PERFORMANCE OF THE SSC MAGNETRON ION SOURCE AND LEBTS

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Abstract

The Superconducting Super Collider (SSC) Ion Source is required to provide 30 mA of H^- beam at 35 kV with normalized rms emittance of less than 0.2 π-mm-mrad. Furthermore, the beam quality is to be preserved in the low energy beam transport section (LEBT) while the beam is being matched into the RFQ. A Magnetron ion source, because of its proven performance and characteristics, has been adopted as the near term ion source for SSC. Electrostatic LEBTs, more specifically HESQ and Einzel lenses, are possible choices of the LEBTs for SSC. An extensive experimental program is under way to characterize the SSC Magnetron ion source and the LEBT concepts to identify the best LEBT for SSC. The available experimental results pertinent to the performance of the SSC Magnetron ion source and LEBTs will be discussed.

Introduction

The H^- ion source as the first component of the SSC LINAC is to provide 30 mA at 35 keV with a pulse width of 7-35 µsec at 10 Hz repetition rate. The magnetron source was chosen for the baseline design partly because it has been used at large high energy physics facilities where long-term operation with high availability is required (Fermi Lab., Brookhaven National Lab.) and partly because it would require little effort to optimize it to the SSC beam parameters. A prototype magnetron source has been built and delivered to the SSCL by the Texas Accelerator Center (TAC). We were able to achieve the SSC required beam current at the required energy in the spring of 1991. However, we still needed to achieve the required beam emittance at the out put of LEBT and improve the reliability and availability of the source.

Emittance measurement

Figure 1 shows the magnetron source test stand. A slit & collector[1] emittance measurement unit (EMU) was developed to characterize the magnetron source by measuring its transverse output beam emittance. A pair of EMU's is utilized in our studies, one in the horizontal plane and one in the vertical plane. The slits are made of graphite and have a spacing of 0.1 mm. The collector consists of 48 copper foils that are oriented parallel to the slit and have a thickness of 0.203 mm and are spaced 0.254 mm with respect to the foil centerline. The drift distance between the slit and collector can be varied for the desired angular resolution. The data acquisition system is comprised of 48 channels of inverting pre-amplifiers, five LeCroy 2249w charge ADC's, a LeCroy

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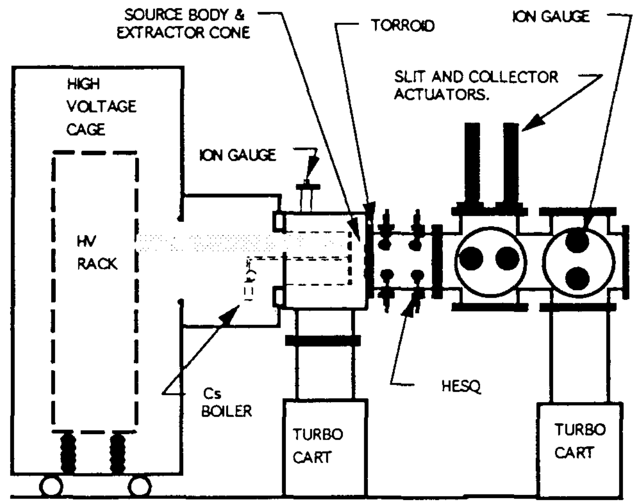

Figure 1. Magnetron Source test stand

2323 timing module, and an HP workstation. Through software the operator can vary the charge integration time (gate width) and the data acquire time (gate delay) with respect to the leading edge of the beam pulse. The collector foils are biased to a positive 20 volts to repel the secondary emission electrons. This results in a net positive charge on the collector wire and it is this charge that is measured[2]. Software control of stepper motion, timing and data transfer is thru a CAMAC-GPIB interface and data is displayed and analyzed by TACL[3]. An average measurement takes about 3-4 minutes depending on the angular resolution chosen. The emittance is measured by stepping the slit & collector system across the beam. At any step, the angular distribution of the beamlet that passes through the slit is measuered by letting it drift to the collector where the beam intensity is measured. After each beam pulse the slit and collector are moved to a new position for the next measurement. This process will continue until the entire beam cross section is covered. In order to minimize the effect of differences between each collector channel, at the start of each run a back ground measurement is made far away from the beam center and this value is used for back ground subtraction during data analysis.

