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Design of A 350MHz RFQ for The KOMAC 1GeV Proton Linac

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Abstract

As the first stage accelerator of the Korea Multipurpose Accelerator Complex (KOMAC) 1GeV proton linac, a 350MHZ, cw Radio-Frequency Quadrupole (RFQ) will be built to produce 20mA of 3MeV. High current RFQ with cw operation is a major program in the KOMAC project to understand beam dynamics, engineering design, construction, control and diagnostics techniques. The beam dynamics and the engineering design of RFQ are described and the present status of the KOMAC RFQ project is discussed.

I. Introduction

Invented in the Russia by Teplyakov and Kapchinskii[1] in 1970, the RFQ was first brought to the attention of Western physicists by Joe Manca[2] at Los Alamos. Their first RFQ was a small and highly successful 425MHz proton accelerator, a "proof of priciple" device. The RFQ has dominated the area of low energy linear accelerators (linacs) in the last few years.

The RFQ is a low-velocity, high-current linac with high capture efficiency that can accelerate ion species from protons to uranium. Ion sources need only to operate at relatively low extraction and preacceleration voltages to inject the RFQ. The RFQ output energy is well matched to the input energy requirement of linear accelerators that accelerate ions to higher energy, and has been included in most new linac designs.

The small, compact, cost-effective and reliable RFQ is promising in various science areas that include ion-beam implanters, neutron radiography, gamma-ray radiography, detection of explosive, and general purpose source of pulsed ion beams.

In order to develop the technology related to the accelerator driven transmutation, KAERI is pursuing the project named the Korea Multipurpose Accelerator Complex (KOMAC)[3,4]. Final goal of the KOMAC project includes 1-GeV proton accelerator. The first step of the project is to build 3-MeV RFQ[5] and 20-MeV coupled cavity drift tube linac (CCDTL)[6]. 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.

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, trans./norm.	0.02 /0.023 π-cm-mrad rms
Output Emittance, Longitudinal	0.246 MeV-deg
Transmission	94.5 %
RFQ Structure Type	4-vane
Duty Factor	100 %
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
Maximum Local Heat Flux	12 Watt/cm^2 for 60% Q
Inlet Coolant Temperature	10°C (refrigeration system)

Table 1. KOMAC RFQ specifications.

The design of an RFQ to deliver an average proton current of 20 mA at 3.0 MeV is a significant challenge for beam dynamics and thermal analysis. The original concept of the KOMAC RFQ was developed in 1997 [3]. Since then a number of the physics parameters have changed to reflect revised requirements for matching the low energy beam transport (LEBT) and CCDTL well to take advantage of improvements in the transport codes.

Subsequent sections of this paper describe the beam dynamics, the engineering design, and the present status of the KOMAC RFQ

II. Beam Dynamics

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 synchronous phase varies from –90° to –30° and the vane parameters are rapidly vary at the end region of the gentle buncher, as shown in figure 1. At the end of gentle buncher, a significant beam loss occurs.

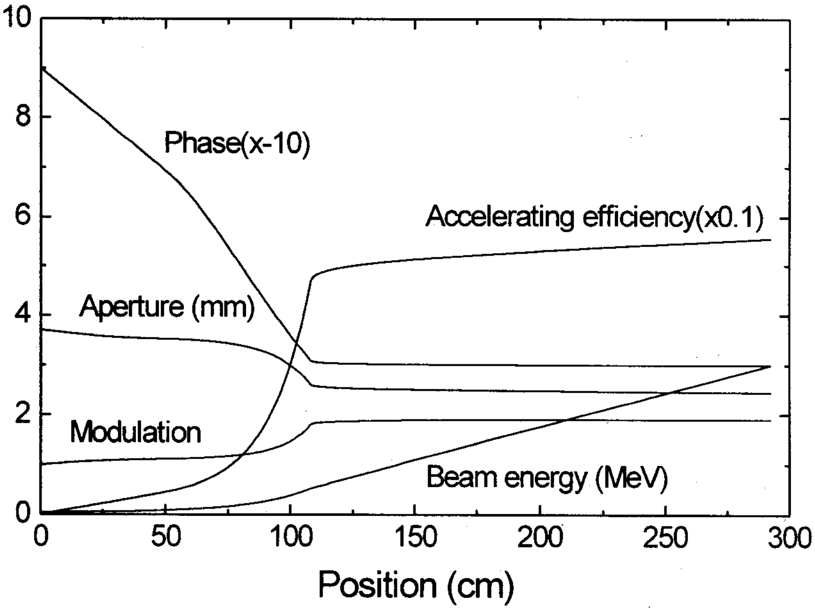

Figure 1. Calculated physics parameters.

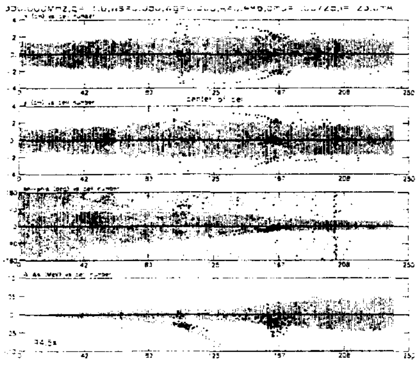

Figure 2. PARMTEQM simulated the RFQ using 5000 particles. From top to bottom are: x, y, phase, and energy coordinates versus cell number. Bold-black points indicate lost particles. The percentage transmission is 94.5%.

