BEAM DYNAMICS INVESTIGATIONS FOR 433 MHZ RFQ ACCELERATOR

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Abstract

Modeling results for deuteron dynamics in RFQ structure with operational frequency 433 MHz and 1 MeV output energy are presented. The results are compared with experimental data. The purpose of investigation is to find optimal input RFQ emittance parameters for off-nominal values of input current and vane voltage.

INTRODUCTION

There are presented theoretical and experimental results of researches short length 1 MeV, 433 MHz RFQ which is part of RF neutron generator (NG). Description of this RFQ was given in article [1] where were discussed problems design and tolerances under manufacturing of such resonator. In [1] installation was considered with ECR deuteron (D^+) source and forming beam system including electrostatic preacceleration, focusing solenoid, electromagnetic correctors and electrostatic focusing lens before RFQ entrance. Later injection system was changed because D^+ source don't permit to obtain required beam emittance on RFQ input. The new injection system have multicusp D^- ion source and it is shown on fig.2 together with RFQ and foil monitor which was used for energy measuring during NG testing.

RFQ DESIGN

RFQ design was based on following main parameters presented in table 1.

Table 1: Initial parameters for RFQ design

Frequency	433 MHz
Ions	$D^{\pm}$
Output beam energy	1 MeV
Output pulsed current	10 mA
Output average current	10 mkA
Input beam energy	25-30 keV
Input beam current	≥10 mA
Maximal surface gradient	≤2xKP

Items 2-5 are determined by use of NG for its proper purposes; item 6 is determined by requirement of small gabarits of feed system; item 7 take into account possible loss of beam; item 8 is determined by requirement of absence of electrical break-down. Calculated RFQ parameters are given in table 2.

Table 2: Calculated RFQ parameters

Beam injection energy	25 keV
Beam output energy	1 MeV
Input pulsed current	13 mA
Output pulsed current	10 mA
Input phase length of bunches	360°
Output phase length of bunches	36°
Input beam synchronous phase	-90°
Output beam synchronous phase	-23.4°
Average channel radius	1.8 mm
Minimal radius	1.18 mm
Intervane voltage	50 kV
Vane length	1090 mm

Data of tables 1, 2 may be added experimental results, obtained during tests and working of NG.

Assembling of four-vanes RFQ was made with high accuracy. Difference of distances between adjacent vanes not more 10 mkm (see fig. 1). Vane modulation was roduced with an accuracy of 2…5 mkm Measured quality factor is 6800. It value was provided by good in quality of machining of four-cavity RFQ surfaces. Maximal measured vane voltage without breakdown under testing is 70 kV. Deviation of electrical field tensity from average value along RFQ length is ±5%.

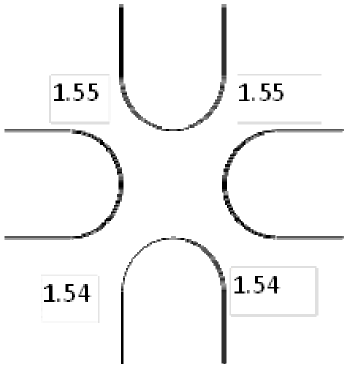

Figure 1: Distances are given in mm between vanes.

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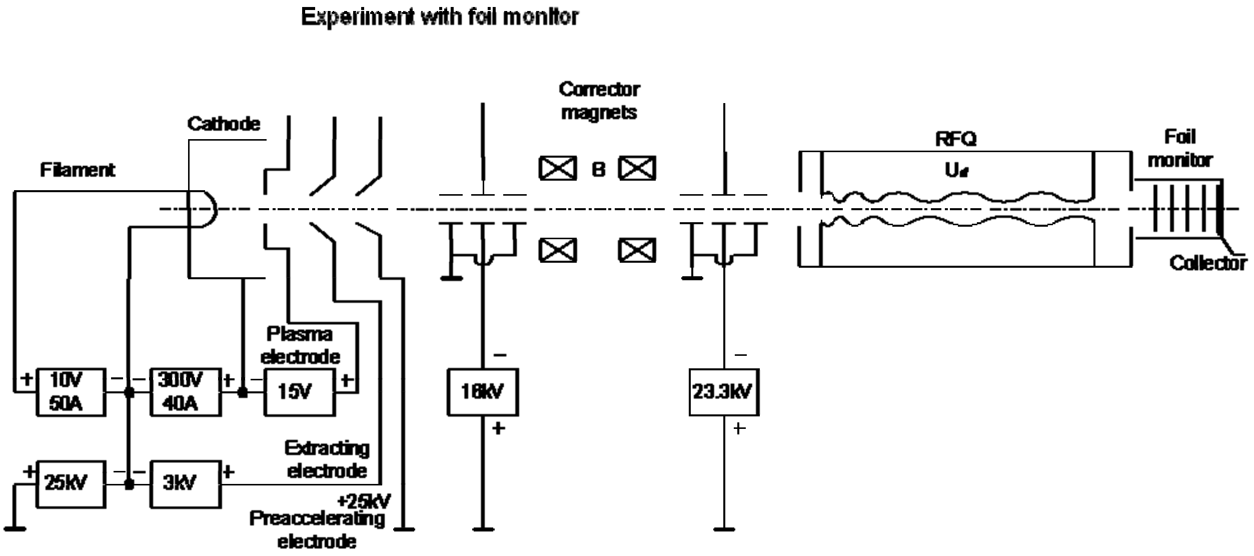

Figure 2: The new injection system together with RFQ and foil monitor.

