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PROGRESS ON THE TAC ION SOURCE AND LEBT

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Abstract

A 500 keV RFQ accelerator is being developed at the Texas Accelerator Center. The ion source for this machine is a magnetron type ion source with a single extraction gap. The design current is 10 mA of H^- with an energy of 30 keV and $\epsilon_{n,90\%} = 0.2\ \pi$ mm-mrad. To date, peak currents in excess of 28 mA have been extracted from this ion source indicating that the current density at the extraction aperture is 2.1 A/cm^2. Preliminary emittances have been obtained 10 cm from the extraction aperture. The extracted beam is transported approximately 30 cm by a helical electrostatic quadrupole lens (HESQ). Initial low current tests of the HESQ have shown that 55 % of the focused beam lies within the RFQ acceptance.

Introduction

A 500 keV prototype RFQ accelerator is being developed at the Texas Accelerator Center. One of the prominent features of this accelerator is the inclusion of a short electrostatic low energy beam transport (LEBT) line between the ion source and the RFQ. This work is being performed as a part of a larger project to construct a 2.5 MeV RFQ linac.

The requirements on the ion source are derived from several sources: the current and pulse length requirements of the SSC, and longer pulses for other applications. such as isotope production. The length of the beam pulse that is produced from the ion source and LEBT ranges from 8 μs to 200 μs, with a risetime of 100 ns. The desired current is 10 mA which is determined by the current limit of the 500 keV RFQ prototype. The present work describes the current state of the development of the ion source and LEBT for this project.

Ion Source

The ion source is a BNL[2] type magnetron H^- ion source with diode extraction optics. The basic mechanical design follows the work done at BNL: a cathode with a spherical dimple to provide geometrical focussing, a re-entrant source mount, an external cesium supply, and permanent magnets to provide the source's magnetic field. There have been, however, several changes made to the extraction geometry to adapt the source to the requirements presented above. First, the inner molybdenum anode cover plate and stainless steel extraction plate used at BNL has been joined into one stainless steel anode cover plate which provides both the gas seal for the magnetron source volume and the extraction aperture. This particular modification has been quite reliable and has not yet shown significant wear. The second design change has been to adjust the extraction optics to provide a 10 mA H^- beam whose normalized 90% emittance is 0.2 π mm–mrad. The initial anode aperture is 1.3 mm in diameter with a 4.5 mm gap between the electrodes. Figure 1 shows the extraction geometry used in these tests.

The test beams were extracted from the ion source by applying a constant −30 kV potential to the ion source and grounding the conical extraction electrode. The intensity of the extracted beam was measured by a 6.6 X 8.3 cm planar Faraday cup located 10 cm downstream from the extraction gap. The discharge was operated in 100 μs long pulses with an arc voltage of 147 V and an arc current of 20 A. The extracted H^- current measured by this cup was 28 mA, which indicated that the current density at the extraction aperture was 2.1 A/cm^2.

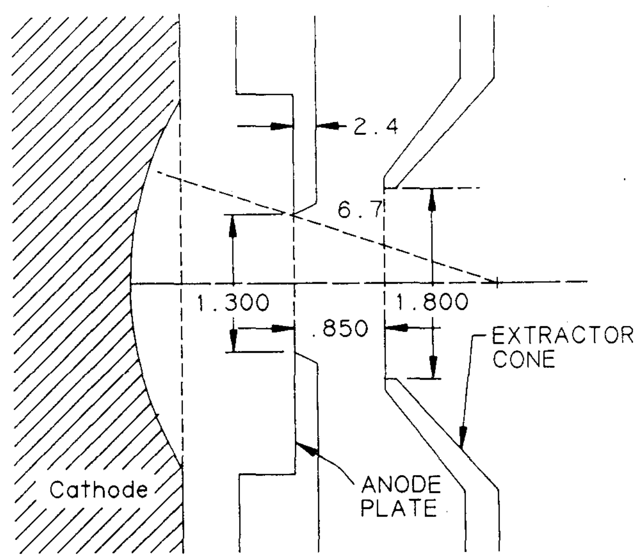

Fig. 1. Extraction geometry (not to scale) for 28 mA source. All dimensions are given in millimeters.

Using this density the area of the extraction aperture in the anode cover plate was scaled down to provide a 10 mA beam. This density is roughly equivalent to the the densities reported by BNL[3].

The ion source emittance was measured with an electrostatic emittance scanner[4] (EES) located 10 cm from the extraction gap. The current incident upon the face of the scanners was measured to provide pulse-to-pulse normalization of the data.[5] The current waveforms in each of the EES Faraday cups, located immediately after the second analyzing slit, and the face current were recorded by a Hewlett-Packard Model 54501B digital oscilloscope. Due to the fact that the neutralization time of an H^- beam in hydrogen is roughly as long as the pulse length, the EES was used in two different modes to see the behavior of the beam. The first mode placed the EES at a fixed radial position and had fixed deflection plate voltages permitting us to view the behavior of the beam at a fixed point in $x-x'$ or $y-y'$ space. Figure 2 shows the extracted H^- current measured on the scanner face and the analyzed current when the scanner was located at -3 mm and the deflection voltage set for -18.7 mrad. Since the shape of the analyzed current pulse is in good agreement with the shape of the extracted pulse, it would appear that the ellipse rotation due to neutralization is not a major problem. The second EES mode was to use it to obtain emittances in a manor described by Allison[4]. Preliminary values for the measured normalized, 90% emittances are 0.29 π mm–mrad for the horizontal axis, and 0.36 π mm-mrad for the vertical axis. It should be noted that there was an angular offset of 25 mrad in the vertical direction due to the presence of the magnetic field required to operate the source.