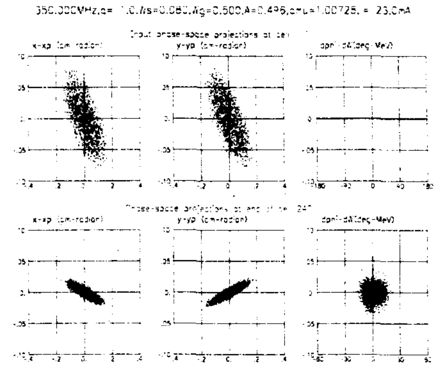

Figure 3. PARMTEQM simulation showing phase-space plots of the input beam and the beam at cell 240. The phase-space plots from left to right are: x-x′, y-y′, and phase-energy, where x′=dx/dz and y′=dy/dz.

The code PARMTEQM simulates the beam transport through the RFQ. Figure 2 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 3 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 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.

III. Engineering Design

The cavity cross-section is the triangular shape and the cavity will be fabricated as four 75.0cm long sections. A quarter section of the RFQ is shown in Figure 4. The electric field and heat load are 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. There are 24 longitudinal coolant passages in each of the sections to remove the 0.33 MW 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 with water-to-vacuum braze joints. In the coolant passages, the maximum bulk velocity is 4.5 m/sec. The rf power in each of the four resonant segments is smoothly varied and the

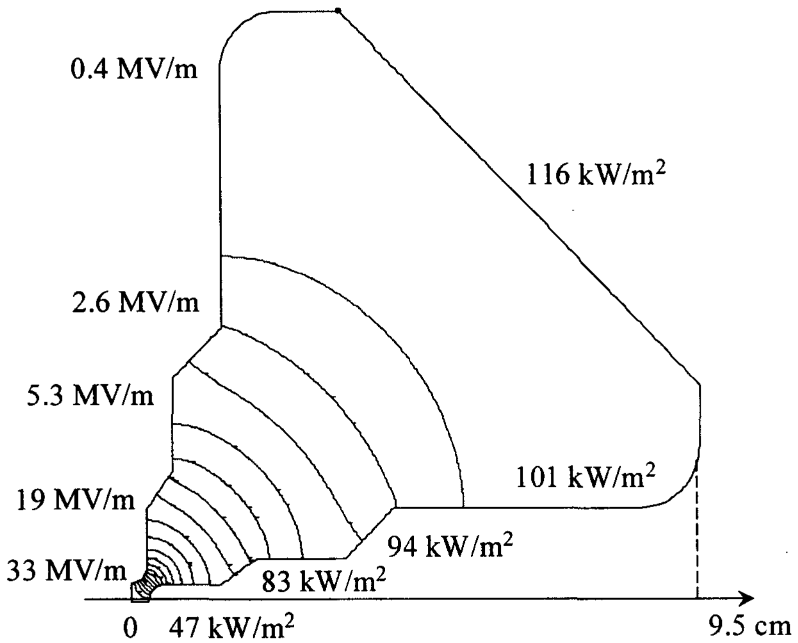

Figure 4. Distribution of the electric field and heat load of the RFQ vane.

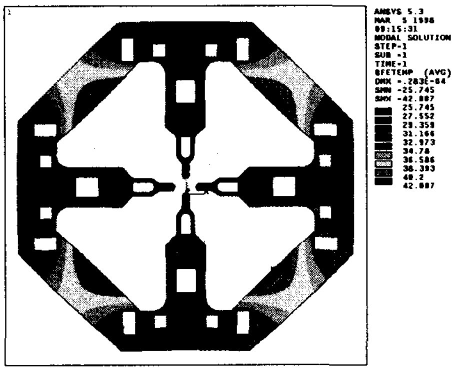

Figure 5. The distribution of temperature of the RFQ vane.

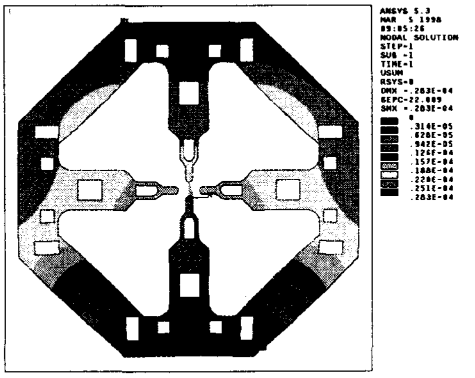

Figure 6. The distribution of displacement of the RFQ vane.

inlet temperature of the coolant is varied accordingly. For resonance control, the tip coolant passages will be operated with 10° C coolant while the temperature of the coolant in the outer passages will be modulated to maintain the cavity on resonance. The 10° 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 coolant temperature of about 25° C with correspondingly higher peak surface temperature on the cavity walls and undercut regions. The higher temperatures on these surfaces have higher thermal loads due to increased surface electrical resistance. Figure 3 shows the distribution of temperature of RFQ. From the thermal analysis, the maximum displacement is 28.3 μm as shown in Figure 4 and the maximum stress is 26.4 MPa. For OFH-copper this represents about 38 % of the yield stress (70 MPa) for annealed material. This stress is well within the allowable and does not present any design problems.

IV. Present Status of the KOMAC RFQ

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.

Acknowledgement

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