DESIGN of a 350 MHz, CW RFQ for the KOMAC PROJECT

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Abstract

As for the first stage accelerator of the Korea Multipurpose Accelerator Complex (KOMAC) project by Korea Atomic Energy Research Institute (KAERI), 3-MeV radio-frequency quadrupole (RFQ) is considered. It will produce 20 mA CW proton beam for the accelerator driven transmutation technologies. We will describe the design of this RFQ. The status of the project is also discussed.

1 INTRODUCTION

In order to develop the technology related to the accelerator driven transmutation, KAERI is pursuing the project named the Korea Multipurpose Accelerator Complex (KOMAC) [1]. Final goal of the KOMAC project includes 1-GeV proton accelerator. The first step of the project is to build 3-MeV RFQ and 20-MeV CCDTL. So, KAERI and Pohang Accelerator Laboratory (PAL) are developing 3-MeV RFQ. Samsung Heavy Industries Company will carry out the actual fabrication of this RFQ. The technical specifications for the KOMAC RFQ are given in Table 1.

Table 1: KOMAC RFQ parameters.

Parameter	Value
Operating frequency	350 MHz
Particles	H+ / H-
Input/output energy	0.05 / 3.0 MeV
Input/output current	23 / 20 mA
Duty factor	100 %
Input/output emittance (trans./norm.)	0.02 / 0.023 π cm-mrad rms
Output emittance (longitudinal)	0.246 MeV-deg
Transmission rate	94.5 %
RFQ structure type	4-vane
Peak surface field	1.8 Kilpatrick
Average structure power	328.3 kW
Average beam power	67.9 kW
Average total power	396.2 kW
Length	293.0 cm
RF feeds	4 waveguide irises
Max. local heat flux	12 W/cm^2 for 60 % Q
Inlet coolant temperature	10^{o}C (refrigeration system)

The design of an RFQ to deliver an average proton current of 20 mA at 3-MeV is a significant challenge for beam dynamics and thermal analysis. The original concept of the KOMAC RFQ has been developed in 1997 [3]. Since then, a number of physical parameters have been changed to reflect the good match with the low-energy beam transport (LEBT) and the CCDTL. Also, the fabrication concept has been changed from the electroformed-joint design developed for the BEAR project [4] to a furnace-brazed design [5].

Subsequent sections of this paper describe the physical design, the cavity design, thermal analysis results, and the present status of the fabrication.

2 PHYSICS DESIGN

Conventional RFQ design with a small entrance aperture requires a very strong focused beam at the entrance aperture for proper matching to the RFQ. In KOMAC RFQ, the final lenses in the LEBT are far enough from the input of the RFQ to require a large aperture and weak focused beam at the beginning of the RFQ. Low vane modulation at the RFQ entrance allows weaker focusing, but still has a large transverse current limit. The combination of a large radial matching section and the weak focus makes matching the beam into the RFQ easy. The transverse focusing strength smoothly increases in the first 70 cm of the RFQ. At about 130 cm, the vane gap voltage starts ramping up, the aperture starts increasing, and the focus starts decreasing. The combination of these parameters reduces the beam loss at the end of gentle buncher, which is the usual choke point where significant beam loss occurs. The code PARMTEQM simulates the beam transport through the RFQ. Figure 1 shows the results of PARMTEQM simulation. Notice that the transverse beam size shrinks in the first part of the RFQ where the focus increases. Figure 2 shows the phase-space projections at the input of the RFQ and at the output of cell 240. The bold-black points in the input-phase-space projections are particles that were lost before reaching the cell 241. At this point

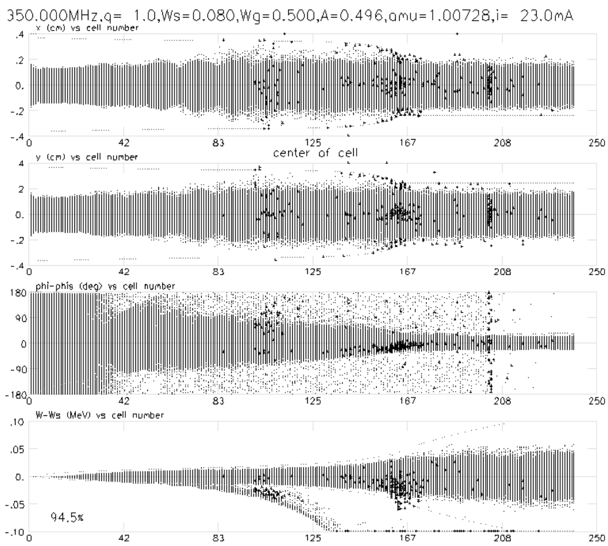

Figure 1: Results from PARMTEQM simulated the KOMAC RFQ using 5,000 particles. From top to bottom, the vertical axes are x, y, phase, and energy coordinates versus cell number, respectively. Bold black points indicate the lost particles. The transmission rate is 94.5%.

