RF DESIGN OF AN 81.25 MHz BENT-VANE TYPE RFQ*

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Abstract

The bent-vane type RFQ is proposed at IMP, Chinese Academy of Sciences, which can downsize cross section and has the simple cooling system in low frequency field. The vanes of the four-vane type RFQ are bent to form the new RFQ structure. In order to research its RF properties, the prototype cavity of an 81.25 MHZ bent-vane type RFQ is designed. This paper presents the preliminary RF design of the prototype cavity.

INTRODUCTION

Radio frequency quadrupole (RFQ) can accelerate, focus and bunch particle beam in the low energy field, which is generally used as an injector for high energy accelerator. Four-rod type and four-vane type are main RFQ accelerator structures. Four-rod RFQ is used in the low frequency field and four-vane RFQ is applied in the high frequency field [1]. However, the cooling structure of four-rod RFQ is quite complex so that it is difficult to design and machine cavity and the lateral dimension of four-vane RFQ is large in the low frequency band which increases machining difficulty and cost [2]. In addition, four vane with windows RFQ can decrease the cross-section length in the low frequency band, but its cooling structure is extremely complicated and the windows can directly influence mechanical strength of the cavity and electric field flatness.

In order to overcome the disadvantages of above three kinds of RFQ accelerators, a new RFQ structure is proposed called bent-vane type RFQ at Institute of Modern Physics (IMP), Chinese Academy of Sciences. 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.

This paper presents the preliminary RF design of the prototype cavity for an 81.25 MHz bent-vane type RFQ.

THEORETICAL FOUNDATION

Considering an ideal four-vane RFQ with a cloverleaf geometry (Fig. 1), its equivalent circuit is shown in Fig. 2 [1]. According to the equivalent circuit, the cavity quadrant radius is

$$r^2 = \frac{16}{\mu_0(4 + 3\pi)\omega_0^2 C'}$$

where ω_0 is the resonant frequency, C' is the total capacitance per unit length and μ_0 is the permeability constant.

This equation indicates that the lateral dimension can be decreased by increasing the capacitance at a fixed frequency.

Based on the discussion above, the vanes of four-vane RFQ are bent to increase the capacitance for reducing the lateral dimension of cavity. Hence, a new RFQ structure is proposed called bent-vane type RFQ, shown in Fig. 3.
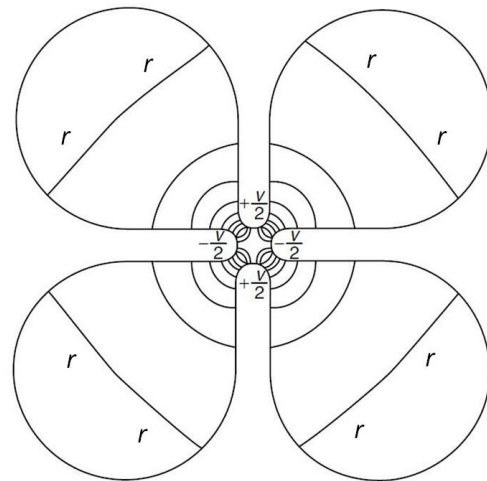

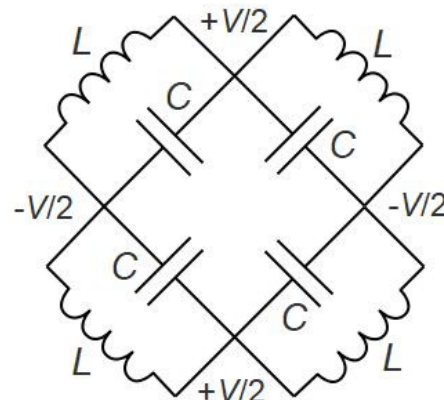Figure 1: The ideal four-vane RFQ with a cloverleaf geometry.

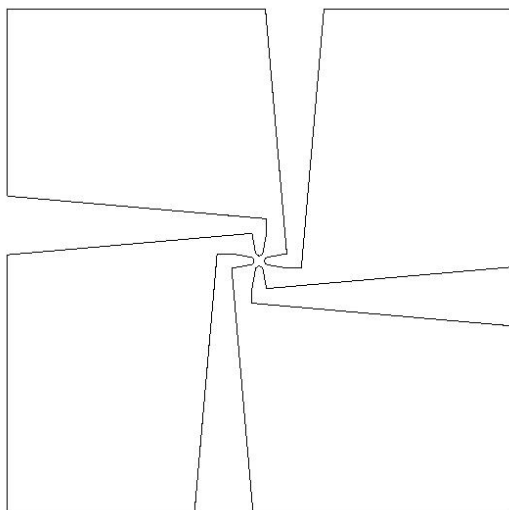Figure 2: The equivalent circuit of the ideal four-vane RFQ with a cloverleaf geometry.

