PERFORMANCE OF THE LANSCE H^- SOURCE AND LOW ENERGY BEAM TRANSPORT AT HIGHER PEAK CURRENT

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Abstract

The Los Alamos Neutron Science Center (LANSCE) 800 MeV accelerator facility uses a multicusp-field, surface production ion source to produce H^- beam for delivery to the Proton Storage Ring (PSR) and to the Weapon Neutron Research (WNR) areas. The average current delivered to the short-pulse spallation target is nominally 70 μA. One goal of the present PSR upgrade project is to increase the average beam current to 200 μA. This will be accomplished by a combination of increased repetition rate (from 20 Hz to 30 Hz), upgraded PSR bunchers, and a brighter H^- ion source that is being designed to produce higher peak current with lower beam emittance. The present ion source and LEBT system were studied to investigate beam quality and performance at higher peak currents. Beam parameters from the ion source and in the LEBT at higher currents are comapred to those for standard operating conditions.

1 INTRODUCTION

An H^- ion beam is produced using a cesiated, multicusp, surface-production source[1]. This source uses a large area converter electrode biased at ~250 V to attract H^+ ions in a plasma produced by filament arcing. Cesium is used to enhance electron emission from the converter by lowering its work-function. About 1-2% of the H^+ ions are converted into H^- ions by electron attachment and are repelled back by the converter. The ion beam produced on the surface of the converter electrode has sufficiently large emittance to completely fill the phase space region defined by the extraction aperture. Thus, theoretically, the beam emittance is determined by the source geometry. However, several other factors can cause emittance growth[2]. At the exit of the source, the cusped magnetic field focuses the beam. A dipole field at the extraction region suppresses secondary electrons from the converter. The source typically operates at a duty factor of 9.6% (120 Hz, 800 μsec long pulse) delivering a peak current of about 14 mA at 750 keV. Each beam macropulse is chopped to create a sequence of 360 ns long pulses, each with a 110 ns "extraction notch" for injection into the PSR.

The 750 keV beam is produced in a two-stage acceleration system. In the first stage, beam from the source, which is housed in the dome of a 670 kV Cockcroft-Walton accelerator, is increased to 80 keV. Following the source, the transport consists of an 80 kV column, focusing solenoid, a deflector called the dome-level deflector, an emittance measuring station, a 4.5^o bending magnet to remove electrons from the beam, a second solenoid magnet, steering magnets, and current monitors as shown in Figure 1. The total length of this section is 3.3 m. The 670 kV Cockcroft-Walton accelerates the beam to an energy of 750 keV for injection into the drift tube linac. The 750 keV LEBT is shown in Figure 2 and consists of quadrupole magnets, a slow-wave chopper to produce the desired micropulse pattern for PSR and WNR, RF bunchers, emittance measuring stations, apertures, and steering magnets. An electrostatic deflector (ground-level deflector) is used to inhibit beam delivery to the linac when warranted.

