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RESEARCH ON THE NEW CAVITY STRUCTURE OF RFQ ACCELERATOR WITH BENT VANES AT IMP *

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Abstract

A new cavity structure of RFQ accelerator with bent vanes has been proposed at IMP. The new structure can reduce the lateral dimension of the cavity and possesses simple cooling structure in the low frequency field. In this paper, the dynamics of an 81.25 MHz bent-vane RFQ has been designed as a prototype device of the bent-vane RFQ. The 2D EM simulation of the bent-vane RFQ has been performed. Detailed description is presented in this paper.

INTRODUCTION

Four-vane type and four-rod type are commonly used in radio frequency quadrupole (RFQ) linac structure. Four-vane type RFQ is mainly used in the high frequency field and four-rod type RFQ applies to the low frequency field prevailingly [1]. In continuous wave (CW) operating mode, it is necessary that RFQ structure should have a complete cooling structure so that it can fully cool the RFQ cavity to ensure stable operation with a large amount of heat generated by the cavity during CW mode. The CW four-rod type RFQ cooling structure is quite complicated, which makes it difficult to design and machine the cavity, which limits the application and development of four-rod type RFQ in CW condition. Although the four-vane type RFQ is suitable for working in CW condition with single cooling structure and sufficient cooling efficiency，in the low frequency field, its lateral dimension is large, and the lower the frequency, the larger the lateral dimension, which increases machining difficulty and cost.

In order to overcome the disadvantages of four-rod and four-vane RFQ in the CW condition and the low frequency band, we put forward a kind of new RFQ accelerator structure called bent-vane type RFQ at Institute of Modern Physics (IMP),Chinese Academy of Sciences. The bent-vane type RFQ combines the advantages of four-rod type RFQ and four-vane type RFQ. It significantly reduces the lateral dimension of the cavity in the low frequency field and has a water-cooled system with a simple structure and sufficient cooling efficiency. In this paper, we present an 81.25 MHz bent-vane RFQ beam dynamics design and two-dimensional electromagnetic field (2D EM) simulation.

RFQ BEAM DYNAMICS DESIGN

The beam dynamics design of the bent-vane RFQ is simulated by the code RFQGen [2]. Taking into account research requirements and cost, the design parameters of the bent-vane RFQ are listed in Table 1.

The bent-vane RFQ accelerates He^+ (q/A=1/4) from 4 keV/u to 42.5 keV/u. In order to decrease the cavity length, the maximum peak surface electric field is 18.23 MV/m, which is 1.73 times higher than the Kilpatrick limit. The transverse focusing strength (B) keeps constant to decrease the cavity machining difficulty. The simulation results of beam transmission are shown in Fig. 1. The transmission efficiency is 96.9 % at 5 mA.

Table 1: The Design Parameters of the Bent-vane RFQ

Parameter	Value
Particle	He^+(q/A=1/4)
Frequency(MHz)	81.25
Beam current(mA)	5
Input energy(keV/u)	4
Output energy(keV/u)	42.5
Vane voltage(kV)	70
Vane length(mm)	533.76
Kilpatrick factor	1.73
Transmission efficiency(%)	96.9

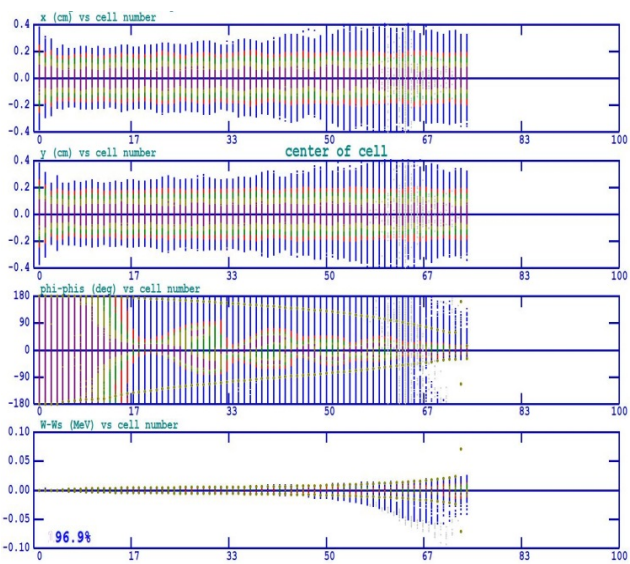

Figure 1: Beam dynamics simulation of the bent-vane RFQ (RFQGen).

