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Overview of the Final Focus Test Beam Alignment System*

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Abstract

The Final Focus Test Beam was conceived as a technological stepping stone on the way to the next linear collider. Nowhere is this more evident than with the alignment subsystems. Alignment tolerances for components prior to beam turn are almost an order of magnitude smaller than for previous projects at SLAC. Position monitoring systems which operate independent of the beam are employed to monitor motions of the components locally and globally with unprecedented precision. An overview of the FFTB alignment system is presented herein.

1. INTRODUCTION

The primary objective of the Final Focus Test Beam (FFTB) is to consistently and repeatably focus a 50 GeV electron beam onto an area which is 1 µm wide (horizontal) and 80 nm tall (vertical). The FFTB alignment system contributes in three ways.

(1) Tight initial alignment tolerances reduce the time required to initially focus the beam.

(2) Sensors which monitor the motions of magnets during a run, independent of the beam, are new tools which improve our ability to focus and control the beam.

(3) Sensors which monitor motions of the magnets between runs reduce the time required to return to a successful configuration.

2. INITIAL ALIGNMENT

2.1 Tolerances

The FFTB is composed of four straight sections as shown in figure 1.

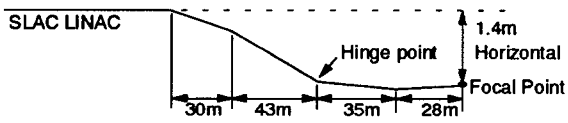

Figure 1. FFTB composed of 4 straight sections.

Initial alignment tolerances for FFTB quadrupoles and sextupoles are quite small: 30µm horizontally and 100µm vertically. Additionally, the intersections between adjacent straight sections must have closest vertical approach of no more than 30µm.

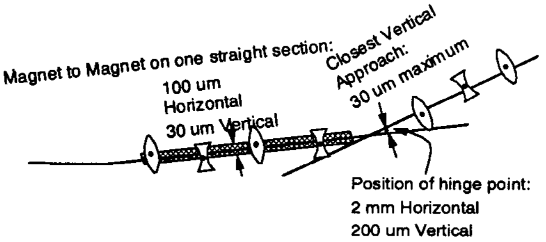

Figure 2. FFTB initial alignment tolearances illustrated.

2.2 Tooling plates

The 30µm vertical alignment tolerance applies to 23 quadrupole magnets and 4 sextupole magnets[1,2]. We have fiducialized these magnets to within 12µm using a technique developed here at SLAC[3]. The fiducials for these magnets are press fit into invar tooling plates. Two of these tooling plates are kinematically mounted on the horizontal and vertical split planes of each of the 23 quadrupole and 4 sextupole magnets. The mounting scheme of the tooling plates on a quadrupole is illustrated in figure 3. One spherical contact point touches the vertical split plane, two spherical contact points touch the horizontal split plane and 3 spherical contact points press against the magnet in the longitudinal direction. We have found that these tooling plates may be removed and replaced on the magnet to within 3µm of their original location.

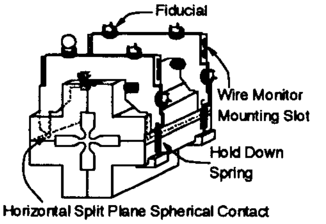

Figure 3. Tooling plates on a quadrupole.

Mounting slots for 2 wire position monitors (WPMs) are located on each tooling plate. WPMs will be described in section 3.2.

2.2 Alignment Instruments

In addition to theodolites, we will use two new alignment instruments for FFTB initial alignment: (1) Laser Tracker (2) Portable Water Hydrostatic Level.

2.2.1 Laser Tracker

The laser tracker[4] is an interferometer whose pointing direction "tracks" a retroreflector mounted

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inside of a 1.5 inch diameter sphere. By moving the sphere between fiducials, one may quickly measure the relative azimuth and elevation between the fiducials, as seen by the tracker, to within a few arcseconds. Relative line of sight distance between fiducials may be measured to within about 10μm.