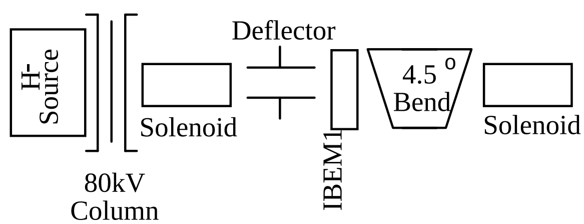

Figure 1: Schematic of the H^- source, 80 kV colum and LEBT

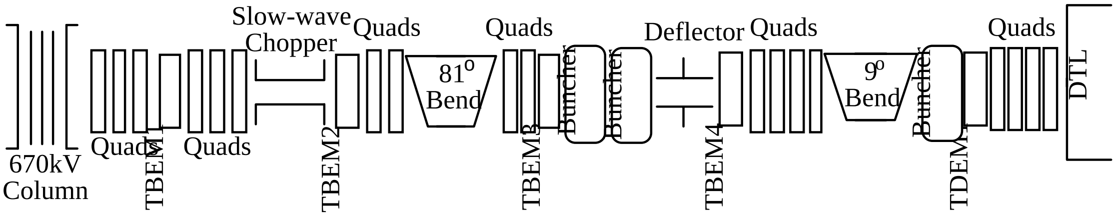

Figure 2: Schematic of the 670 kV column and 750 keV LEBT

2 EXPERIMENT

The beam measurements were made in two stages. First, the beam emittance and transmission were measured in each LEBT under normal operating conditions. The beam emittance was first measured in the middle of the 80 keV LEBT (IBEM1). To determine the time it takes for the beam to stabilize, the emittances were measured at different times during the beam pulse. The 80 keV beam was drifted to the location downstream of the 670 kV column (TBEM1) to determine the emittance growth, if any, of the 80 keV beam in this section of the transport.

The 670 kV column was then energized to accelerate the beam from 80 to 750 keV. The beam emittance was measured at five locations in the 750 keV LEBT: 1) TBEM1, 2) TBEM2 (downstream of the slow-wave chopper), 3) TBEM3 (downstream of the first RF buncher), 4) TBEM4 (downstream of the ground-level deflector) , and 5) TDEM1 (just before the entrance to the drift tube linac). The beam transmission was also measured along the 750 keV LEBT.

Second, the ion source current was increased to 20 mA by increasing the filament currents and then adjusting the hydrogen gas flow and Cs temperature to attain equilibrium operating conditions at the normal converter voltage of 250 volts. Measurements of the beam emittance and transmission were repeated in both the 80 keV and 750 keV LEBT under these new conditions. Results of these emittance measurements, along with the program TRACE, were used to tune the channel for maximum transmission and the desired Twiss parameters at the entrance to the 201.25 MHz drift tube linac.

Finally, attempts were made to increase the peak current of the ion source above 20 mA by increasing filament currents and then adjusting the gas flow and Cs temperature. Maintaining a stable beam above 20 mA was not feasible for the present source.

3 RESULTS

Figures 3 and 4 show the results of the emittance measurements under both normal and high-current operating conditions. The “source emittance” shown in these figures is a calculated geometric admittance and is used to estimate the emittance at the source exit. It can be seen that for the 15 mA peak beam the emittance, as measured at IBEM1, is a factor of 1.6 larger than the “source emittance”. For the 20 mA peak beam, it is a factor of 2.1 larger. Thus, the total emittance for the 20 mA peak beam is about 31% larger than that of the 15 mA peak beam as measured at IBEM1. Larger total emittance observed for the 20 mA peak beam is due in part to the larger tails in the beam as shown in Figure 5.

Emittance of the 80 keV beam measured at TBEM1 (670 column off) showed no significant increase compared to that measured at IBEM1. This indicates that the 80 kV LEBT after IBEM1 does not introduce any noticeable emittance growth to the 80 keV beam. A comparison of the emittance measured at TBEM1 for the 750 keV beam with that measured at IBEM1 for the 80 keV beam indicates that the effect of the 670 kV column on the emittance of the beam is minimal.

The results of the emittance measurements at different times during the beam pulse revealed that source stabilization occurs about 175 μsec after turn-on for the 15 mA peak beam and after about 200 μsec for the 20 mA peak beam. This means that higher peak beams may take longer time to stabilize.

The results of the emittance measurements at the other five locations in the 750 keV LEBT are also shown in Figures 3 and 4. An 18±5% emittance growth was observed between TBEM1 and TDEM1 for both beam currents, indicating no dependence on beam currents up to 20 mA. No significant degradation in the transmission was observed for a well-tuned 20 mA beam in the LEBT.

The majority of beam losses (~1 mA) occur at limiting apertures used to remove beam tails. By using the measured emittances as input to TRACE calculations, beam sizes were calculated at different locations in the LEBT. These calculations show that the beam sizes at a few locations in the LEBT are nearly equal to the beam pipe diameter indicating a potential limitation to operating the present ion source at higher currents.

