ALIGNMENT OF THE BOOSTER INJECTOR FOR THE DUKE FREE ELECTRON LASER STORAGE RING*

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Abstract

This paper presents the methodology and initial results for mechanical alignment of the booster synchrotron for the Duke Free Electron laser Laboratory (FELL) storage ring. The booster is a compact design and requires special considerations for alignment. All magnets and vacuum chambers in the arcs have been designed such that a laser tracker can be best utilized for alignment. A parametric 3D design package has been used to determine target coordinates. These target coordinates evolve from design goals to physically verified dimensions by modifying the parametric model to match mechanical measurement data after fabrication. By utilizing the functionality of a laser tracker system [1] and a parametric 3D modeler, a direct and efficient measurement and alignment technique has been developed for the booster ring's complex geometry.

INTRODUCTION

In the summer of 2004, construction of approximately 1200 SF of a building adjacent to the North East corner of the main FEL lab was completed. Immediately after completion of this facility, preparation for installation of the booster ring components began.

The booster ring is designed to provide full energy electron injection into the storage ring over a range of 275 MeV to 1.2 GeV. Commissioning of the booster ring will enable continuous operation of the High Intensity Gamma Ray Source (HIγS) facility.

Booster's conceptual and magnetic optics design was accomplished by the scientific staff at the Duke FEL lab and the Triangle University Nuclear lab (TUNL). All magnets (except sextupoles), vacuum chambers, and mechanical supports were then designed and fabricated at the Budker Institute of Nuclear Physics (BINP) in Novosibirsk Russia. In the Fall of 2004 shipment of the magnets and vacuum chambers to Duke FEL lab was completed. We have just finished the installation and initial alignment of both arc magnets. Alignment of the south straight section components are currently in progress.

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BOOSTER RING DESIGN PARAMETERS

The booster ring consists of: twelve dipole magnets; eight focusing (QF) and eight defocusing (QD) quadrupoles; eight sextupoles, eight horizontal and vertical trim dipoles; one 178.55 MHz RF cavity for ramping electron bunches to 1.2 GeV; one injection and one extraction septum magnet; one extraction and one injection kicker magnet. It is to be noted that the RF cavity and the sextupoles were originally designed for the storage ring. Several other publications have addressed these design parameters in more details [2,3]. Each arc in the booster ring will consist of 6 magnet clusters; each cluster consists of a dipole and a quadrupole. Each cluster will be mounted on individual extruded aluminum strong backs. In preparation for installation of these girders, a Leica LTD500 laser tracker was used to locate the bolt holes on the floor for anchoring the girder pedestals. At the time of installation, all six girders in each arc were securely mounted in place and then bolted together as one solid support assembly. A Leica DNA03 digital sight level was used to set the height of these girders.

MAGNET MECHANICAL QC

At the time of fabrication, the BINP has incorporated alignment fiducials into each magnet. The BINP has performed thorough mechanical quality inspection of all magnets and created a list containing relative positions of these fiducials and other relevant QC data. Magnetic measurement was performed at the BINP. At the time of magnetic measurements the offset between the geometric center line and the magnetic center of each magnet is measured and recorded. Upon arrival at the DFELL, the magnets were physically inspected for any sign of damage. One magnet of each type was mechanically and magnetically measured to verify repeatability with measurement instruments at the BINP.

ALIGNMENT CONCEPT

A two foot thick reinforced concrete was poured on a 2.5 feet of compacted crushed stone to prepare the floor of the booster area. This was necessary In order to meet the stringent stability requirements and also to meet the compatibility with the storage ring floor slab. A few weeks after pouring the slab, a series of 13 ring type floor monuments [4] were installed on the floor slab as shown in Fig. 1. Also a total of eighteen 1.5"corner cube reflector mounts, part # 1.5 SM-HC [5] were installed against adjacent walls, column and ceiling of the booster area in order to integrate (tie) these monuments to the existing storage ring floor monuments to establish a global network to facilitate the alignment with our laser tracker. The North East corner of the storage ring's floor monuments, MN1 and MN2 were used as a control network to ensure precise location and orientation of the booster magnets.

ALIGNMENT TOLERANCES

In order to achieve a successful operation of the booster ring, the following tolerances for the absolute and relative positioning of the booster magnets have to be met. Tables 1-3 quantify the acceptable mechanical accuracy.