2.2.3 Portable water level

In order to achieve 30μm vertical alignment of the magnets we will use a portable hydrostatic level[5]. The measurement range of this instrument is approximately 25mm, and we typically achieve 10μm repeatability after a series of measurements spanning several meters and taken over the course of an hour. For increased accuracy over large distances, the hydrostatic level, and the laser tracker will use the Fresnel laser system as a global straight line reference.

2.3 Fresnel Laser Reference System

Figure 4. A Laser Station.

The SLAC linac Fresnel laser alignment system has been extended to the FFTB[6]. Thirteen new zone plates have been installed and calibrated to within 10μm with respect to fiducials on the outside of their respective laser stations. By detecting the images produced from these zone plates we may compute to within 5μm[7] the relative offset of each zone plate from a straight line which goes through the center of two zone plates. Thus the relative positions of the laser station fiducials throughout the FFTB may be computed to within about 10μm. These fiducials will serve as a straight line reference extending the length of the FFTB.

3. ON LINE MONITORING

3.1 Description

On line monitoring is the process by which the stretched wire alignment system monitors the relative motions of the magnets in a straight section while the beam is turned on. Each of the magnets with tooling plates is installed on a mover which can roll the magnet in increments of several μradians and which can move the magnet horizontally and vertically in increments of approximately 1μm. On line monitoring using the stretched wire system will allow us to directly observe subtle changes in the relative alignment of the magnets in one straight section. Previously such changes were observed indirectly via beam position monitors and other devices which monitor the beam.

3.2 Stretched wire alignment system

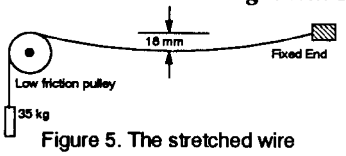

Figure 5. The stretched wire

Our colleagues from DESY have provided a stretched wire alignment system which will be used for on line (and off line) monitoring of magnet positions. The system consists of a pair of wires for each of the 4 straight sections. Three WPMs are installed on the tooling plates of each of the 23 quadrupoles and 4 sextupoles. Each WPM is similar to a beam position monitor (BPM) in that it contains 4 antenna and the differential signal strength received from opposite pairs of antenna is the quantity of interest. However, unlike a BPM which receives its signal from a packet of charged particles, the WPMs receive their signal from a stretched wire which is excited at the fixed end with a 3 Watt, 140 MHz signal and which is grounded through a 250Ω resistor at the pulley end. The wire is centered to within +/-150μm inside an 8mm (inner diameter) brass tube. The tube serves as the outer conductor in a coaxial structure which presents a constant impedance to the 3 Watt signal and which shields the signal from the outside world where it would interfere with FM radio broadcasts. A precision made aluminum extrusion provides a straight and rigid support for the brass tube.

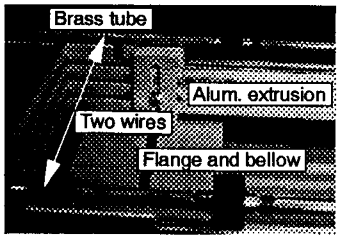

Figure 6. Support structure for the wire system.

The 3 WPMs on each magnet allows us to measure horizontal, vertical, roll, pitch and yaw motions of the magnet. The standard deviation of a set of readings from one WPM is typically less than 1μm. The stretched wire oscillates at approximately 5 Hz with an amplitude of several micro meters. Therefore it is necessary to average readings from each WPM for about a second in order to achieve sub micro meter standard deviation.

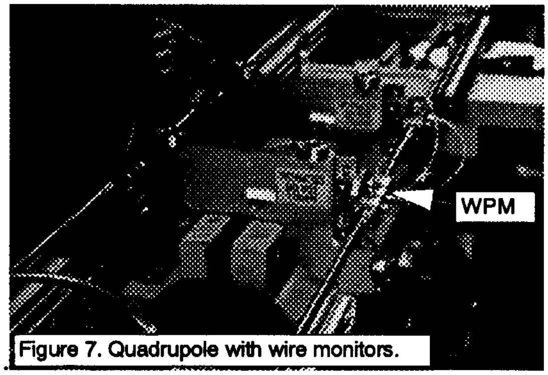

Figure 7. Quadrupole with wire monitors.

