INVESTIGATION OF 26MHZ RFQ ACCELERATORS*

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Abstract

Integral Split Ring (ISR) RFQ accelerators with four mini-vanes have been developed at Peking University . A 26MHz RFQ prototype with cavity diameter of 50cm was constructed. N^+, O^+ and O^- ions have been accelerated to 300keV at inter-vane rf voltage of 80kV. It showed that the RFQ suits to accelerate heavy ions at low rf frequency stably and effectively. Now a 26MHz ISR RFQ has been designed and is being constructed, which cavity diameter and length are 75cm and 260cm, respectively. O^+ and O^- ions will be accelerated to 1MeV at rf voltage of 70kV. All the results and discussions are presented in the paper.

1 300 KEV ISR RFQ CAVITY

The structure of a 26MHz prototype ISR RFQ cavity is shown in Fig. 1[1-3]. The drift tubes in the conventional split ring cavities are replaced here by 4 mini-vane electrodes,which can be replaced whenever necessary with fast easy. The whole structure can be assembled and adjusted outside the cavity. It is cooled by water flowing through the spiral tubes, supporting rings and quadruple electrodes, so such a structure has high duty factor and hence high average beam current. The end of the electrodes was shaped specially to minimize the end effect and to improve the transverse beam quality. The diameter and the wall thickness of the copper spiral tubes are 30 mm and 1.5 mm respectively, which turn out to be strong enough to ensure mechanical stability. The parameters of this RFQ are listed in Table 1.

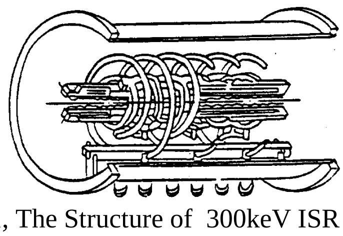

Fig.1, The Structure of 300keV ISR RFQ

Table 1. Principle parameters of ISR RFQ

	300keV RFQ	1MeV RFQ
f(MHz)	26.0	26.0
Charge/Mass	1/14	1/16
W_f(keV)	300	1000
W_{in}(keV)	20	22
Cavity Diameter(cm)	50	75
Cavity Length(cm)	90	260
Vo(kV)	75	70
Duty factor	1/6	1/6

2 THE RF SYSTEM OF ISR RFQ

The rf system includes two parts. One is AGC (Automatic Gain Control) , which is made of DBM (Double Balance Mixture) and stabilizes the accelerating electric field in RFQ cavity. The other is PLL (Phase Lock Loop),which consists of phase shifters and phase discriminator . The PLL tunes the operating frequency of RFQ cavity in time . The rf power is coupled by a magnetic coupling loop,which is cooled by circulating water and excited by a linear power amplifier (XFD-D5) with maximum output CW power of 30 kW or 50 kW pulsed peak power . A 30 pF distributing capacitance was added to the rf feeder to compensate the input inductance of the power coupling loop. Fig.2 and Fig.3 show us the rf feeder structure and its input impedance of 75Ω at 26MHz. Table 2 lists the results of rf power test with duty factor 1/6.The intervane voltage is measured by energy spectrum of Roentgen ray with Ge detector cooled by liquid nitrogen[4-6] .

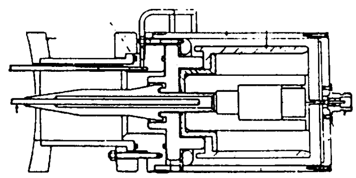

Fig.2 The rf feeder structure

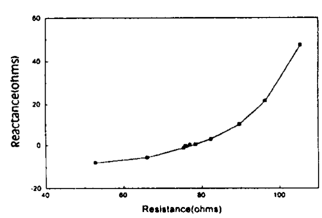

Fig.3 The input impedance of 300keV ISR RFQ

Table 2 The results of the rf power test

P_{rf}(kW)	V_o(kV)	f(MHz)	T(^{0}C)	ρ(kΩm)
19.66	62.3	25.739	16.5	168
24.62	66.9	25.737	18.0	155
29.70	71.6	25.737	19.0	147
39.57	78.5	25.732	22.0	132
44.36	81.7	25.728	23.0	128

* Supported by NSFC

3 LAYOUT OF BEAM TEST

Fig .4 shows the schematic layout of 300keV ISR RFQ accelerator[7] . It has two ion sources , located at ±45° with the beam axis.One is PIG ion source with side extraction cold cathode, the another is end extraction sputtering PIG ion source. These two ion sources can provide oxygen positive and negative or N^+ ion beams. The extracted beam is focused by the Einzel lenses (EL) and bent by CM , steered by two parallel plates , then focused by another EL to match with the RFQ acceptance. The beam current of positive or negative ions accelerated by the RFQ is to be deflected by a small magnet (DM) and measured by two Faraday cups (FC) located at a range of 8 cm off the central axis respectively. Two additional beam monitors (BM) are mounted at the RFQ entrance and exit to measure the input and output beam intensity. The energy spectrum of the beam is to be measured by using the analyzing (AM) magnet.