Nomenclature for Alignment Positions and Angles:

X	Transverse (Horizontal) Position
Y	Vertical Position (Height)
Z	Longitudinal Position (Beam Direction)
X'	Angular Rotation about X axis (Pitch)
Y'	Angular Rotation about Y axis (Yaw)
Z'	Angular Rotation about Z axis (Roll)

Table 1: Absolute (global) Alignment Tolerances

Placement of each magnet from ideal position	0.5 mm
Circumference of the booster ring	1.00mm

Table 2: Relative Alignment Tolerances

	X	Y	Z	X'	Y'	Z'
	mm	mm	mm	mrad	mrad	mrad
Dipoles	±0.50	±0.15	±0.5	±0.50	±0.50	±0.40
Quadrupoles and Sextupoles	±0.20	±0.10	±0.5	±0.50	±1.50	±0.20
Septum magnet	±0.15	±0.10	±0.15	±0.50	±0.30	±0.20
Kicker Magnets	±0.50	±0.20	±1	±2	±2	±2

Table 3: Maximum tolerable offset for a magnet relative to adjacent magnet for Linac To Booster (LTB) and Booster To Ring (BTR)

	X	Y	Z	X'	Y'	Z'
	mm	mm	mm	mrad	mrad	mrad
Quads	±0.30	±0.30	±1.5	±1.5	±1	±1
Dipoles	±0.50	±0.50	±1	±1	±1	±1

ALIGNMENT PROCEDURE AND RESULTS

Due to a complex geometry of the vacuum chambers and the support structure of the booster ring, the following steps of alignment are currently in progress:

1. Primary alignment
2. Fine alignment
3. Magnet smoothing

In preparation for alignment, all relevant monuments including the floor monuments in the north east corner of the storage ring were surveyed utilizing the Leica laser tracker. Axis alignment function in the Core Data Module (CDM) of the laser tracker's Axyz software was used to establish a 3D spatial coordinate of the magnet fiducials with respect to the origin (reference) monument. In this practice, floor monument MN1 was used as the origin and MN2 as a primary axis. Fiducial coordinates of all dipoles and quadrupoles were then imported as reference points in the CDM's Data Manager. 'Build Points' mode was used to continuously display the difference between the current fiducial position and its reference (ideal) value. For the first step of alignment, magnets were positioned close to the tolerance values. As the second step, magnets were aligned to within the tolerance values. Following the second step, all top halves of the magnets were removed and two big assemblies of vacuum chambers, for each arc covering all six clusters per arc were installed. Before reinstalling the top magnet halves, one last height survey of the bottom halves (mid-plane) was performed with a Leica digital sight level DNA03. Given the complexity of the geometry of the booster ring, initial results from the first two steps of the arc alignment showed that most of the magnets were positioned well within the specified tolerances. Just a few magnets were beyond the tolerance levels. A three dimensional smoothing algorithm was developed for the final stage of alignment to correct the position of those magnets which are not within the tolerance values. Final survey and alignment of the magnets will be performed after all of the magnets in the booster ring are installed and individually aligned some time during the summer of 2005.

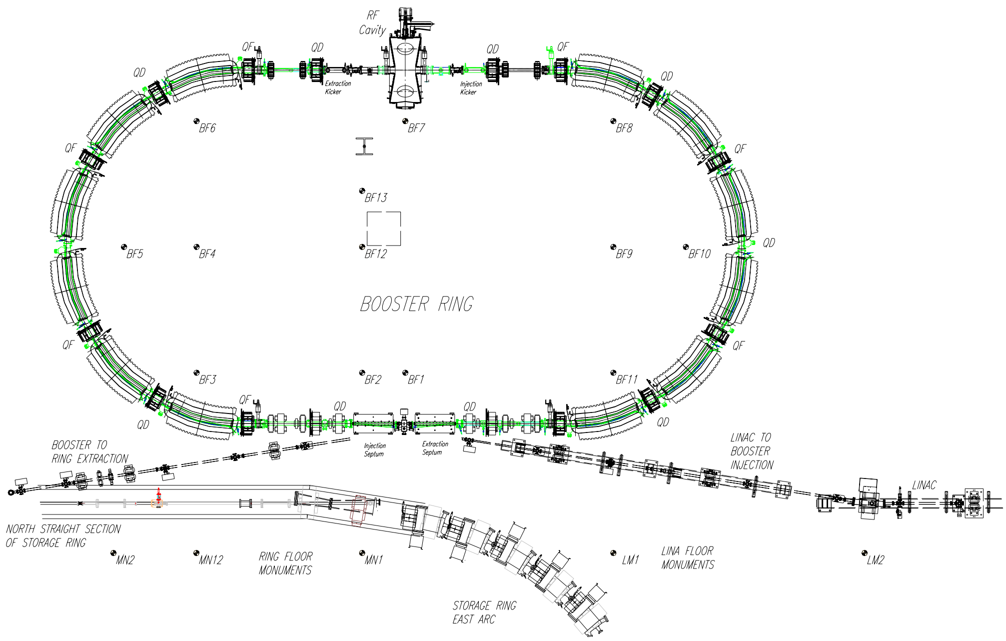

Figure 1: Layout of the Booster Ring Facility

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