THE FNAL INJECTOR UPGRADE STATUS*

C.Y. Tan †, D.S. Bollinger, K.L. Duel, P.R. Karns, J.R. Lackey, W.A. Pellico, V.E. Scarpine, R.E. Tomlin, Fermilab, IL 60510, USA

Abstract

The new FNAL H- injector upgrade is currently being tested before installation in the Spring 2012 shutdown of the accelerator complex. This line consists of an H- source, low energy beam transport (LEBT), 200 MHz RFQ and medium energy beam transport (MEBT). Beam measurements have been performed to validate the design before installation. The results of the beam measurements are presented in this paper.

INTRODUCTION

The new FNAL H- RFQ injector which was first conceptualized in 2008 may be installed in the 2012 shutdown after four years of work [1]. All the components from the source, LEBT and the RFQ have been tested with beam while the components in the MEBT have been powered and conditioned. The main show stopper is the discovery that the RFQ does not accelerate beam to its design energy of 750 keV. Instead, its output energy is about 700 keV which is 6.7% lower than designed. A possible source of the problem has been traced to warped rods in the RFQ and they are being fixed. The hope is that straightened rods can fix this problem and the design energy can be achieved. If the RFQ energy can be corrected quickly, installation of the new injector in 2012 is still possible.

The test line used for testing the source, LEBT and RFQ is shown in Figure 1.

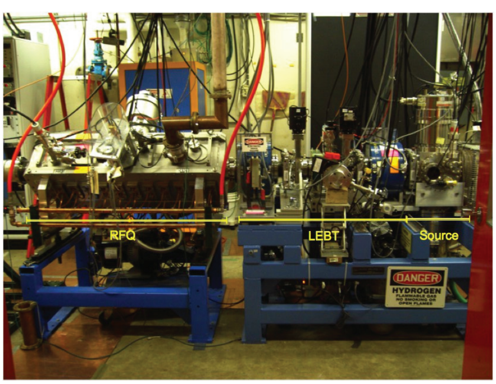

Figure 1: The test line used for measuring the beam parameters.

SOURCE

The source for the new injector is a circular aperture magnetron that was developed by J. Alessi at BNL [2]. The source is mounted reentrant in a vacuum chamber (See Figure 2) that has a total vacuum pumping speed of 2200 L/s. The source has a spherical dimple on the cathode that focuses the H- ions at the anode aperture which improves its overall efficiency. The other big improvement in H- production efficiency is the extraction scheme. The source is pulsed at -35 kV with the extraction electrode at ground potential. The extractor sparking with this voltage is reduced by a 0.095 inch gap and low vacuum pressure (around 1.2×10^{-6} Torr). With the high extraction voltage the source operates in the space charge limited regime, extracting almost all available H- ions, as shown in the beam current roll off at higher extraction voltages in Figure 3.

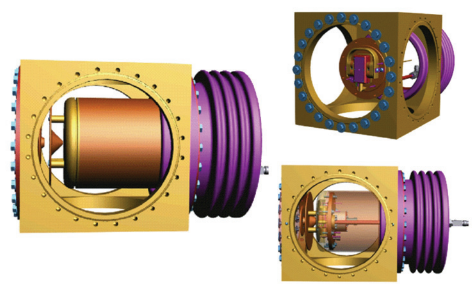

Figure 2: The H- source.

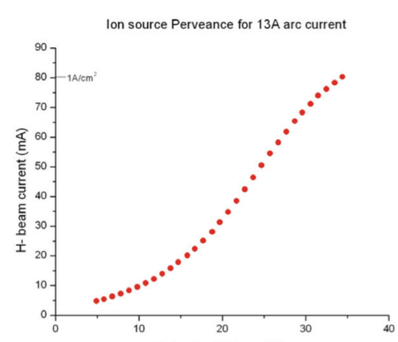

Figure 3: The perveance curve of the source shows that there is a roll off in beam current above 35 kV.

LEBT

The LEBT has been designed with two H- sources to ensure high reliability. Figure 4 shows the proposed layout of the LEBT with source A as the operational source.

* Work supported by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the United States Department of Energy.

† cytan@fnal.gov

ISBN 978-3-95450-115-1

Both source A and B are mounted on a slide so that either source can be slid into the injection line for operations. Two solenoids are used to transport and focus the beam into the RFQ. At the end of the LEBT is an Einzel lens chopper. The reason for installing the chopper at the end of the LEBT is to keep the de-neutralized region as small as possible.

