POISSON Study of Electrostatic Septa for the MIT–Bates SHR*

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Abstract

The POISSON group of computer codes [1] was used to study the details of field distributions of electrostatic septa for use with the MIT–Bates South Hall Ring (SHR). Studies were made to minimize field penetration and field gradients near the foil strips while satisfying the technical constraints. In addition, effects of upstream guard foils and an additional electrode opposite these foils on the field shapes were studied in great detail. The guard foils will shadow the main foils from the direct beam, and the electrode will prevent the secondary low–energy electrons from the guard foils from reaching the anode. Our optimal configuration of foils and electrodes as well as the electric field shapes are presented.

1 Introduction

The SHR under construction at the MIT–Bates Linear Accelerator Center will be a high intensity pulse stretcher facility with high quality cw electron beams of up to 1.0 GEV, operating in both storage and extraction modes. The ring lattice will consist of over 200 electromagnets distributed over a ring circumference of 190 m. A description of SHR is given in ref. [2]. As any other pulse stretcher rings with extraction capabilities, SHR requires two electrostatic septa near the injection and extraction regions for providing the required deflection to the circulating electron beam during the injection and extraction periods. After the short injection period, these septa should have no effect on the circulating beam. A 40 mA 1.6 μsec wide electron pulse which raps around the ring twice, by its nature, makes the requirements on the septa very demanding. The septa must have two distinct field regions: (a) a field–free region for circulating beams, and (b) a high transverse field region for injected and extracted beams with a field strength of 50 KV/cm. The purpose of these studies have included finding an optimum design in which the field penetration to the region (a) is minimum while maximizing the field uniformity in region (b).

These septa will have an active length of about 150cm formed by a row of thin foil strips at ground potential and positioned 2 cm from the solid anode at 100KV. The foils are mounted on a long semicircular carrier at ground potential with foils stretched vertically along its diameter. Figure 1 shows the basic components of the septa. Our POISSON calculations included 5 mm wide foil strips and a range of spacing from 0.3mm to 1.mm.

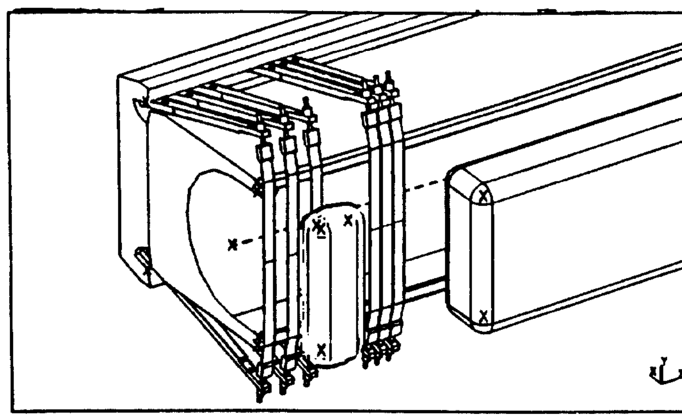

Figure 1: schematic view of the electrostatic septa.

Because of optics considerations and because a few μA of beam will strike the extraction septum under normal operation, the design seeks to minimize thermionic, field and secondary emission as well as thermal distortions of the foils. To accomplish this, guard foils have been added upstream of the main foils to protect them from the direct beam. The guard foils will shadow the main foils from the direct beam and an additional electrode opposite these foils will confine the secondary low energy electrons from reaching the anode, thus reducing the current drawn on the power supply. POISSON has been instrumental in finding the negative potential for the guard electrode which will optimize this confinement while maintaining good field uniformity.

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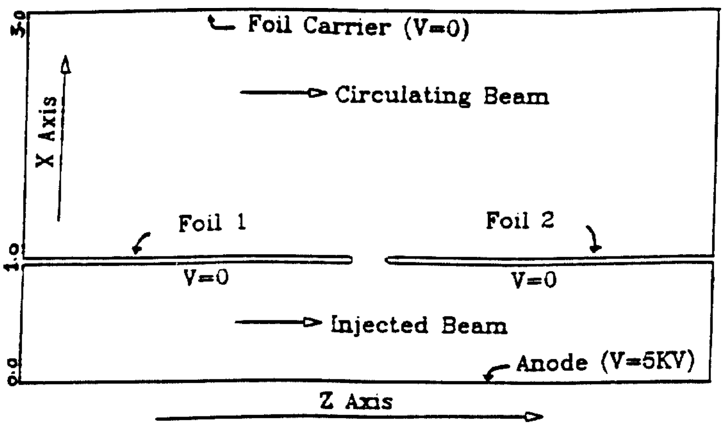

Figure 2: Schematic of POISSON input geometry for the "uniform" field region of septa.

