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THE TUNING RF PARAMETERS OF 40 MHz RFQ

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Abstract

The new linac for ions with mass(A)-to-charge(Z) ratio 8 (A/Z=8), output energy 4 MeV/u and 10 mA current is under development at NRC "Kurchatov Institute"-ITEP. The linac consists of Radio-Frequency Quadrupole (RFQ) and two sections of Drift Tube Linac (DTL).

The 40 MHz 11 meters long RFQ is based on a 4-vane structure with magnetic coupling windows [1]. The paper presents results of tuning radio-frequency (RF) RFQ parameters.

INTRODUCTION

The cavity with Radio-Frequency Quadrupole is wide used as an initial part of ion linac [2, 3].

The RFQ accelerating structure is based on H-cavity with four electrodes with modulated tips. Each electrode has one or few coupling windows. In order to minimize field non-uniformity the coupling windows shifted in vertical electrodes line related to horizontal electrodes line (or vice versa) [1]. Thus, the RFQ linac could be divided on odd number separated identical sections with similar RF parameters (front/end sections have an input/output gaps).

The results of RF tuning of the RFQ linac which is under development in NRC "Kurchatov Institute"-ITEP are presented in this paper.

THE RFQ LINAC

According to particles dynamics simulation the RFQ should has vanes length equals to ~11 m, average aperture radius R_0 = 12.5 mm, vane tip radius R_e=0.8* R_0 = 10 mm and operates at f_0 = 40.625 MHz. The RFQ cavity consists of 1000 mm long 11 identical sections and input/output flanges. The shifted windows structure was chosen for RFQ linac. The windows` areas were chosen as bigger as possible in order to minimize the cavity`s inner diameter [4]. The regular RFQ section is shown on Fig. 1. The main dimensions and RF parameters are presented at Tables 1 and 2, correspondently.

THE RFQ LINAC RF PARAMETERS TUNING

It should be mentioned that:

1. All further explanation was done for ideal model;
2. All describing methods of RF tuning have an influence to resonant frequency as well as field distribution.

The RFQ Linac RF Parameters Tuning Under Manufacturing Stage

The simulated RF parameters and measured one could be different to each other because of various reasons such as manufacturing or simulating errors. Thus, in RFQ linac design the special elements which could be modified at manufacturing stage should be provided.

The coupling window (area of coupling window) is the simplest element to be modified at manufacturing stages. It was tried out in [5]. The face of coupling window which could be modified is shown on Fig. 1.

The simulation has shown that resonant frequency has a linear relationship at coupling window`s height as it is shown at Fig. 2. The gradient is equal to $\Delta f / \Delta h =$ -45 kHz/mm. The same simulation was done for coupling window`s length. In this case the gradient is equal to $\Delta f / \Delta l =$ -90 kHz/mm.

Changing the coupling window`s height seems more simple and more precisely compared to changing coupling window`s length.

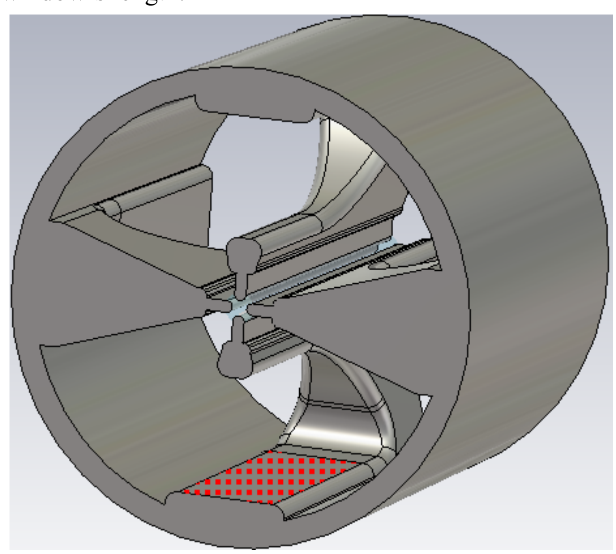

Figure 1: The regular RFQ section (the area for modification is highlighted with red).

