Proceeding of the Korean Nuclear Society Spring Meeting

Kori, Korea, May 2000

A 3.0MeV CW KOMAC/KTF Radio-Frequency Quadrupole Linac

Jang Min Han, Kyungsin Kim, Young Jun Kim, Yong-Sub Cho, Byung-Ho Choi

Korea Atomic Energy Research Institute
B.O.Box 105, Yusong, Taejon, Korea 305-600

In Soo Ko and Youngsoon Bae

Pohang University of Science and Technology
San 31 Hyoja Dong Nam-Gu, Pohang, Kyungbuk, Korea 790-784

Abstract

A proton linac that will accelerate a 20mA beam from 50 KeV to 3 MeV has been designed and is being fabricated for the KOMAC (Korea Multipurpose Accelerator Complex) Project at Korea Atomic Energy Research Institute (KAERI). This 3.2m radio-frequency quadrupole (RFQ) structure consists of two resonantly coupled segments and is being fabricated using vacuum furnace brazing as a joining technology. The physical and engineering design of the H^+/H^- *RFQ linac are described. The fabrication status the first section of the RFQ linac are presented.*

I. Introduction

The linear accelerator for the KOMAC Project [1,2] will include a 3 MeV RFQ linac. The first phase of the project, KOMAC Test Facility (KTF), is to demonstrate performance of the RFQ [3] plus a coupled-cavity drift-tube linac (CCDTL) [4] to 20 MeV. The KOMAC/KTF RFQ concept is shown in Fig. 1 with the technical specifications given in table 1. RFQ is a 4-vane type and consists of 60 tuners, 16 vacuum ports, 1 coupling plate, 4 rf drive loops, 192 cooling passages, and 8 stabilizer rods.

The physics and engineering design study is presented in section 2. Section 3 describes the fabrication status and brazing test of the first section of the KOMAC/KTF RFQ with OFHC.

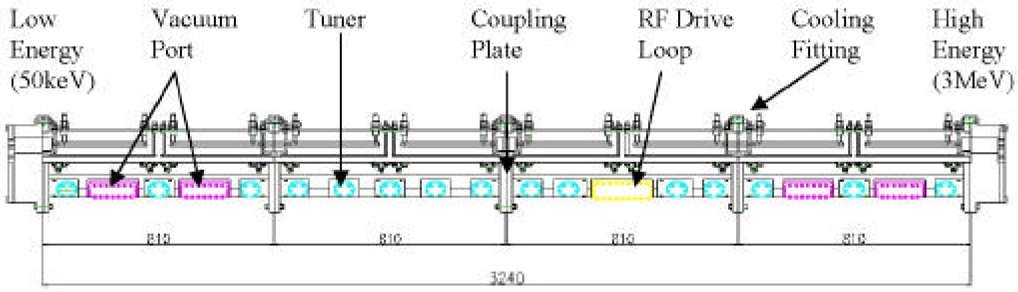

Figure 1. 3MeV, cw KOMAC/KTF RFQ linac drawing.

Table 1. KOMAC/KTF RFQ Specifications.

PARAMETER	VALUE
Frequency	350.0 MHz
Particles	H^+ (90%)/ H^- (10%)
Input / Output Current	21 / 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 (norm.)	0.246 MeV-deg
Transmission	95 %
Duty Factor	100 %
Peak Surface Field	1.8 Kilpatrick
Average Structure Power	350.0 kW
Average Beam Power	67.9 kW
Average Total Power	417.9 kW
RF Feeds	2 Waveguide Irises / Loop Couplers
Average Heat Flux	11 W/cm^2
Resonant Segments	2 @ 0.8 m each
Slug Tuners	60 Total
Length	8.0 m
Structure Type	4-Vanes

II. Physics and Engineering Design

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

- To understand the transmission of the mixing H^+/H^- beam into the RFQ.
- To obtain the tuning frequency by undercutting the end regions of the vane.
- To determine the locations and shapes of the coolant passages.
- To determine the shape of the brazing surface.

The motion of the mixing H^+/H^- beam into the RFQ has been studied by using a time marching beam dynamics code QLASSI [5]. Fig. 2 shows the dependence of the beam transmission rate and the H^- mixing ratio. The longitudinal beam loss increases with the concentration of negative ions by the bunching process which is distributed by attractive forces. Because of the space charge compensation in the low energy sections, the transverse beam loss decreases with the mixing ratio of H^-. In the RFQ, the mixing ratio of H^- is less than 10%.

