Survey and Alignment of an MLI Model 1.2-400 Synchrotron Light Source

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Abstract

A cost effective technique was developed for the timely alignment of the magnets, support stands, and diagnostic equipment using readily available instrumentation. The procedure includes use of a commercially available theodolite coordinate measurement system for alignment of the dipole magnets, and optical tooling techniques for smoothing out errors in the position of the quadrupoles to sub-millimeter tolerances. The monument network, fiducialization of magnets and supports, and special tooling are discussed.

I. Introduction

The survey and alignment of an MLI Model 1.2-400 synchrotron light source is underway. This is a 1.2 GeV Chasman-Green lattice with an average radius of 17.6 meters and circumference of 55.2 meters. The primary ring magnets to be aligned are eight dipoles, twenty quadrupoles, and sixteen sextupoles. Twenty magnets in the transport line are also to be aligned.

Commercially available and cost effective instrumentation is used. The magnet supports incorporate screw adjustments for six degrees of freedom. Special fixtures were necessary for some of the magnets.

II. Monument Reference System

The monument network consists of fourteen primary monuments, twelve in the ring and two in the linac tunnel, as shown in figure 1. A central monument was not used because of interference with the building structure.

The monuments are very precise 3.5 inch diameter steel spheres that hold optical targets at the geometric center of the sphere; the target remains at the center regardless of the angular position of the sphere. The spheres rest in stainless steel cups epoxied into the concrete floor, and fitted with a protective cover when a sphere is not installed. These primary monuments each have x, y, and z coordinates in the global coordinate system.

Additional secondary monuments of the brass plug type with scribe marks are used as required in the ring and especially in the transport line to simplify optical tooling setups.

