CONCEPTUAL DESIGN STUDY OF KOMAC DTL

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Abstract

KOMAC (KOrea Multipurpose Accelerator Complex) DTL has been designed to accelerate 20 mA cw proton/H- beam from 3 MeV to 100 MeV. For the structure and the frequency of the KOMAC DTL, 700 MHz CCDTL (Coupled Cavity DTL) with electro-magnetic quadrupoles has been chosen. The transverse focusing structure is 8 βλ FODO. The detail design of the accelerating structure with beam tracking using the code PARMILA will be reported. Matching with the KOMAC RFQ at 3 MeV will be also reported.

1 INTRODUCTION

The KOMAC DTL has been designed to accelerate 20 mA cw proton/H- beam from a 350MHz, 3MeV cw RFQ and to inject the 100MeV beam to a 700 MHz, final energy 1GeV cw superconducting linac. The DTL is a coupled cavity drift tube linac (CCDTL) structure [1, 2] which allows the focusing magnets to remain outside the vacuum system and does not require permanent magnets that are susceptible to radiation damage due to the high average beam current. The CCDTL structure is less efficient that conventional DTL, but relatively easier to fabricate and operate.

2 RF STURCTURE DESIGN

The 700MHz frequency, which is the same frequency of the superconducting linac, can be used for the CCDTL due to the ample space for the quadrupoles. The design parameters of the CCDTL cavity are shown in Table 1. These values except the aperture are conservative for fabrication and cw operation.

Table 1: Design Parameters of the CCDTL cavity

- Frequency : 700MHz
- Space for Quadrupole : >8cm
- Real Estate E : <1MV/m
- Surface E : <0.9 Kilpatrick
- Synchronous Phase : -60 ~ -30 degree
- Focusing : 8 βλ FODO
- Aperture : Acceptance > 2 transverse emit.

The aperture of the CCDTL can be determined by iterative calculations of the shunt impedance and the beam trajectory for the optimization. A larger aperture decreases the shunt impedance (less RF-efficient), but increases the ratio of aperture to beam size (less beam loss). The optimized aperture of the CCDTL is shown in Figure 1. The transition energy for the number of gaps per focusing period is determined by the space for quadrupole magnet.

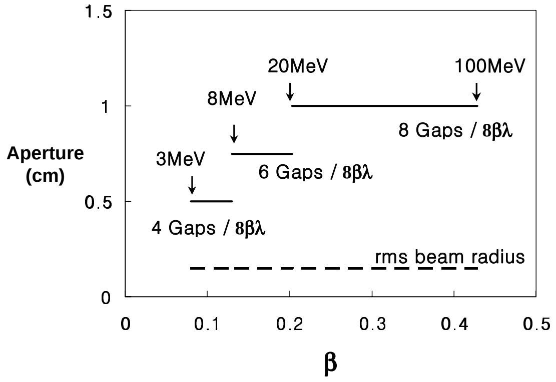


Figure 1: Aperture of the CCDTL and Beam Size

The cavity shapes are determined by SUPERFISH code. Figure 2 shows the plot of the effective shunt impedance for the cavity and the real estate effective shunt impedance versus particle velocity. In spite of the small aperture, the effective shunt impedance is small in the first part of the CCDTL. This is not serious problem because this part works as a buncher and a matching section.

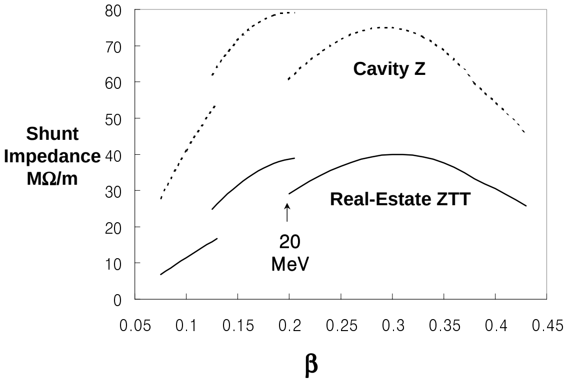


Figure 2: Shunt Impedance versus particle velocity for the CCDTL Cavity

3 BEAM DYNAMICS

Beam dynamics for KOMAC DTL are performed using the PARMILA code. For longitudinal matching with 350MHz RFQ, the synchronous phases and the amplitudes of the first part of CCDTL are adjusted as shown in Figure 3 [3].

