Electrostatic Septa Design and Performance for Injection and Extraction to and from the MIT-Bates South Hall Ring(SHR)*

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Abstract

The MIT-Bates South Hall Ring (SHR) is an electron storage ring undergoing commissioning. Electrostatic septa are used to inject electrons into and resonantly extract electrons from the ring. This report describes the engineering design and performance achieved for 2 electrostatic septa constructed with 270, 50 micron thick, 5 mm wide molybdenum foils stretched over a long precision machined, C-shaped carrier. The septa gaps are 2 cm and are designed to operate at 50 kV/cm over their 1.5 m effective lengths to produce a 7.5 mr horizontal bend for 1.0 GeV electrons.

I. ELECTROSTATICS

The septum gap is 2.0 cm and the anode will be excited to +100 kV maximum to produce the desired gradient of 50 kV/cm. The deflection of an electron traveling transverse to the electric field is determined by the following formula:

a = (e/m)* E * L/[c*exp(2)] radians
c = 3*10exp(8) m/s
L = length (m)
E = electric field (V/m)

e/m at 1.0 GeV = 9.0030*10*exp(7)

The field quality in the mid-plane of the septa is very good based on POISSON[1], and calculations of the geometry[2], which was varied in the height of the foils above and below the mid-plane and the spacing between foils to obtain the design selected. The ratio of the maximum field gradient to the average field gradient is called the field enhancement factor[3] and for the foil septa design this factor is minimized, consistent with reasonable spacing needed for assembly.

II. MECHANICAL AND VACUUM

There are 270 active foils and 3 guard foils made out of molybdenum, produced by Metalwerk Plansee GmbH of Austria, and procured from SAL. Other materials, such as tungsten, had been considered, but molybdenum was chosen based on its optimum combination of parameters, which include atomic weight, tensile strength at elevated temperature, and emissivity. The raw foil stock was produced by a continuous shearing process and exhibited a typical sharp edge roll-up as a result. For this reason, all foil edges were carefully burnished and inspected under a microscope (as shown in Figure 1) to make sure they were properly rounded off and smooth.

Figure 1. Foil burnishing to eliminate sharp edge roll-up.

The foils were mounted along a carefully machined foil carrier, which was fabricated from Type 316 SS and annealed 3 times during various phases of manufacture in order to produce a stable, stress-free structure, which would be immune to thermally-induced warpage.

A creative foil tensioning/extraction mechanism (shown in Figures 2 and 3) was developed, to maintain a constant 3.9 kg tensile force per foil, in order to prevent both excessive and non-uniform deflection in the electrostatic field, as well as to allow rapid spring-activated removal of a failed foil from the active gap area. This action averts a high-voltage short and enables continued operation of the septum, but at a somewhat lower (-0.35%/foil) deflection angle.

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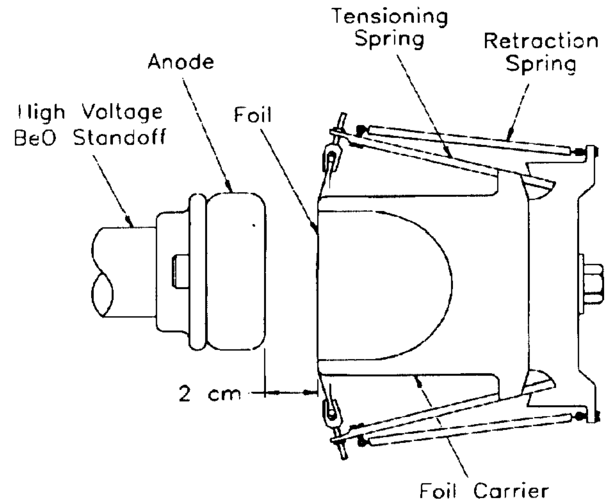

Figure 2. Foil carrier cross-section. Shown: foil tensioning/retraction mechanism.

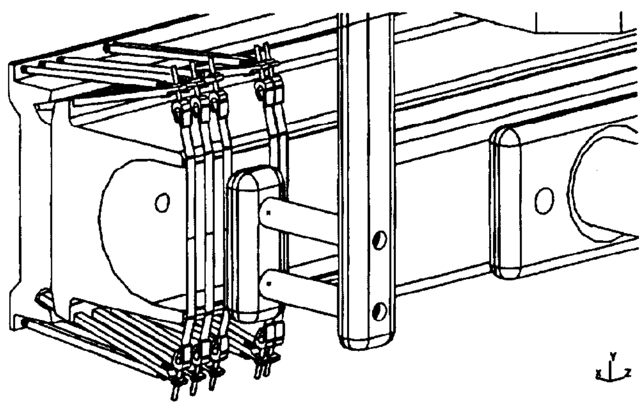

Figure 3. Leading edge of the foil carrier with 3 guard foils and first 2 out of 270 active foils shown.

All internal components of a septum, such as: the foil carrier assembly, the anode assembly, the high voltage feedthrough, the guard electrode, the signal feedthrough, and the viewing ports, were mounted/suspended from the top cover of the cylindrically shaped vacuum vessel as shown in Figure 4. This configuration allows easy access to all internal components during the various phases of the assembly, alignment, as well as for future maintenance or repairs.

The vacuum vessel was fabricated from Type 304 SS following all prescribed UHV practices[4]. A 230 1/s ion pump attached under the vessel to a large diameter pumpout port is the only septum component not attached to the top cover.