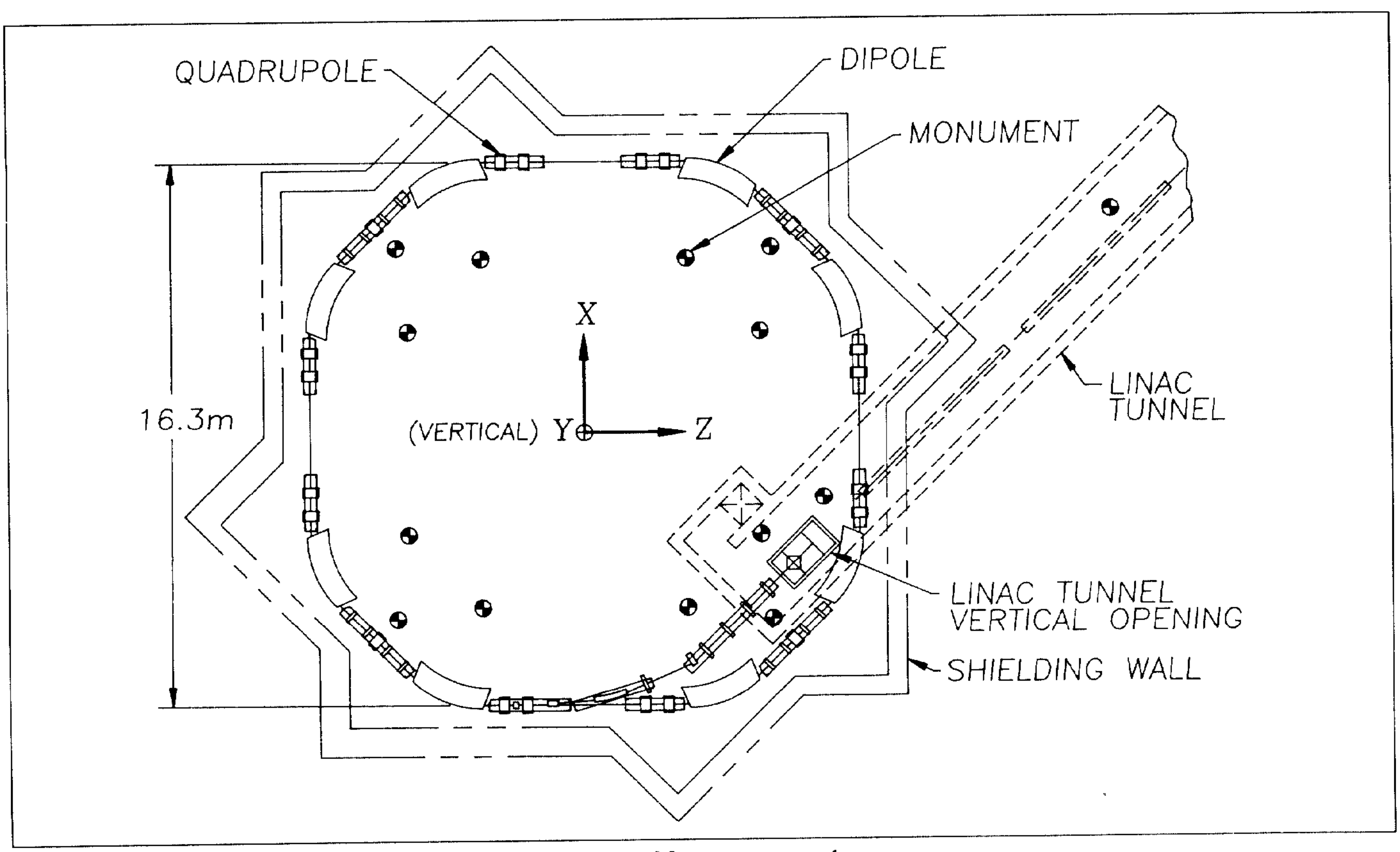

Figure 1. Monument network.

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III. Tolerances

The tolerance definition is based on a Gaussian distribution and the values below represent one standard deviation (1 σ). The dipole tolerances are relative to the primary monument network; the quadrupole tolerances are relative to the neighboring dipoles. The largest acceptable tolerance for any single item is twice the 1 σ value.

The tolerances must include the total of all the errors generated: the error from magnetic center to pole tip, the lamination edge feature with respect to the pole tip, the survey target to lamination edge feature repeatability, the survey error, and the alignment tolerance.

Table 1. Tolerances of ring magnets

	DIPOLES	QUADRUPOLES
x	0.60 mm	0.30 mm
y	0.60 mm	0.30 mm
z	0.60 mm	0.50 mm
pitch	1.0 mrad	1.0 mrad
yaw	1.0 mrad	1.0 mrad
roll	0.34 mrad	0.80 mrad

IV. Instrumentation and Data Reduction

The alignment of the ring magnets is performed in a two-tier hierarchy. First, the dipoles are aligned relative to the primary monument network, and then the girders with quadrupoles and sextupoles are aligned relative to the dipoles. The linac and transport line are aligned with respect to the primary monument network.

For preliminary placement of all the magnet supports, and for final alignment of the dipole magnets relative to the geodetic coordinate system, an industrial measurement system (IMS) is used. A typical IMS system has at least two electronic theodolites which can measure vertical and horizontal angles to 0.5 arc seconds. The theodolites enter digitized angular data into a minicomputer for conversion into x, y, and z coordinates.

Leveling of magnets and stands is accomplished with the use of a precision optical level, accurate to 0.025 mm at distances up to 20 meters.

Alignment of the quadrupoles and sextupoles relative to the neighboring dipoles, as well as alignment of some magnets on the transport line, is accomplished with an optical tooling setup that measures offsets (see figure 2). The optical tooling scales are fitted with interchangeable feet that have either a round end for use against the laminations directly, or a conical seat for use with tooling balls.

