BEAM DYNAMICS STUDIES OF RADIO FREQUENCY QUADRUPOLE ACCELERATOR FOR PROJECT X

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Abstract

The Beam dynamics of 2.5 MeV Radio Frequency Quadrupole (RFQ) accelerator for Project-X has been studied for operating frequencies of 325 and 162.5 MHz using the codes PARMTEQM/TOUTATIS. The simulations have been done using two different techniques: LANL technique and Non-adiabatic technique. According to the requirements of the Project X Linac, the longitudinal emittance at the end of the RFQ should be < 0.1 deg MeV. In order to reduce the longitudinal emittance in the RFQ, the non-adiabatic type of bunching process has been employed. We compare the simulation results of the two design procedures of the RFQ and these details will be presented in this paper.

INTRODUCTION

The Radio Frequency Quadrupole (RFQ) accelerators are known for their remarkable capability of simultaneous focusing, bunching and accelerating the low energy ion beams with high transmission and good beam quality (low emittance). By proper choice of structure parameters (like modulations and synchronous phase) along the length of the RFQ one can reduce the output longitudinal emittance. The longitudinal emittance at the RFQ output for the Project X [1] should be ~0.85 keV-nsec.

In view of these criteria, we have done design studies for the RFQ for project X. There are different methods for the design of RFQs [2-4] but we have studied two different methods for the design of Project X RFQ. The first method is a generalised method proposed by LANL, where RFQ was divided into four sections, namely Radial matcher (RM), shaper (SH), gentle buncher (GB) and accelerator (AC) sections. In this generalized method the zero current phase advances ($\sigma 0t$ and $\sigma 0l$) are kept constant in the GB section. The second method is a Non-adiabatic method. The details of these studies are presented in the following sections.

SIMULATIONS

Initially the design frequency for the Project X RFQ was chosen to be 325 MHz. However, due to some problems in the design of chopper in the MEBT line it has been decided to change the operating frequency of RFQ to 162.5 MHz. We have done the comparison of the above mentioned methods for 325 MHz and implemented the non-adiabatic (NA) method for 162.5 MHz RFQ.

The input parameters for design of the RFQ are given in Table 1.

Table 1: Input parameters

Parameters	Values	Units
I/O energy	0.025/2.5	MeV
Frequency	325	MHz
Beam current	10	mA
Vane voltage	64	kV
RMS emittance	0.25	pi mm-mrad

In both the designs vane voltage and focusing factor were kept constant. In the conventional design the $\sigma 0t$, $\sigma 0l$ and spatial bunch length (Zb) are kept constant in the GB region, which leads to the adiabatic bunching, where as in Non-adiabatic (NA) design we have not kept these parameters constant in any part of the RFQ. This type of variation has a significant effect on the longitudinal emittance. The output parameters of the optimized designs are shown in Table 2.

Table 2: Ouput parameters of the 325 MHz RFQ

Parameters	LANL	Non-adiabatic	Units
Ions	H-	H-	
Modulation	2.0534	1.96	
Beam current	10	10	mA
Vane voltage	64	64	kV
Peak Field	29.79	29.26	MV/m
R0	0.31	0.31	cm
Trans □$_{nrms}$ (p/t)*	0.27/0.27	0.25/0.25	pi. mm-mrad
Long □$_{nrms}$ (p/t)	89/96	46/46	deg-keV
Transmission (p)	98.8	99.8	%
Transmission (t)	98.9	99.9	%
Accelerated (t)	98.6	99.9	%
Length	302	359	cm
Cu Power**	145	173	kW

*(p/t) = Parmteqm/Toutatis
** As calculated by SUPERFISH

The variation of σ0t, σ0l, modulations, and synchronous phase for both the designs along the length are shown in figures 1-3.

