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DESIGN PARAMETERS AND RF PROPERTIES OF 433.3MHZ PROTON RFQ LINAC AT ICR

H.Okamoto, M.Sawamura, Y.Iwashita, K.Fukunaga, M.Inoue and H.Takekoshi
Institute for Chemical Research, Kyoto University
Awataguchi-Torii-cho, Sakyo-ku, Kyoto, 606, Japan

ABSTRACT

A 433.3-MHz proton radio frequency quadrupole(RFQ) linac was constructed at Institute for Chemical Research(ICR),Kyoto University.[1] The RF-properties of this linac were measured. Design procedure of RFQ fundamental parameters and the first results of the RF measurements are discussed. The axial field distribution was almost controlled by using the side tuners.

INTRODUCTION

A 7-MeV proton linac system[2),3),4)] is under construction at ICR and will be completed next spring. This linac is composed of a 2-MeV RFQ linac and an Alvarez DTL whose operating frequency is 433.3MHz. The RFQ linac had already been fabricated and the RF properties are being measured. A unique feature of the RFQ linac is constant-curvature vanetips including the correction to the variation of the intervane capacitance. Because of the high frequency, this RFQ linac is quite sensitive to the vane misalignment. Therefore twentyfour tuners are used to get a good RF field distribution.

In this paper the design procedure for the fundamental parameters of this RFQ linac is discussed. The first results of RF measurements are also described.

RFQ DESIGN PROCEDURE

General view of RFQ linac is shown in Fig.1. RF power is fed by loop coupler. Six side tuners are installed in each quadrant and the end tuners are inductive tuners. The parameter search process, vane machining method and vane cooling problem are discussed below.

PARAMETER SEARCH[5),6),7)]

The specifications of the fundamental parameters of this RFQ linac are following;

(1) accelerating particles : H^+,H^-
(2) operating frequency : 433.3MHz
(3) energy : 50keV(input)- 2MeV(output)
(4) output current : 50mA(peak)

In addition to these conditions next two demands have been considered.

(A) the vanes are cut by 2-dimensional process with a concave cutter
(B) overall length of the cavity is about upto two meters

Main parameters were searched by using computer code "PARMTEQ". The cell number of radial matching section is ten.[8)] In buncher section, fundamental parameters were searched in consideration of demand-(A). The main parameters obtained by PARMTEQ simulation are shown in Table 1.

operating frequency (MHz)	433. 3
kinetic energy (MeV)	0. 05～2. 0
vane length (cm)	219. 48
cavity diameter (cm)	17. 04
characteristic radius (mm)	2. 999
min. bore radius (mm)	1. 99
max. modulation	1. 90
focusing strength	4. 54
intervane voltage (kV)	80
transmission efficiency (normalized emittance of input beam : 0. 7π mm·mrad)	
99% (0mA) 95% (30mA) 88% (60mA)	

