ALIGNMENT OF COMPONENTS AT THE UNIVERSITY OF MARYLAND ELECTRON RING*

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Abstract

Alignment of experimental components is critical to operation of The University of Maryland Electron Ring (UMER). Procedures and equipment used to align components of the electron ring are presented. The compact nature of UMER (ring diameter ≈ 4 m) presents unique challenges and advantages associated with the placement of vacuum components, confinement and steering magnets, and diagnostic equipment. Alignment of all components has been accomplished with a set of two T3000 theodolites and a three-dimensional software package from the Leica Corporation. A set of fiducial monuments has been used to establish a permanent coordinate system. The position of UMER components has been measured to an accuracy of less than 100 microns in that coordinate system.

I 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]. Due to its compact nature, alignment of the experimental components within the ring is critical. The UMER ring diameter is approximately 4 meters. Previous attempts to align components utilizing mechanical armatures, micrometers, and shims were found to be cumbersome and inadequate. This paper presents the methods used to solve the unique challenges associated with the placement of vacuum components, confinement and steering magnets, and diagnostic equipment. Procedures and equipment used to align components of the electron ring are presented in Sec. II. Results of our work are presented in Sec. III. In this section we also discuss possible future improvements and recommendations for further refinement of alignment issues.

II ALIGNMENT PROCEDURE

Establishment of a Coordinate System

The problem begins with the same question every experimentalist faces, "Where can we put all this stuff?" The experimental area assigned to UMER is shown in Fig. 1. The room is only approximately six meters wide on the left and has several obstacles in the form of steel support beams scattered throughout the area intended for setup of the ring. The problem is further complicated by the addition of approximately two meters for the injection line and two meters for extraction 140º further downstream.

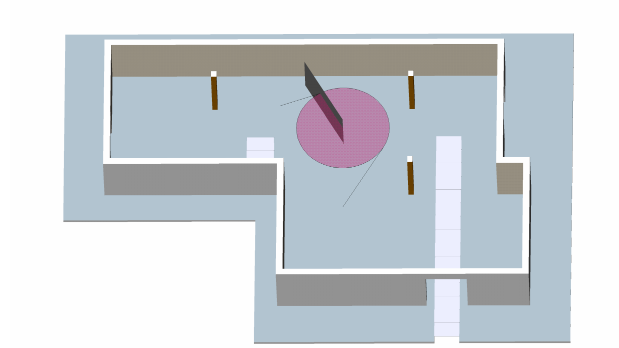

Figure 1: Experimental floor plan. Ring location (circle) and 12:00 position (plane) shown.

As seen in Fig. 1 the center of the ring was chosen to give adequate clearance to the wall and prevent interception of the corner at the lower left. To fix this location a hole was bored into the concrete and a stainless steel cylinder (monument base) was cemented in place. The cylinder has a precision 0.25 inch hole on its top side which allows a target to be inserted without error and removed when not in use. The rotational orientation of the ring was fixed with a target approximately two meters high on the wall. All angular positions are measured clockwise from the plane formed by this target and the center monument. Eight additional monuments and four wall targets have been placed around the experimental area and referenced to the ring center and angular reference plane to ensure line-of-sight from all locations.

Assembly Modeling

Next, we needed to know exactly where all the pieces of the experiment should be placed. To accomplish this, all parts and assemblies have been drawn in the three-dimensional CAD package, Pro/Engineer [3]. Those assemblies are then constrained to their ideal positions with the knowledge that the ring is divided into 18 individual sections of 20º subtended arc length each. Each section has been constructed with a central chamber and two arms, each with a 10º bend. From these

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geometric constraints the exact radius to the center of each ring chamber is 1833.456 mm.

Mounted on each section are two dipole magnets to bend the beam and four quadrupole magnets for confinement [4]. The diameter of the ring is fixed by the spacing of 16 cm between quadrupoles. The dipole and quadrupole mounts are fixed in place on a cluster plate with alignment pins. The cluster plates have been machined from 0.875 inch thick aluminium plate. Figure 2 shows the detailed drawing of one of the ring sections.

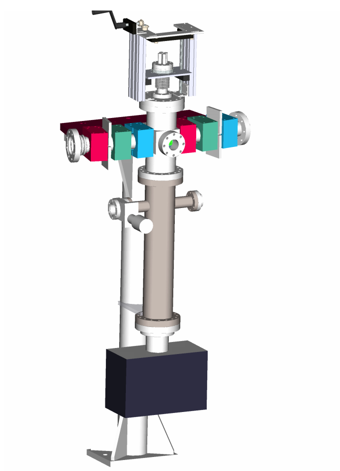

Figure 2: ProEngineer drawing of one 20º ring section.

Both the injection and extraction lines are 10º off the tangent to the ring. The diagnostic chamber has been repositioned during ring construction as sections have been installed to allow beam experiments to continue, but will be attached to the end of the extraction line upon closure. Figure 3 shows the current experimental setup with 180º of the ring installed.

