DESIGN OF THE KOMAC H^+/H^- RFQ LINAC

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Abstract

A 350MHZ, cw Radio-Frequency Quadrupole (RFQ) will be built to produce 20mA of proton beam at 3MeV for the KOrea Multipurpose Accelerator Complex (KOMAC) projects 1GeV linac. The beam dynamics and the engineering design of the RFQ linac are described. The length of the RFQ is 324cm long and the longitudinal stability is mitigated by the coupled-cavity concept. In order to minimize the power deposited on the cavity walls, the longitudinal variation of the width of the vane base is given. The peak temperature on the cavity wall is 50C, the displacement is about 18 μm.

1 INTRODUCTION

The Radio Frequency Quadrupole (RFQ) linac proposed for the Korea Multipurpose Accelerator Complex (KOMAC)[1-3]. Project is a cw linac which will produce a 20 mA beam of H^+/H^- with energy of 3 MeV. This paper addresses the physics and engineering design plus the present status of the KOMAC RFQ. The RFQ concept is shown on Figure 1 with the parameter values given on Table 1.

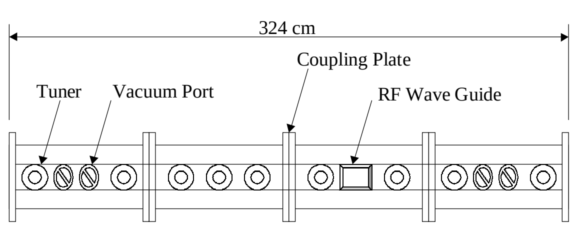

Figure 1. Preliminary drawing of a 3MeV 350MHz RFQ linac for the KOMAC.

The main focuses of this physics and engineering design in the KOMAC RFQ are as follows:

- To obtain the focusing required to match the H^+/H^- beam to the RFQ..
- To maintain a constant capacitance per unit length along the axis of the RFQ.
- To minimize the power dissipated on the cavity walls and the end region of the vanes.
- To stabilize the longitudinal mode in the structure.

The physics design study is presented in section 2. The physics design codes used for RFQ include space- and image–charge effects and have been proved against existing linacs [4-6]. The engineering design of the RFQ is described in Section 3. The thermal analysis is studied by ANSYS code. The section 4 describes the fabrication status of the KOMAC RFQ.

Table 1. RFQ linac parameters for the KOMAC

PARAMETER	VALUE
Operating frequency	350 MHz
Particles	H^+ / H^-
Input / Output Current	23 / 20 mA
Input / Output Energy	0.05 / 3.0 MeV
Input / Output Emittance, Transverse/norm.	0.02 /0.023 π-cm-mrad rms
Output Emittance, Longitudinal	0.246 MeV-deg
Transmission	95.4 %
RFQ Structure Type	4-vanes
Duty Factor	100 %
Peak Surface Field	1.8 Kilpatrick
Structure Power	350.0 kW
Beam Power	67.9 kW
Total Power	417.9 kw
Length	324.0 cm

2 PHYSICS DESIGN

The KOMAC system requires 20 mA of H^+/H^- beams from the 350 MHz RFQ. The proper energy needs for injection into the coupled cavity drift tube linac(CCDTL). The maximum vane voltage is given by the peak electric field that could cause sparking. In this design, the peak electric field was limited to 1.8 times the Kilpatrick criterion [7].

Figure 2 shows the various parameters defining the KOMAC RFQ design versus position. These parameters were obtained by CURLI, RFQUICK, PARI, and PARMTEQM [4]. The curves labeled “V”, “Phase”, ”B”, “A”, “r”, “ a”, “m”, “E_z” and ”W” show the voltage difference adjacent vane-tips, synchronous phase, focusing strength, accelerating efficiency, average radius, aperture radius, modulation factor, average axial electric field and beam energy along the RFQ, respectively.

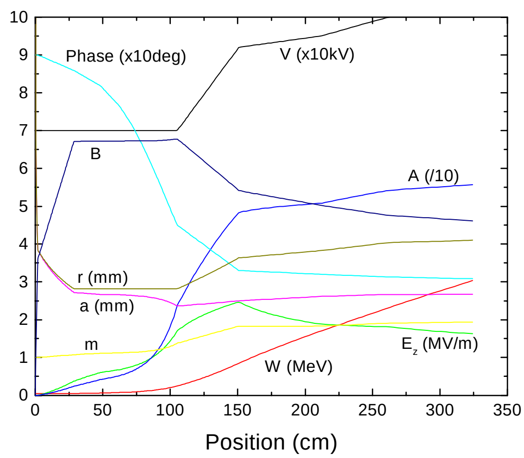

Figure 2. Various parameters defining the RFQ design versus position.