Table 1 RFQ main parameters

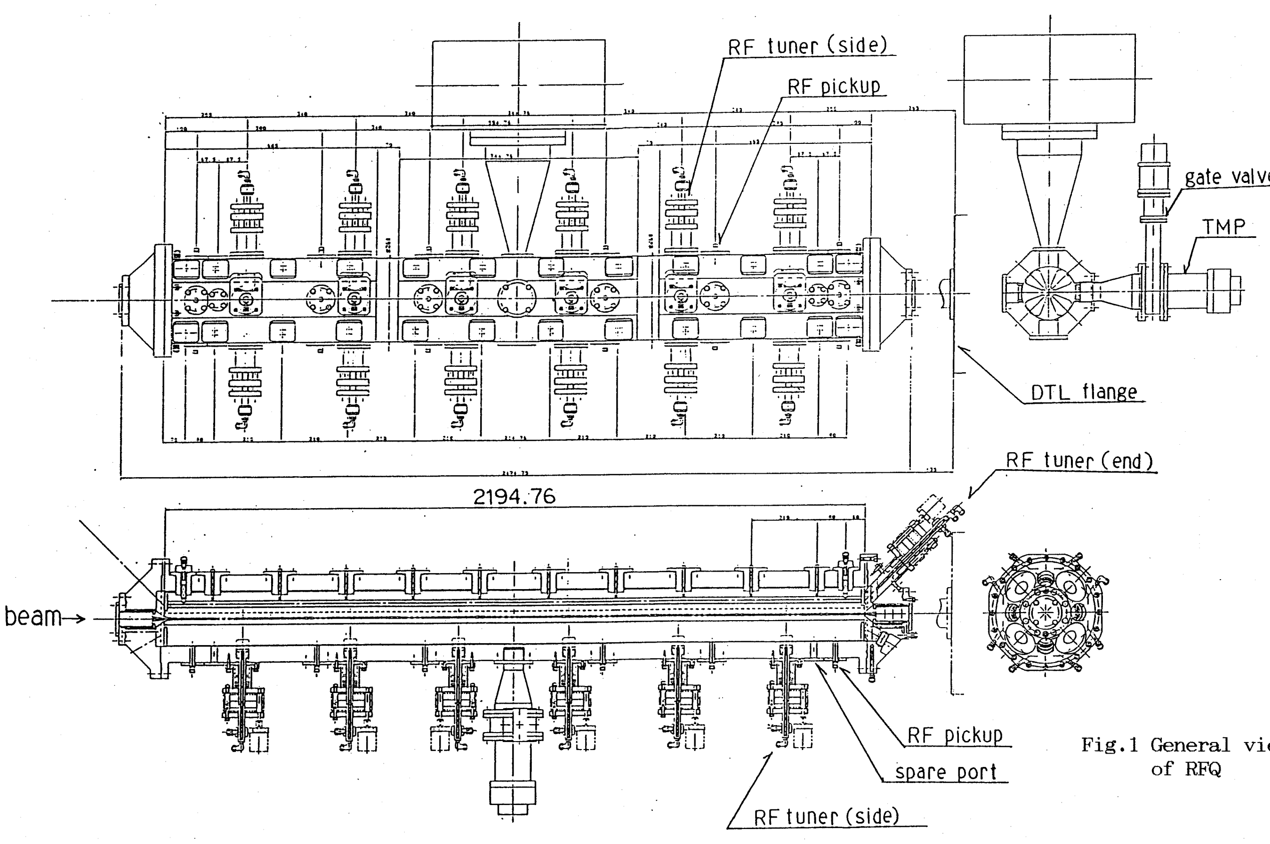

Fig.1 General view of RFQ

VANE MACHINING

In order to make easy machining, we adopted two dimensional vane cutting process. Therefore the transverse curvature of the vanetip becomes constant. In our design the curvature is equal to the average bore radius r_0. The cell averaged intervane capacitance(pF/m) is varied longitudinally due to the modulation change of the vanetip. According to SUPERFISH culculations, the frequency will rise as modulation increases. It comes from the capacitance decrease at the vanetip. The electric field was calculated as a two dimensional electrostatic boundary problem by boundary element method. The assumption of two dimensional problem is good when the cell length is large enough compared to the modulation size. The shape of the problem is shown in Fig.2. Capacitance and potential on axis on the circle of r=1.5mm were evaluated. Fig.3 and Fig.4 shows the capacitance contour and the potential contour on axis as a function of x and y respectively. According to this figure the capacitance will be almost kept constant if Δx and Δy satisfy the following relation;

$$\Delta y=-(\Delta x+\Delta x^2/5) \quad (\text{for } -1\text{mm}<\Delta x<0\text{mm}) \qquad (1)$$

Due to this correction the modulation size becomes a little smaller than the original size. But the difference of the accelerating field between before and after the correction is small as shown in Fig.4.

VANE COOLING

The total peak RF power dissipation is estimated to be about 500kW by SUPERFISH calculation. About two-thirds of the power is dissipated on the vane wall. A temperature rise of the RFQ vane caused by RF power dissipation was calculated by boundary element method.