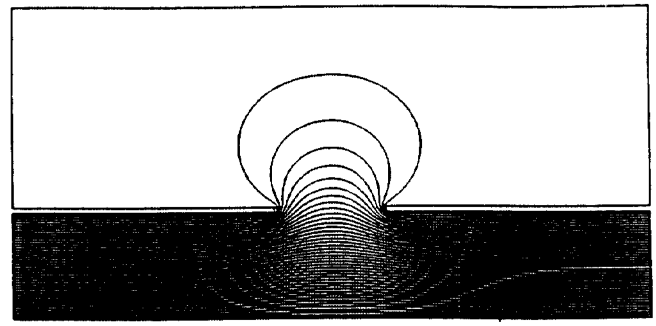

Figure 3: Equipotential lines for the "uniform" field region of the septa

2 Programming Considerations

A full scale POISSON layout of these septa would require a mesh size of less than 50μm (foil thickness) spanned over several centimeters; this makes the number of mesh points extremely large, exceeding the program's normal limits. Instead, one lays out only that portion of the geometry which is relevant to the question under study. For instance, when studying the field near the foils, we used a mesh size of 20μm and limited the overall area under study. When studying the field in the entrance region over several centimeters along the beam, a coarser mesh size has been used as well as an artificial foil thickness of 0.2mm. For the former case, we placed an anode at a distance of 1.0 mm from the wire to provide the 50 KV/cm field gradient. The results presented in this report are for foil spacings of 0.3 mm and edge radius of 0.025 mm.

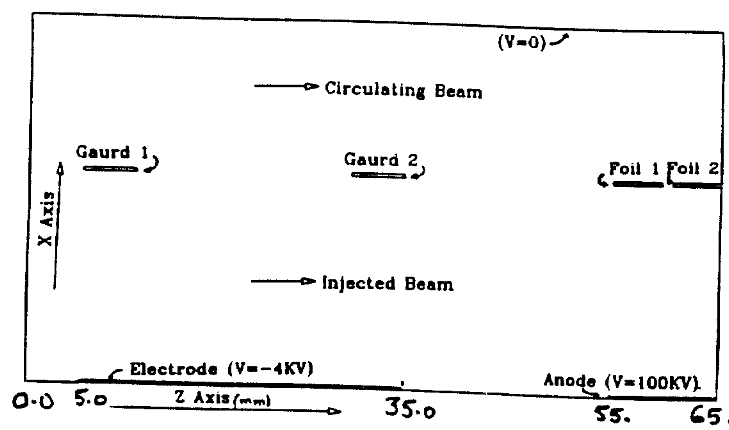

Figure 4: Schematics of POISSON input geometry for the entrance region with guard foils and additional electrode.

3 Uniform Field Region

To study field penetration, we examined a segment of the uniform region of septa away from the entrance and exit areas. The layout is shown in Figure 2. To limit the total number of mesh units and to set correct boundary conditions, we have used a 5 KV anode located at a distance of 1mm from the foils and required that the equipotential lines be normal to the surfaces of the anode and the ground plates at opposite ends of the gap. Figure 3 show the equipotential lines in a unit cell. The transverse field E_X integrated along the beam direction is used to define the effective field:

$$LE_{eff} = \int_{Z=0}^{Z=5.3(mm)} E_X(X,Z) \cdot dZ \qquad (1)$$

The integral here includes one half of two adjacent foils and the gap in between. This quantity has a variation of the order of 2×10^{-5} for $0.05 \leq X \leq 0.9$ mm which is well within the specified tolerance for the septa.