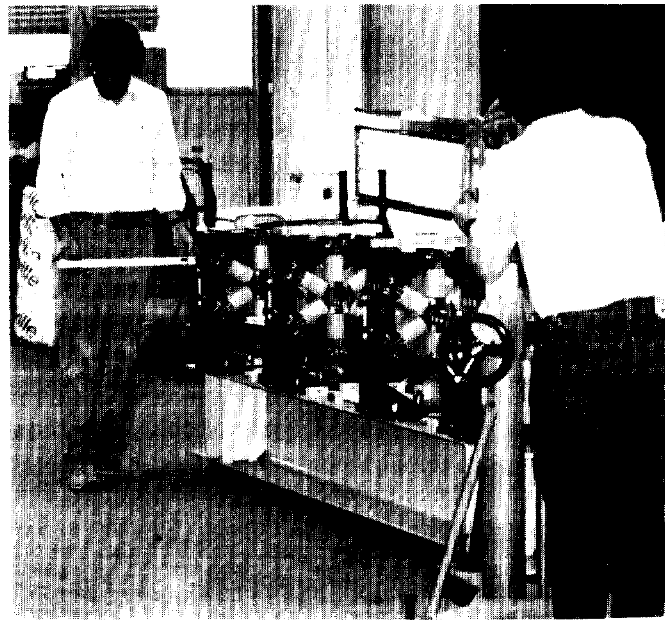

Figure 2. Optical tooling setup for measuring offsets.

V. Fiducialization of Magnets

The magnetic axis determines the path of the particles through the magnetic field. The magnetic axis is virtual, and needs to be related to physical fiducials on the outside of the magnet. In this application, the mechanical axis of the magnet is sufficiently collinear with its magnetic axis to allow individual pedigrees for each magnet to be avoided. Since all laminations for any one magnet are stamped from a single die set, all outside edges and features stamped into the laminations carry a high dimensional accuracy with respect to the pole tips. The relative position of the mechanical center to features such as notches and edges on the outside edges of the laminations can be readily determined. These features are used to locate fixtures which incorporate fiducials, and the position of the fiducials relative to the mechanical axis is known within a certain tolerance.

For example, at each end of each dipole, on the magnet midplane, is a welded tab with a precision 0.250 inch diameter hole (see figure 3). The relationship between this hole and the

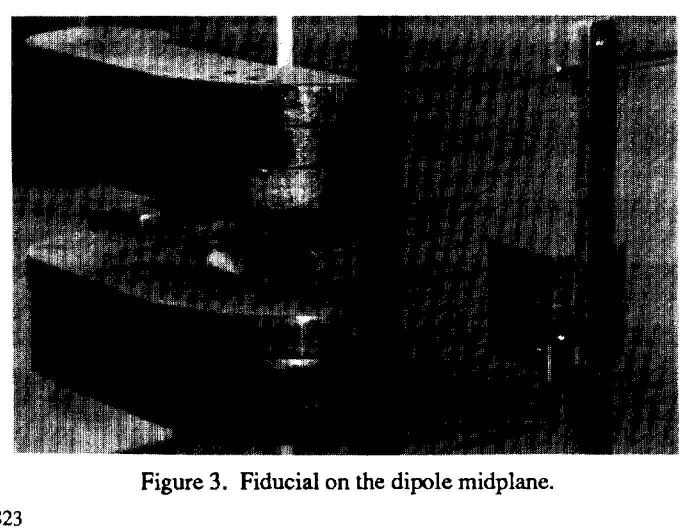

Figure 3. Fiducial on the dipole midplane.

mechanical center of the magnet is known to be within ±0.15 mm in the x-z plane. The holes will accept either theodolite targets or tooling balls, and are sufficient to align the dipoles in x, z, and yaw. The tabs were located with a large aluminum tooling plate which keyed to the magnet in a reproducible and determinate fashion. The magnetic measurements were also referenced to this plate, so that if it becomes necessary to pedigree the magnets later, there is a known mechanical relationship between the magnetic measurements and the fiducial positions.

The magnets are aligned in roll with bridge fixtures containing 20 arc second bubble levels. The fixtures rest on the unpainted surfaces on top of the magnets (see figure 4).

