DEVELOPMENT OF AN INTEGRATED FIELD MEASUREMENT SYSTEM (IFMS) FOR NSLS II

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Abstract

This paper describes the mechanical design, control instrumentation and software for the Integrated Field Measurement System (IFMS) for the Magnetic Measurement Lab for the National Synchrotron Light Source II (NSLS-II) project at Brookhaven National Laboratory.

INTRODUCTION

Insertion devices (IDs) at NSLS II need to be accurately surveyed using an integrated field measurement system prior to insertion into the storage ring and can also be used in the tunnel for final tuning of IDs. It is a fast and precise measurement system required in determining the ID magnetic field integrals.

The design is a set of long coils supported by two sets of 3-axis X-Y-Z precision linear and two precision rotary positioning stages as shown in Figure 1. The PC is the primary control unit executing Wavemetrics IGOR 6.0. The motion control is based on a Delta-Tau GeoBrick with 8 axes of servo control and general IO. The integration is based on a MetroLab FDI 2056 which interfaces with one of 4 field measurement coils. These measurement coils consist of a flip coil, vertical and horizontal moving coils and a stretched wire. These are described in more detail below.

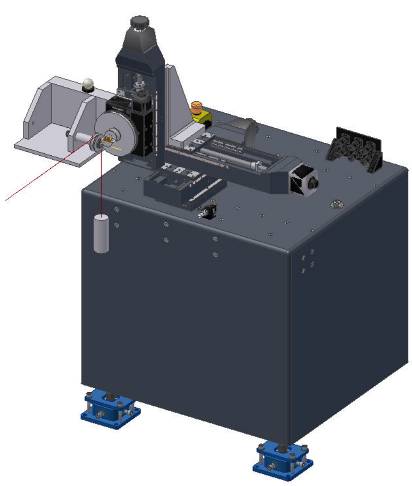

Figure 1: Integrated Field Measurement System (IFMS).

OVERVIEW

The IFMS is shown in Figure 2. This view shows the left and right pedestals with the 4 meter moving coil G10 board shown between them. Below the moving coil board is shown the channel for the return lines that complete the loop. The pedestals are made from granite with extremely flat tolerance on the top surface. Each pedestal has 3 leveling feet that also provide 10 mm adjustment in the X and Y directions and 50 mm in the vertical direction. Aluminum plates have been added to the top and 2 sides of the granite to make EMO switch and cable bracket mounting as well as future mounting changes easier.

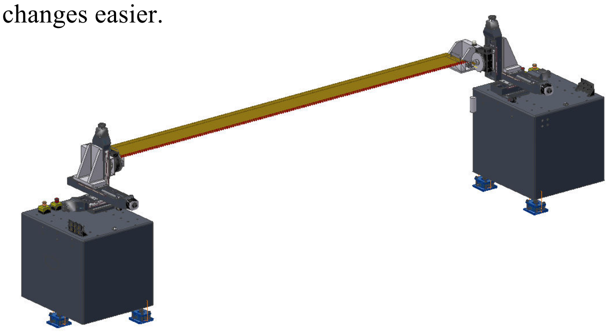

Figure 2: IFMS with the 4-m moving coil G10 board.

LINEAR STAGES

There are six of ADC's ultra high precision linear stages. The Y and Z axes will have 150 mm travel and the X axis will have 300 mm travel. All linear axes have a Renishaw RELM linear encoder with +/- 1 um accuracy and .1 um resolution. All axes have limit switches and a home limit switch that is used to tell the motion controller that it is near the home pulse located on the encoder. Several tooling holes are provided for survey targets consisting of a ¼-20 threaded hole and a ¼" reamed hole. A list of axis specifications is shown below in Table 1.