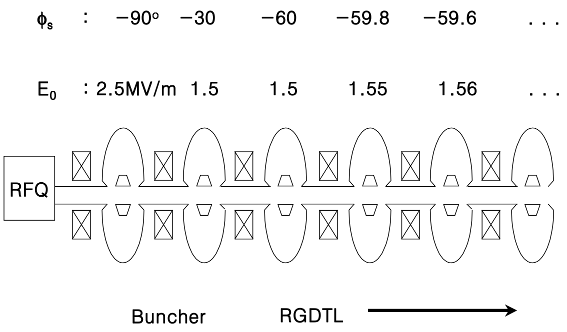


Figure 3: Matching between the RFQ and the CCDTL

The beam trajectory and the emittance in the CCDTL are shown in figure 5, 6 with the beam from the RFQ (longitudinal emittance: 0.4 π degree·MeV, transverse rms emittance; 0.032 π cm· mrad) with 100,000 particles. The GL of EMQ is 2.6 T, and the length of poles is 6 cm.

The phase and amplitude of the first part for matching is given to obtain the smallest emittance growth. In the final simulation, there is virtually no growth in transverse emittance, and no more than 20% growth in longitudinal emittance, which is not critical.

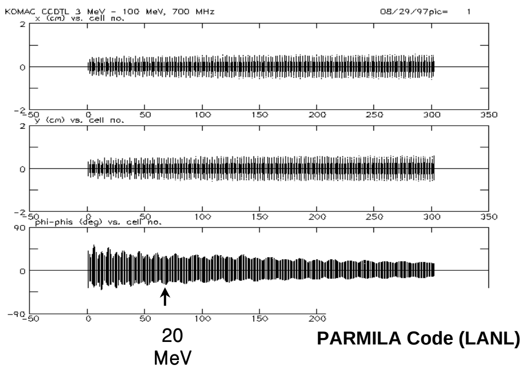


Figure 4: Beam trajectory in the CCDTL

To estimate the tolerances of the CCDTL structure, the error analysis has been done with PARMILA code. With the error in Table 2, which is achievable, the beam envelop calculated with PARMILA code does not grow more than 20% as shown in Figure 6. For the completion of this analysis, simulations from injector to end of superconducting linac should be performed.

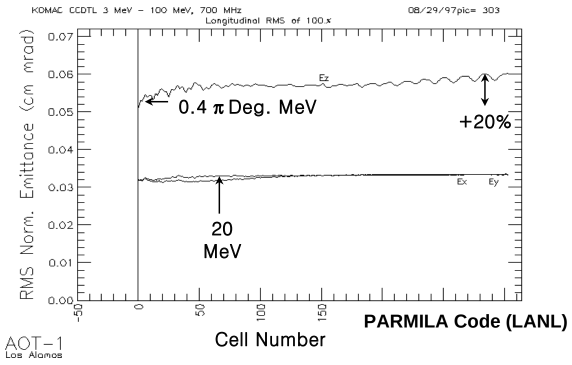


Figure 5: Emittance Profile in the CCDTL

Table 2: Tolerances of the CCDTL

- Field Amplitude : 1%
- Field Gradient : 1%
- Phase : 1 Degree
- Quadrupole displacement : 0.05mm
- Quadrupole rotation : 1 Degree
- Quadrupole strength (GL) : 1%

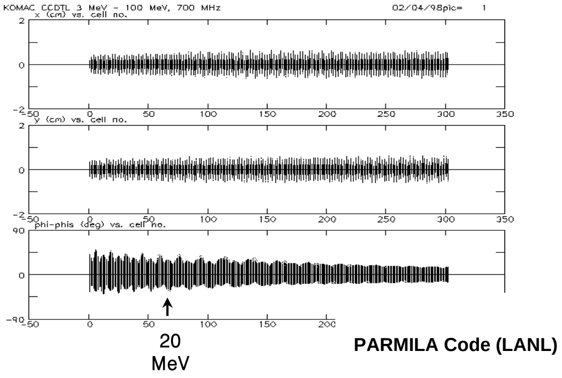


Figure 6: Beam trajectory with the errors in the CCDTL structure

4 MECHANICAL DESIGN

To evaluate the manufacturing tolerances of the CCDTL cavity, the perturbation analysis of coupled resonators is used [4]. The tolerance of the cavity frequency is 100kHz, and the coupling coefficient is 0.02 with the tolerance of 1%.

