Status of TAMUTRAP facility

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We began the year by continuing the systematic studies of radio frequency quadrupole (RFQ) trap (Section 1 in Fig.1), which included the testing and optimization of the RFQ in bunched mode, injection optics and the extraction optics. For these studies, we used microchannel plate (MCPs) for single ion counting and beam optics optimization in bunched and pulsed operation modes (Diagnostic 3 station in Fig. 1). The diagnostic stations along the beam-line are combinations of MCPs and Faraday cups (FC).

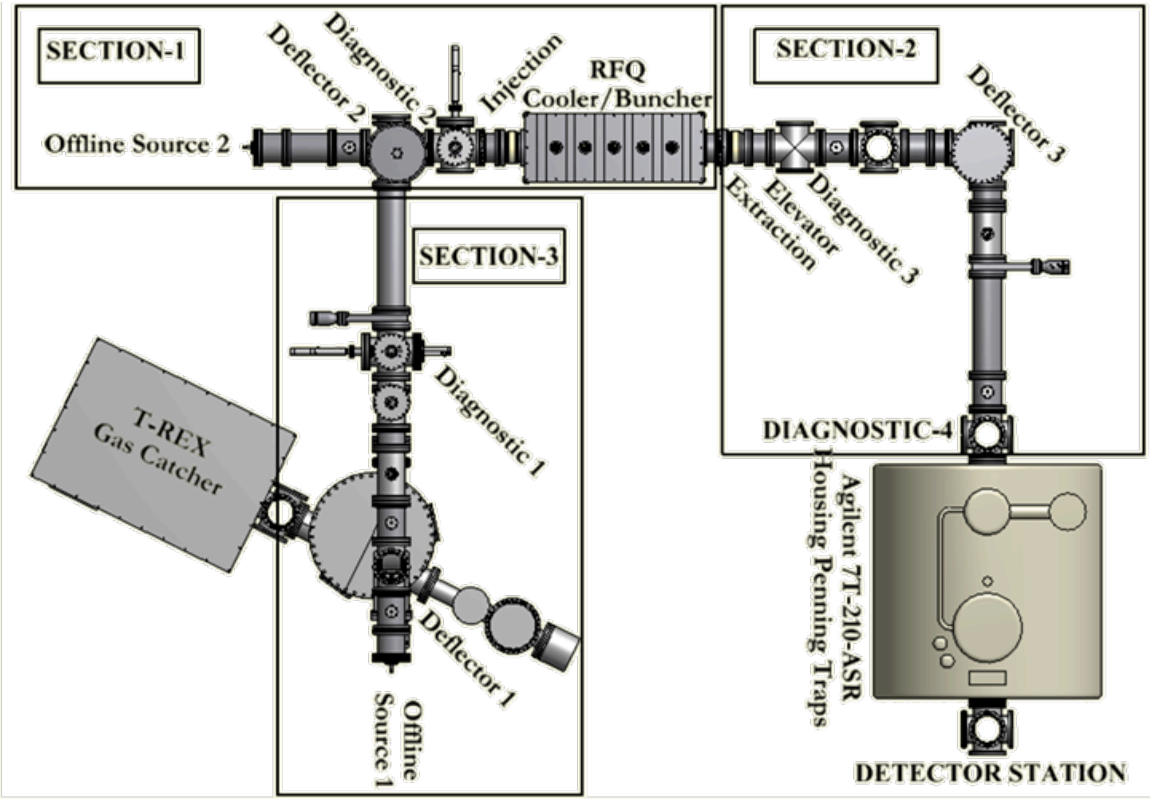

FIG. 1. Commissioned TAMUTRAP beamline, which includes the RFQ, pulsing cavity, diagnostic station, cylindrical and spherical deflectors, and two ion guns.

The time spectrums were recorded for different gas pressure in RFQ, different ejection time, and different cooling time. In addition to these studies, three different modes of extraction of the bunched beam from the RFQ trap were studied. In the first mode, only the potential on the last electrode (#30) was lowered and the ions drifted out of the trap. In the second mode, the potential on the last electrode (#30) was lowered at the same time as the potential on the third from the last electrode (#28) was raised, thus kicking the ions out of the trap. In the third mode, we coupled the last two electrodes (#29 and #30) and the trap was formed using the third electrode (#28) from the last. These systematic studies helped us to confirm further that the multi peak observed in the timing spectrum for some settings of ejection time was not because of the multi traps being formed in the RFQ, but because of more than one mass being released from the ion source. The FWHM of the bunch's time spread is around 1.1 μs with energy of the extracted bunch's being 10 keV (See Fig. 2).