When characterizing the magnetron source the slits were located 11.75 cm down stream of the extractor electrode. The distances between slit and collector were 32.27 cm and 13.44 cm for the horizontal and the vertical EMU's respectively. Figure 2 shows a typical horizontal emittance contour plot. The rms normalized emittance (extrapolated to 100% of the beam assuming a gaussian beam[4]) is measured to be 0.11 π mm mrad. This emittance value is about half the required emittance for the SSC ion source. The preliminary analysis of measured emittance in the vertical plane seems to indicate a

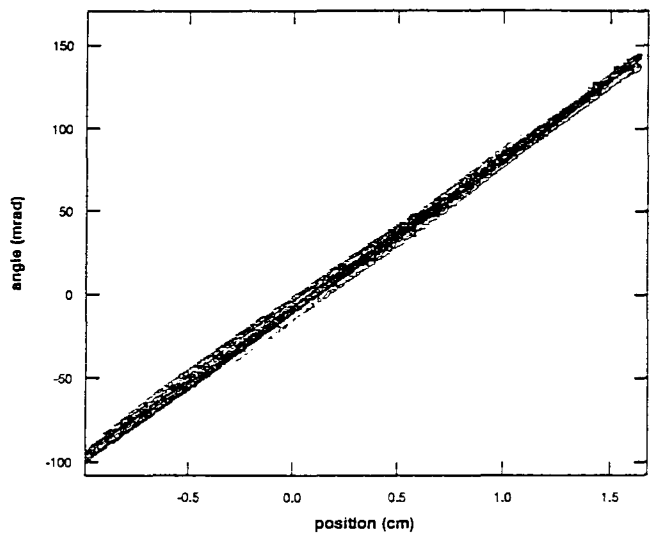

Figure 2 Phase-Space horizontal emittance plot (Source)

30%-100% higher emittance. Even though it is possible that the beam has a higher emittance in the plane of the bend (vertical plane) of the magnetron source, part of difference in the measured emittances could be due to lower measurement resolution in the vertical plane (shorter distance between slit& collector). We are in the process of upgrading our magnetron ion source test stand which include supervisory computer control of its operation. We will pursue the answers to these questions later this year when we will resume the characterization of the magnetron source.

Reliability and Availability

We operated the magnetron source with 30 mA current at 35 keV for 21 days straight without any major problem and down time. This has given us confidence that we can achieve reliability and availability similar to that of other major labs using magnetron source. However, the down side of the magnetron source is the operation with the cesium. At both Fermi Lab and BNL long LEBTs are used. At Fermi, an RFQ is not utilized. However, here at SSC we have the RFQ only at a maximum distance of 25 cm from the ion source. The possible cesium contamination of RFQ is a major concern.

LEBT

The relatively large diverging beam from the ion source is matched to the RFQ in the LEBT. The LEBT also contains source diagnostics and provides the differential pumping between the source and the RFQ. Since SSC LINAC requires short pulses, it was decided not use a plasma neutralized LEBT. Instead, we will use electrostatic focusing. The 30 mA operating current is small enough that several concepts using electric field focusing can be considered. The einzel lens and helical electrostatic quadrupole (HESQ) lens are the leading candidates for the SSC LINAC.
The einzel lens is probably the most mature technology for this application. However, it requires voltages similar to the source voltage and is prone to aberrations. We have designed and built a dual einzel lens LEBT. This LEBT was partially characterized with 10mA of beam at 24 keV. Figure 3 shows a typical beam phase space emittance contour plot out of the einzel lens. The aberrations are quit pronounced, and a large emittance growth is apparent. However, one should remember this LEBT was designed to operate at 35 keV for a 30 mA beam.

