Latest progress of the RFQ cooler and buncher RFQ1L *

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Abstract The RFQ cooler and buncher RFQ1L is a key device of the SHANS (Spectrometer for Heavy Atoms and Nuclear Structure). The status of the machining and assembly of the central part is introduced, and the structure of the whole RFQ1L system and the preliminary plan for the testing are discussed also.

Key words SHANS, RFQ cooler and buncher, super heavy, RFQ1L

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1 Introduction

Figure 1 shows schematically the setup of the Spectrometer for Heavy Atoms and Nuclear Structure (SHANS), which is being constructed in Institute of Modern Physics (IMP). The main tasks of the SHANS are (1) to perform nuclear structure and decay studies with exotic isotopes far from the beta stability valley and (2) to perform studies on super heavy nuclides by assigning directly their charge number Z and mass number A. The RFQ cooler and buncher RFQ1L is one of the key devices in the SHANS[1, 2].

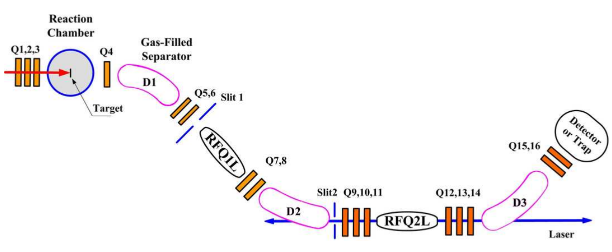

Fig. 1. Schematic drawing of SHANS.

It will collect the recoils from the gas-filled separator, cool and bunch them in order to convert the poor beam to a beam with mono energy, low emittance, and small beam spot. The cooled beam will be shot into a detection array for precise nuclear structure and decay study or transported into successive devices for additional manipulations, such as high precision mass measurement in LPT (Lanzhou Penning Trap).

The structure of the RFQ1L is shown in the top panel of Fig. 2. The bottom panel shows also the corresponding axial field for guiding and Paul trap for ion accumulation. The operation of the RFQ1L can be separated into four parts by their functions[3] as following:

(1) Buffer gas cooling. Due to the collisions with gas molecules, ion suffers a continuous viscous force and lose its kinetic energy, thus the oscillation amplitude will decrease gradually.

(2) Radial confinement. The quadrupole field for the confinement is provided by the four hyperbolic electrodes. By applying a suitable RF voltage between two adjacent electrodes, ion keeps moving between the electrodes and is thus confined radially. At the same time, since the kinetic energy of the ion becomes smaller and smaller due to the buffer gas cooling effect, the ion will be confined in a very small

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space near the axis at last.

(3) Axial guide and confinement. The field for ion guide is provided by 21 segmented wedge electrodes, which are placed sequentially in the axial direction. The ion will be accelerated in the axial direction and thus the transport time to the end of the RFQ1L will be shortened. By applying suitable potentials on the wedge electrodes the ion can also be confined and stored in the linear Paul trap near the end of the RFQ1L.

(4) Extraction of the cooled beam. By switching the potentials applied on the last few electrodes, the stored beam will be extracted and transported to the successive skimmer system by another static electric ion guide.

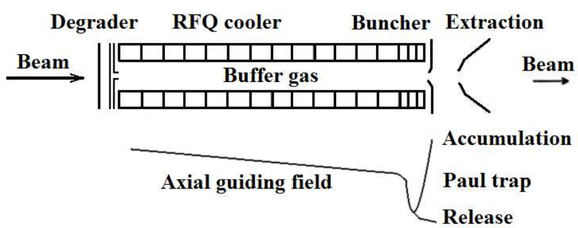

Fig. 2. Structure of RFQ1L (above) and its corresponding axial guiding field (below).

2 Machining and assembling of the central part of RFQ1L

To minimize the influence from the material the central part of RFQ1L was made of stainless steel. The aluminum oxide insulators were used by considering the rigidity and outgassing property. Because the ion in the RFQ1L would be lost due to the collision with the impurities, all machining and assembling have been done according to the technical requirements for the ultrahigh vacuum. After degassing in the high temperature and vacuum environment, the magnetic permeability of the electrodes has been reduced to <1.05. By overcoming a lot of difficulties, we have finished the assembling of the RFQ1L in almost half a year. Cross checks and measurements have been performed during and after the assembling. All measurements show that the final displacement of all parts are within 0.5 mm and all the insulators and conductors work well. Fig. 3 shows the assembled hyperbolic and wedge electrodes and a photography taken just after the finish of the assembling is shown in Fig. 4.