Table 1: The Main Dimensions of RFQ Sections

Parameter	Value (mm)
Cavity inner diameter	860
Cavity length	1000
Vane base width	250
Vane base height	37.5
Vane top width	60
Vane window length	770
Vane window height	290
Vane tip height	30

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Table 2: The Main RF RFQ Parameters

Parameter	Value
Resonant frequency, MHz	40.625
Resonant frequency of the dipole mode, MHz	53
Inter-vane voltage, kV	170
Self quality factor	14000
RF power losses, kW/m	44
Full RF power losses, kW	484

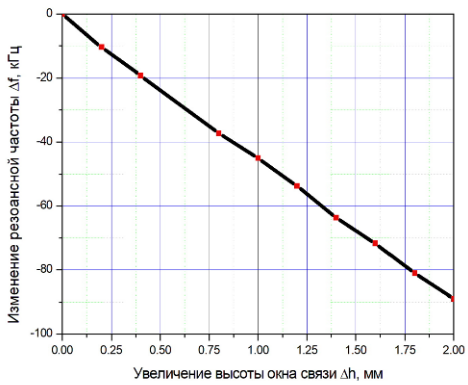

Figure 2: The resonant frequency to coupling window`s height dependence.

The RFQ Linac RF Parameters Tuning by Movable Plungers

The RF tuning of manufactured and assembled RFQ linac would be achieved by different plungers. Plungers should play two main roles – tuning the resonant frequency and change the RF field distribution. Plungers could have different geometry, be motorized or stationary.

The motorized plungers usually injected into cavity through side flanges and use for resonant frequency tuning [6] as it shown on Fig. 3. The resonant frequency relationship on plunger`s diameter and length is shown on Fig. 4. From Fig. 4 one can see that maximal resonant frequency changing is reached at Ø140 mm and $h$ = 120 mm plunger`s diameter and length, correspondently.

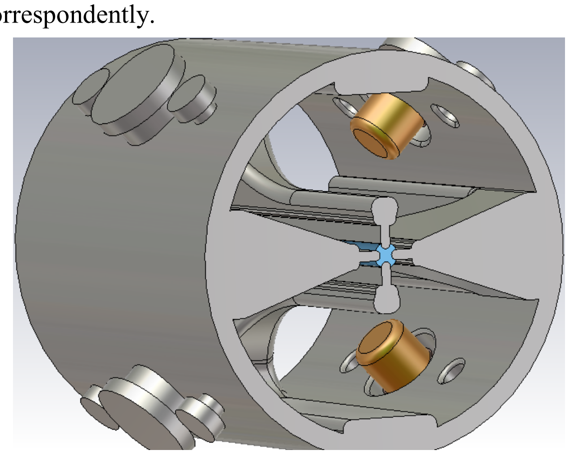

Figure 3: Plungers injected through side flanges.

The plungers which were injected into the RFQ cavity also have an influence to RF field distribution. As an example, four cylindrical plungers with diameter 140 mm and length 100 mm injected into first cell would lead to non-uniformity RF field up to δE = 5% and resonant frequency change Δf = 22 kHz. In order to compensate RF field non-uniformity the additional plungers should be injected into central (four plungers) and last sections (four plungers). In this case, the non-uniformity of the RF field would be decreased to δE = 2.4% while resonant frequency would be changed up to Δf = 65 kHz (see Fig. 5).

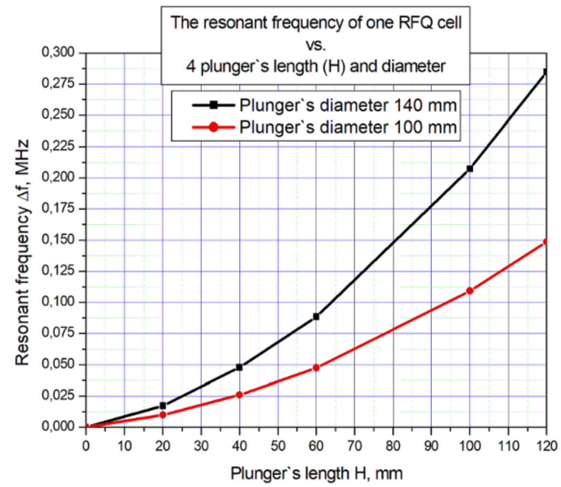

Figure 4: The resonant frequency dependence on plunger`s diameter and length.

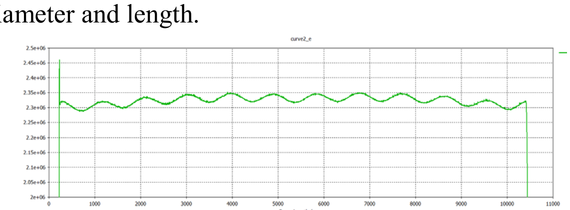

Figure 5: The non-uniformity of the RF field with 4 plungers in the first, last and central sections.