Table 1: X-Y-Z Motion Specifications

	X-Axis	Y-Axis	Z-Axis
Travel Range	150 mm	100 mm	100 mm
Position Resolution	0.5µm	0.5µm	0.5µm
Absolute Position Accuracy	±5µm	±5µm	±5µm
Relative Position Accuracy	±1µm	±1µm	±1µm
Minimum Speed	20 mm/min	20 mm/min	20 mm/min
Maximum Speed	300 mm/min	300 mm/min	300 mm/min

ROTARY STAGES

Two rotary direct drive servos made by Yaskawa are used to achieve a 1 revolution per second (1 RPS) flip coil requirement. The Yaskawa motors can achieve 2.5 RPS while providing up to 1.4 million encoder counts per rev.

Table 2: R-Axis Motion Specifications

Minimum Travel Range	±180º
Angular Positioning Resolution	0.005º
Angular Positioning Accuracy	<40 arcsec
Angular Positioning Repeatability	<2 arcsec
Reversal Error	<20 arcsec
Eccentricity	<5 µm
Wobble	<10 arcsec

FLIP COIL

The flip coil mounts to a special spool on the rotary axis located on each pedestal. 25 turns of 38 AWG beryllium copper wire, is strung between these spools to form one continuous loop. An ADC custom circuit card will amplify and drive the long line signal back to the Metrolab Integrator card. The coil spacing is set by a replaceable grooved plastic part. Wires are soldered to gold pins mounted in the spool. The connecting cable is light AWG twisted pair shielded. The cable is tensioned with a lanyard to prevent tangling as the spool revolves. The flip coil has a tension sensor located in the bobbin as shown in Figure 3. Mounting the tension sensor in the bobbin removes the need to use a free slide under the stages thus improving the stability of the XYZ stack. The flip coils can measure first and second integrals. The first integral is measured inside the area of the coil, the second integral is measured by twisting one end by 180 degrees essentially reducing this area to zero by forming two equal but opposite areas.

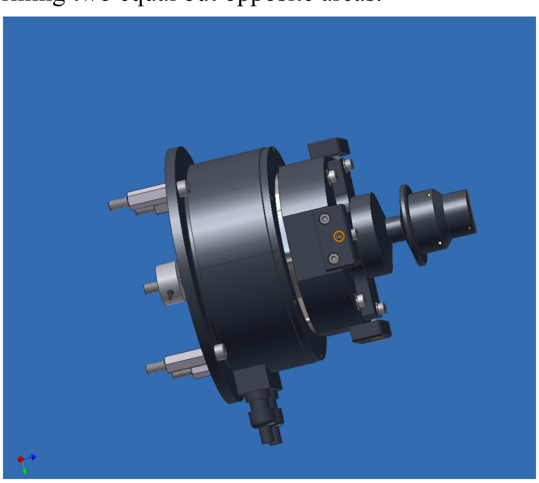

Figure 3: Rotary servo with tension sensor.

MOVING COIL

The moving coil also measures the first and second integrals. This design is based on a similar concept developed for LCLS at SLAC [1]. The moving coil consists of 150 turns of wire formed from a flat cable with ten, 38 AWG, wires. The cable is held in a slot cut into a board made from a special fiberglass made by Strongwell called “Extren”. This coil is oriented horizontally to pickup the vertical field. A second coil, wound vertically, consists of 10 turns and measures the horizontal field.

The board is a single piece 4 meters long. The slot that carries the wires is milled into the 100 mil edge of the board. The board must be flat to function properly. For this reason the thicker portion is mounted to a G10 I-Beam that is 4 inches tall and 2 inches wide. The board is attached to the I-Beam with a set of push-pull screws that are held captive by another set of locking screws.

The 38 AWG wires are very delicate and must be assembled carefully. They are first laid into the slot in the front of the board but return through an aluminum channel. The aluminum channel is supported by the pedestals. The board must be removed for shimming. Provisions are made to clip the return channel to the board for local transport. Bull’s-eye levels are mounted to each end of the board. The photo below in Figure 4, shows the board in the process of being flattened prior to coil winding.

Figure 4: Moving Coil Board under construction.