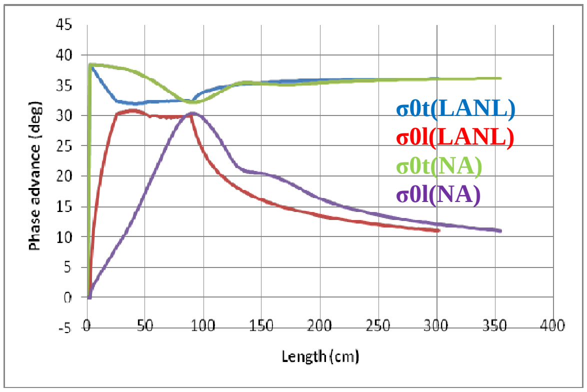

Figure 1: Variation of zero current phase advances along the RFQ.

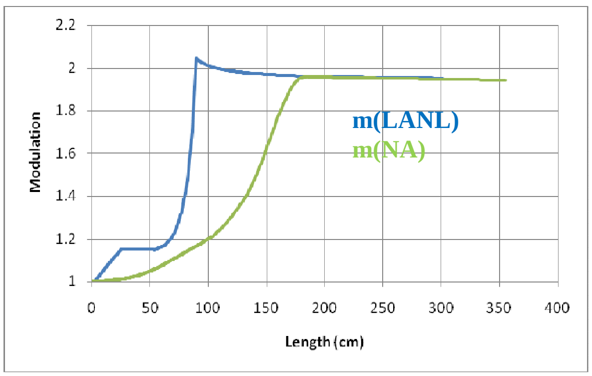

Figure 2: Variation of modulation along the RFQ length.

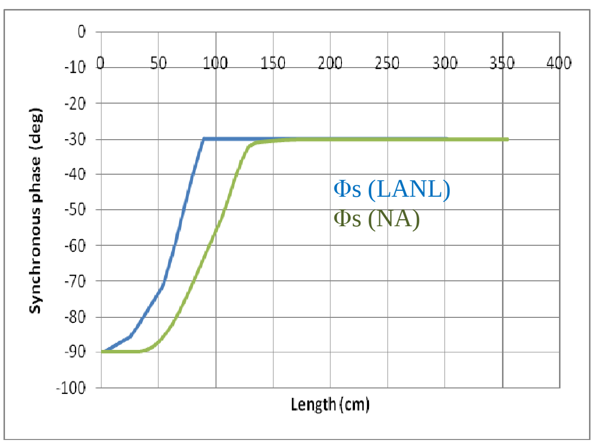

Figure 3: Variation of Synchronous phase along the RFQ length.

In the Non-adiabatic type of design, there is a significant decrease of the longitudinal emittance at the end of RFQ. The evolution of the emittances in both designs is shown in figure 4.

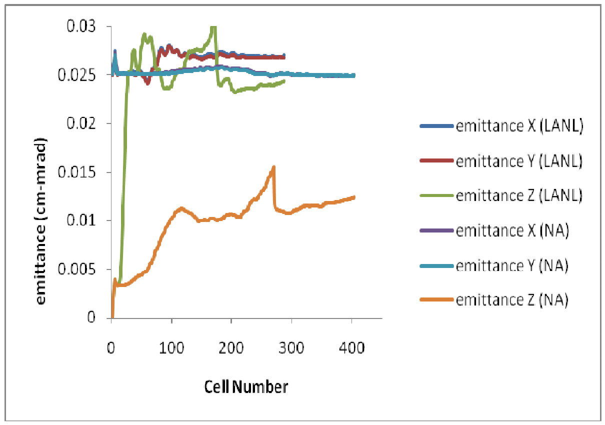

Figure 4: Evolution of emittances along RFQ.

Since the longitudinal emittance in the Non-adiabatic design is almost half of the conventional design this type of design has been chosen for the design of 162.5 MHz RFQ. The main output parameters of the 162.5 MHz RFQ are given in table 3.

Table 3: Parameters of 162.5 MHz RFQ

Parameters	**Values**	**Units**
Ions	H-	
Frequency	162.5	MHz
Vane voltage	108	kV
Peak Field	21.5	MV/m
R0	0.72	cm
Transmission (p)	98.9	%
Length	4.01	cm

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