An ECR Oxygen Source and a LEBT System Developed for 1MeV ISR RFQ Accelerator Upgrade*

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Abstract An ECR O^+ ion source and LEBT system have been developed for the upgrade of 1MeV Integral Split Ring RFQ at Peking University. To satisfy the requirement of RFQ, a more than 10mA oxygen beam has been extracted at 22kV through a 5mm diameter aperture. Its normalized root-mean-square emmitance is less than 0.1π·mm·mrad, which is required by RFQ accelerator. The LEBT matching section is redesigned upon the bench test results. The preliminary results will be presented in this paper.

Key words ECR ion source, LEBT, emmitance, matching

1 Introduction

The radio frequency quadruple (RFQ) accelerator has been accepted worldwide because of its capability of focusing and accelerating a lower-energy high-intensity ion beam efficiently at the same time. Two Integral Split Ring RFQ (ISR RFQ-300 and ISR RFQ-1000) have been developed at Peking University and fruitful results have been obtained[1—3]. ISR RFQ-1000 was completed in 1998. The O^+, O^- and N^+ ions have been accelerated with high duty factor of 16% and repetition frequency 166Hz since then[3]. As for O^- ions, the peak output beam current reached 660μA with beam transmission of 83%, while for N^+ and O^+ ions, they are 300μA and 320μA respectively, both with a transmission of 86%[2]. No emmitance measurement was taken at that time.

With the increasing interest on the material science, biological irradiation and RFQ-AMS carbon chronology, a few mA heavy ion especial O^+ ions is needed. In order to breakup the beam current limitation and to improve the matching efficiency between the LEBT and RFQ accelerator (including emmitance, α, β), modification has been carried out on ion source, LEBT as well as 1MeV ISR RFQ itself recently[4]. The original PIG ion source will be replaced by a new ECR ion source. Beam current will be improved up to 5mA from ion source and the emmitance will be less than 0.1π·mm·mrad. A LEBT matching section with Einzel lens has been redesigned and the results of experiments on test bench were compared with the simulating results obtained using Trace 3d. Details will be reported in this paper.

2 Upgrading project

Figure 1 is the outline of ISR RFQ-1000 before upgrade. Two permanent magnetic cold-cathode penning ion gauge (PIG) ion sources located at ±45° are used to produce positive and negative ions, respectively. A Combining Magnet (CM) was used for both beams. Two Einzel lens (El) were used to satisfy the matching with RFQ accelerator. Two Faraday cups

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(FC) are mounted at the RFQ entrance and exit to measure input I_1 and output I_2 beam current. The energy spectrum of the beam is analyzed by an analyzing magnet (AM). The third faraday cup is installed at the exit of AM to measure the analyzing beam current I_3. A cut-off coaxial fast target (FT) is mounted at the end of beam line to measure the micro-pulse beam. After simultaneous acceleration, 320μA O^+ ion beam current and 660μA O^+ ion beam current (I_2) have been obtained by the FC2 located after RFQ[3].

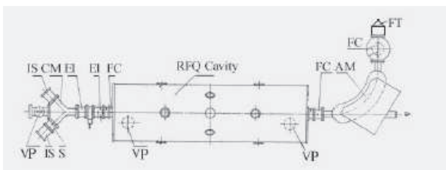

Fig. 1. Outline of original ISR RFQ-1000.

Parameters required by upgrading project are shown in Table 1. Study is carried out on developing a suitable ion source and an efficiency matching LEBT system. The ion source should produce more than 5mA peak current of O^+ ions with $\varepsilon_{\mathrm{RMS}} \leqslant 0.104\pi$·mm·mrad, and the beam should be focused properly so that both α and β are satisfying the requirement of RFQ accelerator at its entrance.

Table 1. Main Parameters at the entrance of ISR RFQ-1000.

ions	O^+
peak current/mA	5mA
emmitance/(mm·mrad)(unnorm)	176.4
$\varepsilon_{\mathrm{RMS}}$/(π·mm·mrad)(norm)	0.104
α	0.87
β/(cm/rad)	4.84

3 Preliminary experiments

3.1 Ion source

ECR ion sources are widely used to produce high current O^+ ions in various accelerator and plasma facilities because of it excellent advantages[5, 6]. Our lab has good experience on this kind of source[7]. To meet the requirements of R&D of our 1MeV ISR RFQ, we developed a new ECR ion source to produce a few mA O^+ ions (Fig. 2). This one is similar as the one we reported at ICIS'05 in France[8]. It is a permanent magnet source with operation frequency at 2.45GHz. The source body is about 10cm in diameter and 10cm in height, and its weight is less than 5kg. Compared with the one we report last year, more safety considerations have been brought out on this new ion source. First, an oil circulation cooling system is used to instead of the water cooling system that was located on high voltage platform. Second, with a longer gas inlet pipe the gas cylinder is moved to ground level. Third, a HV break wave guide is inserted between the 3-stub tuner and the circulator so that microwave