To obtain the focusing required to match the beam from LEBT to the RFQ requires a weaker focusing and a larger aperture at the entrance of the RFQ. However, the transmission rate of the beam decreases with the inverse of the aperture at the entrance of the RFQ. In order to design a radial matching section with a weak focusing and large aperture, we used CURLI and RFQUICK. The aperture in the KOMAC RFQ is smoothly reduced as it moves from the entrance to z=26.8 cm where the focusing strength is peak , as shown in Figure 2. In general, the end of the gentle buncher is a point where significant beam loss occurs. By the proper combination of V, a and B, the beam loss at the end of the gentle buncher was reduced. At about 104cm, the vane gap voltage, V, and aperture, a, start increasing and the focusing strength, B, starts decreasing. The increase in the vane gap voltage increases the accelerating gradient in the high-energy portion. The increase in the vane gap voltage also decreases the design length of the RFQ

Another important factor in the RFQ design is to maintain a constant capacitance per unit length along the axis of the RFQ. In order to maintain a constant capacitance, the average radius from the vane tip to the axis of the RFQ is changed, as shown in Figure 2. A change in the average radius would result in a change in the capacitance and in the local resonant frequency of the waveguide by a severe tilt in the fields. To maintain a constant capacitance per unit length, we fix the ratio of the vane tip transverse radius of curvature, ρ, to the average radius, r. For the KOMAC RFQ, the value of ρ/r is kept constant at 0.792. The resonant frequency is kept constant by varying the cavity cross-section by adjusting the width of the vane base while r changes. Because the power dissipated in the cavity walls will not be longitudinally uniform, this also minimizes the structure power.

We used PARMTEQM to match the beam into the CCDTL. Figure 3 shows the result of the PARMTEQM simulation. The percentage transmission is 95.4%.

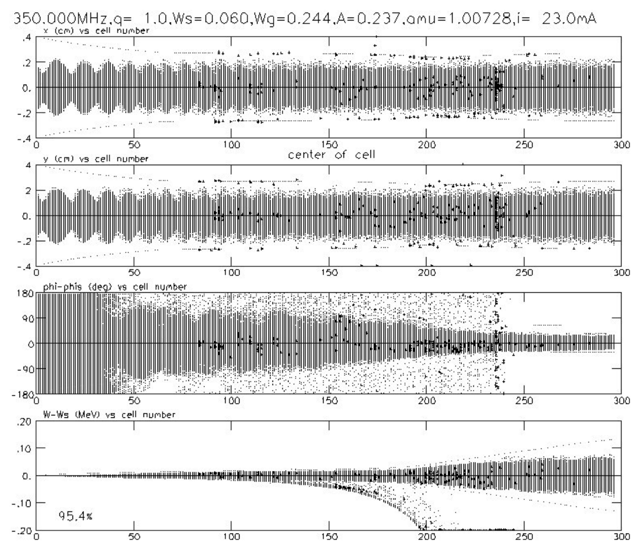

Figure 3. PARMTEQM simulation of the RFQ using 5000 particles. From top to bottom are: x, y, phase, and energy coordinates versus cell number. Bold black points indicate lost particles in the RFQ.

3 ENGINEERING DESIGN

The length of the KOMAC RFQ is 3.24 m long and consists of two resonantly coupled 1.62m sections. The length is determined by the final energy which is 3.0 MeV. The resonant coupling provides the longitudinal field stabilization and a stop band in the dipole mode, which is improved the transverse stability by eliminating dipole modes. In order to tune the resonant frequency of the end regions of the RFQ, we have used the three-dim. MAFIA code [8]. There is the rectangular undercut of the vanes. However, the exact shape of the undercut will be determined empirically by the cold model which is being fabricated into the aluminum alloy. The cavity cross-section is four triangular shape with the axial variation in the width of the vane base as shown in Figure 4. The vane-cavity will be joined longitudinally by a brazing. Thus the RFQ is the completed monolithic structure and the vanes are permanently aligned. This structure serves to mitigate the cost and to simplify the mechanical support system.

A serious problem in the design of the KOMAC RFQ with cw operation result from the rf thermal loads on the cavity walls. The average structure power by rf thermal loads is 0.35 MW and the peak surface heat flux on the cavity wall is 0.13 MW/m^2 at the high energy end. In order to remove these heat, we consider 24 longitudinal coolant passages in each of the sections, as shown in Figure 4. Figure 4 also shows a temperature distribution of the cavity at the high energy end. The material is oxygen-free copper. The thermal loads was given by the SUPERFISH [9] analysis. The heat transfer coefficients is between 11kW/m^2-C to 15 kW/m^2-C. Because of the flow erosion of the coolant passages, we consider the maximum allowable bulk velocity of the coolant as 4.5 m/sec. From the thermal-structural analysis of ANSYS, the peak temperature on the cavity wall is 50C, the displacement is about 18 μm and the intensity stress .is 30 MPa.

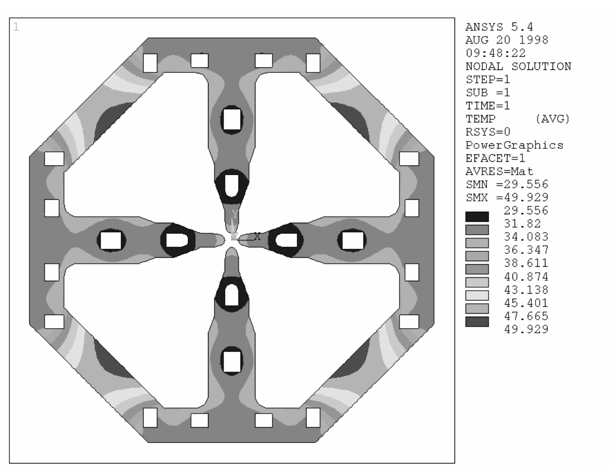

Figure 4. Temperature distribution of the cavity at the high energy end of the KOMAC RFQ.

4 PRESENT STATUS

A prototype of the RFQ is being machined at the Samsung Heavy Industies Co., Ltd and the Dae-Wung Engineering Co.. We are going to test a brazing of one section at next month.

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