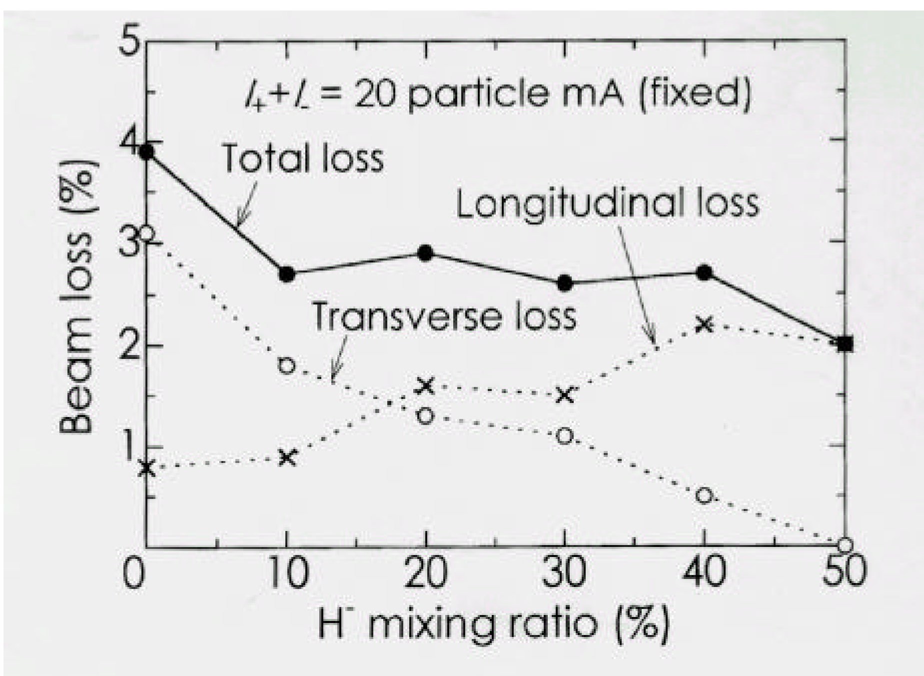

Figure 2. Dependence of beam transmission rate and H^- mixing ratio.

The cavity cross section is the conventional triangular shape with a significant longitudinal variation in the width of the vane skirt. The skirt profile is shown in Fig. 3. This profile minimizes the power deposited on the cavity walls.

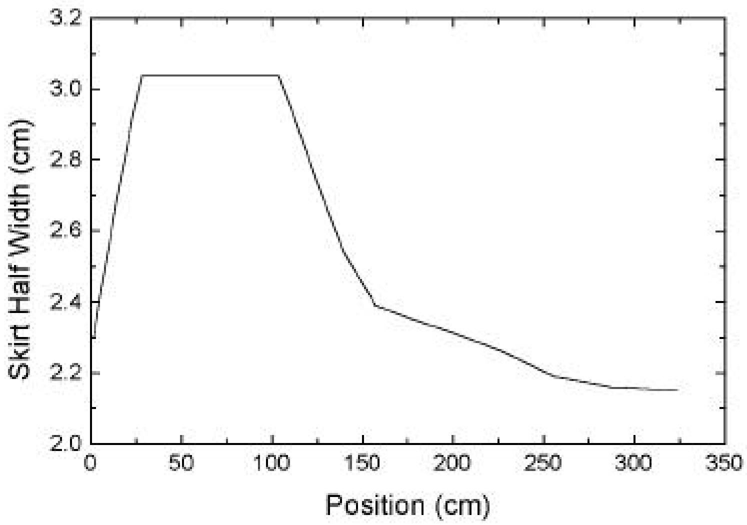

Figure 3. Vane skirt width variation.

In general, most of the RFQ structure can be understood in a two-dimension model. However, the end regions and the joints need full three-dimensional modelling. These regions have been investigated with the three-dimensional electromagnetic code, MAFIA [6]. Fig. 4 shows a three-dimensional simulation model of the end region of the RFQ. The end-gap distance and undercutting depth were varied until the quadrupole mode frequency of the model was tuned to 350.3MHz. In this case, the end-gap distance and undercutting depth are 7.5cm and 2.7cm, respectively. Fig. 5 shows MAFIA model of a two-section coupled RFQ. The simulation result has shown that a 0.205cm coupling gap-distance, a 2.5cm undercutting depth and a 5.2cm coupling plates inner radius results in a near optimum separation between the quadrupole modes. Resonant coupling by the coupling plate provides a longitudinal field stabilization and a stop band in the dipole mode dispersion curve around the frequency of the RFQ. This stop band improves the transverse stability of the RFQ by eliminating dipole modes close to the frequency of the quadrupole mode TE210.