2D EM SIMULATION

The cross-section profile is important in the bent-vane RFQ EM design, which is shown in Fig. 2. The cross-

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section geometry of the bent-vane RFQ is defined with 13 independent variables. Their Preliminary optimization values are listed in Table 2.

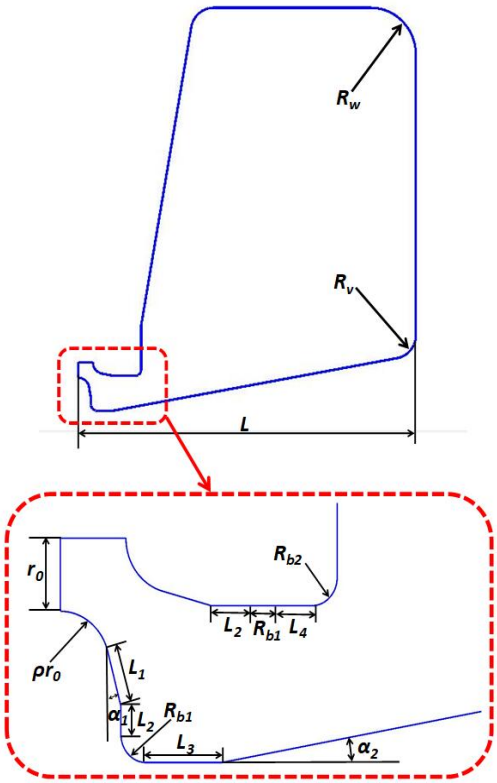

Figure 2: The cross-section profile of the bent-vane RFQ.

Table 2: The Parameters of the Bent-Vane RFQ Cross-section

Parameter	Value	Parameter	Value
r_0	5.347 mm	L	275 mm
ρ	0.75	R_v	20 mm
α_1	10 Deg.	α_2	5 Deg.
L_1	10 mm	R_w	40 mm
L_2	5 mm	L_4	10 mm
R_{b1}	5 mm	R_{b2}	5 mm
L_3	10 mm		

Verifying TE210 Mode of the Bent-Vane RFQ

RFQ can accelerate particle beam because the EM field mode of its electrode tip is TE210. Particle beam can be accelerated, focused and bunched in TE210 mode. In the bent-vane RFQ, TE210 mode is found in electrode tip, shown in Fig. 3.

Parameters Optimization

The main parameters of RFQ are obtained from the 2D EM simulation. The parameters of cross-section profile can be achieved and optimized by using the CST MWS [3]. The slice model of the bent-vane RFQ is effectively used to verify the parameters of the cross-section profile. The slice model is shown in Fig. 4.

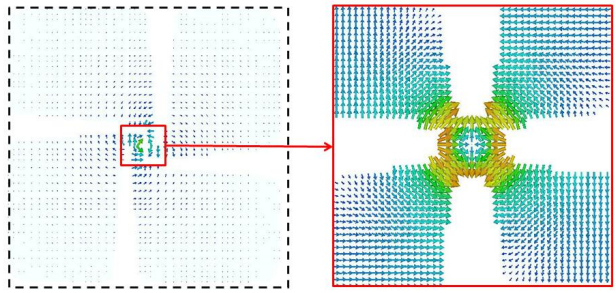

Figure 3: The electric field distribution of the bent-vane RFQ.

