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LANSCE MODERNIZATION PROJECT AT LANL*

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Abstract

In the framework of LANSCE Accelerator Modernization Project (LAMP) preliminary research and evaluation of critical technology elements it was found that the proposed RFQ design had not been yet demonstrated experimentally worldwide. Such an RFQ should combine the ability of traditional light ion RFQs, and flexibility of acceleration pre-bunched beams, like RFQs for heavy ions.

Proposed RFQ should be able to accelerate beams with 35mA beam current and at the same time preserve prescribed macro-bunch time structure required by experiments. New algorithms for RFQ geometry generation have been proposed and optimization algorithms are being developed at LANL.

LAMP technology demonstration plans also include development of new set of electrodes for our RFQ test stand that will allow us to demonstrate the critical technology in laboratory experimental setup with low duty factor and low energy.

LAMP PROJECT AT LANL

The LANSCE Modernization Project (LAMP) is now at planning stage, and its CD-0 is expected this year. The LAMP goal is to replace the obsolete front end (FE) of the LANSCE linac with a modern reliable front end [1, 2]. The existing FE evolved over the 40+ years and now provides five different beam flavors (beam species – protons and H$^-$ ions, various beam currents, different beam pulse structures) for various end users. However, it is based on the obsolete Cockcroft-Walton (C-W) high-voltage injectors, and multiple components are in the near-failure state and cannot be readily replaced. The threshold requirements for the new injector are to provide reliably the presently available five beam flavors [1, 2]. The present conceptual design of the new front end is based on a single radio-frequency quadrupole linac (RFQ) that will accelerate all five beam flavors to 3 MeV [1, 2].

The RFQs are widely used, and their design and technology are well developed. However, for the beam currents comparable to the ones at LANSCE, they are usually designed and optimized for a single beam flavor with continuous injection into RFQ, e.g., [3, 4]. Alternatively, there are multi-species RFQs that can preserve complicated prebuncher beam structure, but only for very low beam currents typical for heavy ion beams, e.g., [5].

The proposed FE concept includes novel RFQ that combines the features of the two RFQ types mentioned above and can be considered critical technologies.

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Figure 1 shows the schematic view of the LANSCE facility, and the Fig. 2 – LAMP upgrade close-up, which also includes DTL upgrade (not shown in the Fig. 2).

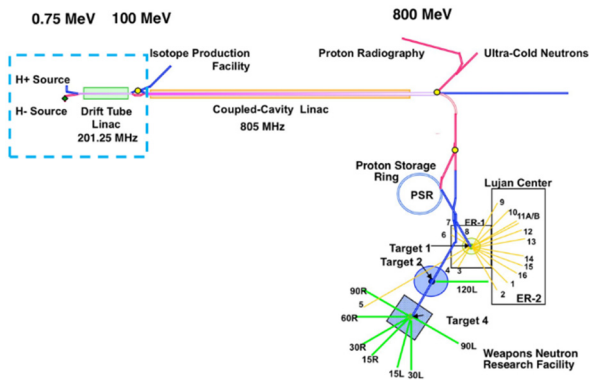

Figure 1: Schematic picture of the LANSCE facility.

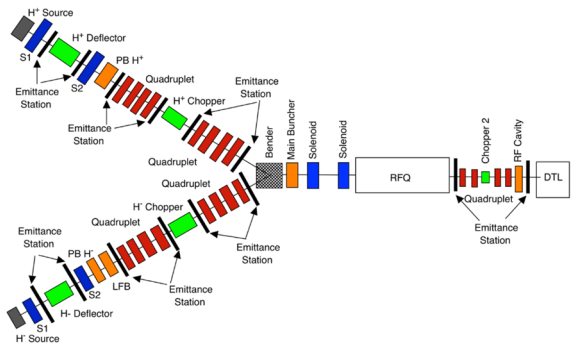

Figure 2: Schematic picture of the LAMP upgrade, including DTL.

RFQ BEAM DYNAMICS AND GEOMETRY GENERATION

The most prominent Critical Technology Element in LAMP project is the RFQ with the set of requirements unprecedented in any other RFQ accelerator design worldwide. New specific design procedure and algorithm were developed to meet the RFQ geometry requirements. In this contribution the proposed procedure and major parts of the developed algorithm are presented, and the preliminary longitudinal beam dynamics (BD) results are discussed.

The major difference of the proposed RFQ, compared to existing high current light ions RFQs [3, 4], is the requirement to start with the pre-bunched beam and preserve pre-existing time structure of the macro pulses or beam bunch trains in the RFQ and in the following DTL. At the same time, the beam loss and the beam halo formation requirements are usual for high beam current RFQs, and stricter compared to the heavy ion RFQs [5], that were designed to

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accelerate and shape the beam at lower RF frequency and lower velocities.

