PROGRESS OF RFQ ACCELERATORS AT PEKING UNIVERSITY*

C.E.Chen Z.Y.Guo J.X.Fang Y.R.Lu X.Q.Yan K.Zhu S.X.Peng Z.Wang C.Zhang
S.L.Gao J.F.Guo W.G.Li Z.Z.Song J.X.Yu M.L.Yu
IHIP, School of Physics, Peking University, Beijing 100871, P.R.China

Abstract

The progress of two RFQ accelerators at Peking University is presented: one is Separated Function RFQ (SFRFQ), which separates the focusing and acceleration of traditional RFQ to get higher acceleration efficiency. The first prototype of the SFRFQ is designed to accelerate O^+ from 1MeV to 1.5MeV and used as a postaccelerator for ISR RFQ-1000 (Integral Split Ring) [1]. The other is high current deuteron 201.25MHz RFQ, it will accelerate 50mA D+ beam to 2MeV with a duty cycle of 10%. The design study of SFRFQ and high current Deuteron RFQ accelerator are outlined.

INTRODUCTION

The RFQ accelerators are extensively used to accelerate low energetic heavy ions and proton nowadays. Accelerator Driven Subcritical system (ADS), Spallation Neutron Source and other applications drive the RFQ developing towards high average beam power [2-4]. The RFQ team at Peking University has been engaged in developing RFQ technology since 1980s. A 300keV heavy ion Integrated Split-ring Resonator RFQ (ISR RFQ-300) with the mini-vane electrodes was constructed and put into operation in 1994[5]. Based on these experiences, A 1MeV heavy ion ISR RFQ was completed and run successfully in 2000[6]. The experiment [7] and simulation [8] for simultaneous acceleration of both positive and negative ions were realized.

To increase accelerating efficiency, a new accelerator structure, Separated Function RFQ (SFRFQ), has been proposed and investigated. It separates the transverse field for the focusing and axial component for ion acceleration by inserting a series of periodical gaps [9-12]. In order to explore the feasibilities of SFRFQ, a prototype is going to be manufactured. A match section between 1MeV RFQ and SFRFQ is designed for the transverse emittance matching. Meanwhile to upgrade the beam current to mA for ISR RFQ-1000, a new designed ECR ion source for this accelerator has been developed in the last two years [13].

A high power Deuteron RFQ accelerator has been launched for neutron radiography. The beam dynamics has been studied in detail and improved by equipartition method[14-16]. The RFQ structure, mechanical and cooling system design have been investigated.

*Supported by NSFC (Contract No.10455001)
Email: chenje@pku.edu.cn

SFRFQ

SFRFQ is an accelerating structure which is suitable for accelerating middle energy beam [10]. A SFRFQ prototype is being constructed to explore its feasibilities, which compose an accelerating system with ISR-1000. The whole system include ECR ion source, LEBT, ISR1000, match section and SFRFQ. Figure 1 gives the sketch map. Figure 2 shows SFRFQ's structure schematically, where diaphragms were mounted onto the electrodes.

