DESIGN OF A 10 MeV, 352.2 MHz DRIFT TUBE LINAC

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Abstract

A conventional 10 MeV Drift tube linac is designed as a part of the H^- front end accelerator system for the future Indian Spallation Neutron Source. The front end linac consists of a 50 keV H^- ion source, low energy beam transport and a 3 MeV Radio Frequency Quadrupole, followed by a prototype of 10 MeV Drift tube Linac (DTL), which will be operated at a maximum of 3% duty factor. Cell geometry of the DTL is optimized to house quadrupole magnets and to get maximum shunt impedance. This paper describes the 2D electromagnetic and beam dynamics simulation of the 352 MHz, 10 MeV Drift tube linac. The 3D electromagnetic simulation is done using CST Microwave studio and the ports are modeled to study their effect on resonant frequency. Details of the DTL design are reported in this paper.

INTODUCTION

A low energy front end for high power pulsed H^- injector Linac system for the future proton synchrotron is being developed at RRCAT. As a part of this, it is proposed to develop a prototype DTL structure. The aim of this is to validate the design and perform the low power characterization. DTL is a cavity operating in TM_{010} mode loaded with drift tubes each of length $\beta\lambda$, (β=v/c and λ is the wavelength) which increases as the beam energy increases. This structure is quite efficient at energies of about 3 to 50 MeV, where the space charge forces are considerable. A schematic of 1/4th unit cell is shown in Fig. 1. The design parameters of 10 MeV DTL are given in Table 1.

CAVITY DESIGN

2D Electromagnetic Simulation

The goal of the physics design is to capture the H^- beam from the RFQ and accelerate it keeping the beam loss as low as possible. Cells are tuned to generate the cell geometry using SUPERFISH [1]. Apart from the frequency and the field distribution, Q factor, power loss, surface electric fields etc. were calculated. For ease of fabrication, bore, drift tube and tank diameter are kept constant throughout. Gap to cell length ratio (g/L) was varied to optimize transit time, effective shunt impedance per unit length (ZT^2) etc [2]. The electromagnetic design aims at high ZT^2 and the plot of ZT^2 vs. β for tank diameter of 52 cm is as shown in Figure 2. The DTL has been designed and after optimization a tank diameter of 52.4 cm, drift tube diameter of 14 cm, with bore radii of 1.0 cm were arrived at as one of the suitable choices.

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Beam Dynamic studies

Details obtained from SUPERFISH for a sample set of cells is given as input to PARMILA [3]. Detailed studies with different accelerating field gradient (E_o), synchronous phase and quadrupole gradient were performed to evolve the optimized design. Table 2 lists the output beam parameters obtained with the beam dynamic simulation. The focusing requirement for the low energy end is high and the quadrupole gradients in FODO lattice is very high [4] making the design of electromagnetic quadrupoles (EMQs) difficult, while for FOFODODO lattice the required quadrupole gradient is reduced. Both the lattices have been studied and FOFODODO lattice is selected to overcome the limitation on quadrupole gradients.

Table 1: Parameters of DTL

Tank diameter (TD)	52.4	cm
Drift tube diameter (DTD)	14.0	cm
DT stem diameter	2.6	cm
Bore radius (BR)	1.0	cm
Avg. Accelerating field	1.8-2.2	MV/m
Synchronous Phase	-45to -30	deg
Cavity Loss @ 1.25%	6.914	kW
Total Power Loss @1.25%	9.539	kW

Beam dynamic simulations have resulted in a total length of 5.62 m with 60 cells and the RF power required is 12 kW. Transmission efficiency of 100% is obtained without much increase in output emittances. The transverse rms normalized emittance is 0.023 cm mrad and the longitudinal emittance is 0.114 deg MeV. The ratio of aperture to rms beam size is around 7. Figure 3 shows the transverse and longitudinal profiles i.e. the beam size in both the transverse planes and the phase variation along the length. Figure 4 shows the phase space plots for the 60th cell.

Table 2: Output Beam Dynamics parameters

Total Length	562.345	cm
No. of cells	60	
Cell Length	6.81-12.29	cm
Transmission efficiency	100	%
Quadrupole Length	3.5- 5.5	cm
Quadrupole gradient	55-35	T/m
Transverse rms normalized emittance	0.0235	cm mrad
Longitudinal emittance	0.1148	deg MeV

Error Analysis

It is of importance to study the effect of variations in the input parameters on beam dynamics of the DTL as transmission efficiency, emittance etc depend on these.

Errors in alignment leading to quadrupole displacement, tilt, yaw or roll error will degrade the beam. With different errors applied on all the cells, the beam is traced with 10000 particles, and no loss is detected. Effect on the emittance of the DTL due to off axis injection and beam tilt are also studied [5]. The acceptance criterion of 100% transmission with 5% increase in the normalized rms emittance is met with misalignments of about 1mm of the input beam and divergences upto 5 mrad.