The RFQ Linac RF Parameters Tuning by Stationary Plungers

The rational way is to place stationary plungers inside the cavity do not occupy the side flanges. As an example, the stationary plungers could be made as blocks and mounted inside the coupling windows (see Fig. 6).

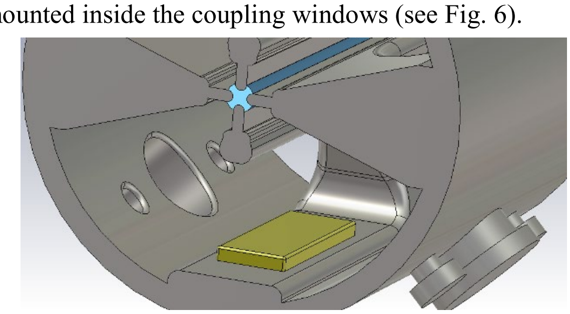

Figure 6: Plunger mounted inside the coupling window.

The dependence of the resonant frequency changing vs. dimensions of four stationary plungers mounted inside the coupling windows is shown on Fig. 7. One can see that

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maximum frequency changing is equaled to $\Delta f = 1.8$ MHz and achieved with plunger`s L*W*H = 400*150*100 mm.

If four stationary plungers mounted in the first section the RF field non-uniformity would be rise up to $\delta E = 12\%$ (see Fig. 8) while frequency changing doesn`t exceed $\Delta f = 66$ kHz. In order to compensate such non-uniformity the additional four stationary plungers (in each section) should be mounted in the last section and in two sections nearby central. In this case the non-uniformity of the RF field would be worse than $\delta E \leq 5\%$ while frequency changing $\Delta f = 272$ kHz (see Fig. 9).

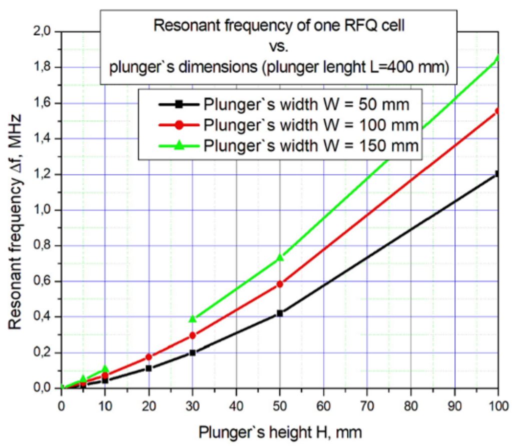

Figure 7: The resonant frequency dependence on plunger`s dimensions.

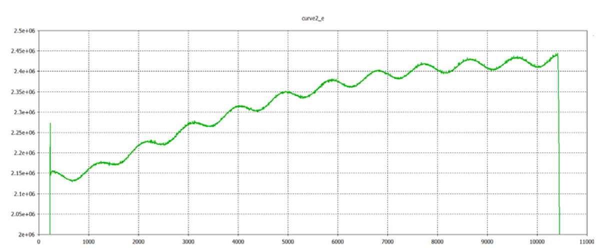

Figure 8: The non-uniformity of the RF field with 4 stationary plungers in the first sections.

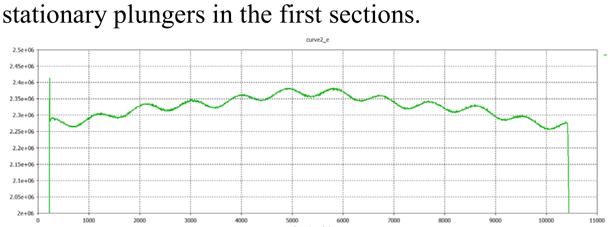

Figure 9: The non-uniformity of the RF field with 4 stationary plungers in the first, last and two nearby central sections.

CONCLUSION

Based on simulation the next conclusion could be done:

1. The RFQ linac design should have elements which could be modified after primary cavity assembling and RF parameters measurement. Particularly, increasing coupling windows lead to decreasing resonant frequency. Thus, RFQ linac design should have a smaller coupling windows compared to simulated one;
2. It is appropriate to tune RF field distribution by stationary plunger taking into account its influence to resonant frequency changing;
3. The motorized plungers should be used for Automatic Frequency Tuning system (AFT).

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