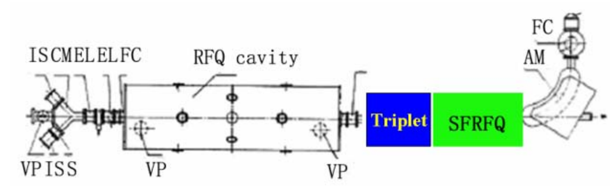

Fig. 1: Accelerating system composed by ISR-1000 and SFRFQ

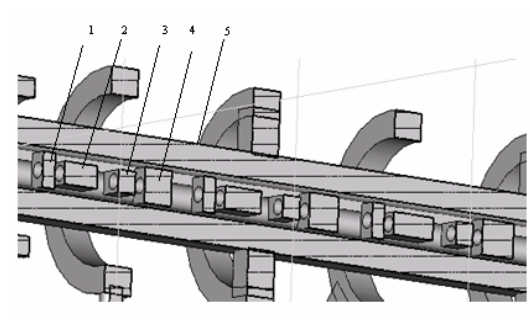

Fig. 2: Schematic view of the SFRFQ 1,2,3&4 diaphragm, 5 electrode

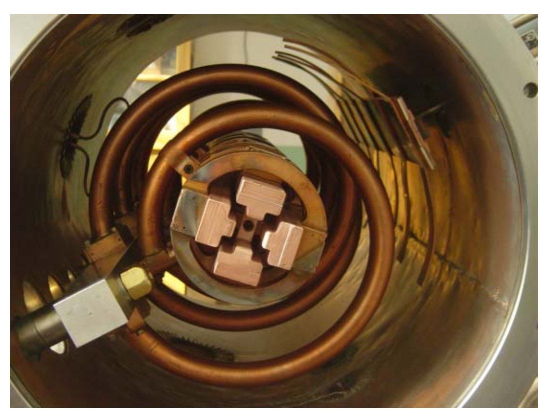

Fig. 3: Power test model of SFRFQ

The beam dynamics of the SFRFQ is being investigated by self-developed code. The longitudinal electric field and its RF property were simulated by Microwave Studio(MWS). Based on the simulations, an optimized design of SFRFQ structure was completed to improve RF efficiency, and to get better mechanical performance, etc[12]. Figure 3 shows the SFRFQ cavity that is especially designed to investigate the longitudinal field distributions and to do RF conditioning and its intervane voltage measurements.

The longitudinal field distribution was measured by perturbation method and Angilent Network Analyzer. The measured results are consistent with the simulated field distribution (shown in Figure 4). It is remarkable here that the field between two neighbouring higher peaks is actually inverse field. It will decrease the effective energy gain in SFRFQ, but RF quadruple field provides additional transverse focusing. The high power RF test shows that gap or intervane voltage can reach to 79kV when RF amplifier delivers 35kW peak power (shown in Figure 5).

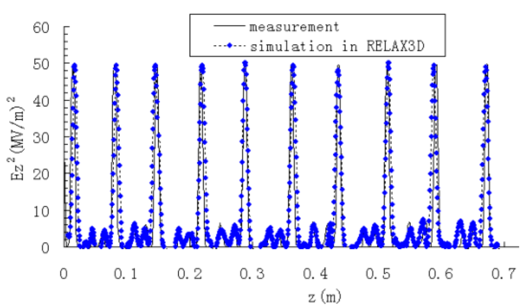

Fig. 4: The measured and simulated electrical field distribution

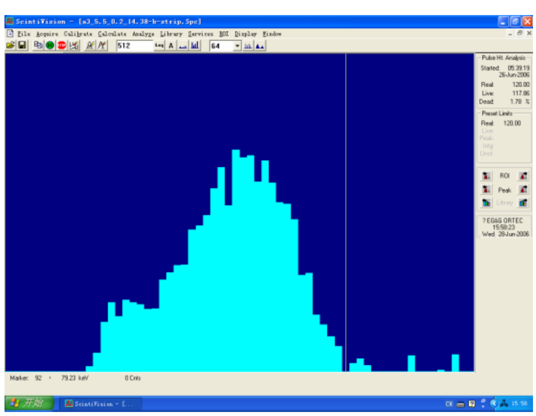

Fig. 5: Roentgen spectrum of the model cavity at RF power 35kW, which showed a gap voltage of 79kV

The 1MeV RFQ, working as injector of SFRFQ, is upgraded. An ECR ion source with extracting voltage of 22kV and a new LEBT have been designed and tested. The peak current of extracted O^+ beam reached 5 mA with duty factor 1/6 and pulse duration 1ms. Figure 6 shows the new ECR ion source for 1MeV RFQ. To realize the beam matching from 1MeV ISR RFQ-1000 to SFRFQ cavity, a match section with triplet magnetic quadruples has been designed and is under construction.

Fig. 6: New ECR ion source

DEUTERON RFQ

Meanwhile a high current and high duty factor deuteron RFQ has been designed for neutron generator. It will accelerate D^+ from 50keV to 2MeV with 10% duty factor and operating frequency 201.25MHz. The RF amplifier using Thomson tetrode TH781 could deliver RF peak power 400kW[17]. In order to avoid cavity radioactivity by D-D reaction, the beam transmission efficiency is designed over 90% while the energy of most lost deuterons is below 100keV[14]. And the beam dynamics design has been further improved by equipartitioned design method [15]. Table 1 lists the principal parameters of deuteron RFQ accelerator.

Table 1: The Deuteron RFQ parameters

Input energy/keV	50
Output energy/MeV	2.0
Beam current/mA	50.
Frequency/MHz	201.25
Electrodes voltage/kV	74
RFQ length/mm	2700.
Accelerating cells	181
Max modulation	1.8
Aperture radius/mm	3.78
Transmission	93.6%
Kilpatric	<2.0

In RF structure design, the influence of electrodes' shape on RF loss has been investigated by simulation. The effects of distance, height and width of stem have also been investigated. RF loss of the whole RFQ structure can be reduced to about 270kW by optimizing above parameters[18]. The dipole component of quadruple field has been reduced to 4% by adjusting the slope of stem centre part [19]. The tuning blocks were inserted to RFQ structure and fixed between two neighbouring stems. It behaves as a volume tuner, which will tune the cavity resonant frequency and the longitudinal field distribution more flat [20]. Figure 7 gives the simulation results.