3d Electromagnetic Modeling

A 3D design using CST Microwave Studio (MWS) was done to include tuners, vacuum ports, post couplers etc. to know the effect of these on the frequency of the structure. Due to limitations on number of mesh points, only a few cells are modeled namely, 4 and 7 cells. Figs. 5 shows vacuum port and tuner modeled in MWS. Slug tuners of 120 mm and 100 mm diameter are modeled with a maximum penetration depth of about 100mm. These will tune the frequency of the DTL to give a maximum tunability of about 2 MHz. A detailed 3D analysis of the post-coupler modes is being done.

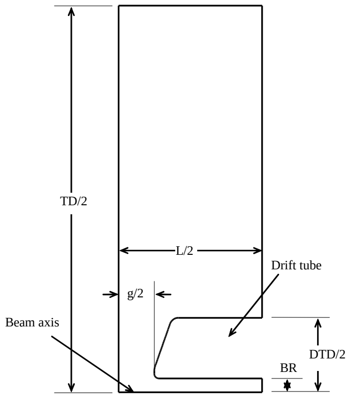

Figure1: Schematic of 1/4th unit cell geometry

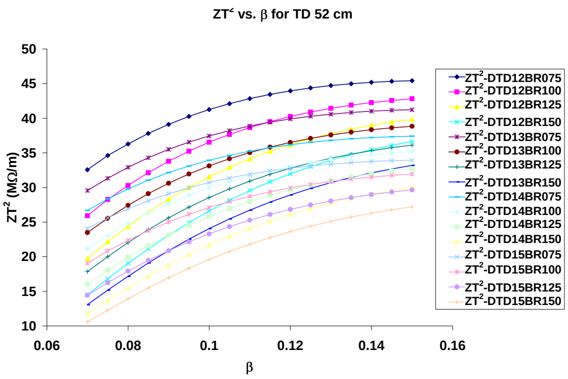

Figure 2: Plot of ZT^2 vs. β for tank diameter 52 cm

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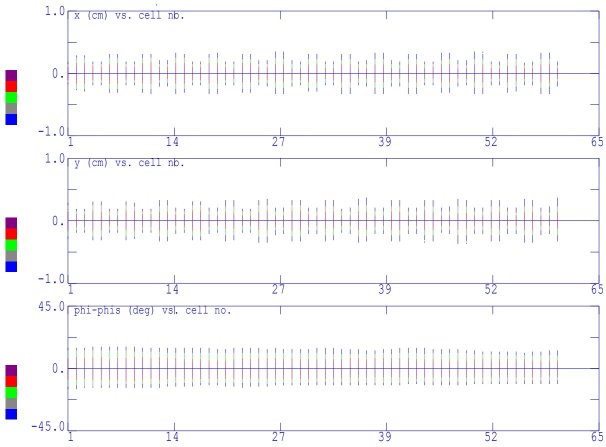

Figure 3. Transverse and longitudinal profiles

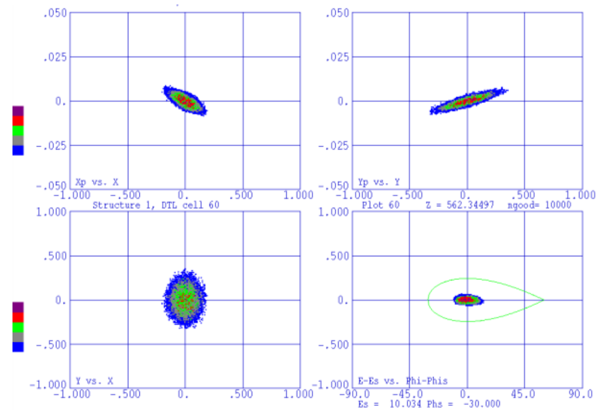

Figure 4. Phase space plots for the 60th cell.

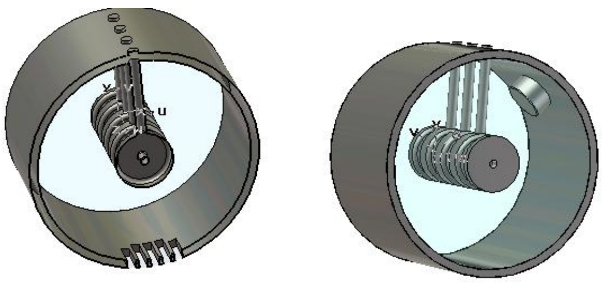

Figure 5: 3D plot with vacuum port & Tuner port

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