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Magnetic Field Measurement System

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Abstract. A magnetic field measurement system was designed, built and installed at MAX Lab, Sweden for the purpose of characterizing the magnetic field produced by Insertion Devices. The measurement system consists of a large granite beam roughly 2 feet square and 14 feet long that has been polished beyond laboratory grade for flatness and straightness. The granite precision coupled with the design of the carriage yielded minimum position deviations as measured at the probe tip. The Hall probe data collection and compensation technique allows exceptional resolution and range while taking data on the fly to programmable sample spacing. Additional flip coil provides field integral data.

Keywords: Undulators, Insertion Devices, Magnets, Flip Coil, Granite
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INTRODUCTION

A stand-alone, turn-key, magnetic field measurement bench for the characterization of the field produced by insertion devices is presented. This state-of-the-art magnetic field measurement system is vital for the shimming process of the magnets in both in-vacuum and in-air devices. Field data is acquired in 3 orthogonal axes. The device exceeds the precision typically achieved with a rail system mounted to the insertion device and would pay for itself through the elimination of only a few rails systems. The measurement system can also be used for characterization of devices after shipment, for on-site acceptance testing, periodic maintenance and upgrades, and actual shimming as necessary. Combined with an ADC flip coil the first and second order field integrals can be measured to provide complete device characterization.

MECHANICAL DESCRIPTION

The magnetic field measurement system is based on a granite beam for accuracy and stability. Special mounts are provided with vibration dampening characteristics. Levelers provided on the mounts for 3 point leveling. The front edge of the granite beam is the precise surface on which the carriage is guided. This is the right hand side facing the laser mount end. The long axis is driven by a linear servo motor. The magnetic track for this motor is glued with epoxy to the top surface of the granite. The slider is mounted inside the carriage bottom.

The carriage is supported on 3 NewWay Precision vacuum air bearings on the top and 2 on the front side. Vacuum provides mass-less preload for the bearings while air provides friction free bearing for the carriage. The carriage is additionally preloaded by the slider due to the attractive force between the slider and magnet track. The vertical and horizontal axes are supported and guided on steel cross roller bearing rails. Total travel is 300 mm less limit region. Preloaded ball-screws have 10 turns per inch and are stepper motor driven. The vertical and Horizontal axes use Renishaw tape scales, with 50 nm/count resolution, for position feedback. The vertical axis is provided with a brake that is on with Servo Off and Off with Servo On.

Cables for encoders, motors, and limits, and hoses for air an vacuum are fed thru an Igus flexible wireway for low friction. An aluminum "I" beam is glued to the back of the granite to support the cable wireway. Controls are located in a 19 inch cabinet on the laser end of the beam. Cables have connectors at the back of the cabinet and at the back of the carriage. The Hall probes are mounted orthogonally on a non-magnetic stick that attaches to X stage of the carriage. This stick is supported on 3 ball bearings in V grooves that allow accurate realignment of the stick to the carriage. This is done to allow different probes and indicators to be mounted to the carriage as well as providing a means for the stick to breakaway in a crash condition thus preserving the hall probes.

The flip coil consists of 2 towers that provide X, Y, and theta motions. There are then 6 axes. Three axes on one tower form the master and three on the other are slaves that follow the master. All motions are Stepper motor driven. Stepper motors have rotary encoders with 4000 counts per revolution. The coil is strung between the two towers and forms a 3 mm loop. One tower provides a tensioner in the Z axis.

ELECTRICAL DESCRIPTION

The motion controls are based on the Parker Accroloop 1505 and 8020 cards. These reside in the local PC. The 1505 supports the long axis servo, and the vertical and horizontal steppers. The 8020 supports 6 axes of stepper for the Flip Coil and produces the triggers for the long axis measurements. The long axis linear servo motor is driven by a Parker Gemini servo amp. All stepper motors are driven by a Parker E-AC stepper drive. The long axis position feedback is derived from the Optodyne LDDS 1000 laser. The laser is mounted on one end of the beam on a mount that provides adjustment for pitch, roll, yaw, and lateral offset. Output signals are A Qaud B (quadrature) and differentially driven. The position feedback for the vertical and horizontal stepper axes is provided by Renishaw tape scales. All feedback is A Qaud B (quadrature) and differentially driven.