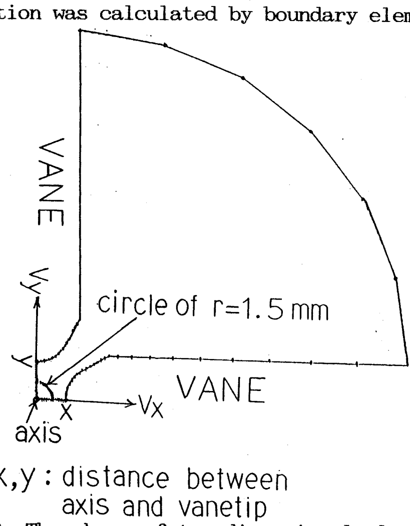

Fig.2 The shape of two dimensional electrostatic boundary problem

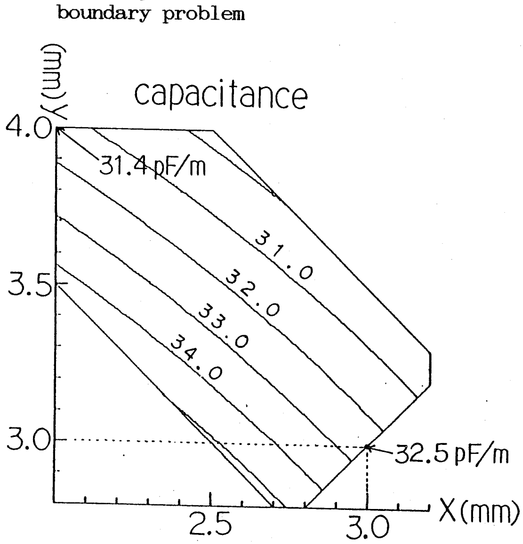

Fig.3 The capacitance contour as a function of x and y

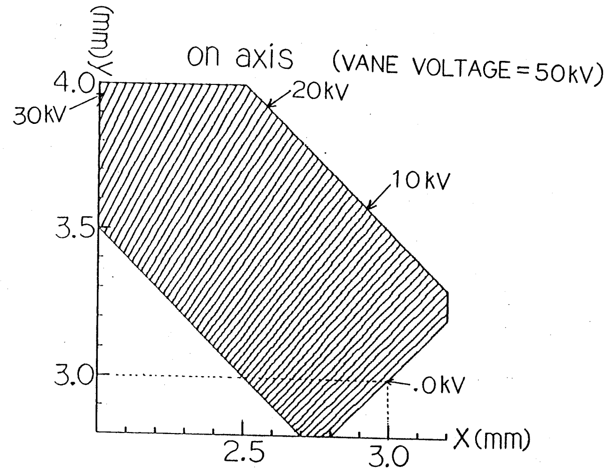

Fig.4 The potential contour on axis

The 20-mmϕ cooling passage is located at 50mm from the cavity axis. The temperature distribution on the vane surface is shown in Fig.5 when 30°C water is flowing at a speed of four meters per second and the vane voltage is 40kV. The difference of the temperature on the vane is small enough.

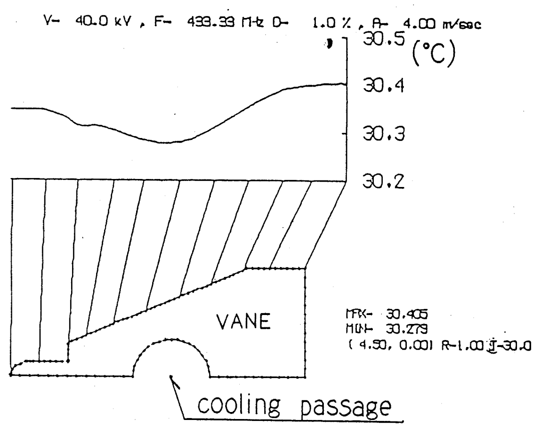

Fig.5 The temperature distribution on RFQ vane cooled by single cooling passage of 20-mm diameter

FIELD DISTRIBUTION

Electric field distributions were measured along the vane-to-vane gap in every quadrant with the bead perturbation method. 4mm diameter plastic bead was moved midway between the adjacent vanes at 13mm from the beam axis as shown in Fig.6. Around this position the electric field variation is small according to the SUPERFISH calculation, so the electric field errors due to the bead position errors were thought to be small.

Magnetic field distributions were measured with the twenty-four pick-up loops in the cavity. As the measured electric and magnetic field distributions agreed within about 3% errors, the pick-up loops were used to adjust the longitudinal field distributions in each quadrant in order to save the measuring time.

