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H SOURCE AND BEAM TRANSPORT EXPERIMENTS FOR A NEW RFQ*

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Abstract

A new RFQ preinjector is being built for the 200 MeV Linac at the AGS. For injection into this RFQ, a symmetric emittance has been obtained from a circular aperture magnetron H^{-} source. Transport studies are beginning to address possible problems with space charge or instabilities in the 35 keV line. A volume H^{-} source is being tested as an eventual replacement for the magnetron.

Introduction

One of the Cockcroft-Walton (C-W) preinjectors of the AGS 200 MeV Linac will be replaced by a 750 keV RFQ [1]. For this we require a 50 mA, 35 keV H⁻ beam having an emittance properly matching the RFQ acceptance (preferably symmetric in the two planes). The normal H⁻ source used for the AGS operation is a magnetron surface-plasma source, having a 1 mm \times 1 cm slit aperture which gives an asymmetric emittance. This source has been modified to have a circular aperture. These results will first be given.

To maintain the symmetry of the beam, the 35 keV transport line from the source to the RFQ will employ two magnetic solenoid lenses for focusing. This transport line is planned to be 1.9 m long, primarily to give sufficient space to implement a 35 keV, 2.5 MHz electrostatic beam chopper [1] which will reject the part of the linac beam which is normally lost during capture in the AGS. A test line has been set up to study questions related to beam instabilities and space charge effects in this long transport section, and this will be described.

Finally, a volume H^- source is under development to replace this symmetric magnetron as soon as sufficient H^- intensity is demonstrated. This source offers the great advantage of cesium-free operation. The progress on this development will be mentioned.

Experimental Setup

Figure 1 shows a schematic of the test stand used for the magnetron source and beam transport studies. The magnetron source is the same as that used for normal operations [2], except for modifications to provide a symmetric emittance. The extraction voltage was limited by the power supply to <20 keV for these measurements. Final operation will be at 35 keV. The extracted beam is transported through a 90°, n = 1/2 magnet, which provides equal focusing in both planes. A similar magnet, but with an n =

1.35 gradient, is installed in the C-W source, and in addition to its focusing, serves to reduce possible cesium contamination of the 750 keV accelerating column. Horizontal and vertical emittances can be taken 8.3 cm after the exit of this magnet with slit and collector units. There are retractable Faraday cups before and after the bend. This source box is pumped by a 1500 l/s cryopump.

Following this is a 2 m transport section (4" diameter), and a beam diagnostic box. The solenoid, which is laminated for pulsed operation (10 Hz), produces a field of 4.2 kG at 500 A, and has an effective length of 15.7 cm. A current transformer is used to measure the beam current at the entrance to the diagnostic box, which also has horizontal and vertical emittance measuring devices, and at the end a beam profile monitor. This box is pumped by a 150 l/s turbopump, but a larger pump will soon be installed.

In order to simulate the space charge effects of the chopper, vertical deflecting plates were placed in the beam pipe, centered 1.35 m from the upstream end. These plates are 35.4 cm long and 7.3 cm wide, with a 5 cm separation. Electrically isolated, 4.8 cm long, 6.3 cm diameter cylinders were placed at both ends of the plates to try, with appropriate bias, to confine the loss of space charge neutralization of the beam to the region between the plates. A vacuum gauge and gas bleed valve were also placed in the plate region to allow the study of pressure effects in the line.

Source Experiments

Figure 2 shows the geometry used for the circular aperture magnetron. A spherical dimple in the cathode geometrically focuses \sim 150 eV surface produced H⁻ to the 3.6 mm diameter anode aperture. This dimple was offset in one plane to compensate for the deflection of the ions between the cathode and anode by the source magnetic field. As mentioned previously, the bending magnet poles were changed to an n = 1/2 gradient to provide equal focusing in both planes.

To simplify the extraction optics, first tests were made with an 88% transparent tungsten grid over the anode and extraction apertures. Currents in excess of 100 mA can be measured on the first Faraday cup, and 70-80 mA after the bending magnet, for a 50-60 A, 140-160 V discharge. Total extractor power supply loading is measured, and the difference between this loading and the H^T current on the first Faraday cup is assumed to be electrons. Typically, the ratio of electrons to H^T was 1.5-2.0, essentially the same as is measured with the slit source. An emittance measured for a 36



Figure 1. Schematic of the source/transport test stand.

*Work performed under the auspices of the U.S. Department of Energy

mA, 20 keV beam is shown in figure 3. The normalized (90%) emittances were 0.094 and 0.101 π cm-mrad. Scraping of a part of the beam on the magnet poles in the x-direction probably accounts for the slightly smaller emittance in that plane. Essentially the same emittances as those shown were still obtained at a beam current of 70 mA on the second Faraday cup. Under "noisy" discharge conditions this emittance can become larger. The grid lifetime was short at 5 Hz operation, but they did serve show that sufficient H⁻ current and symmetric emittances could be obtained.



Figure 2. Geometry of the circular aperture magnetron.



- $E(x) = 0.094 \ \pi \ \text{cm-mrad} \qquad E(y) = 0.101 \ \pi \ \text{cm-mrad} \\ \text{(normalized, 90\%)}$
- Figure 3. The emittances from the circular aperture source (grids on anode and extractor). I(H) = 36 mA; V = 20 keV; n = 1/2.

The grids were removed and 3 mm and 4 mm extractor gaps were studied. Without the grids the extractor perveance was lower, and a beam could only be focused and optimally transported around the magnet by reducing the discharge current to 15-20 A, where the H[°] current was -30 mA. Emittances taken at this optimum current were the same as those with the gridded extractor, and the ratio of electrons to H[°] was still 1.5-2.0. Once the extraction voltage is raised to our final value of 35 kV, one should be able to transport >50 mA without the grids. The final extractor geometry will be optimized by computer calculations.