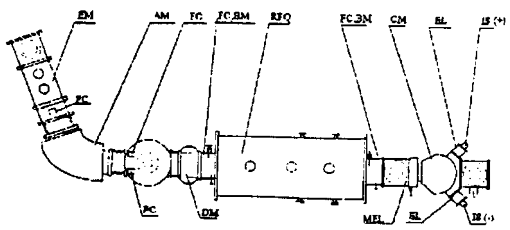

Fig. 4 Layout of the ISR RFQ Accelerator

4 RESULTS OF BEAM TESTS

From the beam tests, we found the beam quality at RFQ entrance is very important to get higher beam transmission efficiency. This can be observed by changing the working condition of ion source.For example , if we decrease the arc current and increase the discharging voltage of ion source, we can get much higher transmission efficiency. We can also see this if we add a beam diaphragm in front of RFQ to limit beam dimension , the beam transmission efficiency can also be higher. The operating frequency is also important for beam transporting. We ever injected N^+, O^+,O^- DC ion beams respectively , Fig.5 gives the energy spectrum of N^+ beam at 45kW with duty factor 1/6 ,which is analyzed by AM in fig.4. Table 3 lists several group datas of beam tests. Iarc is the arc current of ion source, Varc arc voltage, Vex extracting voltage,Ia the accelerating beam current, Ie the injecting beam current,η the beam transmission efficiency. From this table we can see simply why η changes.It agrees RFQ theory. The unaccelerating beam is deflected by DM in fig.4 ,therefore it shouldn't affect the measurement of the acclerating beam current. After the DC beam tests the ion source has been modulated. The modulating signal is synchronized with rf modulating pulse.Its width is 1ms with duty factor of 1/6. The devices connect to ion source through optical cable. Fig.6 shows the pulse form of O^+ beam current at entrance of RFQ, the sampling resistance is 5kΩ. When the injected beam is completely or partly put into the rf pulse power, the beam in rf pulse will be accelerated. Such results are recorded by HP digital oscilloscope and printed in Fig.6,Fig.7,Fig.8 and Fig.9. The accelerated O^+ peak beam current has been reached to 280μA at 45kW with duty 1/6 from Fig.6 and Fig.7, and the beam transmission efficiency is about 84%. Fig.10 gives the relation of the O^+ beam transmission efficiency on the rf power in RFQ cavity. The relation of O^+ transmission via vacuum status is shown in Fig.11.

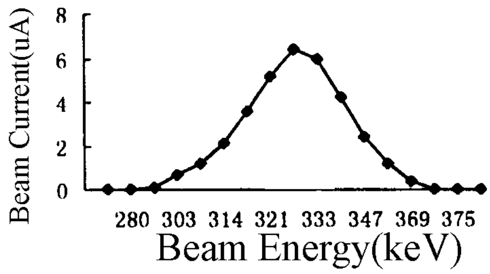

Fig.5 N^+ energy spectrum at 45kW

Table 3. N^+,O^+ and O^- beam test results

Ion	Iarc mA	Varc (V)	Vex kV	Prf (kW)	Ie (μA)	Ia (μA)	η
N^+	70	500	20.0	37.8	137	17.3	76
N^+	100	600	20.0	40.0	120	15.0	75%
N^+	120	500	18.3	35.0	165	14.0	51%
O^+	70	300	20.0	40.0	220	15.8	43%
O^-	80	350	18.0	35.0	175	14.0	48%
O^-	80	350	18.0	30.0	173	13.0	45%

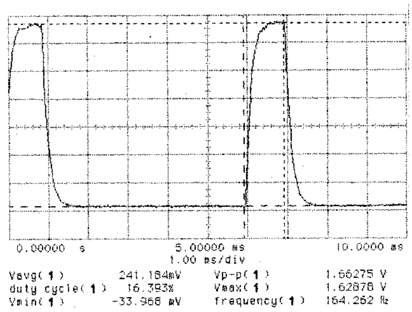

Fig.6 The O^+ pulse beam at RFQ entrance

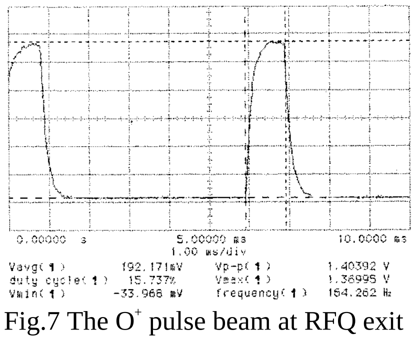

Fig.7 The O^+ pulse beam at RFQ exit

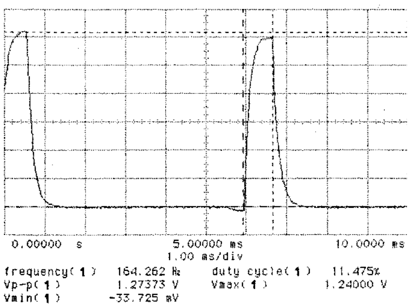

Fig. 8 The output beam wave form when 70% injected O^+ beam is put in rf pulse and accelerated