STRETCHED WIRE

The stretched wire is similar to the moving coil in that only one leg of the coil is in the field during the measurement. The return wire is outside the field. The stretched wire consists of a single beryllium copper wire with a diameter of .125 mm. The wire is tensioned with a weight as shown below in Figure 5. The return wire lies along the floor. The stretched wire is moved in the field to produce a signal which is very small and needs a good deal of amplification. ADC designed and built a special instrument amplifier for this purpose.

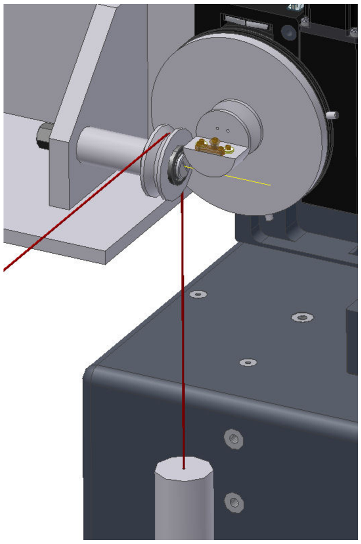

Figure 5: Stretched wire.

ELECTRICAL DESIGN

The control system provides 8 axis of servo control and has a position synchronized triggering on 3 axes, X, Y and rotary. The motion control system is based on a Delta-Tau Geobrick controller. Four axes (X,Y,Z, Theta) are master and four are slaves so each direction consists of a master and a slave. The flip coil can be tensioned by the Z master slave combination. The Electronics are housed in a standard 19 inch rack cabinet 42 inches high. See Figure 6 below. A Dell precision T3500 PC forms the central control point and operator interface. The PC runs Wavemetrics IGOR 6.0 which is a graphical analysis software package. ESRF's B2E was also included. The IGOR XOP (external operations) Toolkit 6.0 is provided. This is used in conjunction with NI-VISA commands provided by Metrolab and MicroSoft's VC10 C++ compiler to produce a seamless interface between IGOR and the Metrolab integrator.

Figure 6: Standard 19 inch rack cabinet.

METROLAB INTEGRATOR

The Metrolab FDI2056 integrator was chosen for this application. This integrator provides the highest rate of sampling with the best stability and smallest signal capture of the integrators that were researched. This is also the same integrator used at SLAC Undulator Field Integral Measurements [2].

The Metrolab FDI2056 resides in a 3 board MXI rack that is connected to the PC using a National Instruments express PCI serial bus. The NI serial bus consists of two cards, the PXI 8361 which resides on the PC and the PXI 8360 which resides in the integrator rack. The two cards are connected with a special 10 meter NI cable.

This instrument integrates the voltage between external triggers. These triggers can be time or special based. The resolution is 1 microvolt on the lowest gain setting. There are 10 internal gain settings. The coil can connect directly to the input of this device. This was originally developed for magnetic field characterization at CERN.

CUSTOM MULTIPLEXER CARD

Since there are potentially 4 sources of signals that can be input to the Metrolab (ie the flip coil, vertical moving coil, horizontal moving coil, and single wire), and 5 triggers (Upstream and Downstream X, Y, and Timed), ADC designed a custom card to multiplex the analog and trigger signals into the integrator. The selection is made with IO lines available from the Geo-Brick. The multiplexing circuit is devised from NEC/Tokin relays that are used by Keithley in their 20 channel input card. ADC has used this card to switch between flip coil and hall probe signals on our magnetic field measurement systems for many years with no trouble [2].

REFERENCES

[1] Zachary Wolf, Yurii Levashov "Undulator Long Coil Measurement System Tests", LCLS-TN-07-03, SLAC, April 2, 2007.

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[3] A. Deyhim, D. Waterman, J. Kulesza, E. Van Every, "Portable Magnetic Measurement System", European Particle Accelerator Conference, EPAC'08, Genoa, Italy, 23 to 27 June 2008.