RECENT DEVELOPMENTS IN DTL DESIGN FOR LAMP PROJECT AT LANL *

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Abstract

The LANSCE Accelerator Modernization Project (LAMP) at Los Alamos National Laboratory is under way. One of the significant parts of this project is replacement of the existing 50-years old Drift Tubes Linac (DTL). The LAMP DTL will accommodate the existing LANSCE DTL species, namely protons and H- ions, as well as frequency 201.25 MHz and output energy 100 MeV. The input energy of the DTL determined by the optimization of radio frequency quadrupole (RFQ) and medium energy beam transport (MEBT) is 2.1 MeV. This paper is focused on the most significant details of the modeling and simulation of the proposed DTL.

INTRODUCTION

The LANSCE accelerator modernization project (LAMP) is the first stage of the upgrade of the linear accelerator facility at Los Alamos National Laboratory (LANL). This project proposes replacement of the existing CW ion sources for protons and H- with new ion sources and Low Energy Beam Transport (LEBT) at 65 keV, a new RFQ accelerator, and Medium Energy Beam Transport (MEBT) at 2.1 MeV. A new DTL will be designed to accelerate beams up to 100 MeV.

DTL DESIGN PRINCIPLES

The main limitations of the DTL design are the existing RF power amplifier systems at frequency 201.25 MHz and maximum power ~2 MW each. Hence we are planning to have 6 DTL tanks with rf power requirements below 2 MW each.

The other hard limitation is the existing LANSCE tunnel. The total length of the tunnel and the available RF power dictate the range of the accelerating gradient, that can be used in the new DTL.

We are planning to use Permanent Magnet Quadrupoles (PMQs) embedded in the DTL drift tubes for transverse focusing, since their performance give us the desired results without the drawbacks of the electromagnets, as are used in the LANSCE DTL.

One of the important methodological principles of the DTL design is the tunability of the accelerating gradient along the DTL tanks. According to [1], the post couplers used for fine-tuning the accelerating field magnitude, dictate the tank diameter be approximately λ/4 at the fundamental frequency. Other parameters (e.g. drift tube outer diameter, gaps between drift tubes and post-couplers, etc) must be chosen accordingly. This requirement led us to the choice of having tanks 1 and 2 to have diameter of 0.997 m, and tanks 3, 4, 5, and 6 – 0.9375 m.

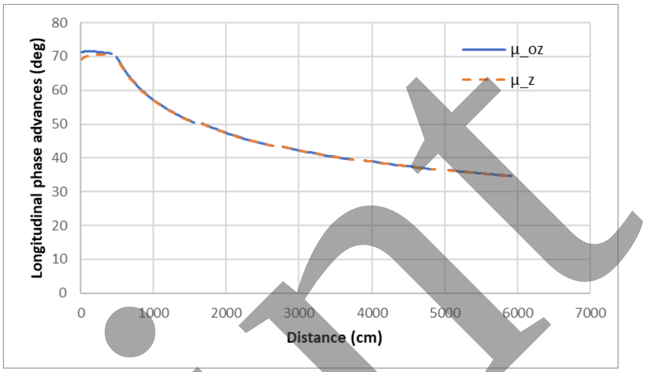

Figure 1: Synchrotron oscillations phase advance per focusing period for negligible beam current and for the design beam current of 35 mA.

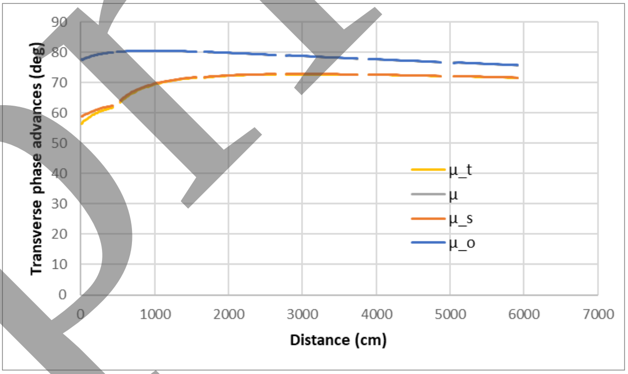

Figure 2: Betatron oscillations phase advance per focusing period for negligible beam current and for the design beam current of 35 mA.

We start the design process with choosing of the suitable synchrotron and betatron oscillation frequencies along the DTL by finding adequate transverse focusing period length and PMQs strength, that can be achieved in practice. The focusing lattice F0D0 was found to satisfy our requirements for the beam dynamics, where “0” represent empty drift tubes, and “F” and “D” – focusing and defocusing quadrupole in horizontal transverse plane respectively. The result of our choice is presented in Fig. 1 and 2. The nomenclature of the variables correspond to Refs. [2, 3].

The presented combination of the phase advances avoids the dangerous parametric resonance anywhere along the DTL, as well as stay below 90º, which is the limit of stable region for beam with high current [4]. Sufficient adiabatic continuity of the oscillation frequencies was preserved and should not cause significant emittance growth in the DTL.

