COMMISSIONING OF THE LOW-ENERGY DEMONSTRATION ACCELERATOR (LEDA) RADIO-FREQUENCY QUADRUPOLE (RFQ) *

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Abstract

Initial commissioning of a 6.7–MeV 100–mA RFQ is underway. The RFQ is part of LEDA, the H^+ injector for the Accelerator Production of Tritium (APT) project. To benchmark the RFQ performance, beam physics experiments will be done with low and high current beams for both pulsed and cw beam operation. Commissioning efforts thus far have been limited to low–current pulsed–beam LEDA operation. Measurements to fully characterize the RFQ will ultimately include the dependence of RFQ beam transmission on RFQ vane voltage, input beam energy, input match, and input transverse centroids. Other commissioning measurements for the RFQ will include output beam energy, phase, noise, transverse profiles, and transverse rms emittances. This paper contains initial LEDA RFQ commissioning results, including RFQ pulsed output beam currents up to 40 mA.

1 INTRODUCTION

The LEDA RFQ [1] is a 100% duty factor (cw) linac capable of delivering >100–mA of H^+ beam at 6.7–MeV. The 8-m-long, 350-MHz RFQ structure [2] is designed to accelerate the dc 75–keV, 110-mA H^+ beam from the LEDA injector [3,4] with >90% transmission. On March 16, 1999 first beam was accelerated through the LEDA RFQ. The preliminary RFQ commissioning results in this paper are for pulsed beams with low rep-rate and short pulse lengths.

2 LEDA CONFIGURATION

The accelerator configuration for beam commissioning of the LEDA RFQ is shown schematically in Figure 1.

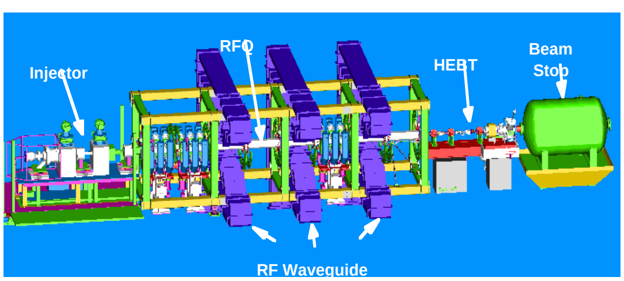

Figure 1: LEDA configuration for RFQ commissioning.

The major accelerator subsystems are the injector [3,4] (source and Low Energy Beam Transport (LEBT)), RFQ [2], High Energy Beam Transport (HEBT) [5], and the beam stop [6].

The layout of LEBT beamline optics and diagnostics is shown in Figure 2. The beamline optics include two solenoids and two steering magnet pairs for proper matching and injection into the RFQ. The suite of diagnostics include two view screens (interceptive diagnostic intended only for low-power density beams), three noninterceptive video profile diagnostics (VD1, VD2, & VD3), three DC current diagnostics (DC1, DC2, & DC3), and two pulsed beam current monitors (not shown in Figure 2). The pulsed beam current monitors are located right after the source and directly before the RFQ.

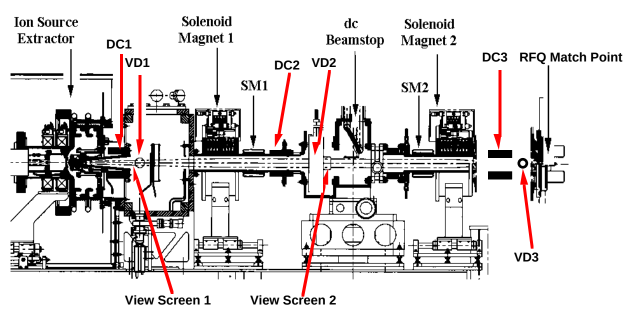

Figure 2: The LEDA LEBT beamline, including optics and diagnostics.

A photograph of the LEDA HEBT showing the location of beamline optics and diagnostics is given in Figure 3. Beam direction is from left to right. The function of the LEDA HEBT is to characterize the properties of the beam and transport the beam with low losses to a shielded beam stop. The beamline optics consists of four quadruples and two X-Y steering magnets. The HEBT beam diagnostics are described in [7]: they include 5 beam position monitors (BPMs), 2 DC and pulsed toroids, 3 capacitive pickoff probes, and 2 profile monitors. This set of diagnostics allow for measurements of beam current (pulsed beam, DC beam, and bunched

*Work supported by the US DOE, Defense Programs.
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beam), transverse centroids, longitudinal centroids (i.e. beam energy from time–of–flight and beam phase), and transverse beam profiles (wire scanner and video fluorescence).