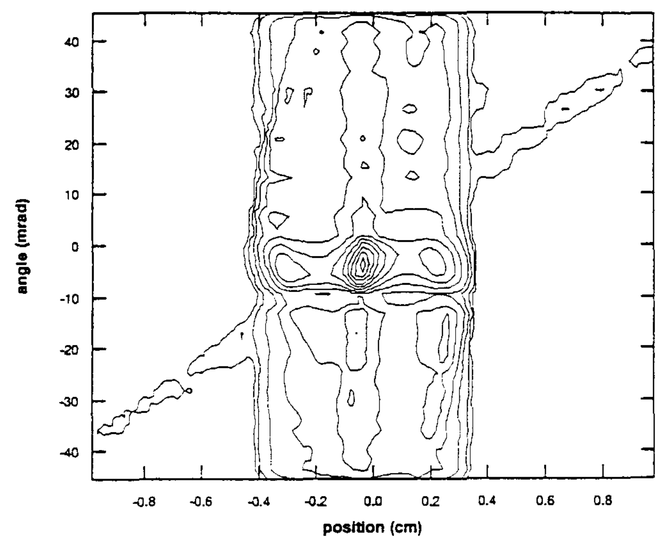

Figure 3 Phase-Space horizontal emittance plot (Einzel)

The HESQ should be a more reliable LEBT since it requires lower voltages for beam matching. A prototype HESQ LEBT has been built with nickel electroformed electrodes. For 30 mA at 35 keV operation, a 22.5 cm HESQ has an operating voltage of 7 keV. Figure 4 shows a typical beam phase space emittance contour plot out of the HESQ. The aberrations are much smaller then the Einzel lens, and the emittance growth does not seem to be as large.

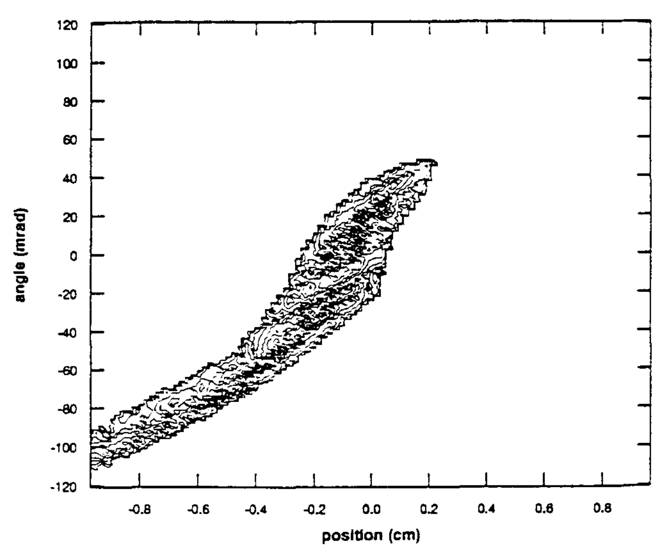

Figure 4 Phase-Space horizontal emittance plot (HESQ)

Conclusion

We have demonstrated that the magnetron ion source is capable of providing the required beam for the SSC LINAC. We still need to address the question of reliability and availability in more detail. We will fully characterize both LEBTs later this year in order to select one for the initial operation of SSC LINAC.

References

[1] Stanley Humphries Jr. "CHARGE PARTICLE BEAMS" published by John Wiley & Sons, Inc. ,1986,p 79-159.

[2] O.R. Sander, AIP Conference Proceeding NO. 212, P127-155(1989)

[3] "TACL" stands for Thaumaturgic Automated Control Logic and was developed at CEBAF.

[4] P. A. Allison, AIP Conference Proceeding NO. 158, P465-481(1987)