ELECTRO-MECHANICAL DESIGN FOR INJECTION IN THE UNIVERSITY OF MARYLAND ELECTRON RING*

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Abstract

Closure of the University of Maryland Electron Ring (UMER) is anticipated in May 2003. An initial prototype of the injection "Y" has been completed. Electro-mechanical aspects of the design and test results of this prototype are presented. The design incorporates an offset quadrupole and a pulsed dipole to achieve the 10-degree bend required from the injection line. To accommodate penetration of the pulsed dipole magnetic field a glass gap has been inserted at the point of injection. A fixture was used to align the sections of the assembly and serves as a permanent mount plate. A similar method will be used for extraction of the beam after the electron ring has been closed.

INTRODUCTION

The University of Maryland Electron Ring (UMER) is a low energy (10 kV), high intensity (100 mA), recirculating electron ring designed to explore the physics of space charge dominated beams [1,2]. Closure of the ring is anticipated in May 2003. In order to close the ring, a "Y" shaped section must replace the 10º bend that is currently installed on UMER at the point where the injection line intercepts the ring.

Design of the injection Y was dependent upon the method adopted for beam injection. Two design schemes are still in competition for the final experimental setup. The first utilizes electrostatic steering of the beam using an applied voltage on parallel capacitive plates in a custom-made vacuum chamber. This scheme would require several components to be precisely placed within the chamber and electrical feed-throughs on custom flanges for connections to the plates and any diagnostics. Due to limited space, the quadrupole magnets may also need to be placed within the vacuum. It was assumed that all these requirements would significantly increase the size, cost, and difficulty of the assembly.

The second method is magnetic steering of the beam using pulsed coils to create an orthogonal magnetic field component. This injection scheme eliminates the requirements for large chambers as all magnetic components may be mounted outside the vacuum boundary. Components may be adjusted, repaired, or even upgraded without breaking vacuum. The latter design was chosen for our first attempt and is described in this presentation. Work done by H. Li [3] describes in detail the magnetic components of this injection scheme. The work presented in this paper is primarily concerned with the mechanical design of this complicated assembly.

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DESIGN PROCEDURE

The design of the injection Y is centered (both physically and mathematically) on the point where the injection line meets the electron ring. Figure 1 shows an overview of the complete assembly. In this figure the beam is injected from the upper left (Arm #1), enters the ring to the right (Arm #2), and returns through the lower left arm (Arm #3).

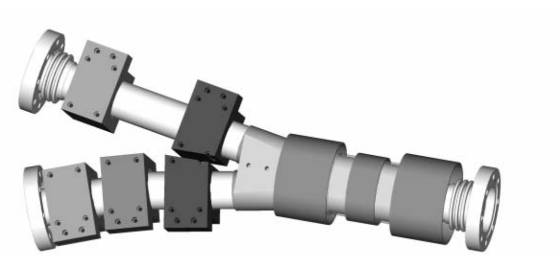

Figure 1: Injection Y assembly with magnets installed.

Glass Gap

The pulsed dipole is centered on the point of injection therefore a nonmagnetic material is required in this region. A glass gap of approximately 10 cm was constructed by Larson Electronic Glass. We wished to minimize disturbances to the magnet field in the region of injection, therefore the glass is joined to one inch of 316 series stainless steel at each end by the use of a "housekeeper" detail in which the steel is tapered down to approximately 0.002 inches of thickness where it meets the glass. This taper accommodates the differences in thermal expansion between the steel and glass. Weld reliefs were cut at the outer edge of the steel to facilitate connection at both ends to the vacuum structure. This bonding method eliminates any magnet material in the joint, but because the steel is so thin, it places limitations on structural strength at the same time. Details of this construction may be seen in Figure 2.

The minimum diameter of the cylinder is limited by its overall length and the fact that it must incorporate a

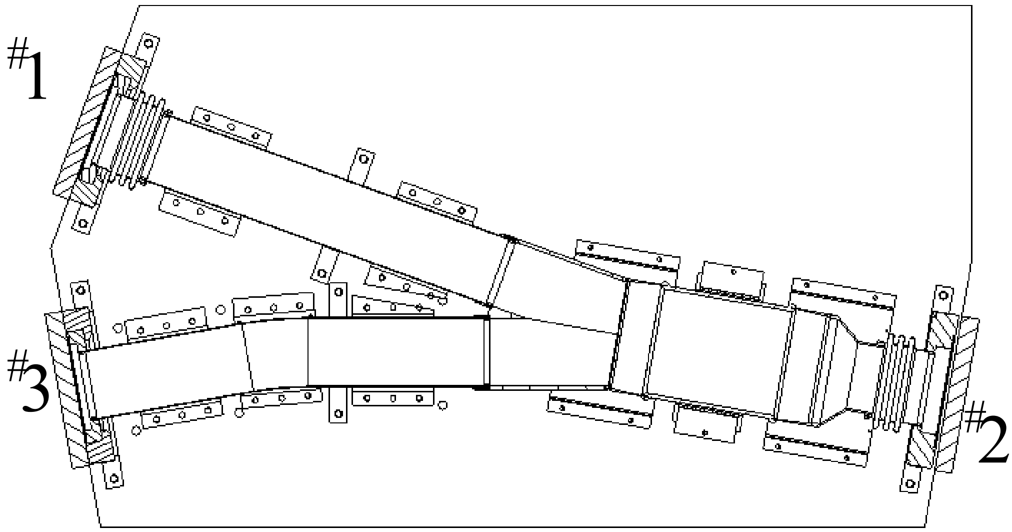

Figure 2: Cutaway view of injection Y assembly.