In the design of the coolant passages, we considered the thermal behaviour of the vane during CW operation and manufacturing costs. The thermal and structure analysis is studied with SUPERFISH [7] and ANSYS codes. 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 this heat, we consider 48 longitudinal coolant passages in each of the sections, as shown in Figs. 6 and 7. Fig. 6 shows a thermal distribution of the cavity at the high energy end. The material is oxygen-free high-conductivity copper (OFHC). The thermal loads was given by SUPERFISH analysis. The heat transfer coefficients are between $11 kW/m^2$-C to $15 kW/m^2$-C. Because of the flow erosion of the coolant passages, we consider

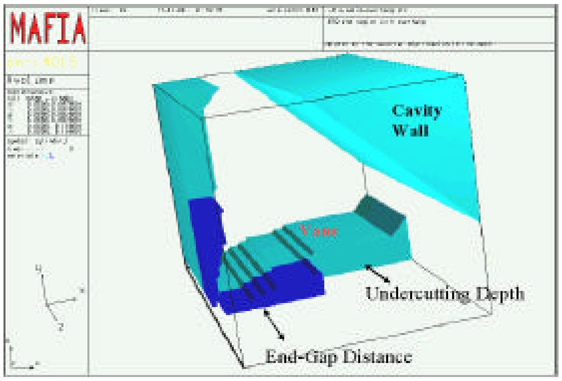

Figure 4. 3-dim. simulation model of the end region.

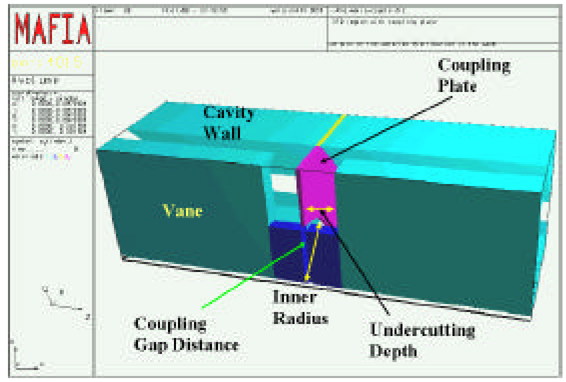

Figure 5. 3-dim. simulation model of a two-section coupled RFQ.

the maximum allowable bulk velocity of the coolant as 4.5m/sec. From the thermal-structural analysis of ANSYS, the peak temperature on the cavity wall is 51.4 °C, the maximum displacement is 42 μm as shown in Fig. 7 and the intensity stress is 13MPa. We use the cooling tower on the cavity walls and the refrigeration system on the vane area. For rf tuning, the coolant passages on the vane area are operated with 10 °C coolant. The RFQ cavity wall and all of the systems interfacing through the cavity wall are cooled with temperature controlled water. By manipulating the cavity wall water temperature, the vane tip gap will either increase or decrease based on whether the cavity wall diameter grows or shrinks, thus manipulating the rf resonant frequency. The coolant passages in the cavity wall and vane area are the deep-hole drilled. The entrances of deep holes at the vane end are brazed.

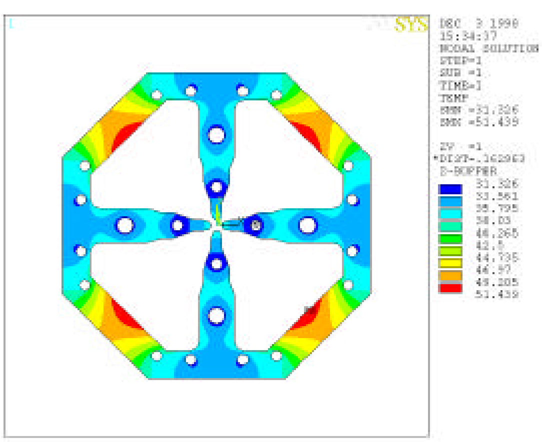

Figure 6. Temperature distribution of a cavity at the high energy end of the RFQ.

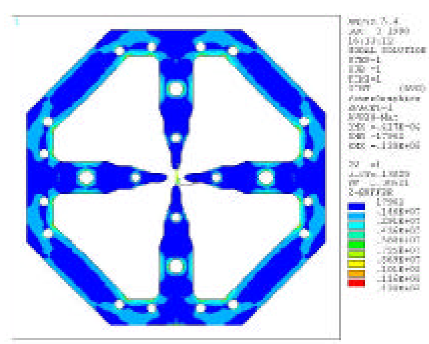

Figure 7. Displacement of a cavi쇼 at the high energy end of the RFQ.

