Design of a Variable Frequency RFQ Linac for the RILAC

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Abstract

A variable frequency RFQ has been designed for a new injector of the RIKEN heavy ion linac (RILAC). It will accelerate ions with a range of M/q = 5 - 28 up to 450 keV/q in the CW mode. The operational frequency will be varied between 16 MHz and 40 MHz. A compact cavity having a wide frequency-tunable range is proposed adopting "double-coaxial" structure and a moving short. A 1/3-scaled model is now under construction.

I. INTRODUCTION

The RIKEN heavy ion linac (RILAC) is the frequency-tunable linac which can accelerate ions with a range of M/q = 5 to 28 up to 16 MeV/q, by varying its operational frequency between 17 and 43 MHz [1]. A 500 kV Cockroft - Walton accelerator with an ECR ion source (ECRIS) [2] on its high-voltage platform has been used as the injector of the RILAC. This ECRIS is equipped with permanent magnets for the mirror magnetic field to reduce power consumption, and its operational frequency is set to be 8 GHz.

Recently, a plan has been proposed to upgrade heavy ion beam currents for the RILAC [3]. Although an ECRIS operated at a frequency of more than 14 GHz would provide more intensive beams [4], it cannot be installed on the high voltage platform for the power consumption problem. Thus an alternative injector is required. Considering the high beam transmission efficiency and the compactness, an RFQ would be suitable for the new injector.

One of the most important problems to be solved in the construction of the RFQ is the frequency-tunability in the RILAC frequency range. Moreover the RFQ has to be operated in the CW mode. Up to now, very few structure has been proposed which satisfies these requirements.

This report will discuss the conceptual design of the vane and the cavity of the RFQ.

II. VANE DESIGN

The vanes are divided into six sections according to the design method developed at INS [5]: By use of the computer codes GENRFQ and the modified version of PARMTEQ, the vane parameters have been determined to obtain the high beam transmission efficiency and the short vane length.

The key parameters are listed in Table 1. The extraction voltage of the ion source is assumed to be 10 kV. A considerably small value of the intervane voltage V = 33.6 kV is sufficient to get the final energy of 450 keV/q. This would be substantial for the CW operation of the RFQ.

Table 1. Key parameters of the RFQ

Vane length	142 cm
Frequency	40 MHz
M/q	5
Incident energy	10 keV/q
Output energy	450 keV/q
Intervane voltage (V)	33.6 kV
Normalized emittance	0.03 π cm-mrad
Minimum bore radius	0.417 cm
Maximum modulation	2.7
Focusing strength (B)	6.80
Max. defocusing strength	- 0.30
Final synchronous phase	- 25 deg.
Transmission (0 mA)	96 %

III. CAVITY DESIGN

Figure 1 shows a schematic drawing of the RFQ cavity. The cavity is a rectangular box with the size of 70 cm × 70 cm × 150 cm. The horizontal vanes are supported by the cavity wall on their ends. The vertical vanes are equipped on the inner surfaces of a rectangular tube which surrounds the horizontal vanes. This tube is supported by ceramic insulators placed on the bottom of the cavity. A stem hanging on the top of the cavity is contacted with the rectangular tube. A moving short is placed surrounding the stem, which varies the resonant frequency.

The magnetic flux of the fundamental mode has the profile illustrated in Figure 2. The flux surrounding the rectangular tube has the same direction as that inside the tube, and they are smoothly joined at the end of the tube. If the cavity is separated into two parts, it would be recognized that this structure consists of two coupled coaxial lines: One is made up with the horizontal vanes and the rectangular tube, and the other is made up with the tube and the cavity wall (Figure 3(a)).

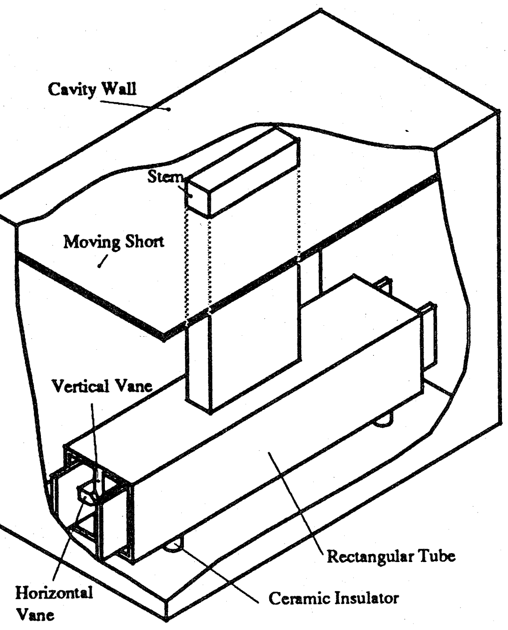

Figure 1. Schematic drawing of the RFQ cavity.