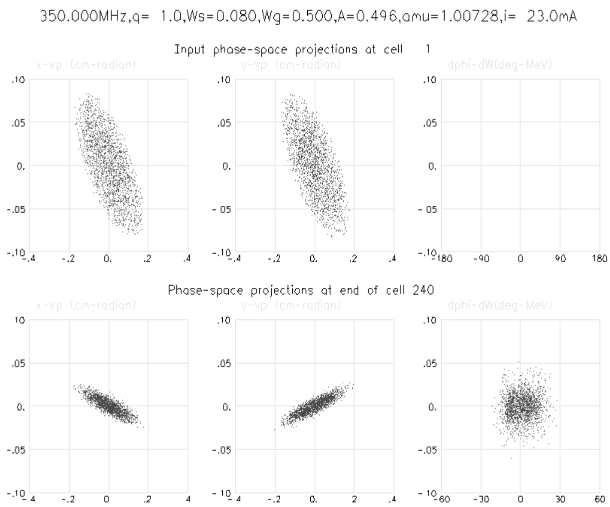

Figure 2: PARMTEQM simulation showing phase-space plots of the input beam and the beam at cell 240. The phase-space plots from left to right are: x-x', y-y', and phase-energy, where x'=dx/dz and y'=dy/dz.

in the calculation, the lost particles are the outer most particles injected into the RFQ. The input beam for this simulation came from the result of the LEBT line. The butterfly shape of the transverse phase-space distributions result from the large variation of the RF phase when the particles reach the exit plane of the cell 240. The particles' transverse velocity at the cell exit depends on the RF phase. Key parameters such as the energy gain, aperture and its modulation are shown in Figure 3.

3 CAVITY DESIGN

The cavity cross-section is the conventional triangular shape with a significant longitudinal variation in the width of the vane skirt. A quarter section of the RFQ is shown in Figure 4. The electric field is also plotted after the calculation by SUPERFISH code. The 3-meter long structure is designed as two resonantly coupled 1.5-meter long segments to assure longitudinal stabilization. Stabilizer rods on the inner-segment coupling plates and the end walls provide azimuthal stabilization without the scalloping of the on-axis fields associated with vane coupling rings or π-mode stabilizers.

The cavity will be fabricated as four 750-mm long sections: each consisting two major and two minor vanes. There are 24 longitudinal coolant passages in each of the sections to remove 330 kW of average structure power. These will be machined into the OFH copper substrate and then plugs are brazed on. In order to provide coolant passages as near as possible to the vane tips, the vane tips will be fabricated separately and brazed onto the vane bases. These are the only water-to-vacuum braze joints that are the double-joint type of nearly 23 mm width.

To control the RF resonance, the tip coolant passage will be operate with 10^{o}C coolant while the temperature of the coolant n the outer passage will be modulated to maintain the cavity on resonance. The RF power in each of the four resonant segments is significantly different and the inlet temperature of the coolant will be varied accordingly. In the coolant passages, the maximum bulk velocity is 4.5 m/sec. The peak surface heat flux on the cavity wall is 12 W/cm^2 at the high-energy end. The 10^{o}C inlet coolant temperature requires a refrigeration system instead of the cooling tower more commonly used for linacs. The cooling tower would provide an inlet temperature of about 25^{o}C with correspondingly higher peak surface temperature on

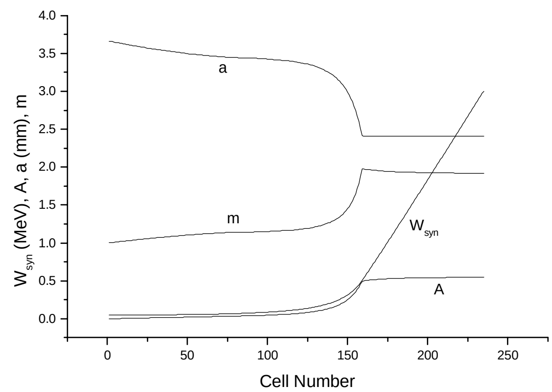

Figure 3: Key parameters such as the aperture (a), the vane modulation (m), the synchronous energy (W), and the acceleration strength (A) are shown along the cell.

Figure 4: A quarter section of RFQ and the electric field calculated by SUPERFISH code.

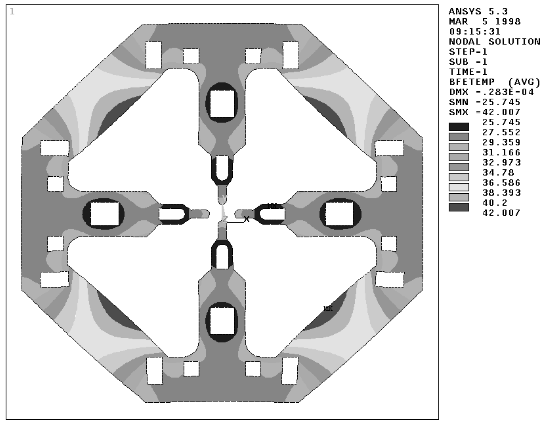

Figure 5: Temperature distribution of RFQ.

the cavity walls and the undercut regions. The higher temperatures on these surfaces have higher thermal loads due to increased surface electrical resistance. Figure 5 shows the temperature distribution of the RFQ.

Form the thermal analysis, the maximum displacement is 28.3 mm and the maximum stress is 26.4 Mpa. For OFH copper, this represents about 38 % of the yield stress (70 Mpa) for annealed materials. This stress is well within the allowable and does not present any design problems.

4 FABRICATION STATUS

Detail design of the KOMAC RFQ has begun in July 1997. Currently, efforts are concentrate to finish basic design of the RFQ as soon as possible. In the mean time, Samsung Co. is concentrating how to fabricate various mechanical components of the RFQ. A test piece of vane structure is being fabricated to develop the necessary techniques. The engineering design will be finished by March 1999. Actual fabrication of this RFQ will be followed.

5 ACKNOWLEDGMENTS

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