III. Fabrication Status

A full-scale (324cm long), low-power, KOMAC/KTF RFQ cold model was fabricated with Al6063 and used to verify structure tunability and to conform the details of the vane undercuts. as shown in Fig. 8.

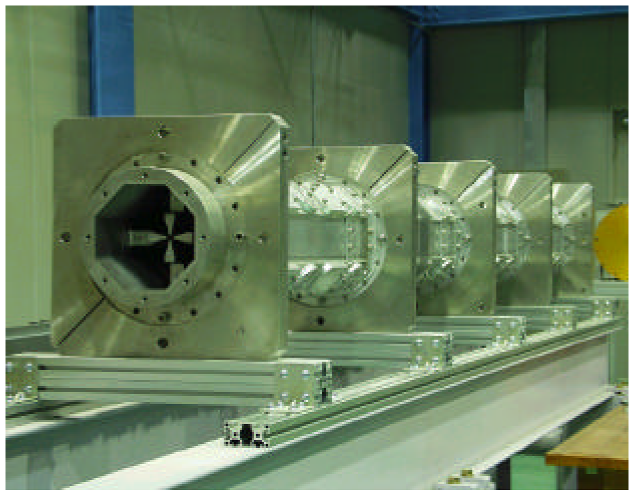

Figure 8. The KOMAC/KTF RFQ cold model with Al6063.

The four quadrants of the RFQ are fabricated with oxygen-free-high conductivity -copper (OFHC) separately and brazed. This method produces a monolithic cavity which has high structural efficiency and serves as an integral vacuum vessel and has an advantage which is able to reduce both cost and schedule. Because of the leak of the brazing surface and the strain of the RFQ structure by the furnace heat, it is important to determine the exact shape

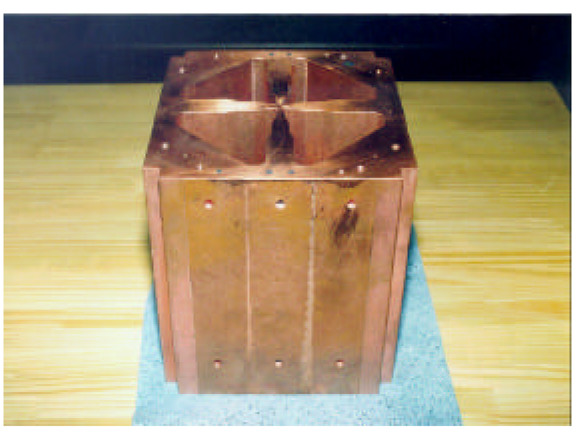

Figure 9. A 25cm-long engineering model.

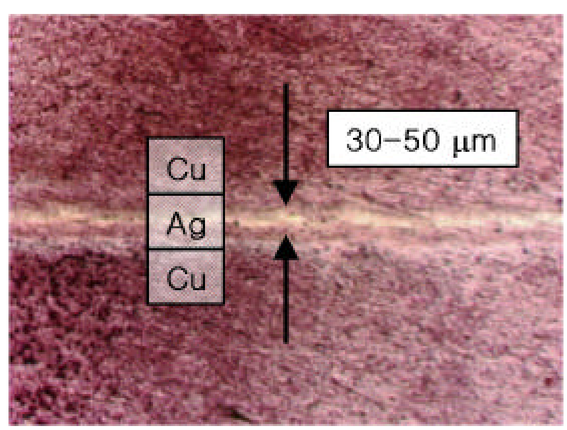

Figure 10. A cutting surface of an engineering model.

of brazing area [8]. After brazing, it is determined that the mechanical alignment has not changed more than 0.025 mm and the resonant frequency has changed less than 90 kHz. The brazed joining concept was tested on a 350MHz, 25cm-long engineering model, as shown in Fig. 9. The alloy used to form the longitudinal joints, LUCAS BVag-8, flows freely over copper surfaces and these joints could be assembled copper to copper. The alloy was supplied from wire placed into grooves. Thus it was not necessary to compensate for the thickness of the alloy in the mechanical alignment and RF measurements. Fig. 10 shows a cutting surface of a brazing surface of the engineering model. A penetration depth of alloy is in the ranges of 30- and 50-μm. At the present time, one of the four sections have been completed and machining of components of the remaining three sections is underway. Section 1 completed is shown in Fig. 11.