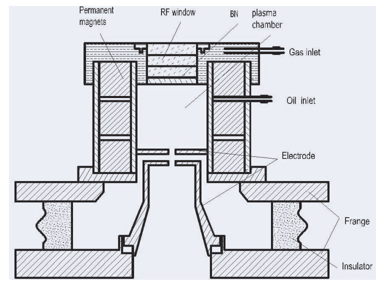

Fig. 2. An schematic plot of the ECR ion source.

generator works on the ground level. On our bench test, both single electrode extraction and double electrodes extraction were tested to extract 22keV O^+ ions through a 5mm diameter aperture with a duty cycle 1ms/6ms. More than 10mA O^+ beam can be easily obtained at an extraction voltage of 22kV with both extraction systems. The unnormalized boundary emmitance is about 150mm.mrad and its normalized root-mean-square emmitance is less than 0.1π·mm·mrad. The most important is that during the above measurement, the microwave power delivered to discharging chamber is only 150W.

Experiment results prove that both the single extraction and double extraction system are sufficient to obtain the beam that RFQ accelerator needs. For single extraction system, about 100 hours experiments have been done on it. No obvious damage can be observed on the ion source. For simplicity consideration, we will choose single electrode extraction system for our upgrading project.

3.2 The LEBT system

To match the requirement of 1MeV ISR RFQ, an Einzel lens is used to focus the beam extracted from ion source. Fig. 3 is a profile of the beam focused by Einzel lens when the focus voltage is 16.5kV. The beam diameter at 330mm away from the extraction electrode is about 4mm.

In the meantime, calculation was carried out to simulate the beam transport using Trace 3d program. Calculation results show that when focus voltage set at 17kV the beam diameter is about 4.6mm. This result agrees very well with the data obtained from experiments.

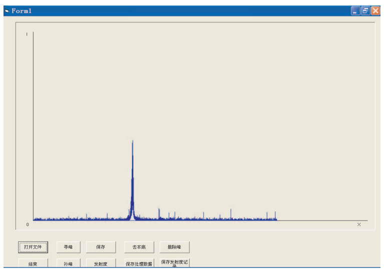

Fig. 3. A beam profile focused by Einzel lens.

3.3 Summary

From the above preliminary study, we can get such conclusion that the system with our new ECR ion source, a single extraction system, an Einzel lens, are proper for 1MeV ISR RFQ upgrading.

4 New system

A new system including a permanent magnet ECR ion source with its LEBT components are developed based on the understanding of bench test and simulation results (Fig. 4). This ion source is just the one we used in our bench test. The LEBT system includes Beam diaphragm 1 (BD 1), X and Y Steers (X-YST), Einzel lens (EL), Quadruple diaphragm (QD); Beam position monitor (BPM), Faraday cup (FC) and Beam diaphragm 2 (BD 2). With specific arrangement, the BPM located at the same position as FC and they can be replaced by each other or offset beamline through a rotation. A $\phi 32\times 35$ cylinder before the Faraday cup serves as electron suppressing electrode as well as beam diaphragm so that it can absorb the large angle beams. A 1200L/m Tubromolecular pump is located down the EL. The total length from the extraction point to the RFQ entrance is about 738mm. The whole system is just finished assembling recently. Fig. 5 is a photograph of this new system. Both the beam current and the emmitance will be measured soon.

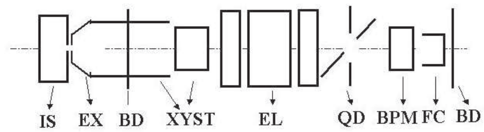

Fig. 4. The new system for ISR RFQ-1000 upgrading. (IS: ion source; EX: Extraction; BD: Beam diaphragm; XYST: X and Y steer; EL: Einzel lens; QD: Quadruple diaphragm; BPM: Beam position monitor; FC: Faraday cup).

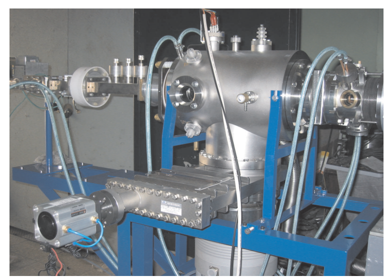

Fig. 5. A photograph of the new system.

5 Conclusion

To explore the possibilities of accelerating a few mA heavy ion beam, an upgrade project of 1MeV ISR RFQ accelerator has been launched out. Bench test results show that a new ECR ion source with an Einzel lens is possible to match the requirement of 1MeV ISR RFQ. The experiment results are consistent well with the simulation consequences using Trace 3d. The ion source with its LEBT system is finished assembling now and the new result will come up before the end of this year.

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