connection to the 2.0 inch pipes from both the injection line and ring return, each offset by plus and minus 10º respectively from the center line of the cylinder. When the length is fixed at 10 cm, these restrictions yield a diameter slightly larger than 3 inches. Since glass this large is commonly manufactured in 0.25 inch incremental diameter, we were forced to step up to outer diameter of 3.25 inches.

Finally, a thin coating of conducting material was required to prevent any possibility of charge buildup and damage to the glass or glass-steel joint. The coating also had to be thin enough to permit the fast pulsed magnetic field penetration. According to Faltens [4] the thickness of a thin coating is related to the field penetration time for a dipole by

$$dR = {}^{ct\rho}\!/_{200R} \tag{1}$$

where dR is the thickness, c is the speed of light, t is the penetration time, ρ is resistivity, and R is the radius. For field penetration times on the order of 5 ns and using aluminium ($\rho=2.4\times10^{-8}\ \Omega$–m), Eqn. 1 yields very thin coating thicknesses of approximately 20 to 30 nm. It was found however, that the resistivity of the coating increases greatly with the formation of an oxide layer over the aluminium. The measured resistance of several prototype aluminium coated cylinders varied from 10 to 30 ohms, an order of magnitude better than needed. The resistance of the final assembly was not measured due to the risk associated with damaging the coating. All the vapor deposition was done within IREAP.

The pulsed dipole has been fabricated from #18 magnet wire wrapped on a plastic cylinder with a diameter of 88 mm. The pulsed dipole's axial length is 44 mm. Initial tests of the dipole indicate that the magnetic field rise time is on the order of 20 ns.

Junction

The three branches of the Y section are welded to one junction piece. The junction has been cut from a solid piece of 316 series stainless steel. Counterbores have been included to facilitate weld reinforcement rings required on arms #1 and #3. A weld relief was cut around the right end to minimize weld stresses when connecting to the glass gap assembly.

An oversized, offset quadrupole mounts over the junction. This quadrupole has been designed to bend the beam approximately 5º and ease the demands placed on the pulsed dipole.

Arm #1

The injection line mates to Arm #1 by means of a 4.5 inch rotatable Conflat flange. A set of formed bellows has been added to allow for small adjustments and connection to the downstream end of the injection line. The length of this arm was determined by the spacing of the focusing quadrupoles mounted over it. Weld support rings were added at both ends of the thin-walled stainless steel pipe to prevent damage during final assembly.

Arm #2

The injection Y mates to the electron ring at Arm #2. Formed bellows were incorporated again to allow for small adjustments and connection of the vacuum flanges. Arm #2 also reduces the diameter of the vacuum boundary back down to the standard diameter throughout the ring (d=1.96 inches). The reduction is done in a tapered section over 1.0 inch axial distance.

Arm #3

The return path of the beam is through Arm #3. No bellows were required because the downstream end of the last ring chamber has bellows. Arm #3 has a 10º bend as determined by the uniform spacing of the ring's 36 bending dipoles. Weld support rings were added at both ends of this arm again to prevent damage. Quadrupole mount blocks placed on both Arm #1 and Arm #3 near the junction will require modification as shown by the tapered cut in Figure 2.

Support plate

All the previously described components must be positioned within tolerances acceptable for UMER. To achieve this, a pair of support plates were manufactured at IREAP. The separate pieces were sandwiched between the two plates, held in position by brackets, and welded. The support plate simplifies alignment of the completed assembly within the electron ring because precision holes were bored under the injection point and the bend in Arm #3. Finally, the support plate provides physical protection to the very fragile glass gap and prevents compression forces on the glass-steel joint. A photograph of the completed assembly with the top plate removed is presented in Figure 3.

Figure 3: Completed assembly of the injection Y.

CONCLUSIONS

The pulsed magnetic beam steering version of the injection Y has been built. A glass gap with a thin conductive coating permits fast penetration of the pulsed dipole magnetic field. A prototype pulsed dipole has been built and successfully tested. Initial beam tests are scheduled for the next phase of experimentation when we will install the injection Y at the end of the beam line. Lessons learned in the design and construction of the injection Y will be used in development of the extraction Y.

REFERENCES

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