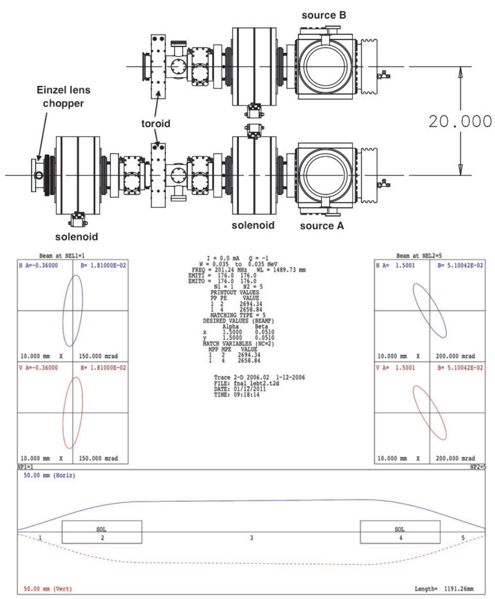

Figure 4: The LEBT has 2 H- sources but only one is used at any given time. The two sources are mounted on a slide so that either source can be slid into operation. The length of the LEBT from the end of the source to the start of the RFQ is about 1.2 m.

Transverse Emitttance

The horizontal and vertical emittances measured at the end of the LEBT for 60 mA H- beam and LEBT pressure at 2.4×10^{-6} Torr are shown in Figure 5. The normalized rms horizontal emittance is $\epsilon_H = 0.21\pi$ mm·mrad and vertical emittance is $\epsilon_V = 0.17\pi$ mm· mrad. The asymmetry of the emittance comes from the vertical dipole field in the H-source.

Einzel Lens Chopper

The Einzel lens chopping concept is shown in Figure 6. When the lens is set to -38.5 keV, 35 keV H- beam is reflected. The capacitance of the lens is ~ 8 pF and so can be discharged very quickly. The rise and fall times of the beam are dominated by the MOSFET switching circuit used to power the lens. Experiments with 60 mA of H- beam and a fast Faraday cup show that the H- beam rise time is $\sim$138 ns and the fall time is $\sim$81 ns. See Figure 7.

RFQ

The RFQ has been designed to take 35 keV H- beam and accelerate it to 750 keV to be compatible with the present

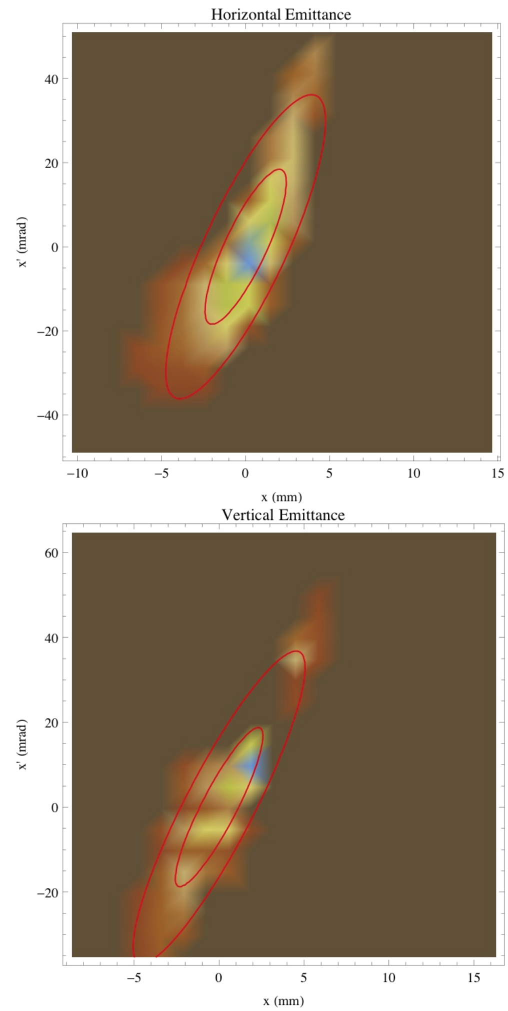

Figure 5: The horizontal and vertical emittance at the end of the LEBT.

Linac. However, measurements using time of flight and energy spectrometer show that the output energy is actually $\sim$ 700 keV which is 6.7% lower than designed. See Figure 8.