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Figure 3 presents the average accelerating gradient and the corresponding effective accelerating gradient along the DTL, which was chosen based on the RF power and available tunnel length.

Figure 4 presents the plot of parametric resonances and the analytic estimate of the reference particle design working point along the DTL. The most dangerous 1^{st} and 2^{nd} parametric resonances are avoided, while the working point stays withing the stable region of oscillations in both longitudinal and transverse phase space projections.

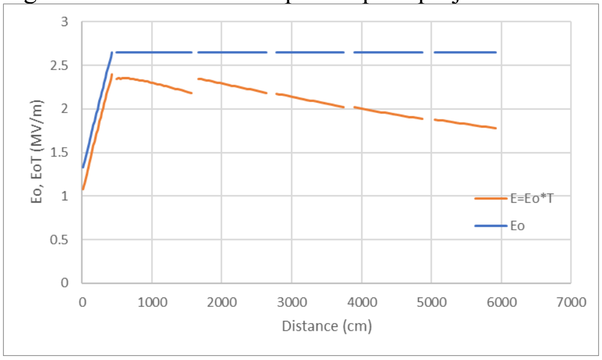

Figure 3: Average and effective accelerating gradients along the DTL.

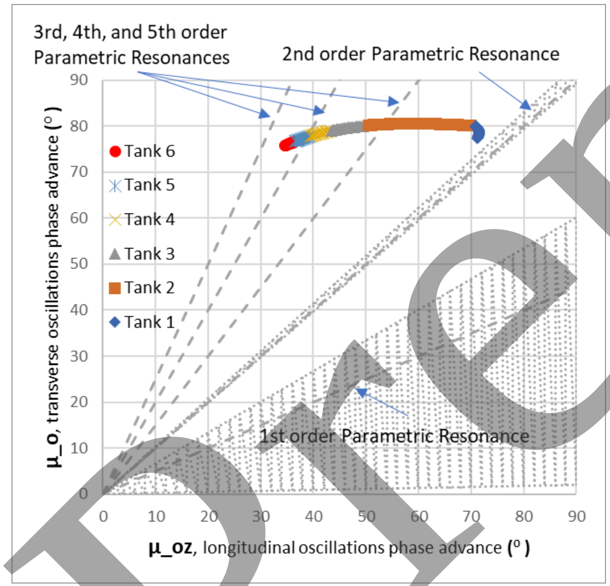

Figure 4: Plot of parametric resonances and the working point of the reference particle along the DTL.

PMQ Parameters of the Focusing Channel

We are planning to use PMQs in all inner drift tubes in the DTL tanks. The total number of required PMQs is 67. The end half-tubes are populated with the electromagnetic quadrupoles (EMQs), so the total number of EMQs is 12.

The main parameters of the proposed PMQs are as follows: the length of all PMQs in the DTL is 44 mm; The design magnetic field gradient is 35.4 T/m; the number of filaments is 16; the material proposed is SmCo with B_R=1 T; the outer radius of the PMQs is 30 mm; and the inner radius 15 mm. The bore radius of the drift tubes is 12.5 mm.

Inter-Tank Matching and Drift Spaces

We propose to use electromagnetic quadrupoles in the first and last tudes of the DTL tanks, that are attached to the end flanges of the tanks. The chosen focusing lattice is preserved over the inter-tank drift spaces, so the only difference of those special focusing periods is absence of the RF gap defocusing effects. This relatively small effect can be compensated by adjustment of the EMQs.

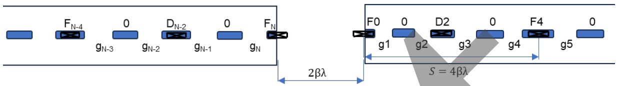

Figure 5: Schematic view of the inter-tank drift space.

Use of the F0D0 focusing lattice allows an intertank drift approximately equal to 2βλ, as shown schematically in Fig. 5, without breaking the periodicity of the focusing channel. Further optimization of the inter-tank drifts and the selection of diagnostics remains to be done.

RF POWER REQUIREMENTS

Our design is also constrained by the available number and maximum power of the existing Diacrode-based RF power stations.

Table 1 lists the major DTL tanks parameters after an initial optimization to obtain approximately equal distribution of the total RF amongst tanks 2-6. Tank 1 is substantially shorter and is anticipated to be driven by a tetrode-

Table 1: Major DTL Tank Parameters After Approximate Distribution of RF Power Per Tank

Tank #	Length [m]	After Tank Drift [m]	Cell #	W_out [MeV]
1	4.31	0.40	30	8.68
2	10.91	0.74	38	30.27
3	10.07	0.94	24	50.01
4	10.08	1.08	20	68.32
5	10.22	1.19	18	85.57
6	9.26	-	15	100.22

Table 2: RF Power Per DTL Tank: Ohmic Losses; Total RF Power With 16 mA Beam, and Total Average RF Power

