PROGRESS ON COUPLED RFQ-SFRFQ ACCELERATOR FOR MATERIALS IRRADIATION RESEARCH

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Abstract

There is always high interest to study material irradiation damage effects based on accelerators. The bombardment of solids with high energy particles causes some changes in many important engineering properties. A materials irradiation facility based on coupled RFQ-SFRFQ accelerator will be built in Peking University. The concept design and the structure optimization have been completed. The progress on the coupled RFQ-SFRFQ accelerator will be presented in this paper.

INTRODUCTION

Based on our experience with ISR-RFQ 1000[1,2] and the commissioning of the prototype SFRFQ (Separated Function RFQ) cavity[3], we have developed a novel structure that couples RFQ and SFRFQ electrodes in a single cavity. The coupled RFQ-SFRFQ structure can improve the accelerating efficiency by replacing the accelerating section in the RFQ with an SFRFQ structure. The SFRFQ structure combines the characteristics of the conventional RFQ and DTL[4,5]. It consists of a series of accelerating gaps and standard quadrupole lenses that are formed by loading diaphragms onto the unmodulated mini-vane quadrupole electrodes.

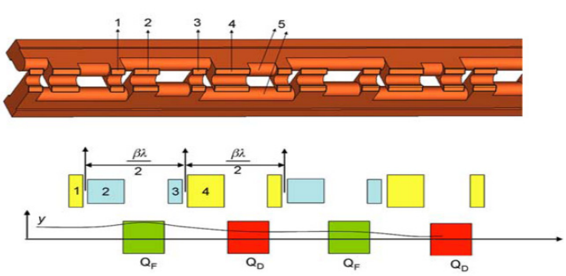

Figure 1: The principle of the SFRFQ (the particles are accelerated between 1&2 and 3&4, focused between 2&3; Q_F and Q_D represent the focusing and defocusing lens, respectively).

The commissioning of the prototype cavity has verified that higher accelerating efficiency is obtained by introducing accelerating gaps. The principle of the SFRFQ was shown in Fig. 1.

BEAM LINE SETUP

The coupled RFQ-SFRFQ accelerating system consists of a 2.45GHz ECR (electron cyclotron resonance) ion source with energy modulated function [6], LEBT(low energy beam transport), coupled cavity and the analyzing magnet and two ACCTs. Figure 2 is the schematic layout of the accelerating system. The LEBT consists of two solenoids and two sets of steerer device. The magnet gradient of the solenoid is 0.5T and the aperture is 110mm. The designed injection system will provide a 30 keV, 20 mA helium beam with a duty factor of 1/6 and a transverse emittance of less than 0.2 mm mrad for the coupled cavity.

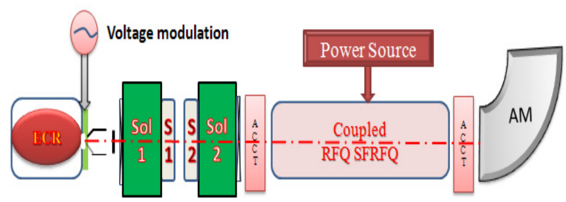

Figure 2: The schematic layout of the accelerating system.

OPTIMIZATION OF THE COUPLED CAVITY

In the first step of the structure design, the choice of the RFQ-SFRFQ transition energy is a trade-off between adequate output energy from the RFQ and an acceptable longitudinal emittance for the SFRFQ. Most RFQs require that wanted to reduce the entire cavity length and the output longitudinal emittance would require an external buncher before the RFQ[7,8]. To design a short RFQ with lower longitudinal emittance, the synchronous phase along the RFQ cell was plotted in Fig. 3. The synchronous phase would increase rapidly by using an external buncher; correspondingly, the energy gain in the RFQ section reach the energy requirement in the 33 cell as shown in Fig. 4. In our design, the external buncher was replaced by an energy modulated ECR ion source [9].

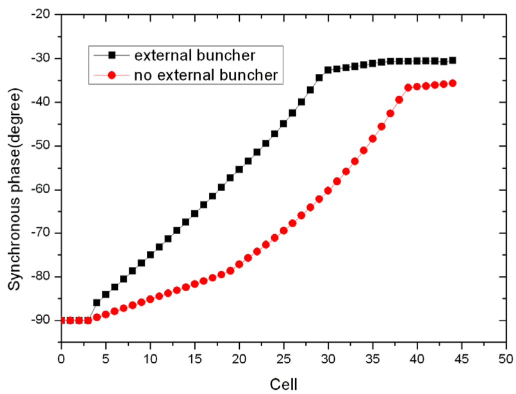

Figure 3: Synchronous phase variations along the RFQ cell number.