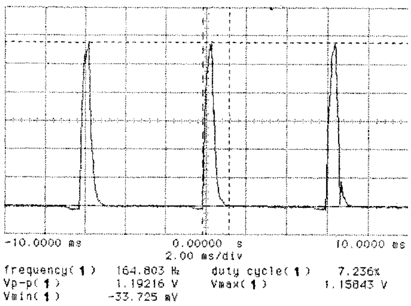

Fig.9 when 30% Injected beam is accelerated

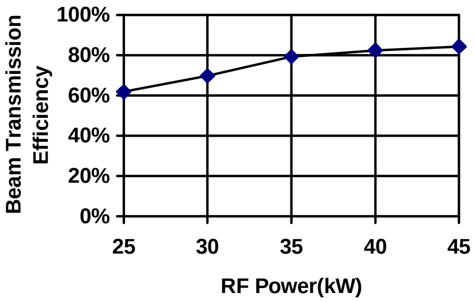

Fig. 10 Beam Transmission via RF Power

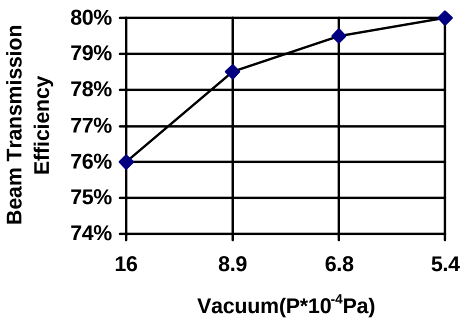

Fig. 11 Beam Transmission via Vacuum status

5 1 MEV ISR RFQ

Based on the experiences of 300 keV ISR RFQ, a 1 MeV O^+ RFQ is being built. In Table 1, its principle parameters are listed. Fig. 12 shows the dynamics parameters. Its cavity tank has been constructed and shown in Fig.13. The tank can be opened at its bottom. The mini-vanes and its supporting arms are set up on the bottom plate. Therefore, the mini-vanes can be easily accessed and set up. They are made of Cr-copper for strengthening its rigidity. Inside the vanes there is a hole for water cooling. Its modulated surfaces are manufactured by two dimensional cutting by NC mill for simplified machining. Now the vacuum of cavity has been reached to $1.6 * 10^{-6}$ mm Hg, and the mini-vanes are being machined. The construction of 1 MeV ISR RFQ will be completed in the Autumn of 1998. Then high power test and beam test will be carried out at the end of 1998.

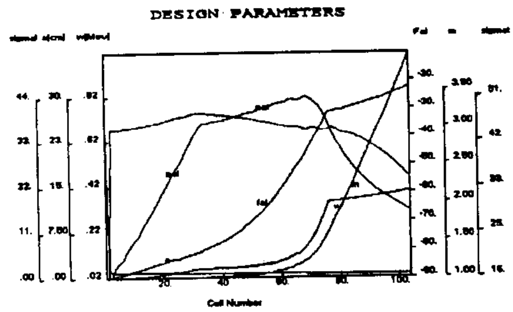

Fig. 12 Dynamical parameters of 1 MeV RFQ

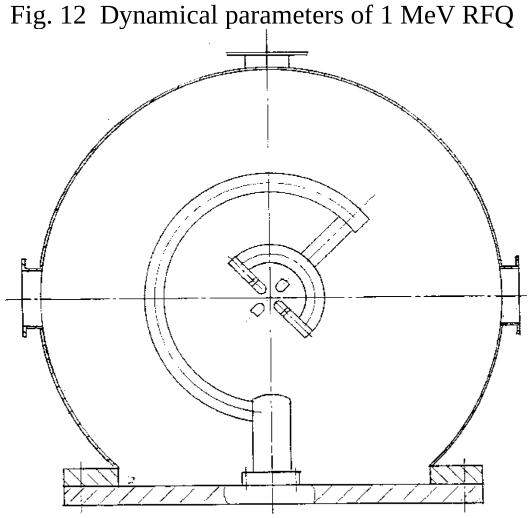

Fig.13 The outline of 1MeV RFQ cavity

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