Six side-tuners were installed in each quadrant to adjust the field distributions. All side-tuners were set at the same level from the inner wall of the tank at first. The field distributions were distorted in the quadrant with the drive loop and in the opposite side as shown in Fig.7. The frequency of Q_0 (TE_{210}) mode was 430.2MHz and one of D_1 (TE_{111}) mode was 429.1MHz. This distribution can be obtained by the mode mixing of Q_0 and D_1 as shown in Fig.8. It is expected that small mode separation makes mode mixing strong and the sensitivity to perturbations (misalignment etc.) large. The side-tuners were adjusted to achieve large mode separation, and almost flat distributions were achieved

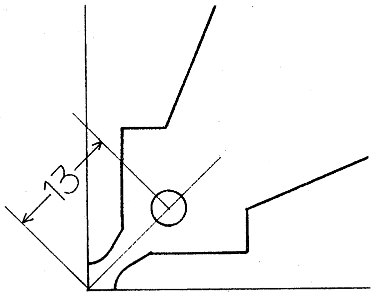

Fig.6 Bead position for bead perturbation method

except the vane ends. Finally the end noses were changed and the almost flat distributions along the cavity were achieved as shown in Fig,9. The frequency of Q_0 mode was 432.3MHz and one of D_1 was 426.4MHz. Large mode separation was obtained.

In these measurement the field strength between different quadrant could not be precisely compared because the electric circuit of the signal pick-up was not symmetric.

In the last measurement the distance between the end nose and the vane of the upstream was so short that the voltage breakdown would occur at high power operation. The structure of the end nose and the end plate are planned to be improved.

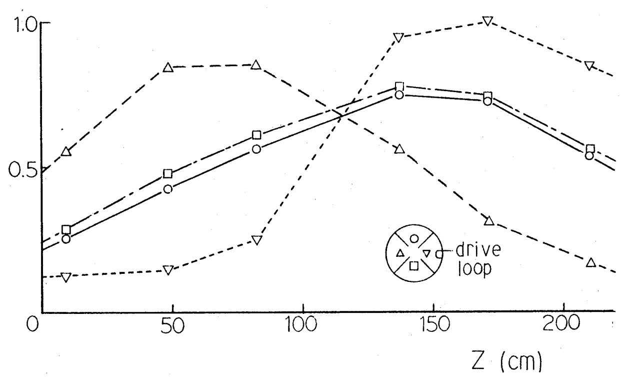

Fig.7 Field distribution in the cavity before adjustment

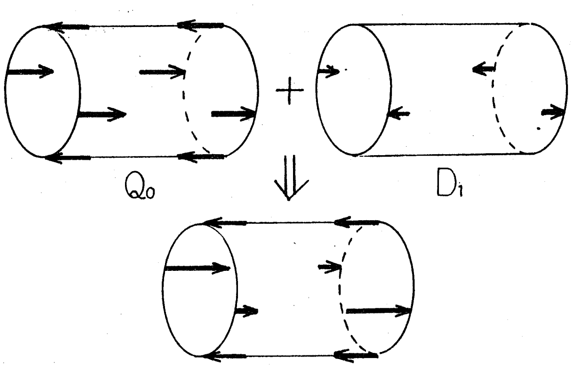

Fig.8 Mode mixing of Q_0 and D_1 mode. Arrows represent the magnetic flux

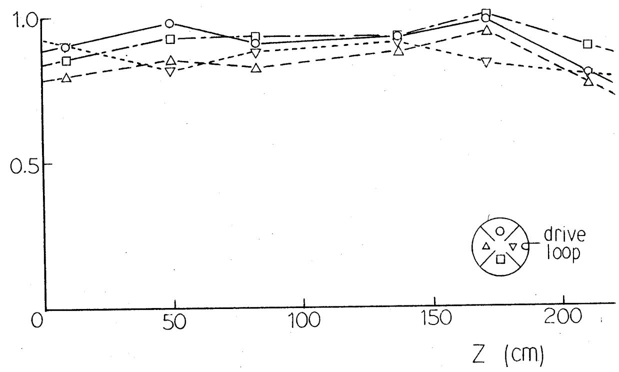

Fig.9 Field distribution in the cavity after adjustment

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