We started a very preliminary BD pre-design study in the proposed RFQ. The first step in this study and algorithm development was done neglecting space charge effects (with only analytic estimates of those effects) and for longitudinal BD only. The Radial Matching Section (RMS), as well as the Transfer Cell (TC) at the beginning and at the end of the accelerating-focusing channel of the RFQ are not considered in simulations and will be included in the modeling at the following steps. The space charge effects will also be included in the simulations when the transverse BD will be fully included. All the formulae used in this contribution are from [6], or immediately derived from them.

The requirement to accept in the RFQ pre-bunched beam dictates the significant change of the classical RFQ structure. So, the proposed RFQ does not have a Beam Shaper section, and the section of the Adiabatic (or Gentle) Buncher is significantly shortened. The small modulation of electrodes is present in the very first cell of the RFQ (since we omitted RMS and TC sections).

In the Figs. 3 and 4 the results of the analytical RFQ geometry generation are shown.

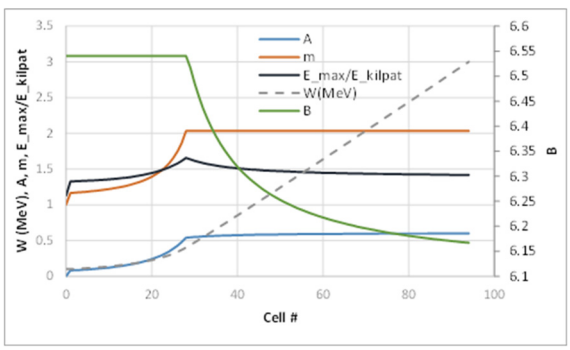

Figure 3: RFQ geometry generation results: all curves, except B-curve use left-side scale, and B-curve use right-side scale.

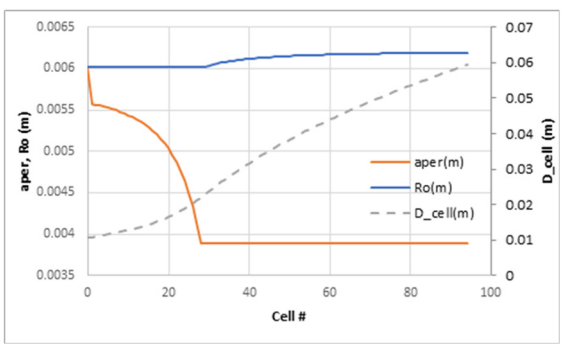

Figure 4: RFQ geometry generation results: all curves, except D_cell curve use left-side scale, and D_cell curve uses right-side scale.

Figure 5 shows the estimated longitudinal and transverse oscillation frequencies for the generated accelerating-focusing RFQ channel for the beam current of 50 mA.

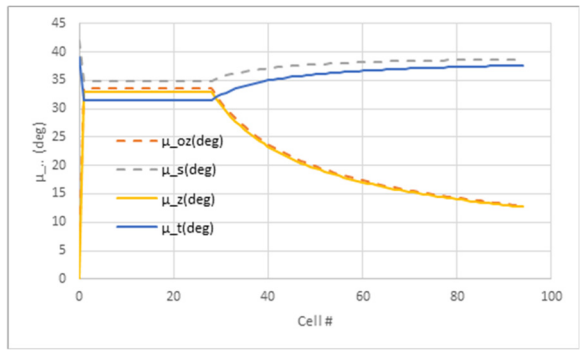

Figure 5: The longitudinal (μ_oz and μ_z) and transverse (μ_s and μ_t) phase advances estimates. Space charge depressed phase advances were estimated for 50 mA beam current.

In Figs. 6 and 7 the initial longitudinal only simulations results using code BEAMPATH [7] are presented.

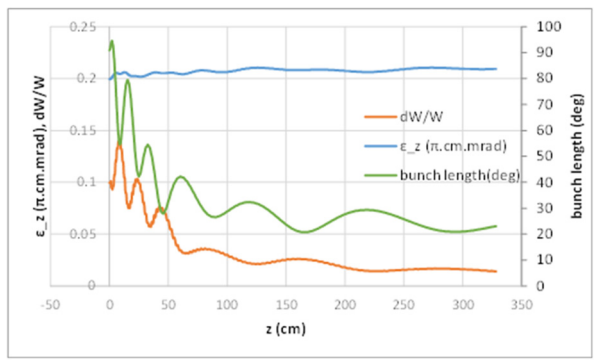

Figure 6: Longitudinal BD envelopes and evolution of the longitudinal emittance.

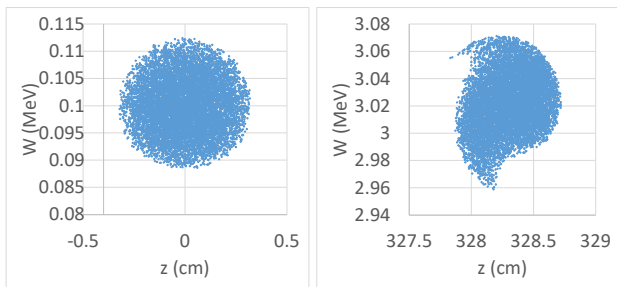

Figure 7: Longitudinal beam phase space portraits at the input (left) and output (right) of the RFQ.

