Transport efficiency of injection optics and RFQ of the TAMUTRAP facility

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Significant progress has been made toward the commissioning of the TAMUTRAP facility over the past year. Different sections of beam line were tested using an in-house-designed ion gun employing potassium and sodium ion sources. As reported in our previous report [1], a low energy beam of 10 keV was successfully decelerated to several tens of eV using custom injection optics. The beam was then transported through the RFQ with and without the presence of a Helium buffer gas, and was extracted using a custom extraction optics. The total transmission efficiency of this beam line consisting of injection optics, RFQ, and extraction optics was around 3%. In order to determine the cause of this low transmission efficiency several offline tests were performed on the constituent sections.

Efficiency of Injection Optics

A modified three element lens is employed as the injection optics to focus the decelerating ions and inject them into the RFQ. This lens is formed by placing an electrode with a circular aperture between a region of low electric potential and a region of high electric potential (Fig. 1). A SIMION simulation predicted the efficiency of injection optics to be close to 100%.

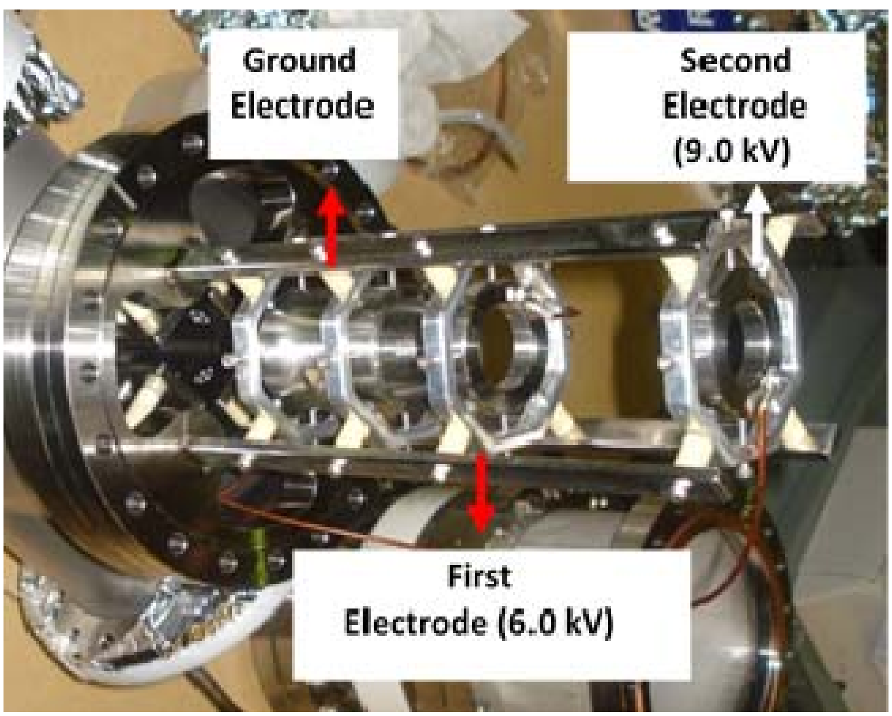

FIG. 1. Injection optics for the TAMUTRAP RFQ.

For testing, the injection optics was decoupled from the RFQ and extraction optics, and a Faraday cup was placed in the location of the RFQ preceded by a diaphragm of 6 mm. Two offline tests were performed by placing the Faraday cup at two different distances from the diaphragm. In the first test, the distance between the Faraday cup and the diaphragm reflected the position of the 1^{st} segment of the RFQ. In the second test, the distance between the Faraday cup and the diaphragm reflected the position of the 3rd segment. The efficiency of the injection optics was determined by measuring the current before (F-cup-01) and after (F-Cup-02) the injection optics. The efficiency of the injection optics at 100 eV beam energy was around 45% when the Faraday cup was at the position of the 1^{st} segment, and around 30% when the Faraday cup was at the position of the 3^{rd} segment. This poor efficiency in the case of the low energy beam was suspected to be the result of two main causes: an insufficient beam line mechanical support structure due to which the beam pipes and the electrodes were not acceptably aligned with each other, and poor ion beam emittance from the ion gun. An improved mechanical support was designed to support the beam pipes (Fig. 2) and to aid in alignment. Collimators of 1 mm diameter were used in conjunction with an optical transit to align the inner electrodes with each other and with respect to the beam pipe. Adjustable PEEK screws were used to hold and adjust the injection optics electrodes as necessary. The improvement in the beam alignment with new support structure is shown in Fig. 2.