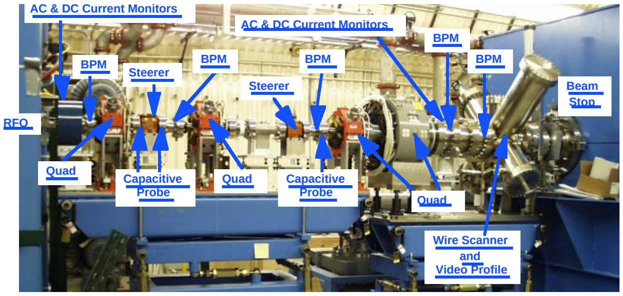

Figure 3: Layout of HEBT beamline optics and diagnostics. Beam direction is from left to right.

3 COMMISSIONING PLAN

Beam commissioning of LEDA will follow a graded approach. Because beam operation will truly be the first fully integrated test of all LEDA systems, commissioning will proceed cautiously. The assumption is that, in all likelihood, subsystems and their interfaces to other subsystems will not operate as expected.

An implication of this approach is that initial beam commissioning of the RFQ is in pulsed rather than cw mode. More specifically, to minimize or even eliminate beam related equipment damage, commissioning began in a pulsed low–power mode defined by short-pulse lengths (i.e. ≤ 500 µs), low-rep rate (i.e. 5 Hz), and low-beam current (i.e. ≤ 10 mA). As the performance of all systems is verified, commissioning will proceed in a stepwise fashion to the full cw high–power mode, 100% duty cycle and full current (100 mA). Pulsed operation is achieved by operating the injector in pulsed mode while operating the RFQ rf system at > 80% duty factor.

Besides protecting equipment (e.g. RFQ, HEBT, and beam stop), beginning beam commissioning with short-pulse lengths, low–rep rate, and low-beam currents has two other advantages. First, it allows for the operation of certain interceptive beam diagnostics that will be unavailable at higher beam-power densities. These diagnostics are for beam profile measurements and include two view screens in the LEBT and a wire scanner in the HEBT. Second, the most complete characterization of the RFQ can occur only when operating in a low-power pulsed mode. For example, measurements of RFQ beam transmission in high-power modes (pulsed or cw) will be considerably restricted due to the risk of beam damage to the RFQ vanes.

A starting pulse length ≤500 µs allows for a variety of transient conditions to stabilize in the first ~100 µs of the beam pulse while providing up to 400 µs in which to sample the time dependence of beam observables. Based on various scenarios of beam loss, especially in the HEBT, the starting beam current of ≤10 mA was considered low risk. A rep-rate of 5 Hz was chosen for initial operation to minimize any potential damage due to beam loss.

Commissioning will proceed in a bootstrap fashion. As systems are commissioned with low-power beam operation, the sequence will be to increase the rep-rate to 10 Hz and to increase both the beam intensity (ultimately to the 100 mA design level) and the pulse length to several 10s of ms. Then LEDA will be switched to a low-power cw mode and, finally, to high-power cw mode.