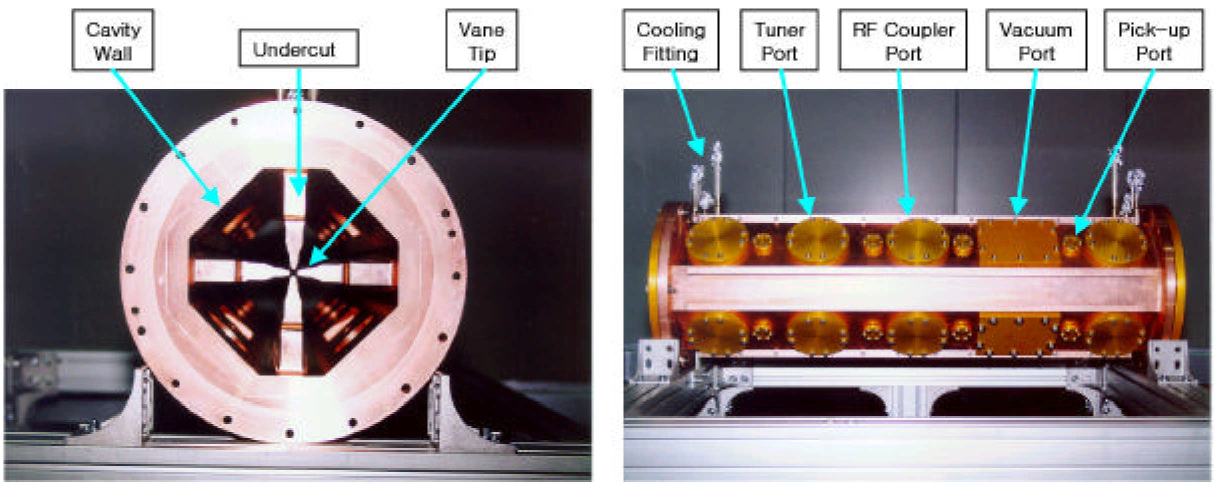

Figure 11. KOMAC/KTF RFQ section 1 after a vacuum furnace brazing.

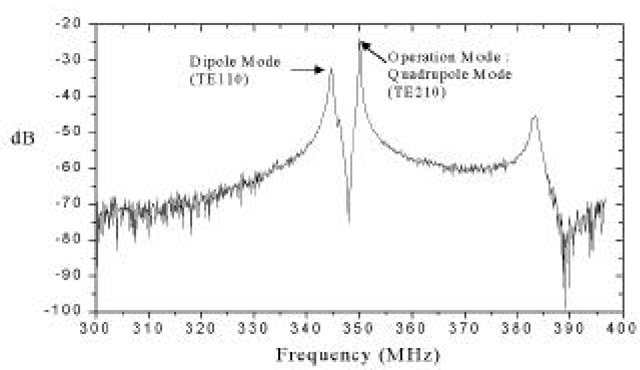

Figure 12. RFQ modes in the section 1.

Fig. 12 shows RFQ modes in a section 1. An operation mode of the KTF/RFQ is quadrupole mode, TE210. The quadrupole mode frequency is very nearly equal to the design mode, which means that the vane undercuts on the low energy end are correct.

IV. Summary

The design and fabrication tasks were partly carried out at KAERI, and the original schedule was adhered to. The brazed-RFQ concept was completed.

V. Acknowledgment

We are grateful to Dr. Y. Oguri at TIT, Dr. Kazuo Hasegawa at JAERI, Dr. Lloyd M. Young at LANL, Mr. B.H Lee and Mr. L.H Whang at KME, and Mr. D.S. Lim at DUE. This work has been supported by the Korea Ministry of Science and Technology (MOST).

VI. References

[1] C. K. Park et al., "The KOMAC Project: Accelerator and Transmutation Project in Korea", Proceeding of APAC98, Tsukuba, (1998).

[2] B. H. Choi, "KOMAC", OECD NEA Workshop, (1998).

[3] J. M. Han et al, "Design of the KOMAC H+/H- RFQ Linac", Proceeding of LINAC98, Chicago, (1998)

[4] Y. S. Cho et al., "Conceptual Design Study of KOMAC DTL", Proceeding of APAC98, Tsukuba, March 23-27 (1998) .

[5] Y. Oguri et al., "Beam Tracking in an RFQ Linac with Small Vane-Tip Curvature", Nuclear Sci. Tech., 30, 477 (1993).

[6] R. Klatt et al., "MAFIA-A Three-Dim. Electromagnetic CAD System for Magnets, RF Structures, and Transient Wake-field Calculations", SLAC-303, 276 (1986).

[7] J. H. Billen and L. M. Young, "POISSON/SUPERFISH", LA-UR-96-1834 (Revised December, 1997).

[8] D. Schrage et al., "A New RFQ Linac Fabrication Technique", LA-UR-94-2483, (1994).