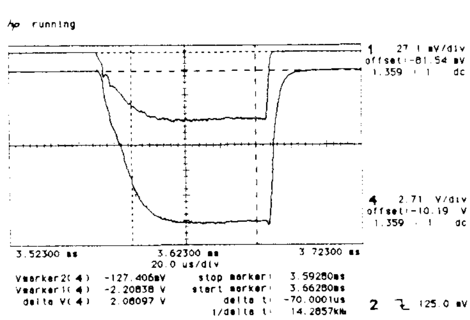

Fig. 2. Waveforms observed on the emittance scanner face and analyzed beam Faraday cup. The upper trace is the scanner face current while the lower trace is the analyzed current pulse shape.

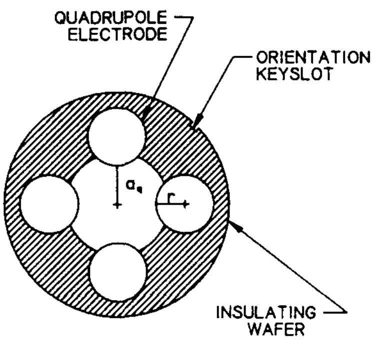

Fig. 3. End view of a HESQ cell. The radius of the electrodes, r, is 1.0 cm. The radius of the available aperture, a_q, is 1.3 cm.

Low Energy Beam Transport

The rotation of the emittance ellipse due to the build up of neutralizing particles during the beam pulse may be countered by imposing an external electric field on the beam. Raparia[6] has developed a helical electrostatic quadrupole which is capable of focussing highly charged beams into a RFQ. A HESQ prototype capable of transporting currents up to 10 mA has been constructed at TAC and initial testing is underway.

The first HESQ prototype has been built using a discretized approximation of the helical pole pieces. The entire lens has been divided into four independent HESQ segments for flexibility during operation. Each HESQ segment has been built from a given number of identical unit cells, where each successive cell has been rotated 18 degrees from the previous cell to form the helical structure. Each segment is electrically isolated from the its adjacent cells to provide flexibility during operation. The first three segments have been constructed using 10 cells, and the final segment has been constructed using 8 cells. Figure 3 shows one unit cell. Each cell consists of four stainless steel disks held in place by a single G-10 insulator. A notch on the outside of the G-10 disk provides the rotational alignment. The diameter of the open aperture is 26 mm. The center of each of the cells in the structure was aligned to within ± 0.05 mm. G-10 end insulators are used to provide electrical isolation from support structure at the end of the lens and to provide enough compression to hold the cells firmly in place. The pole voltages for each segment are supplied by eight separate 10 kV, 0.4 mA power supplies. One positive and one negative supply are connected to the electrodes in each segment. The electrical connection between cells is accomplished by contact between the electrodes in adjacent cells. Each HESQ segment was tested without beam up to 10 kV.

The initial tuning of the HESQ pole voltages was accomplished by inserting a tandem Faraday cup into the beam 4.2 cm from the end of the HESQ. The front Faraday cup had a pair of 6 mm apertures to simulate the entrance acceptance to the RFQ: the first aperture was on the back face of the Faraday cup and the second was located 51 mm downstream from the first. Immediately after the second aperture was a second Faraday cup to measure the current that would pass into the RFQ. The fraction of the beam within the RFQ acceptance, f, was obtained from the ratio $f = I_{back}/(I_{front} + I_{back})$, where I_{front} is the current into the first faraday cup and I_{back} is the current that successfully passes into the second faraday cup. Current striking the second aperture is included in I_{front}. The pole voltages were tuned to maximize both f and the total current.

A low current H^- beam was obtained by detuning the magnetron source and injecting the extracted beam into the HESQ. The current of the injected beam is not immediately known due to the close coupling of the ion source and HESQ. It was found that when a total transmitted current of 2.5 mA was transmitted through the HESQ, the fraction within the RFQ acceptance was 55%. When the transmitted current was increased to 5 mA, f decreased to 42%. The fact that this ratio decreased was due to the 10 kV limit to the pole voltages in the first segment where the beam emerging from the ion source is captured: we were unable to increase the voltage in the first segment far enough for the high current beam to go through a peak in the transmission.

Conclusions

The ion source produced 10 mA of H^- with preliminary normalized, 90% emittances of 0.29 π mm–mrad in the horizontal direction and 0.36 π mm–mrad in the vertical direction, which are in good agreement with computer simulations. The initial trials of the HESQ with low current, 2.5 mA beams have shown that the lens is focusing 55% of the transmitted beam into the RFQ acceptance, but decreased as the injected current increased. It is likely that this fraction will be improved with further improvements such as adding electrostatic or magnetic steering to the system and upgrading the high voltage power supplies on the first segment. This work represents an important first step towards making this lens a usable matching section on future RFQ accelerators.

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