4. RECONFIGURATION

4.1 Description

We anticipate that the FFTB will have runs lasting for one week or less separated by down times of one or more weeks. Therefore, it is important to be able to return the magnets to their previous positions quickly. Our goal is to reconfigure the FFTB to within +/-10μm using the alignment system. Reconfiguration applies not only to the alignment of magnets on one straight section but also to the intersection of adjacent straight sections, see figure 2. In order to do this we need a way of monitoring the motions of the ends of the wires.

4.2 Bridges

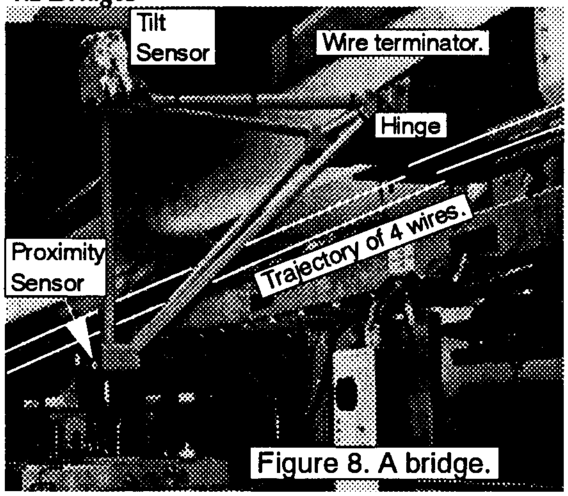

Figure 8. A bridge.

The bridge is a rigid invar structure which transfers the motion of a wire terminator to the top of a laser station whose location may be monitored with respect to other laser stations throughout the FFTB. The bridge rests on a ball which touches the top of the laser station, and the bridge is attached to the wire terminator via a precision hinge. The ends of 4 wires, spanning 2 straight sections, are also mounted on the wire terminator. The roll of the bridge is monitored with sub micro radian precision by a tilt sensor whose temperature is maintained constant to within 1/1000 degree C. The horizontal displacement of the bridge with respect to the laser station is monitored to within 2μm by a proximity sensor. Using these sensors and a number of temperature sensors located on the wire terminator and the laser station, we will monitor the horizontal and vertical motion of the wire ends with respect to the laser station to within a few micro meters.

Summary

- Initial alignment of the FFTB will be achieved by supplementing theodolites with two new survey instruments, a laser tracker and a portable hydrostatic leveling system, used in conjunction with the laser reference system.
- On line monitoring of each FFTB straight section will be accomplished using the stretched wire alignment system.
- Reconfiguration of the FFTB after a down time will be accomplished using information from the stretched wire system, the laser reference system and the bridges which connect them.

References

[1] These magnets were constructed for the collaboration by the Institute of Physics, Novosibirsk, Russia.

[2] The FFTB also includes three quadrupoles just upstream of the focal point which are aligned to within 5μm with respect to one another and which are mounted on their own table which may be translated horizontally, vertically, rolled, pitched and yawed with sub-micro meter precision. This entire system provided to the collaboration by KEK laboratory, Japan.

[3] G.E.Fischer et al.,"Precision Fiducialization of Transport Components", Proc. EPAC 1992, p. 138.

[4] Cheasapeak Corp., Lanham, Maryland U.S.A

[5] Pellissier Instrument Corp., Denver, CO U.S.A

[6] V.Bressler et al., "High Resolution Fresnel Zone Plate Laser Alignment System", Proc. EPAC 1992, p. 1613.

[7] V.Bressler et al., "The Final Focus Test Beam Laser Reference System", Proc. PAC 1993