Energy Problem

It was discovered that the rods were warped transversely (see Figure 9, warp size is ~ 0.7 mm peak to valley) and longitudinally mis-aligned (~ 0.25 mm). However, even after correcting the warp and the alignment, the energy was still below 750 keV. In fact, experiments show that the largest effect on the energy was from the longitudinal misalignment which when corrected increased the beam energy from $\sim$700 keV to $\sim$710 keV. Work is presently being done to understand the underlying reason why the energy is incorrect.

CONCLUSION

The new RFQ injector has been tested up to the end of the RFQ. Unfortunately, the RFQ energy is not at its design value and work is being done to understand the source of

ISBN 978-3-95450-115-1

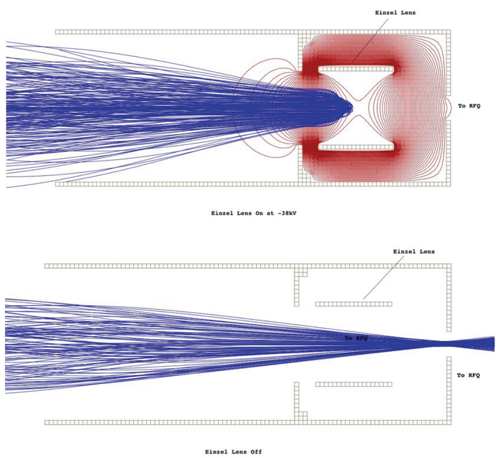

Figure 6: The magnetic field from the solenoid focuses the beam into the entrance of the RFQ when the Einzel lens is off. When the Einzel lens is on, it acts like a mirror on the H- beam by reflecting the beam away from the RFQ.

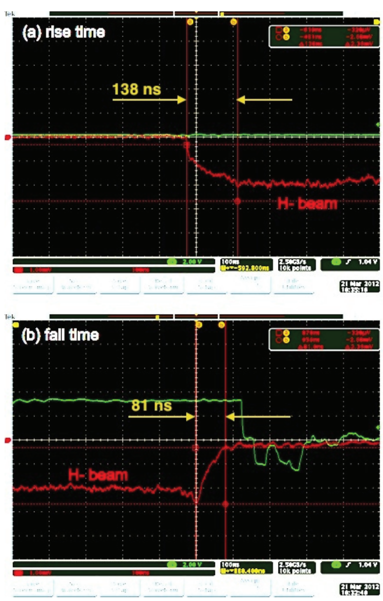

Figure 7: The rise and fall times of the chopped H- beam. The traces have been averaged 16× and background subtracted.

the problem. Hopefully, the problem can be understood in time so that the the energy problem can be remedied. If the RFQ can be fixed quickly, then the plan is to install during the 2012 shutdown.

ACKNOWLEDGMENTS

The authors wish to thank J. Alessi, D. Raparia, V. Lodestro and M. Okamura and the BNL source group for their help and advice. J. Schmidt and B. Koubek (Goethe University Frankfurt) for their help in the RFQ repair.

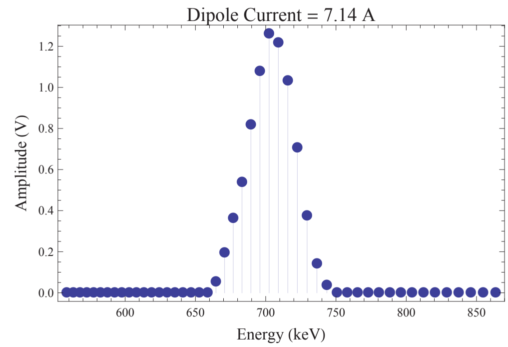

Figure 8: The energy spectrum clearly shows the mean beam energy is 700 keV for 168 kW of RFQ forward and 12 kW reflected power.

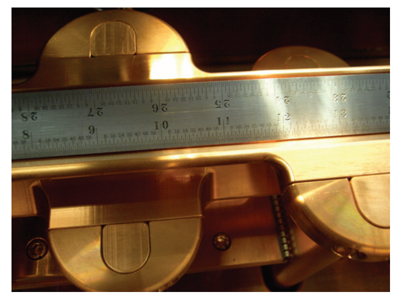

Figure 9: A rod when compared to the straight edge of a ruler clearly shows that there is a gap between the rod and the ruler.

REFERENCES

[1] C.Y. Tan et al, “A 750keV Linac Injector Upgrade PLAN”, FNAL Beams document 3646-v10.

[2] J.G. Alessi et al, “H- Source and Beam Transport Experiments for a new RFQ”, PAC 1987, Washington DC, March 1987, p 304 – 306.