Lifetime of the source filaments is estimated by measuring the variations in the resistance of the filaments. Using this technique, the lifetime of the present source when operated at 20 mA peak current was estimated to be about a week compared to more than 3 weeks when the source is operated at 15 mA peak current.

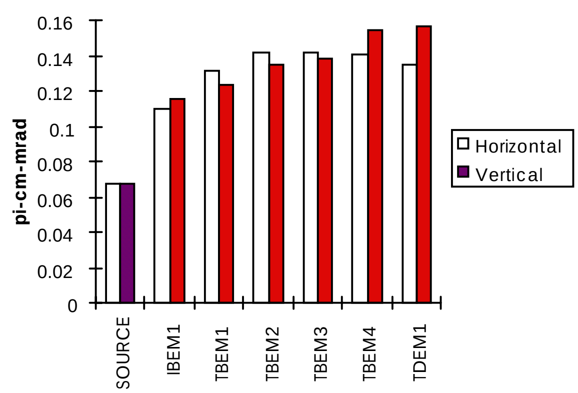

Figure 3: Total normalized emittance for 15 mA beam in LEBT.

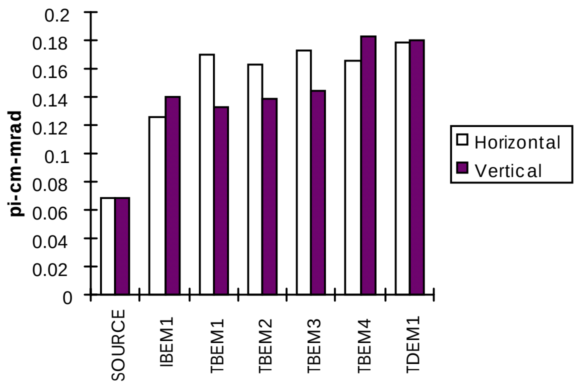

Figure 4: Total normalized emittance for 20 mA beam in LEBT.

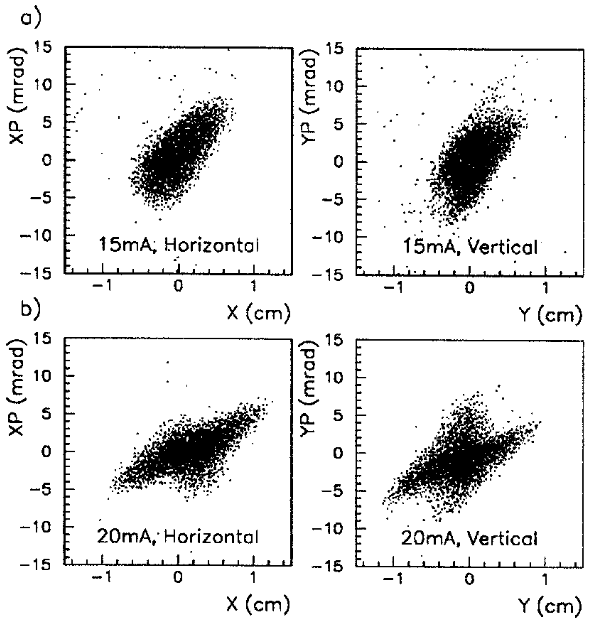

Figure 5: Measured phase-space distributions at TDEM1 for (a) 15 mA peak current beam and (b) for 20 mA current peak beam.

4 CONCLUSIONS

1. Measurements of emittances at IBEM1, TBEM1 (with 670 kV column on and off) and other locations in the LEBT indicate that the majority of the observed emittance growth appears to occur in the 80 kV column. The present design of the 80 kV column which was chosen to reduce arcdowns may be a source of the observed emittance growth[3].

2. Emittance growth in the 750 keV LEBT is not very significant.

3. The ability to transport higher than 20 mA peak beam from the present source may be constrained by beam size and matching requirements to the drift tube linac.

REFERENCES

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[3] R. R. Stevens, Jr. "H^- Injector Upgrade for LANSCE- Beam Extraction and Low Energy Beam Transport", LANSCE internal report, 1997.