Figure 3: The schematic diagram of the bent-vane type RFQ.

RF STRUCTURE

The dynamics design parameters of the prototype cavity was published at Linac 2018 [2]. For the RF design, this reference provides the required dynamics parameters.

Parameters Optimization

In order to obtain suitable lateral dimension and quality factor of bent-vane RFQ, the cross-section profile of bent-vane RFQ is put forward with 13 independent variables, shown in Fig. 4.
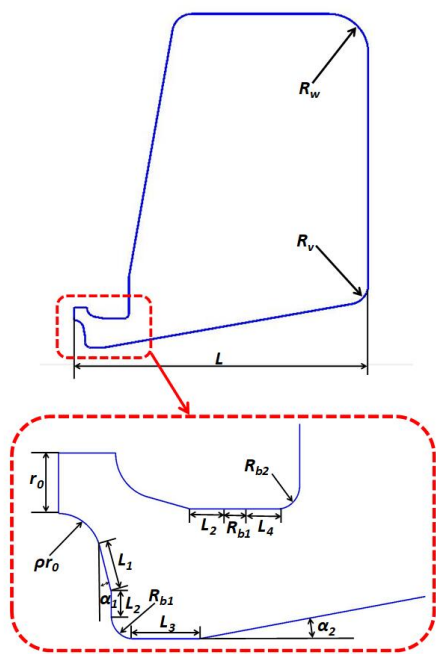

Figure 4: The cross section profile of bent-vane type RFQ.

r_0, ρ and α_1 can be obtained in the reference [2]. The other parameters can be optimized by using CST MWS [3]. The optimization valves of the parameters of cross-section are listed in Table 1.

Table 1: The Cross Section Parameters of the Prototype Cavity.

Parameter	Value	Parameter	Value
r_0	5.347 mm	L	283.67mm
ρ	0.75	R_v	30 mm
α_1	10 Deg.	α_2	5 Deg.
L_1	10 mm	R_w	40 mm
L_2	12 mm	L_4	10 mm
R_{b1}	5 mm	R_{b2}	5 mm
L_3	10 mm		

3D SIMULATIONS

The 3D full length model of the prototype cavity is shown in Fig. 5. Its length is 550.07 mm. It has 8 slug tuners, which are rotationally symmetric in each quadrant. The tuning range of them is -276─483 kHz. The tuning range can meet our research requirements.

The preliminary RF parameters of the 3D full length model are listed in Table 2. Since the nearest dipole model frequency is 91.86 MHz, it is not necessary for the mode separation in the prototype cavity. The frequency is 81.247 MHz and quality factor is 12004.
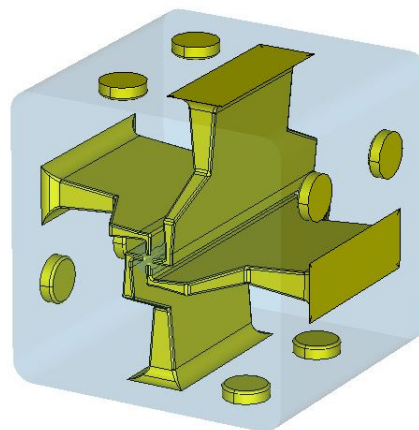

Figure 5: The 3D full length model.

Table 2: The Preliminary RF Parameters.

Parameter	Value
Frequency	81.247 MHz
Nearest dipole mode frequency	91.86 MHz
Quality factor	12004
Power loss	9990 W
Peak electric field	17.8 MV/m

CONCLUSION

The bent-vane type RFQ is proposed at IMP, Chinese Academy of Sciences. An 81.25 MHz prototype cavity of the bent-vane type RFQ is design to demonstrate the new RFQ structure. The cross section profile is defined and

optimized with 13 independent variables. The 3D full length model of the prototype cavity is calculated and the preliminary RF parameters are obtained. The RF parameters will be optimized in the future.

ACKNOWLEDGEMENTS

REFERENCES

[1] T.P. Wangler, *RF Linear Accelerators*, John Wiley & Sons, New York, 2008.

[2] L. Yang *et al.*, "Research on the New Cavity Structure of RFQ Accelerator With Bent Vanes at IMP", in *Proc. 29th Linear Accelerator Conf. (LINAC'18)*, Beijing, China, Sep. 2018, pp. 802-804. doi:10.18429/JACoW-LINAC2018-THPO050

[3] CST Simulation Packages, https://www.cst.com/.