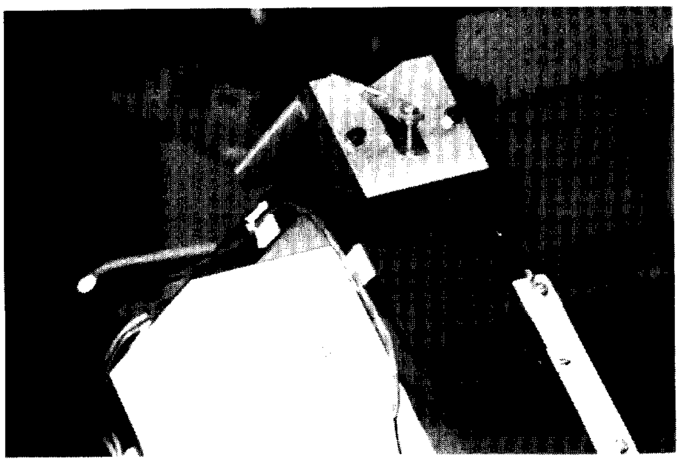

Figure 4. Bridge fixture on quadrupole magnet, showing 20 arc sec bubble level.

VI. Magnet Supports and Adjustments

Each ring dipole stand has three adjustable legs. The leg adjustments are used together for aligning all six degrees of freedom. The horizontal screws allow adjustment in x, z, and yaw, and the vertical threaded rod and nut allow adjustment in y, roll, and pitch.

The quadrupole and sextupole stands have similar adjustments for adjusting the entire straight-section girder (see figure 5). The individual magnets on each shared girder also have provisions for adjustment, using jackscrews for all six degrees of freedom.

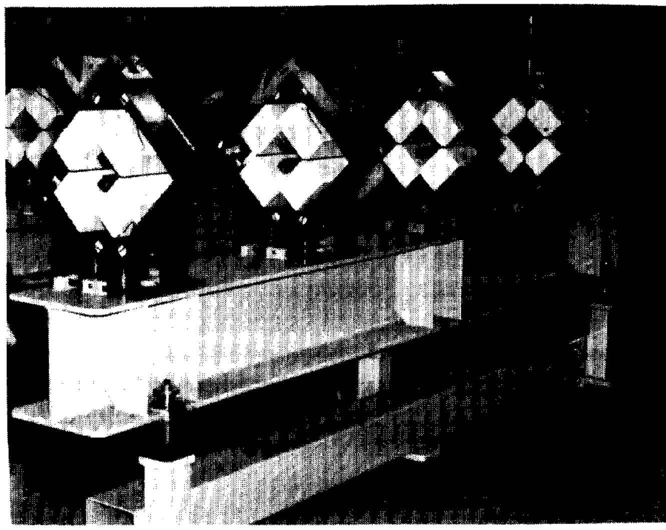

Figure 5. Adjustable legs on multipole magnet girders.

VII. Alignment Procedure

The dipoles are leveled and set at the correct height by using the roll fixtures and an optical level, with adjustments being made on the three large vertical nuts on the support base. A 10 ton hydraulic jack is necessary to partially relieve the load on the adjusting screw for vertical adjustments on the dipoles.

The IMS is used to determine the x-z coordinates of the dipole fiducials; these are compared with the ideal values, and corrections to the x-z coordinates are computed. The magnet is then fitted with dial gauges to measure motion in the x-z plane, and moved the calculated amount with the horizontal push screws.

Each of the quadrupole and quadrupole/sextupole straight section girders (complete with magnets and vacuum chambers) is installed as one assembly on the support base, with the adjustment system set midrange. Leveling is performed first with a roll fixture and the optical precision level for pitch and y. Next, z is set with an inside micrometer. Finally, x and yaw are set with an optical tooling setup between adjacent dipoles. A reference plane is set up by using a jig transit bucked into the fiducials the ends of the dipoles. Measuring horizontal offsets to this plane allows setting x and yaw.

A final survey is then made on all magnets to ensure that they are within the tolerances specified.