4 EXPERIMENTAL RESULTS

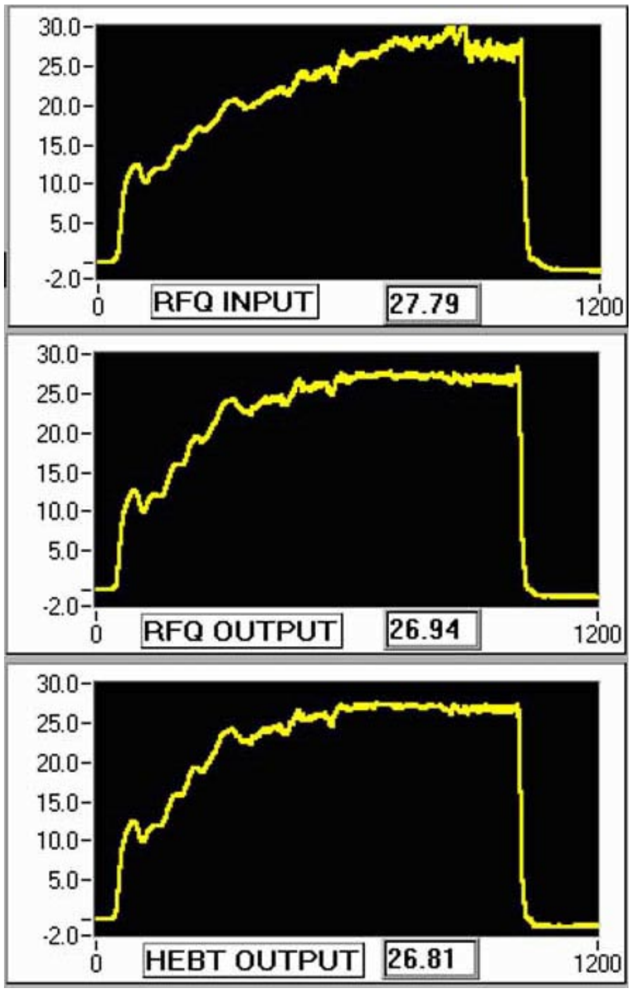

Figure 4: Time dependence of beam current over ~1 ms beam pulse as observed, from top to bottom, at the RFQ entrance, RFQ exit, and HEBT exit. The vertical axis is beam current (mA) and the horizontal is time (µs).

First beam through the RFQ was ~4 mA for a pulse length <500 μs and a rep-rate of 5Hz. As of the writing of this paper, the rep-rate has been increased to 10 Hz, the pulse length to ~2 ms, and the RFQ output current to ~40 mA. Figure 4 shows observed beam currents of >25 mA and ~1 ms pulse lengths at the RFQ entrance, RFQ exit, and HEBT exit.

After optimization of LEBT steering and LEBT match to the RFQ, RFQ transmission >95% and HEBT transmission >98% were obtained. More definitive measurements of transmission will require further tests of the beam current measurement system. Preliminary measurements of RFQ transmission as a function of vane voltage indicate that the RFQ is being operated above the knee in the transmission curve.

Measurements of the RFQ output beam energy, as determined from time-of-flight, and their comparisons to expectations are shown in Figure 5. These first results show that experiment and theory are consistent and that the output beam has the design energy.

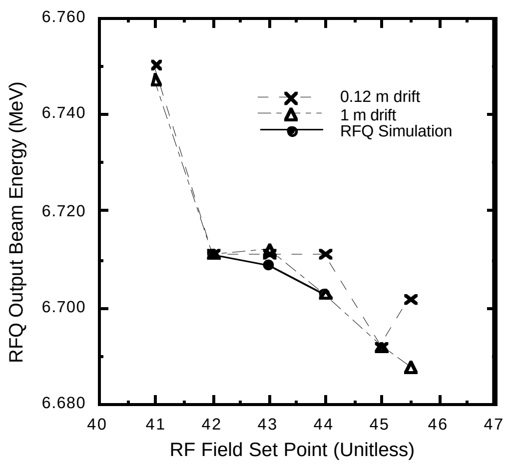

Figure 5: Measured output beam energy from the RFQ as a function of the rf field set point (RFQ design vane voltage corresponds to a set point of ~45).

First measurements of beam profiles using the slow wire scanner have been made and Figure 6 shows a measured horizontal profile. Verification of the BPM system is not complete. However, sufficient data have been taken to demonstrate consistency in beam position determination between BPMs and the wire scanner.

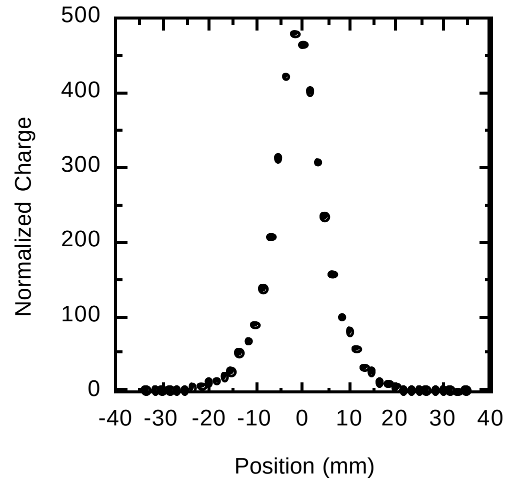

Figure 6: Horizontal beam profile as measured by a wire scanner ~2.8 m downstream from RFQ exit.

5 SUMMARY AND CONCLUSIONS

The initial performance of the LEDA injector, LEBT, RFQ, HEBT, and beamstop is encouraging. Increases in pulse length and current are going well. High RFQ and HEBT beam transmission has been established and the design RFQ output beam energy has been achieved. Observed RFQ transmission, at the present low beam currents, is consistent with PARMTEQM simulations [4] based on modeling of the present injector extraction system.

6 REFERENCES

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