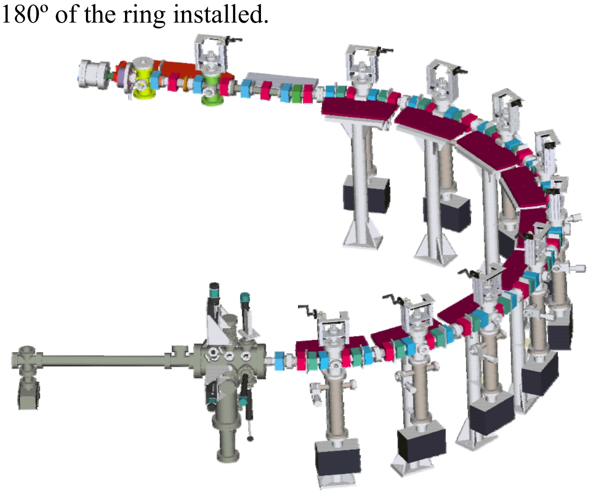

Figure 3: Current experimental setup of 180º of the complete electron ring.

Alignment Equipment

All of the previously described components have been placed in their proper positions by the use of two T3000 theodolites and their associated software package, Axyz, from Leica AG [4]. The T3000 can measure angles with a standard deviation of 0.5 arcseconds. On the scale of distances within our lab, this translates to a few 10's of microns. The minimum focal distance is 0.51 m. Magnification varies with distance, from 13x to 43x.

The theodolites require line-of-sight not only to the component to be positioned but also to the monuments and references previously discussed. In some situations, this may require leapfrogging when only two theodolites are available. The accuracy of measurements is sensitive to the angle formed between the two theodolites and target. Ideally this angle should be kept between 60 and 120 degrees to minimize pointing error. Finally, the accuracy of measurements is highly sensitive to the ability and vision of the operator.

The software package, Axyz, records all angular measurements and calculates data points from the theodolites. It allows user defined coordinate system transformations. Simple shapes, lines, circles, etc., may be constructed to ease alignment problems. Axyz also can calculate projections, intercepts, and distances.

III RESULTS AND DISCUSSION

All the components of the electron ring may now be measured to within less than 100 microns with the theodolite alignment system. Nine ring chambers have been positioned along with all their associated magnets and diagnostics. The injection line and diagnostic chamber have been positioned. Continued refinement of positioning components within this complex system is ongoing. Beam quality has been improved by sound implementation of alignment procedures [2].

The key alignment issues in the UMER setup are the positioning of focusing magnets, component design, and manufacturing tolerances. Beam quality has been found to be extremely sensitive to offsets in the focusing lattice.

Our quadrupoles are placed within mount blocks, which are then bolted to the cluster plate with no ability to modify individual magnet positions. The cluster plate is held in position by a set of push-pull screws. It has been found that these push-pull screws cause a small deformation of the cluster plate and therefore misalignment of magnets. The machining tolerances of the mount block also affect accuracy of magnet placement.

The arms of the ring chambers also introduce error into the system. Both the accuracy of the bend angle and arm alignment during the welding process could cause misalignment. Much of that error can be compensated for with the bellows on the downstream flange of each chamber but errors normal to the ring plane are difficult to correct without tilting the chamber, which in turn would introduce errors in the pitch of the magnets.

Nearly all of the errors in alignment introduced by the magnet mount blocks and ring chambers can be corrected with a redesigned mount block or cluster plate assembly. It would be prohibitively difficult and expense to replace the cluster plates, whereas replacement of the mount blocks is reasonably easy. The magnets are already removed each time the system must be baked to achieve acceptable vacuum.

Figure 4 shows the prototype of the redesigned magnet mount block. The improved design allows correction in roll, pitch, and yaw with push-pull screws and a small increase in the inner bore from 2.210 to 2.335 inches. Sensitivity to the roll angle has been increased by extending the moment arm length where the block attaches to the cluster plate.

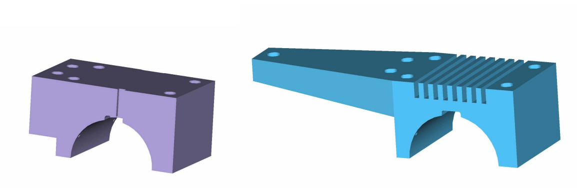

Figure 4: Current magnet mount block (left) and prototype redesign (right).

IV CONCLUSIONS

Alignment is critical to all operational aspects of UMER from injection to diagnostics at beam termination. All components of UMER can now be measured in situ, without breaking vacuum or disrupting experimental activities. A coordinate system for the experiment has been constructed and a trained team of personnel can now align and adjust components quickly and accurately. Maintenance of the ring has also been simplified because pieces may be removed and replaced easily. Alignment issues have now been incorporated throughout, from the initial design phases to finished assembly and installation.

V REFERENCES

[1] http://www.ireap.umd.edu

[2] S. Bernal, et. al., "Beam Transport Experiments over a Single Turn at the University of Maryland Electron Ring", these proceedings.

[3] Pro/Engineer, copyright by Parametric Technology Corporation, 2001.

[4] M. Virgo, "Controls and Alignment for the University of Maryland Electron Ring", proc. PAC, 2001.

[5] Axyz, copyright Leica Geosystems, 2003.