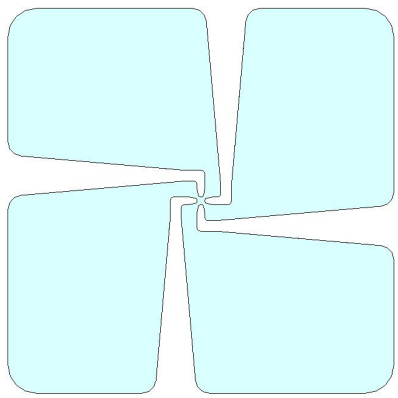

Figure 4: The slice model of the bent-vane RFQ.

The parameters of the cross-section profile can directly influence physical properties of the bent-vane RFQ. In RFQ accelerator, the lateral dimension (L), quality factor and shunt impedance are one of the most important physical quantities. In the thirteen parameters, the values of r_0, ρ and α_1 are defined in the code RFQGen. Hence, keeping the frequency (81.25 MHz) constant, the effects of the other nine parameters are shown in Fig. 5 on the lateral dimension, quality factor and shunt impedance of the bent-vane RFQ (Only presenting two parameters).

The final RF parameters of the slice model of the bent-vane RFQ are listed in Table 3.

Table 3: The RF Parameters of the Slice Model

Parameter	Value
Frequency	81.246 MHz
Nearest dipole mode frequency	79.569 MHz
Quality factor	18446
Peak electric field	16.06 MV/m
Power loss	11.59 W/mm
L	279.11 mm

CONCLUSION AND FUTURE PLAN

A new cavity structure of RFQ accelerator is proposed called the bent-vane RFQ at IMP. The dynamics of an 81.25 MHz bent-vane RFQ has been designed as a prototype device of the bent-vane RFQ. The 2D EM simulation of the bent-vane RFQ has been performed. The cross-section geometry of the new structure is defined with 13

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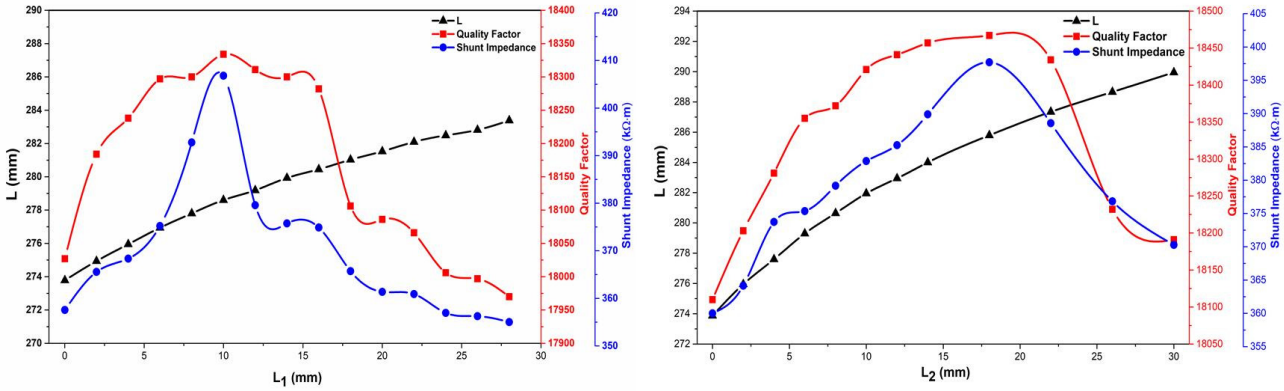

Figure 5: The variation of the lateral dimension (L), quality factor and shunt impedance of the bent-vane RFQ as the functions of the parameters of the cross-section profile (Only presenting two parameters).

independent variables. The TE210 mode is verified in the bent-vane RFQ. The slice model RF parameters are simulated and achieved. 3D simulation and Multi-physics study will be performed in the near future.

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