The coupling coefficient between accelerating cavity and coupling cavity has been calculated by using the frequency shift of modes, which can be calculated with MAFIA code as shown in figure 7. Also the machining tolerances for the coupling coefficient is 0.1mm, which can calculated by MAFIA code.

From this analysis, it has been found that there is no critical problem in fabrication the KOMAC DTL cavities. The technology for conventional CCL, which is well established, can be used in fabrication, tuning, installation, alignment, and operation.

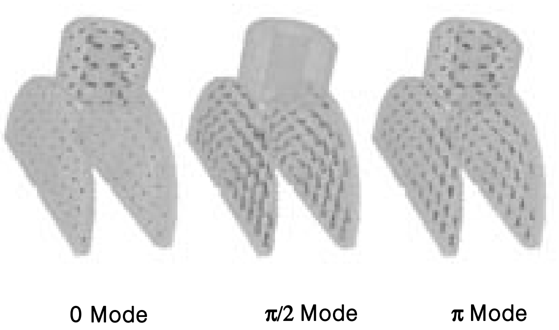
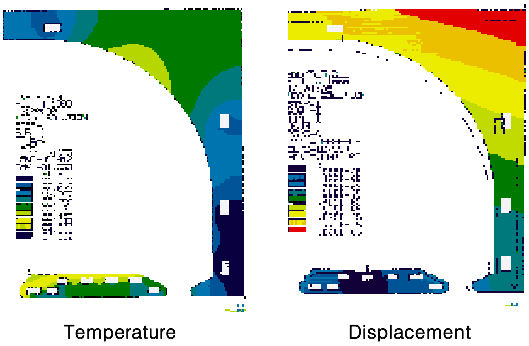


Figure 7: Modes of CCDTL

For cooling of CCDTL cavities, the water cooling channel has been designed and analyzed by ANSYS code as shown in figure 8 [5]. The frequency shift due to the thermal expansion is 50kHz. The coolant water velocity is 3 m/s, and the bulk temperature increase of the coolant water is less than 5 °C.


Temperature

Displacement

Figure 8: Thermal Analysis of CCDTL Cavity

The CCDTL will be fabricated by brazing with the ~3m module length, and the RF will be fed with 200kW per module through waveguide and RF window. There are 2 options for RF system of the KOMAC DTL. 1 MW Klystron based system is one, and 250 kW Klystrode based system is the other. The choice of RF system depends on the KOMAC project, because there is the largest demand of RF in the superconducting linac which has been design to accelerate 20 mA proton/H beam from 100 MeV to 1 GeV.

The 500l/s ion pump will evacuate one CCDTL module through the manifold.

The KOMAC DTL is summarized in Table 3. The design of the KOMAC DTL module at 20MeV is shown in figure 9.

Table 3: Summary of KOMAC DTL

Energy (MeV)	3~20	20~100
Current (mA)	20mA	
Structure	CCDTL	
Focusing	8 βλ FODO	
Gaps per Focusing Period	4 & 6	8
Length (m)	29.8	94.2
# of EMQ	130	173
# of cavity modules	10	32
P_{cu}/P_{total} (MW)	1.15/1.49	3.43/5.03

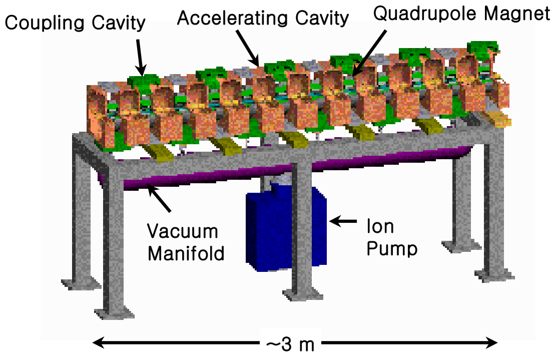


Figure 9: KOMAC CCDTL Module at 20MeV

6 ACKNOWLEDGMENTS

The authors express their thanks to Dr. Y. Cho at ANL for his kind reviews and helpful suggestions on this work.

7 REFERENCES

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