme is designed to meet the user requirement of limiting beam dark current intensity to less than 10^{-5} relative to that of the main bunch. The chopper should provide sufficient deflection to send the satellites off-axis into a chopper target located downstream.

To first order, the deflection that the chopper provides to the satellites is limited by the voltage present between the chopper plates. To keep the rise and fall times short, the voltage across the chopper plates is assumed to be limited to ± 1.9 kV. This corresponds to a 1° deflection angle. Assumed chopper parameters are listed in Table 1. To ensure that the satellite intensity requirement is met, we designed a chopper scheme with two choppers, which together with beam optics, produces sufficient deflection at the chopper target to capture the satellites.

Table 1: MEET Chopper Parameters

Chopper parameter	Value
Chopper length	55 cm
Inter-plate gap	1.8 cm
Inter-plate voltage	± 1.9 kV
Deflection angle	1°
Rise/fall time	3 ns

It is important to keep in mind that in the current front-end concept, a single MEET should transport multiple beams, and so the chopper scheme designed to meet requirements on the WNR beam, will also have effects on IPF and Lujan beams. In particular, the IPF and WNR beams are transported simultaneously during the same machine cycle.

SIMULATIONS

The MEET was designed using the envelope code Trace3D [7] and particle simulations are done in PARMILA [8]. The particles are realistic originated by our model of the ion source and transported to the MEET entrance using our established multi-code simulation framework [2]. Because three beams are being transported through the same MEET, a compromised tune that favors the highest power beam is selected that minimizes beam losses in the linac and the high energy transport lines.

The chopper is modeled in PARMILA using a simple model of parallel plates. Apertures of the beam pipe, bunching cavities and the choppers are included. The chopper target is implemented as a bottom jaw located after the second chopper, but only the upstream face of the target is included, making the chopper scheme independent of the physical target volume.

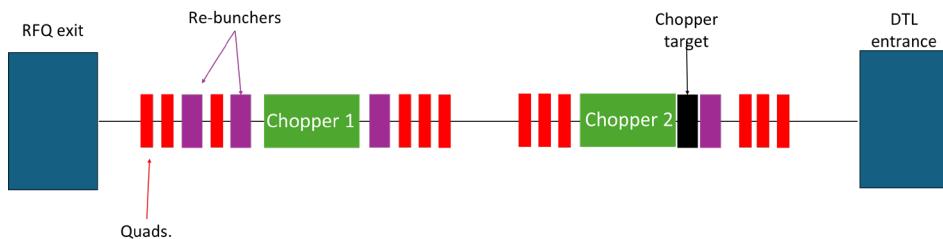


Figure 4: General layout of LAMP MEBT. Quadrupoles (red) and bunching cavities (purple) transport the beam from the RFQ and match it to the DTL. Two-choppers (green) are used to provide centroid deflection of the WNR satellites to guide them to the chopper target for capture.

Using the beam distributions of satellite bunches at the end of the RFQ, we use our MEBT model to propagate the main bunch and satellites through the MEBT. We generate particle distributions with 10^6 macroparticles to be able to resolve the required dark current limit. If the beam gets fully stopped by the chopper target, we claim our threshold can be met. Figure 5 shows the effect of the chopper scheme on individual WNR satellite bunches. All satellites above the required dark current intensity threshold need to be chopped.

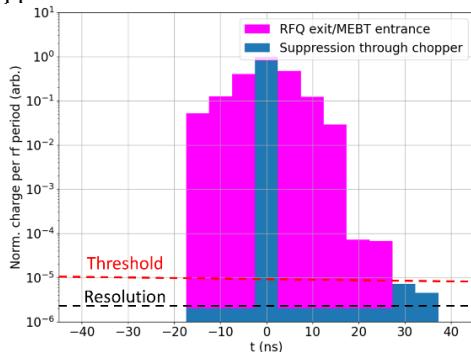


Figure 5: Intensity reduction of WNR bunch train through the MEBT choppers.

Figure 6 and Fig. 7 show the resulting main bunch and satellite transmission through the MEBT when scanning the relative position of the chopper. The aperture position is the edge of the target to the center of the pipe axis. It can be seen the requirement on chopped satellite intensity is achieved at the cost of losses in the main WNR bunch. The dashed line indicates the selected location of the chopper target. Nevertheless, the main bunch carries enough excess charge at the MEBT location [2], and the suppression of the satellites is prioritized.

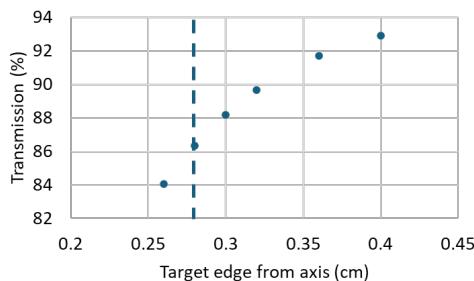


Figure 6: Transmission of WNR bunch vs. target aperture position. The target edge is separated from the axis by 0.28 cm.

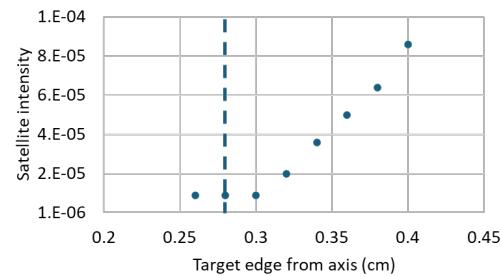


Figure 7: Suppression of a WNR satellite vs. target aperture position. The target edge is separated from the axis by 0.28 cm.

CONCLUSIONS

We present the design of a beam chopping scheme for the LAMP MEBT that removes the parasitic satellite bunches produced during the formation of high-intensity bunches. The satellites need to be removed to ensure the experiment requirement on the beam dark current intensity to be 10^{-5} the intensity of the main bunch. A beam chopping scheme with two fast choppers is presented that successfully removes individual realistic satellites in preliminary beam simulations. Two choppers are required because the fast rise and fall times (2 ns) constrain the available chopper voltage and therefore the beam deflection.

Our preliminary simulations suggest the proposed chopper scheme produces sufficient beam deflection on the satellites to be captured completely by the chopper target. We use a high number of macro-particles to resolve 10^{-5} threshold. The losses on the main bunch do not impact the project requirement at the target.

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