A CIRCULAR APERTURE MAGNETRON FOR INJECTION INTO AN RFQ*

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ABSTRACT

A magnetron with a circular anode aperture and a spherical dimple in the cathode has been operated. With this configuration, a normalized emittance (90%) of $0.1\pi\text{cm-mrad}$ has been measured in both planes for an H^- current of $> 50\text{ mA}$. Other than this symmetric emittance, the source performance is the same as with the typical anode slit and grooved cathode.

INTRODUCTION

The AGS will be replacing the 750 keV Cockcroft-Walton (C-W) preinjector with an RFQ accelerator for H^- injection into the 200 MeV linac. For this, we need a 50 mA, 35 keV H^- source having an emittance which can be properly matched to the RFQ acceptance. It is preferable to have the x- and y-emittances identical, and then transport the beam to the RFQ using magnetic solenoids to preserve the symmetry. The AGS routinely operates with a magnetron surface-plasma source. These sources normally run with a slit aperture, and have emittances which are considerably different in the two planes. While modifications to operate with a circular aperture were straightforward, there was some question as to the effectiveness of cathode focussing from a dimple. Electron loading from the circular aperture was also an uncertainty since the slit, with the narrow dimension parallel to the magnetic field, might be more effective in reducing the extracted electron current. The results of operation with the circular aperture, and the comparison with operation for the slit aperture, will be given in the following sections.

EXPERIMENTAL SET-UP

For all tests, the magnetron source was the same as is used for normal AGS operation.¹ Figure 1 shows a schematic of the source test stand. Following the source, the beam travels through a 90° gradient bending magnet. This magnet provides beam focussing, and reduces the gas load and possibility of cesium contamination of the 750 kV accelerating column when installed in the C-W. Horizontal and vertical emittances can be taken with slit and collector devices 8.3 cm beyond the exit pole of the magnet. A Faraday cup can be inserted approximately 1 cm from the extractor. A second Faraday cup, 15 cm from the exit of the magnet reads the transported current. The test box is pumped by a 1500 l/sec cryopump.

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Figure 1. Schematic of the source test stand.

Figure 2. Geometry of the circular aperture magnetron.

The normal slit source has a $1 \text{ mm} \times 1 \text{ cm}$ anode slit, and a 4 mm wide cathode focussing groove. The extractor plate opening is 2 mm, with a 2 mm extractor gap. A schematic of the circular aperture geometry used for the present experiments is shown in Figure 2. The cathode dimple was offset in one plane to compensate for the deflection of H^- ions by the source magnetic field while travelling between the cathode and anode. The anode aperture diameter was chosen so as to have the same area as the aperture in the slit source (0.1 cm^2). In this way, gas loading, H^- output vs. discharge current, electron loading, etc. could be directly compared between the two.

RESULTS

Figure 3 shows an emittance measured with the normal slit source and a gradient of $n = 1.35$ in the 90° magnet. This is the magnet normally used with the C-W. The normalized emittances for a 45 mA (450 mA/cm^2), 17.75 keV beam were 0.049 and $0.177\pi \text{ cm-mrad}$ for 90% of the beam. Although the measured emittances are somewhat larger than some previous measurements,¹ the ratio of horizontal (x ; = narrow slit direction) and vertical (y ; = wide slit direction) emittances are the same as for the previous measurements, and the emittance orientations are reproduced. The orientations are reasonable for the injection into quadrupole focussing elements, as is presently done in the C-W. The emittances in the two planes are not in the ratio that one might expect from the source geometry, and the differences are normally attributed to some coupling of the emittances in the two planes by the magnetic field, aberrations in the extraction optics in the narrow slit direction, etc.

Figure 3. Emittances measured after the bending magnet for the normal magnetron used with the Cockcroft-Walton. The source has a grooved cathode and a $1 \text{ mm} \times 1 \text{ cm}$ anode aperture. $I(\text{H}^-) = 45 \text{ mA}$; $V = 17.75 \text{ kV}$; $n = 1.35$

The source having the circular geometry was then installed. The magnet poles were replaced with ones having a gradient of $n = 1/2$, to preserve the expected symmetry of the beam. For simplicity, first tests were made with an 88% transparent tungsten grid over the anode aperture (to prevent any plasma boundary effects) and over the extractor aperture (to eliminate aperture defocussing). Emittances taken under these conditions for a 36 mA, 20 keV beam are shown in Figure 4. The normalized (90%) emittances were 0.094π cm-mrad and 0.101π cm-mrad. There was some scraping of the beam on the magnet poles in the x-direction, which probably accounts for the slightly smaller emittance in that plane. Other than this beam scraping, and some misalignment, the emittances are symmetric. Essentially the same emittances as those shown were still obtained at a beam current of 70 mA.

Figure 4. The emittances from the circular aperture source (grids on anode and extractor). $I(H^-) = 36 \text{ mA}$; $V = 20 \text{ keV}$; $n = 1/2$.

The grids were then removed, and beam current and emittance again measured for extractor gaps of 3 and 4 mm. Without the grids the extractor perveance was lower, and a beam could only be focussed and transported around the bending magnet at lower currents ($< 25 \text{ mA}$). This is illustrated in Figure 5, which shows an example of the beam current on both Faraday cups as a function of the discharge current. The emittances taken at the current giving optimum transmission were the same as the emittances with the gridded extractor (Fig. 4). Since these measurements were taken at $\leq 20 \text{ keV}$, the perveance of the ungridded extractor should be high enough to transport the desired 50 mA at the final extraction voltage of 35 keV.

The total extractor power supply loading was measured, and the difference between the power supply loading and the current measured

Figure 5. Measured currents vs. discharge for the circular aperture, without the extractor grid ($n=1/2$ magnet).

on the first Faraday cup was assumed to be electrons. Typically, the ratio of electrons to H^- current was 1.5-2.0, and there was no significant difference in this ratio among the slit source, the circular aperture with grids, or the ungridded circular source when below the perveance limit. When operating without the extractor grid, and comparing operation with and without a grid over the anode aperture, the H^- current, electron loading, and emittance were the same in both cases. This indicates that under the present operating conditions plasma boundary effects are unimportant.

When the slit source was tested with the $n=1/2$ magnet, one was able to get essentially 100% transmission around the magnet (this is not the case with the slit and $n=1.35$ magnet). The emittance measured for a 55 mA, 18.5 keV beam was $0.065 \times 0.105 \pi \text{ cm-mrad}$ (normalized, 90%). This is different than the emittance given at the beginning of this section for the slit source and $n=1.35$ magnet.

SUMMARY

We have obtained, with the circular aperture magnetron, a symmetric emittance well suited for injection into an RFO. Our plans are to next study the beam transport, looking for any emittance growth from beam instabilities in the 2 m transport line. We will then make emittance measurements without the 90° bending magnet to see if operation in that simpler configuration is a possibility. Finally, there will be a more careful design of the extractor for 35 keV operation.

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REFERENCES

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