4 Entrance Region

We have also studied the effects of guard foils together with an additional electrode at ground or negative potential located in the plane of the anode and 20mm upstream as shown in Figure 4. The electrode at some negative potential will reverse the direction of the electric field near the guard foils so that the low energy electrons produced by the beam hitting the guard foils would not find a path to the anode. Several configurations were studied with POISSON and the results follow. The layout includes the entrance region 65 mm upstream of the first main foil, the

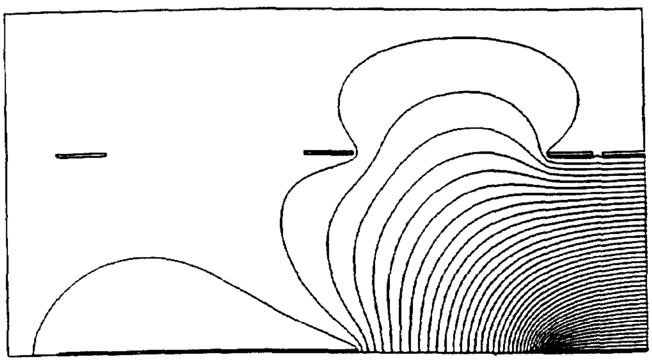

Figure 5: Equipotential lines for the entrance region of the septa with electrode at -4.0KV

anode at 20 mm distance and a ground plane at 10 mm on the circulating beam side. We have studied this case for a range of electrode potentials from 0 to –4 KV. The equipotential lines for the case of –4KV are shown in Figure 5. The transverse electric field as a function of Z is shown in Figure 6 for a range of transverse positions X in the gap. The following observations can be made from these results:

- The additional electrode at V=0 reduces the electric field in the vicinity of the first guard foil, but the field still remains positive.
- For V=–1.0KV the electric field in the entrance region is negative in the lower half of the gap ($0 \leq X \leq 10.$) and is slightly positive in the upper half of the gap near the guard foils; this voltage is insufficient for confinement of the low energy electrons.
- For V=–4.0KV the electric field remains negative for all transverse distances across the gap near the first guard foil and becomes positive after the second guard foil.
- The integrated transverse field over the 65mm entrance region shows a variation across the gap which increases with increasing electrode voltage. The variation is about 1.% for V=0 V, and about 6.5% for V=–4 KV, still acceptable since the entrance effective field is less than 2 percent of the total effective field of the septum.
- At V=–4KV the sign and magnitudes of the longitudinal electric field (E_Z) helps to further confine the low energy electrons (longitudinally) to the entrance region.

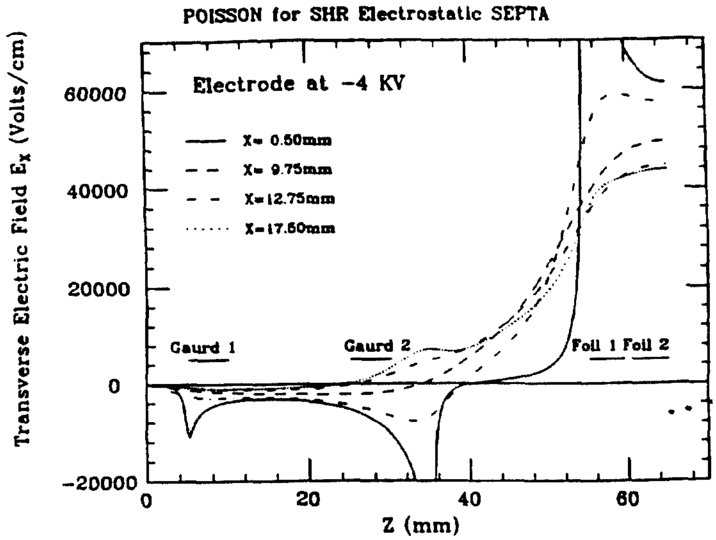

Figure 6: Transverse electric field of the entrance region of the septum for a range of X values, with anode at X=0.25 and foils at X=20 mm.

5 Conclusions

For our configuration the following conclusions can be made:

1. In the "uniform" field region, the relative variation of the effective field as a function of transverse distance across the gap is better than 1×10^{-4}.
2. An addition of an electrode at negative voltage opposite the guard foils lowers the electric field near the guard foils but increases the effective field variation across the gap to about 1×10^{-3}. With the electrode at V=–4 KV both components of the electric field provide confinements of low energy electrons to the entrance region and away from the anode. While higher negative voltage increases the confinement, it also adds to the overall non–uniformity of the field.

References

[1] POISSON/SUPERFISH Group of Codes, Los Alamos Accelerator Code Group, LA–UR–87–115.

[2] J.B. Flanz et al., Proceedings of the 1989 IEEE Particle Accelerator Conference, March 20-23, 1989, p.34.