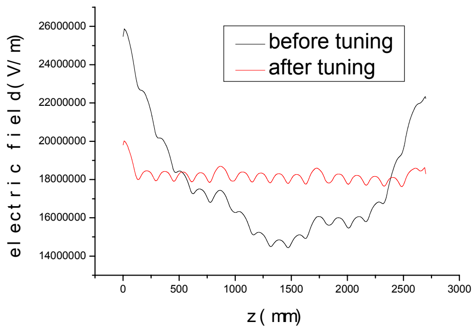

Fig. 7: Simulation results of tuning field

The 80kW pressured water cooling system of the RFQ has been designed and run successfully. The thermal analysis of inner cavity structure has been carried out based on RF power consumptions of different parts. Figure 8 shows the cooling channel sketch and temperature distribution of a stem. From the analysis, the temperature raise and deflection of RFQ structure is acceptable[21]. 400kW RF amplifier with 781 tetrode has been tested successfully with 1% up to 8% duty factor and repetition frequency of 100Hz[22].

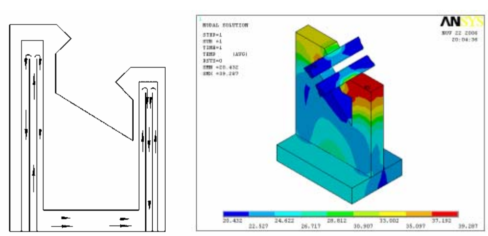

Fig. 8: Cooling channel sketch and temperature distribution

CONCLUSION

The structure of SFRFQ was optimized. The longitudinal field distribution was measured and RF power experiments were carried out with a SFRFQ model. Experiments show the measured results agree with the simulated results. Also the structure can be operated on designed electrode voltage without sparking. The injector of SFRFQ is being upgraded, which includes a new designed ECR ion source, LEBT, 1MeV RFQ and a matching section.

The preliminary design of deuteron RFQ is figured out. The beam dynamics simulation, RF cavity design, RF tuning and cooling system design have been completed. The design objectives, such as relative high beam transmission efficiency, short RFQ length and low power loss and so on, have been realized.

REFERENCES

[1] Y.R. Lu, et al, NIMA, 2003, A515 (3): 394-401.
[2] I.M.Kapchinskij, V.A.Teplyakov, Prib.Tekh.Eksp., 1970,(4),P19
[3] A.Ratti, et al., Proceedings of EPAC 2000, P495
[4] H.V.Smith, et al., Proceedings of EPAC 2000, P969
[5] J.X.Fang, C.E.Chen et al., IEEE NS-32(1985)P2981.
[6] C.E.Chen, J.X.Fang et al., Proceedings of EPAC 2000, P1850
[7] X.T.Ren, Y.R.Lu, J.X.Yu, et al, , High energy physics and nuclear physics, Vol.24, No.4,2000, P.347-351
[8] X.Q.Yan, et al., Phy. Rev. ST Accel. Beams 9, (2006)020201
[9] C.E.Chen, et al., Progress on Natural Science, Vol. 12, No.1,23, 2002
[10] X.Q.Yan, et al., Bulletin of China Academic Journal, Vol.7, No.11, 1441,2001
[11] C.E.Chen, et al., Proceedings of APAC 2004, P595
[12] Z.Wang, et al., Acta Physica Sinica, Vol.55, No.11, 2006, P5575
[13] Z.Z.Song, et al., Rev. Sci. Instrum. 77, 03A305 (2006)
[14] C.Zhang, et al. Phy Rev. ST Accel. Beams 7, (2004) 100101
[15] X.Q.Yan, et al., Proceedings of EPAC 2006
[16] Z.Y.Guo, et al., Proceedings of Linac 2006
[17] Y.R.Lu, et al., Proceedings of Linac 2006
[18] K.Zhu, et al., HEP&NP, 2005, 29(5), P512
[19] H.Podlech, et al., Proceedings of EPAC, 2002, Paris, France. P942
[20] A.Schempp, et al., Proceedings of Linac, 2004.
[21] K.Zhu, et al., HEP&NP, 2005,29(8),P797
[22] Y.R.Lu, et al., Proceeding of Linac 2006