After finishing the assembling, the pressure rise rate of the whole system has been measured[4]. After pumping the chamber for 87 hours by a 550 l/s turbobump continuously, the pressure in the chamber was measured to be 1.7×10^{-4} Pa. The leakage was determined to be less than 1.0×10^{-10} Pa l/s by a INFICON UL1000 Helium leak detector. The pressure rise rate was obtained to be 0.04 ± 0.02 Pa/h after 1200 hour measurement without pumping. Suppose that the RFQ1L is filled with a completely pure buffer gas and the pressure keeps at 100 Pa. After one hour sealing, the percentage of the impurity in the RFQ1L will be 0.04 ± 0.02%. Because the buffer gas is pumped and filled into the system simultaneously and continuously when the RFQ1L works in its normal state, the impurity in the system should become less and is determined by the impurity of the buffer gas itself.

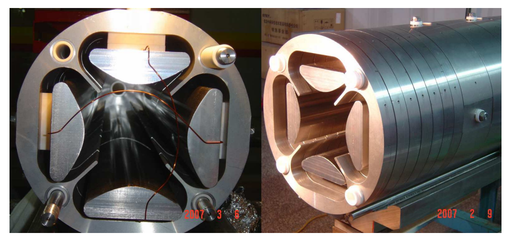

Fig. 3. Assembled hyperbolic and wedge electrodes.

Fig. 4. A photography taken just after the finish of the assembling.

3 Necessary accessories of RFQ1L

Beside the central part described above, the RFQ1L system have four necessary accessories base on their functions: ion source, gas dosing, power supply and detection systems.

A home-made laser ion source will be used in primary testing. The beam from such a source has the following characteristics: The beam energy extends from about 1 keV to several MeV and its emittance is about 30°, the distribution of charge states of the ions spreads quite wide, and the repetition frequency of the laser is about 1 Hz. Such a beam is quite suitable for checking the cooling and confinement ability of the RFQ1L, but it is not for measuring the absolute transmission efficiency due to its low repetition frequency and poor emittance. A well defined ion source will be developed in near future.

Because the collisions between the ions and the impurities, which generally have relatively low first ionization potentials compared to the buffer gas, will cause the ions lost their charges and thus decreasing the transmission efficiency, a buffer gas with very low impurity should be used. A gas dosing system will be built for this purpose and Helium gas with a grade of 6.0 will be used in the RFQ1L. The gas from the bottle will also be cooled in the liquid nitrogen temperature.

There are three types of power supply used in the RFQ1L: (1) A RF power supply for hyperbolical electrodes. Its frequency can be adjusted between 10—500 kHz with an accuracy of 0.1% and its available maximal amplitude is about 2000 V. (2) DC power supplies for wedge electrodes and static electric extraction system[5]. (3) A pulsed power supply to open and close the Paul trap. All the components except the detectors will be placed on a 10 kV high voltage platform to ease the manipulation in the successive devices.

The primary detection system is relatively simple and there are two main detectors will be used: A Si detector for counting and a beveled Faraday Cup[6] for measuring beam current. The latter can restrain effectively the secondary electron emission due to its special shape.

4 Possible procedure of the testing

The testing of the RFQ1L is a complicated, time-consuming and challenging process. A possible procedure is the following:

(1) Measuring the pressure rise rate of the whole system to estimate the impurity of the buffer gas in the RFQ1L. Although we have done this before[4], we have to measure it again because the configurations of the flanges have been modified quite a lot.

(2) Determining the optimal values of the RF voltage. Simulation and experiments[7] show that helium gas will be discharged very easily if the pressure in the RFQ1L is about 100 Pa. To avoid the discharging, it is necessary to optimize the gas pressure, the amplitude and frequency of the RF voltage.

(3) Testing the cooling and confinement ability. The test will start from lower gas pressure, 10 Pa for example. According to the Paschen curves and our experimental results[5], the potential difference between the electrodes can be higher at lower pressure, and thus the ions suffer a stronger confining force. Additionally, the collision between the ion and gas molecules becomes less due to the low pressure. Thus it should be easier to transport the ions in the RFQ1L. After obtaining some reasonable results, the buffer gas pressure will be increased and then testing and optimizing the parameters will be performed. The highest buffer gas pressure will be around 1000 Pa.

(4) Measuring the transmission time of the ions and understanding the influences from the longitudinal guiding electric field.

(5) Testing the Paul trap for accumulation and bunching and determining its parameters.

(6) Determining the transmission efficiencies and times and emittances for different beams.

It should be noted that the above procedure should not be followed exactly. To make the RFQ1L work better, we have to optimize all the parameters according to theories and experimental results.

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