After installing this new mechanical support, the injection optics was once again tested by placing

FIG. 2. Beamline mechanical support (middle) and images through the optical transport demonstrating the improved alignment.

a Faraday cup (F-cup-02) in place of the RFQ. The distance between the Faraday cup and the diaphragm was set to the position of the 3^{rd} segment of the RFQ. The observed efficiency was two times better compared to the previously measured efficiency at 100 eV. Next, we studied the efficiency of the injection optics as a function of beam energy (Fig. 3) entering RFQ. The efficiency was found to be greater than 80% for beam energies greater than 75 eV, and dropped substantially when the beam energy was less than 30 eV. A likely cause for this low efficiency at 30 eV beam energy is large emittance of the beam exiting the ion gun. We believe improving the emittance of the ion gun to a more realistic value will increase the efficiency to as high as 90% at 30 eV beam energy.

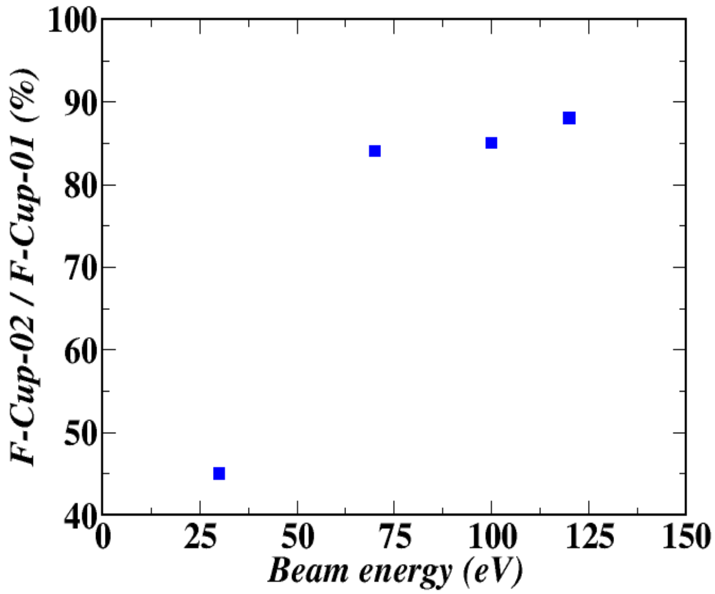

FIG. 3. Efficiency of the injection optics as a function of the beam energy entering the RFQ.

Transport Efficiency

Following these tests, the injection optics was coupled to the RFQ and extraction optics. Two Faraday cups were installed, one before the injection optics and the other at the exit of the extraction optics. The RFQ is 80 cm long with r_0 = 6mm.. In order to apply the longitudinal potential the structure was segmented into twenty eight pieces. The segments in the injection and trapping regions were made shorter than those in the center of the trap in order to give more control over the electric field in these regions. The RFQ was operated in continuous mode and was optimized by scanning the frequency and RF voltage applied to the segments (see Fig. 4). The maximum transmitted current was observed at 1.2 MHz. At each frequency the RF voltage was scanned by changing the power of the power amplifier. The peak-to-peak RF voltage at 1.2 MHz was around 123 V, yielding a total transport efficiency for these three elements of around 13% which was four times more compared to the previous value. It is predicted that the transmission efficiency of the RFQ alone was raised to 20-25% in continuous mode as a result of the improved alignment.

Despite this improvement, the efficiency is still lower than desired, mainly due to the unacceptable beam emittance coming from the ion gun and mechanical misalignment within the RFQ structure itself. As discussed, the electronics for the RFQ are working as expected, yielding up to 160 V peak-to-peak at frequencies between 0.5-1.5 MHz, and will be carried over to the improved mechanical structure. An improved designed is planned and is currently under development.

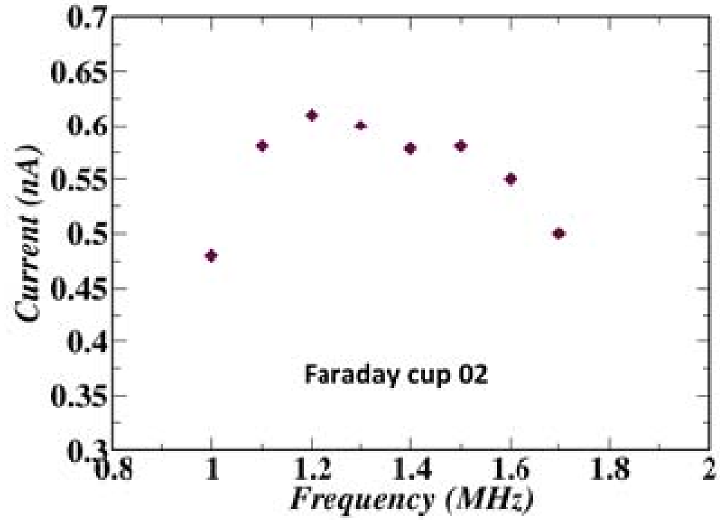

FIG. 4. Current observed at the exit of extraction optics as a function of frequency.

[1] R.S. Behling *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University, (2012-2013), p IV-46.