A six-strut septum support stand shown in Figure 5 was designed to support and allow remotely controlled horizontal motion of each end of the septum by ± 1 cm. Two of the horizontal struts were motorized using stepper motors, and the remaining struts, 3 vertical and 1 axial, were made over 60 cm long to control their "cosine errors" in those struts for the intended horizontal motion.

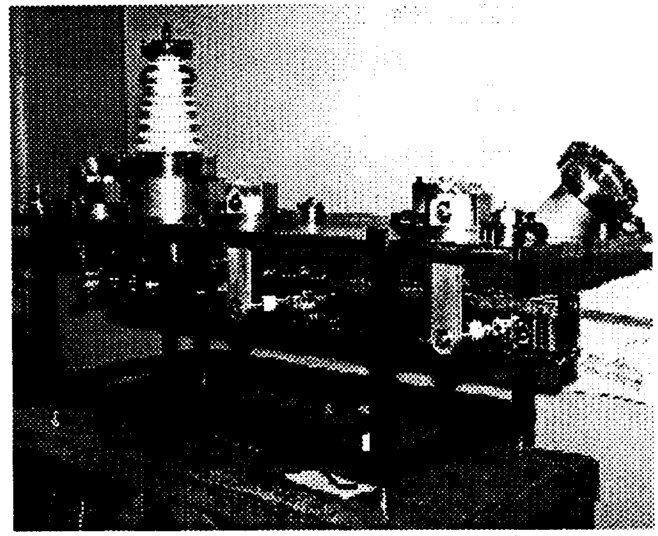

Figure 4. Internal components suspended from the top cover. The anode is shown supported by temporary AL203 insulators.

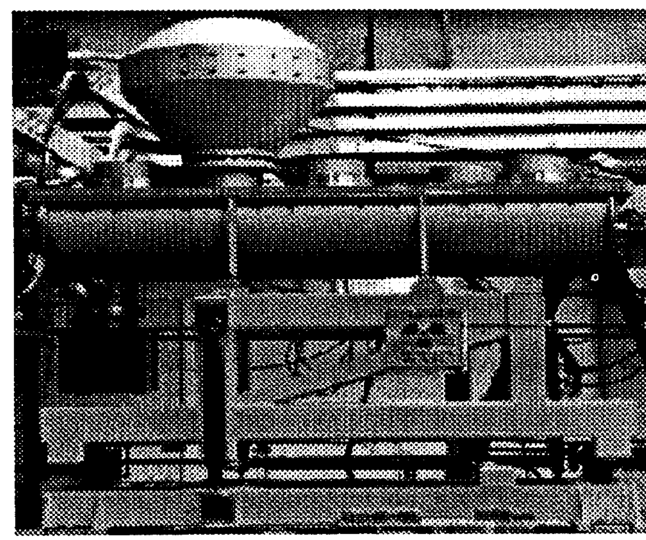

Figure 5. Injection electrostatic septum installed in ring lattice.

III. ELECTRICAL

The stainless steel anode is burnished to reduce asperities, which helps suppress arcing and pitting of the surface. The electrical standoff insulators were made of BeO to provide a high voltage standoff and a high thermal conductance path to the tank for any heat input to the anode.

The high voltage feedthrough is per a commercial design obtained from Ceramaseal. The high voltage power supply, cable connectors and series/resistor box were purchased from Glassman, Inc. The series resistor absorbs the energy in the cable if the septum arcs, reducing the potential damage to the anode surface.

The foil carrier is grounded to the tank through 50 ohms to allow monitoring of any collected current if the beam should hit the septa. The guard electrode can be biased up to -3kV below ground by a separate connector and power supply. The intent is to use this circuit to reduce the flow of secondary electrons to the anode, when the guard foils are struck by the beam, as they must during the resonant extraction process.

During the assembly of the injection septa, the BeO insulators were not delivered in time, so a temporary fix was made by using stock Al2O3 insulators and modifying the supports to allow testing of the septum but not at full voltage. The modified anode circuit withstood 50 kV easily. The septum windows were a source of X-rays when the high voltage processing was performed and bluish light was seen near the modified insulator ends. The rating of the modified unit was reduced by 1/2 from the design. This allowed the injection septum to be installed and inject electrons (5 mr bend) at about 300 MeV operating at 20 kV. The present plan is, at some convenient time, to install the now delivered BeO insulators.

IV. FIDUCIALIZATION

The foil carrier was set up and fiducialized to verify that the edges of the C-shaped foil carrier were flat and parallel. The 2 cm gap spacing between the foils and the anode was surveyed in and verified and the whole assembly was fiducialized to allow placing the septum on the designed beam orbits for injection and circulating beams. An important measurement made at final assembly was the effective thickness of the 270 foils when mounted on the foil carrier. For the injection septum this was found to be 145 microns versus the 70 microns expected thickness. When the extraction septum is constructed, a number of different assembly steps are planned, which are expected to reduce the effective septum thickness to the design value.

V. TESTING

The injection unit was installed in ring lattice and tested to the 50 kV level consistent with the shorter Al2O3 temporary standoff insulators after high vacuum was obtained. The electron beam used to test the deflection of the beam into the ring was 300 MeV so that the operating voltage required was about 20 kV. The electron beam was deflected smoothly by computer control of the power supply.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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