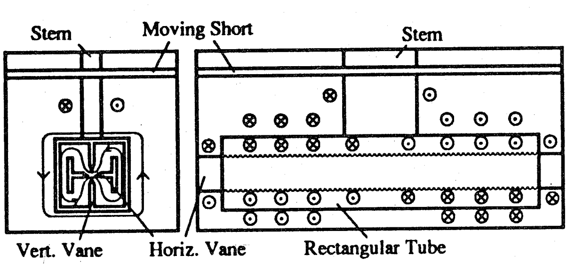

Figure 2. Magnetic flux of the fundamental mode.

This "double-coaxial" structure enables us to obtain considerably low resonant frequency of the fundamental mode with small size of the cavity. As shown in Figure 3(b), this structure is equivalent to that of a coaxial cavity whose wave impedance at the short end is larger than that of the open end. The resonant frequency of such cavity is known to be lower than that having the same wave impedance over the whole length. Moreover, since the moving short lies in the range where the wave impedance is large, the frequency can be varied over a wide range. In fact, the calculations using the computer code MAFIA have shown that the resonant frequency of the fundamental mode can be varied between 16 MHz and 40 MHz, by changing the position of the moving short only by 350 mm. The calculated Q-values are 8000 at 17 MHz and 3000 at 40 MHz.

We have carried out a measurement to examine the resonant frequency and the field distribution of the double-coaxial structure, for a test cavity as shown in Figure 4. The measured resonant frequency was in good agreement with the MAFIA calculations. The electric field distribution of the fundamental mode is flat along the acceleration axis, as shown in Figure 5. Thus this structure would be suitable for the RFQ cavity.

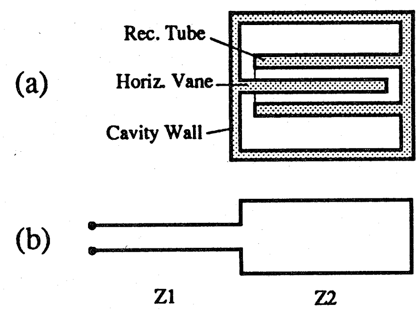

Figure 3. Conceptual drawing of the half of the RFQ cavity (a) and its transmission-line approximation (b). Z1 is the wave impedance of the coaxial line made up with the horizontal vanes and the rectangular tube, and Z2 is that with the rectangular tube and the cavity wall. In our design Z1 is about 10 Ω and Z2 is about 100 Ω.

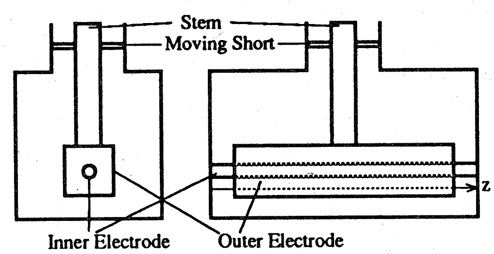

Figure 4. Schematic drawing of the test cavity.

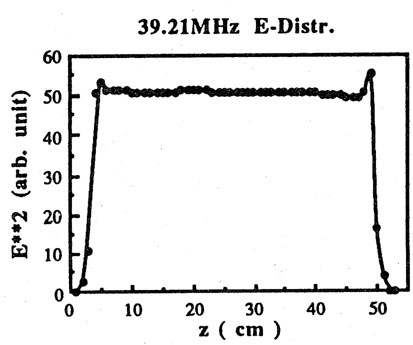

Figure 5. Electric field distribution between the inner and the outer electrode of the test cavity. The abscissa (z) is indicated in Figure 4.

Now a structure without ceramic insulators is under consideration. Also, a 1/3-scaled model is under construction for the cold test of the cavity.

IV. SUMMARY

An RFQ Linac has been designed for a new injector of the RIKEN heavy ion linac (RILAC). It will provide ions with a range of M/q = 5 - 28 of the maximum energy of 450 keV/q in the CW mode. Its frequency range will cover 16 - 40 MHz. The "double-coaxial" structure has been proposed for the RFQ cavity. Measurements using a simple test cavity have shown that this structure is suitable for the low frequency RFQ. A 1/3-scaled model is now under construction.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

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