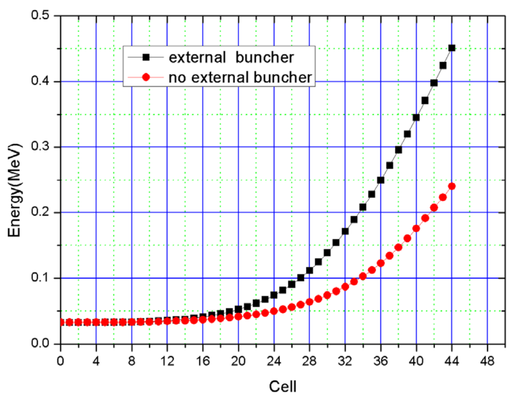

Figure 4: The energy gain of RFQ as a function of cell number.

The planned coupled RFQ-SFRFQ cavity will accelerate the He+ beam to about 0.8MeV with the peak current 5mA. The basic parameters of the coupled RFQ-SFRFQ cavity are listed in Table 1.

Table 1: Parameters of the coupled RFQ-SFRFQ cavity

Operating Frequency	26.0 MHz
Charge to mass ratio	≥1/4
Duty factor	1/6
Inter-vane voltage	65 kV
Synchronous phase	-69~-30 deg
Input energy	7.5 keV/u
Length of RFQ	145.9 cm
Output energy	201.2 keV/u
Length of SFRFQ	97.9 cm

The cavity consists of 14 identical supporting rings. The 8 rings in the left are for the RFQ electrodes (include 33 RFQ cells) and the 6 rings are for the SFRFQ electrodes (include 10 SFRFQ cells). The layout of the coupled RFQ-SFRFQ was sketched in Fig. 5.

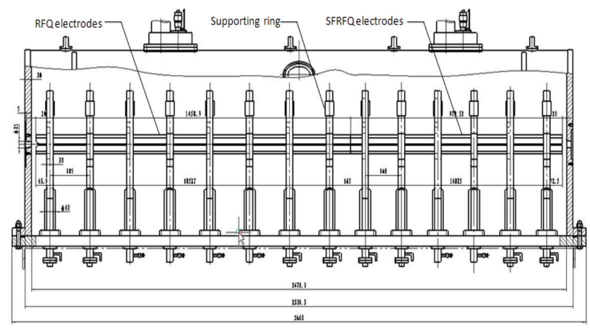

Figure 5: The sketch layout of the coupled RFQ-SFRFQ cavity.

The aperture of the diaphragm confines the envelope of the accelerating beam directly. Generally, larger aperture is advantageous for transmission. However, the accelerating field decreased with the diaphragm's aperture as shown in Fig. 6. The reverse field (make against the energy gain, between 2&3 in the Figure 1) was not changed obviously with the diaphragm's aperture.

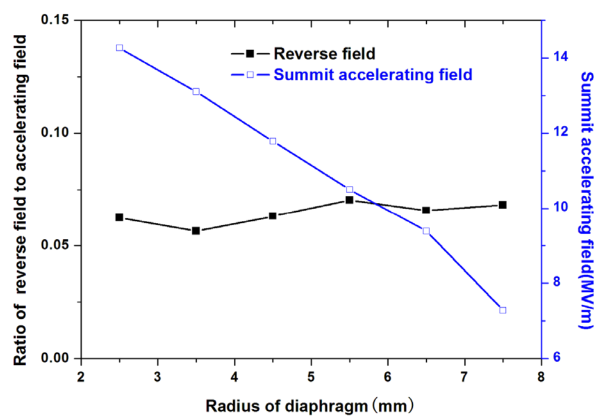

Figure 6: Reverse and accelerating field as a function of the diaphragm's radius.

After the optimizations of the input energy of SFRFQ section and the diaphragm's radius, the parameters of the supporting rings were determined by the structure calculations. The detailed dimensions of the coupled cavity as listed in the Table 2.

Table 2: The cavity dimensions

Cavity radius	37.5cm
Cavity length	253.85cm
Radius of RFQ electrodes	0.936cm
Radius of SFRFQ electrodes	0.8cm
Radius of the supporting rings	19.6cm
Distance of the RFQ rings	18.5cm
Distance of the SFRFQ rings	16.8cm
Radius of the diaphragms	0.6cm

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SUMMARY AND FUTURE PLAN

The structure of the coupled RFQ-SFRFQ has been optimized. To design a compact cavity, the energy transition has been a consideration throughtout the design.In order to accomplish a well bunched beam at the entrance of SFRFQ, the external buncher method was adopted. Howerer, this can be costly. In our plan, the buncher cavity will be replaced by an energy modulated ECR ion source. Further studies will be needed to address the ion source experiments by loading a sine wave voltage onto the extracted electrodes of the ECR ion source.

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