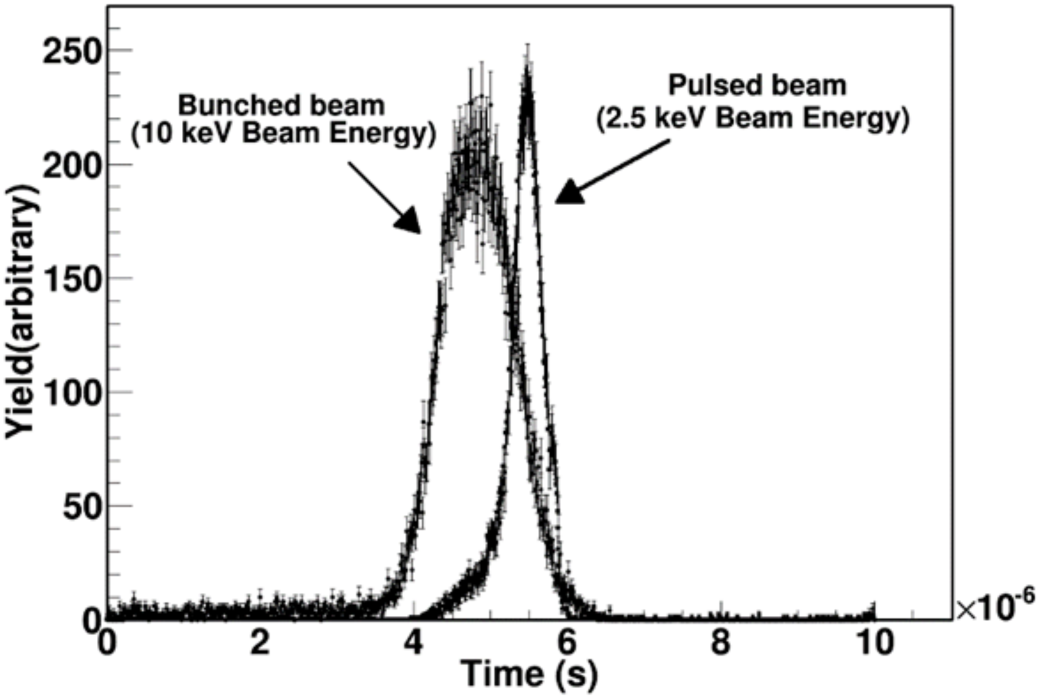

FIG. 2. Time spectrum of bunched and pulsed ions.

After the systematic studies with RFQ, a pulsing drift tube (elevator in Section 2 of Fig.1) was coupled to the extraction optics to redefine the energy of the extracted bunch. The pulsing drift tube employs a 400 mm long drift tube and has been designed as a floating element able to sit within the beam line. The support structure consists of three semi-circular legs that can be placed arbitrarily along the length of the electrode, and are held in place via set screws. In pulsed mode the energy of the extracted bunch is the potential difference between the floating voltage of RFQ platform and drift tube. The principle is illustrated as follows: the ion pulse is accelerated towards a pulsing drift tube and the kinetic energy gained by the ion pulse is the potential difference between the RFQ high voltage platform and drift tube. Once the ions are inside the drift tube, its potential is switched to ground potential using a behlke high-voltage switch. Thus, the ions leave the drift tube at a ground potential with a kinetic energy equal to the potential difference between the RFQ and drift tube. The kinetic energy of the ion pulse after the pulsing drift tube is around 2.5 keV. Following the pulsing drift tube, the pulsed beam is guided using a combination of einzel lens and x-y steerer and, further bent by 90 degree using cylindrical deflector. Additional einzel lens, x-y steerer and a beam diagnostic station (Diagnostic 4) is coupled after the final bend (Section -2 of Fig.1).

Alignment of section-1 collinear to section-2 was performed by setting up two optical transits, one along the axis of RFQ and one along the axis of superconducting magnet. After aligning the electrostatic components of both the sections, offline tests were performed using offline ion source 2 (see

Fig.1). Beam was successfully loaded into the RFQ, bunched and cooled in RFQ, pulsed using pulsing drift tube, and bent by 90 degree using cylindrical deflector (deflector 3 in Fig.1). The time spectrum was recorded using MCP detector at diagnostic station-4 for different settings of RFQ, and for different combination of cylindrical deflector plate voltages. The settings of other electrostatic components (Einzel lens, steerer, injection optics, and extraction optics) were also optimized to maximize the transport efficiency. The timing spectrum of bunched and pulsed ions is compared in Figure 2. The FWHM of pulsed ions is narrower than the bunched ions. One of the main reasons for this is the existence of more than one mass in the bunched spectrum, which gets separated by time of flight in pulsed mode. The FWHM of pulsed ions is less than 1μs.

Section-3 (Fig. 1) was further coupled to the spherical deflector (Deflector 2 in Fig.1). This includes three einzel lenses, 2 x-y steerer, beam emittance and diagnostic station, cylindrical deflector, and offline ion source (Offline Source 1 in Fig.1). To achieve the required vacuum, turbo pump with pumping speed 450 L/s and backed by dry scroll pump is placed before beam diagnostic station. Alignment of section-3 collinear to section-1 and section-2 was performed by setting two optical transits, one along the axis of section-3 and one along the axis of RFQ. Detail procedure of alignment is explained in last year's annual report [1].

An in-house-designed ion gun employing a sodium ion source (offline source 1 in Fig.1) was developed and mounted before the first cylindrical deflector for testing lenses, steerer, and spherical deflector of Section-1. The beam was transported with high efficiency from offline source 1 and further bent by 90^0 using spherical deflector. The settings of spherical deflector plate voltages were optimized by measuring current in the Faraday cups located at diagnostic stations 1 and 2. The functioning of lenses, x-y steerer, and spherical deflector guided the ions into the RFQ from offline source-1. The ions were cooled/bunched, pulsed and bent by 90 degree using cylindrical deflector (Deflector-3). The time spectrum observed at diagnostic station 4 was similar to that shown in Fig.2.

The immediate outlooks for the TAMUTRAP facility involves the coupling of Penning trap system to the TAMUTRAP beam line and trap the ions from the stable ion source. The large bore magnet (Magnex Scientific) for the Penning trap has been energized to the full 7T field with <2 ppm inhomogeneities at the centre. We are in the process of installing the assembled prototype trap system after the completion of scheduled maintenance. More details about the Penning trap system are provided in another report.

[1] E. Bennett *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. IV-36.