Tank #	P_wall [MW]	P_tot [MW]	P_tot,avg [MW]
1	0.25	0.354	0.042
2	1.07	1.42	0.170
3	1.11	1.43	0.171
4	1.15	1.44	0.173
5	1.20	1.48	0.177
6	1.18	1.43	0.172
total	**5.97**	**7.55**	**0.906**

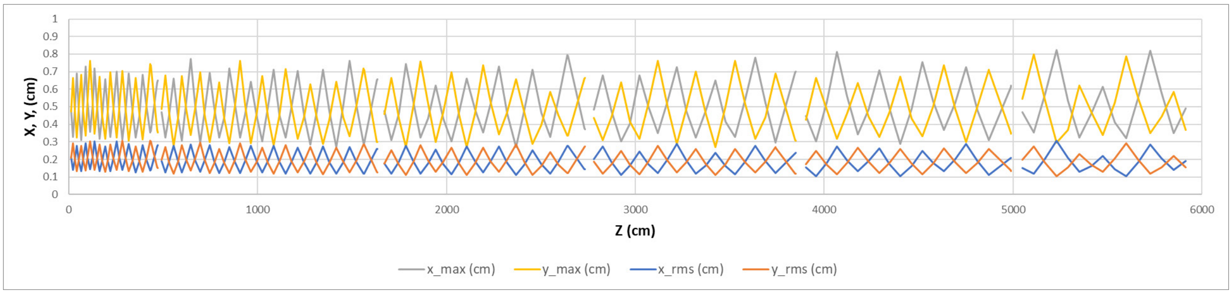

Figure 6: Transverse beam envelopes along the DTL.

based RF power system.

Total length of the DTL is ~59.2 m for the average accelerating gradient of 2.65 MV/m after initial ramping from 1.33 MV/m in the first DTL tank. This corresponds to the existing LANSCE DTL and the length of the existing tunnel.

Table 2 summarizes the RF power per tank in the simulated DTL. The ohmic power loss (P_{wall}) is given with 15% contingency of the calculated value from SUPERFISH [5]. Beam power (P_{beam}) is calculated for 16 mA macropulse beam current. Total RF power, needed for this DTL, considering 12% duty factor, is ~1 MW. The DTL can be shortened at the expense of the additional RF power in linear proportion.

Special conceptual provisions were included in the DTL design to guarantee RF frequency and accelerating gradient magnitude tunability. The major part of accelerating gradient ramp tuning in tank 1 is done using varying ratio of gap length to cell length for individual cells. This procedure is not needed for tanks 2-6. Additional mid-range tuning by groups of cells will be done with multiple slug tuners along the tank. And final small-range tuning will be done using post-couplers for each individual cell.

More details of the present stage of this work can be found in [2].

BEAM DYNAMICS SIMULATIONS

All of the beam dynamics simulations were done using LANL code PARMILA [6] in conjunction with the code SUPERFISH (DTLfish) [5]. Additional details of these studies can be found in [2]. Initially PARMILA simulations were performed using the self-generated beam distribution with set parameters. As such, beam loss in those runs was neither expected nor observed.

Figure 6 shows typical transverse envelopes of the beam in the DTL. The minimal matching between tanks was sufficient, but better matching can be done during further optimization.

RMS longitudinal emittance growth along the DTL, that is shown in Fig. 7, can be mitigated by better matching of the beam into the accelerating-focusing channel of the DTL from MEBT. The DTL inter-tank matching can be improved to eliminate the variation of the transverse rms envelope.

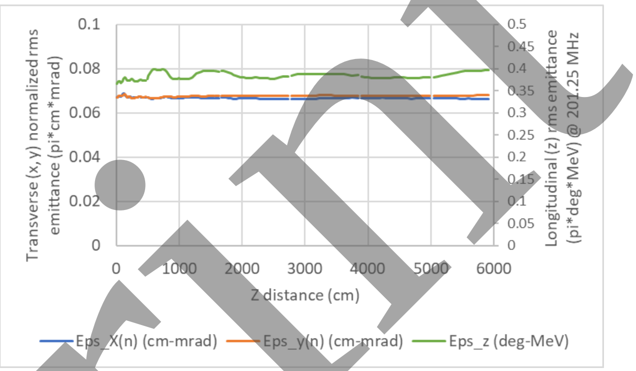

Figure 7: Transverse and longitudinal beam emittances evolution along DTL.

CONCLUSIONS AND FUTURE PLANS

The major accomplishment of this design work was development of the methods of DTL design for concise beam dynamics with reasonable RF power and flexible focusing lattice. The results of simulations of multiple versions of the DTL with improved parameters demonstrated robust approach and consistent results.

Several of the aspects of the DTL should be further optimized. Present studies show that the proposed approach to the DTL design can be successfully implemented, and the DTL design can be created in a timely manner.

Several subjects are to be granted additional attention:

- Optimization of the RF properties of the DTL tanks.
- Mechanical design and optimization of the PMQ cooling in the drift tubes.
- Improvement of the beam matching from MEBT to DTL tank 1 and between DTL tanks to minimize transverse emittance growth.

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