DYNAMICS PROBLEM

Initial design of RFQ usually supposes dynamics calculation with vane geometry what is known as "ideal" or hyperbolic modulation. "Real" vane's modulation is produced by machine tool and can differ from "ideal" one. Output beam characteristics depend on voltage vane, value and orientation of beam phase volume in phase space. In our calculations three of types of vane's modulation take place. "Ideal" vanes with special match section had places where intensity of electrical field was more than 2KP. Smoothed out "ideal" vanes which satisfy conditions of table 1. Third type is "real" vane modulation which formed by manufacturing process. Below one may see calculation results for different vane types and orientation of beam phase volume in phase space (convergent and divergent beam). Now NG is working with cyclotron multicusp D- ion source which have small enough output current 2..2.5 mA so one consider two possibilities of calculation: nominal output RFQ current 10 mA and variant with input RFQ current 2 mA.

In tables below:

Tr_acc - capture of particles into the acceleration (the number of accelerated particles that have reached the end of the channel to the initial total number of particles)

Ex,y - transverse rms-emittance of the output beam, cm • mrad

P – average total power of lost part of the beam, W

Data of table 5 in principle consistent with the experimental results obtained under NG tests.

Table 3: Calculation results (initial data from table 1, current on RFQ input – 14 mA, beam emittance 0.052π•cm•mrad)

U/U0	**Tacc**	**Ex,y**	**P**
	ideal smooth real	ideal smooth real	ideal smooth real
1	0.906	0.08	0.2
	0.900	0.08	0.17
	0.599	0.09	0.24
1.1	0.932	0.08	0.2
	0.923	0.08	0.20
	0.787	0.09	0.21
1.2	0.2	0.09	0.15
	0.20	0.09	0.19
	0.21	0.09	0.19
1.3	0.937	0.10	0.15
	0.929	0.09	0.19
	0.859	0.10	0.23
1.4	0.927	0.11	0.24
	0.924	0.11	0.22
	0.863	0.11	0.31

Table 4: Calculation results (initial data: current on RFQ input – 2 mA, emittance 0.03π•cm•mrad; “ideal” vanes; initial beam x,y=1.002 mm; dx/dz, dy/dz=-27.4 mrad; “real” vanes; initial beam x,y=1.386 mm; dx/dz, dy/dz=-49.6 mrad)

U/U0	Tacc ideal real	Ex,y ideal real	P ideal real
1	0.997 0.940	0.06 0.06	0. 0.
1.1	0.999 0.991	0.06 0.06	0. 0.
1.2	0.999 0.996	0.06 0.06	0. 0.
1.3	0.999 0.998	0.07 0.07	0. 0.
1.4	0.999 0.998	0.08 0.08	0. 0.

Table 5: Calculation results (initial data: current on RFQ input – 2 mA, emittance 0.03π•cm•mrad, “real” vanes, initial beam x,y=1.386 mm; dx/dz, dy/dz=+30 mrad)

U/U0	Tacc	Ex,y	P
1	0.580	0.13	0.14
1.1	0.698	0.14	0.16
1.2	0.764	0.15	0.16
1.3	0.791	0.16	0.16
1.4	0.791	0.17	0.18

CONCLUSION

- Results presented in table 3 for “ideal” and “smooth” vanes have small difference.
- On the contrary in our case difference between “ideal” and “real” vanes gives negative effect: transmission efficiency for “real” vanes is less than for “ideal” ones, because beam channel was calculated for “ideal” vanes.
- Increasing of vane voltage proves increasing of transverse RFQ acceptance, but beam turn out uncoordinated with channel. Transmission efficiency is increasing but less than in case of coordinate beam.
- According to table 5 in our case we have divergent beam in RFQ output. One may hope do better transmission efficiency of divergent beam with help of optimal match section as is shown in paper [2] and optimal tuning of focusing elements of beam forming system.

REFERENCES

[1] Yu.A.Svisunov, Yu.V. Zuev, D.A. Ovsyannikov, A.D. Ovsyannikov, “Development of 1 MeV compact deuteron accelerator for neutron generator,” Bulletin of St.Petersburg University, series 10, 2011, pp.49-59 (in russian).

[2] D.A. Ovsyannikov, “Mathematical Modeling and Optimization of Beam Dynamics in Accelerators,” TUZCH02, these proceedings.