Presently, the source and bending fields are produced by the same magnet, and so the magnet setting is fixed by the beam energy. This coupling of the two fields prevents one from minimizing the "noise" in the discharge. Therefore, beam measurements will soon be made without the 90° magnet. Tracing measured emittances back through the magnet, the divergence of the beam directly after extraction is found to be approximately ± 150 mrad. With the solenoid moved closer to the source, this divergence can be handled without the extra focusing provided by the gradient magnet.

Transport Experiments

The 1.9 meter long, 35 keV transport line causes some concern, since experiences in the Soviet Union [3] and at Los Alamos [4] have shown that beam instabilities can develop in such a long, low energy transport. To our advantage is the low current density in our line (1-2 mA/cm²), since the beam is expected to be ~7.5 cm diameter over most of the length in the final design. The other uncertainty relates to the effect that the 2.5 MHz electric field of the chopper will have on the beam. While the fields are off during beam time, the frequency is too high to allow space charge neutralization to build up between micropulses. The beam can not be transported with the two solenoids if there is full space charge forces over the length of the line. If one can limit this space charge blowup to the region between the plates, the transport before the chopper would be space charge neutralized, and the transport after the chopper would be similar to the transport of a beam with a 2.5 MHz "noise" on it. Should there be significant beam loss or emittance growth over this line, it would have to be shortened and a fast chopper placed at 750 keV, which is much more difficult.

These transport studies have recently begun. The gridded extractor is being used on the source to allow study at high currents at 20 keV. To extend the grid lifetime to at least 1 week of continuous operation, the source is operated at 5 Hz, but the extractor is typically pulsed at ~0.4 Hz. Without any voltages on the plates, up to 35 mA have been transported to the end of the line. Measured emittances show that the solenoid focusing is as calculated. At this stage, the majority of the beam loss seems to be due to scrapping on the deflecting plates and walls of the beam pipe upstream of the solenoid. Until these losses are eliminated, one can not say whether any emittance growth is occurring. A longer rise time is observed on the beam pulse at the end of the line, coming from the buildup of space charge neutralization, and as expected, this risetime decreases as the pressure in the line is increased by adding argon. The study of the effect of DC and RF voltages on the plates is just beginning.

Volume Source

A pulsed, volume production H source has been designed as an alternative to the magnetron, and is being tested on a separate test stand. Its main advantages are the rotational symmetry coaxial with the beam line, and a cesium-free operation. This latter facilitates ease of operation, faster startup, and more reliability with respect to high voltage holdoff. The source chamber is cylindrical, with a 12.5 cm diameter, and is 20 cm long. The magnetic field for plasma confinement is produced by 16 lines of Sm-Co magnets with the peak field on the inside wall surface of about 0.3 T. A plasma electrode can be biased to affect the distribution of potential inside the plasma; it carries also a wire structure to produce a cupshaped dipole field that serves to separate the main discharge from the region around the extraction aperture where a low electron temperature is required for H production. The line integrated dipole field is about 300 G-cm. Two small permanent magnets are mounted in the body of the plasma electrode to produce a dipole field across the extraction aperture in order to reduce the electron component of the extracted beam. Based on the experience with other H⁻ sources of this type and on theoretical scaling laws it is

expected that this source should deliver 20-30 mA of H^{-} in 2 ms pulses.

After trying with little success an oxide coated cathode and a tantalum filament, the final cathode choice was a single LaB₆ filament, enabling a reliable source operation over a wide range of arc currents (up to 250 Å in 2 ms pulses), arc voltages, and gas pressures. Some plasma studies were performed by measuring the ion saturation current on a plane probe (0.1 cm^2) ; estimated values of the plasma density are above 10^{13} cm^{-3} at the highest arc currents. More detailed studies of probe characteristics are planned, with the objective to determine distributions of the plasma (space) potential and electron temperature, without and with the cup-shaped dipole field. Initial results already indicate that the mere presence of the wire structure changes the discharge plasma, and this effect is greatly enhanced with the dipole field present.

First measurements of the H[°] current have shown a yield of up to 5 mA. Figure 4, in which four discharge pulses are superimposed, shows the measured H[°] current, and the effect of varying the dipole filter field. The current in the filter, shown in the lower trace, is turned on ~1 ms into the discharge pulse. At this point, the H[°] current (upper trace) increases from 1 mA to 2.7 mA at the highest filter current of 200 A (where $\int Bdl = 300$ G-cm).



Figure 4. Upper trace: H⁻ current, 1 mA/div. Lower trace: current to dipole filter 200 A/div. Sweep: 500 µs/div.

Summary

A circular aperture magnetron has given the desired symmetric emittance (~0.1 π cm-mrad in both planes, normalized, 90%), and its operation is essentially the same as the normal slit magnetron. H' currents of 70-80 mA have been obtained after a 90° magnet when a gridded extractor was used. Without grids, we expect to obtain at least 50 mA at 35 keV. We also plan on testing operation without the bending magnet to give more control over source plasma oscillations. The studies of the 2 m transport line and chopper effects are just beginning, and emittances of a 35 mA beam have been measured in the diagnostic box. Finally, a volume H' source is being tested. A plasma density of >10¹³ cm⁻³ has been measured, using a LaB₆ cathode. This source will hopefully replace the magnetron in the final beamline, since it offers the advantage of quick start-up and more reliable operation because cesium is not needed for H' the production.

Acknowledgements

We would like to thank Tom Russo for his work on the preparation and operation of the test stand, and also J. Brodowski, R. Horton, W. Shaffer, V. Kovarik, D. McCafferty, F. Usack, and W. Hensel for their assistance.

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