LAMP DEMO RFQ TEST STAND

We have a unique opportunity to use the existing RFQ test stand at LANL to demonstrate some of these novel features relatively fast and with moderate funding.

Figure 8 shows the layout of the exiting RFQ Test Stand. The existing LANSCE RFQ was designed and built as an alternative proton injector for LANSCE linac: to accelerate protons from 35 keV to 750 keV and merge with the 750-keV H^- beams from the existing C-W injector.

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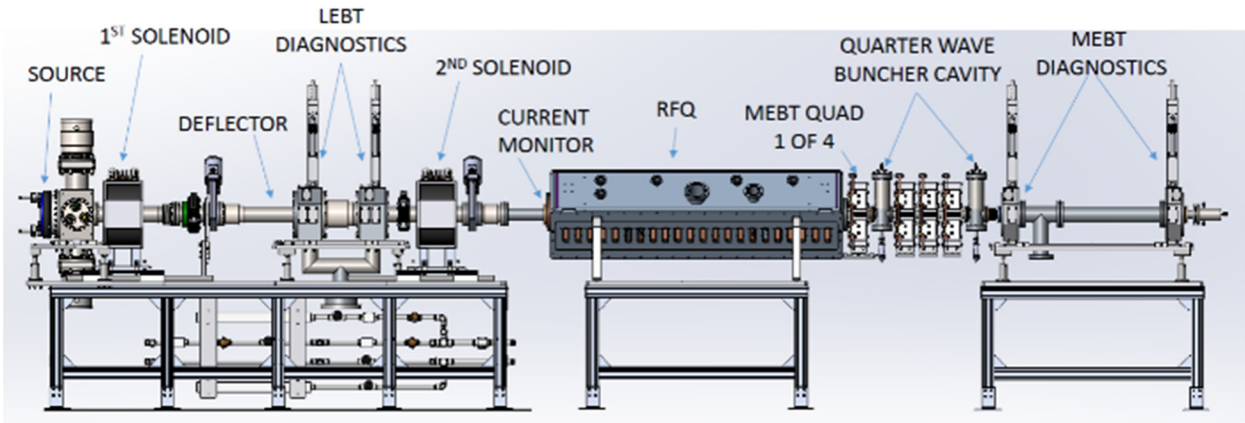

Figure 8: Existing 750 keV RFQ Test Stand at LANL.

For various reasons the RFQ test stand has not been completed though most of the parts are already installed and tested. While this RFQ is different from the one envisioned for LAMP, it can be readily used to test the above LAMP critical technologies evaluation and proof.

We have 2D and 3D computational models of this RFQ. We already showed in 3D simulations that both p and H^- can be successfully accelerated simultaneously in this test RFQ. The models can predict expected outcomes of the technology tests at the RFQ test stand, which will be compared with measurements. Eventually, we will develop similar models for the LAMP RFQ to optimize its design.

Systematic development of the RFQ Test Stand will allow us to enable further R&D studies of the new ion sources, low energy beam transport (LEBT) and beam formation with the properties requested by the experimental end-stations at LANSCE. The maturation of the existing RFQ Test Stand will provide the ability to contribute to multiple future projects required by the facility and making us able to achieve the LANSCE flexibility adequate to the Laboratory goals.

We have staged the LAMP technology demonstration as follows:

- Complete the fixes at the existing RFQ test stand and demonstrate the proton beam out of RFQ. For demonstration, the test stand can run at low duty factor and with lower beam current.
- Develop modifications of the existing LEBT to include chopper and low frequency buncher. Develop new focusing structure and diagnostics for modified LEBT.
- Develop an MEBT after the existing RFQ at 750-keV output beam. We can show chopping needed in the MEBT of the proposed scheme of the LAMP.
- Redesign the existing RFQ electrodes with a different vane profile that enables better capture of pre-bunched beam or short beam pulse. Important condition: the vane length should be the same as in the existing RFQ, so that only the vanes can be replaced. The output beam energy can differ from the present design value, 750 keV.

CONCLUSION AND FUTURE PLANS

The following is the list of further actions that we have in the context of LAMP project:

- Finish start-to-end simulations of the beam line from the ion source to LEBT, to RFQ, to MEBT, to DTL in the next several months.
- Progress with the LAMP Demo RFQ Test Stand 4-stage plan in the next year.
- Prepare and submit CD-0. Start work on the Conceptual Design Report in FY23.
- Start early procurement for LAMP project as soon as possible.

ACKNOWLEDGEMENT

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