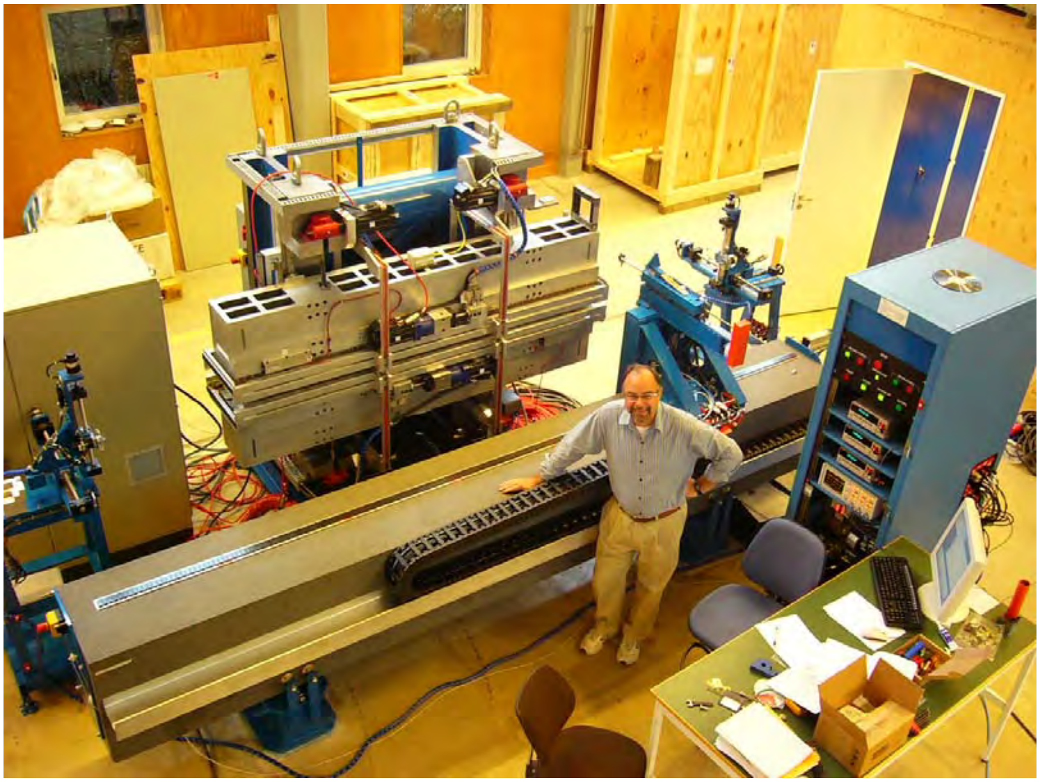

FIGURE 1. A view of the Entire System in Operation on a 2.3 Meter EPU at MAX-lab

The magnetic field is measured by 3 orthogonal axes of Hall effect probes. These probes and the device for converting their signals to analog voltage is provided by an FW Bell 7030 magnetic field measurement system (alternatively Lakeshore probes could be used). This device is located in the control rack. The output of the FW Bell is a 20 bit D-A converter that tracks the raw data coming from the probes, 3 channels are provided. No temperature or other compensation is made on this output. Temperature compensation is performed in the PC. The raw analog signal above is fed, one to each of 3 Kiethly DVMs. The Kiethely's provide 22 bits data conversion and accept triggers for synchronizing the data samples. The Kiethly's also perform averaging on every sample. The maximum reliable sample rate is 40 ms which translates to a measurement velocity of 25 mm/s at a trigger distance of 1mm. Smaller trigger distances require a proportionally slower measurement speed.

Serial communication (RS232) is provided between the PC and each of the 3 Kiethly's, The FW Bell, the Optodyne laser and the Parker Gemini servo amp. All but the Gemini servo amp are permanently cabled, this allows one free RS232 port for general use. The PC is a Kontron industrial rack mount with a Pentium III 2.4 GHz CPU, 80M hard drive, Floppy, 2 USB ports (in the back), CDrom reader, flat panel display, keyboard and mouse. Software required is the Parker ACCRO-VIEW to program and control the Acroloop cards, Parker Motion Planer to program the Gemini Drive, Optodyne SETUP to setup the laser, and IgorPro to communicate with the Kiethly's, transfer and compensate the sample data, and produce plots of the magnetic fields.

SOFTWARE FEATURES

ADC provides several unique software features. One routine corrects for misalignment of the Hall probes on the stick using the fields of an undulator. Another performs automatic data compensation for temperature and Hall probe calibration factors in Igor rather than in the FW Bell, which extends the compensated range of measurement. An Igor routine is provided to find the magnetic centerline of the undulator from 5 runs of data stepped in X or Y. Finally, the flip coil is compensated for the Earths magnetic field. ADC has developed a user "front end" that streamlines the set-up and collection of data. This consists of an Igor operator interface which effectively communicates the desired start and stop points, elevation, and trigger distance to the Accroloop cards, executes the sequence and collects and plots the data from the Kiethly's.

SPECIFICATIONS

Specifications	
Granite Dimensions	Length – 5000 mm, Width - 500 mm, Height - 500 mm, Weight - 3992 Kg
Granite Tolerance	Flatness – 2.5 um per 300 mm or better; Straightness – 2.5 um per 300 mm or better
Power	240 or 480 VAC, Single Phase, 20 Amps, Ground
Air	120 PSI, 1 SCFM, 2 micron, filter, dry,
Vacuum	28 inches of Hg, pump provided
Travel	Long Axis – 3800 mm, Vertical – 290 mm, Horizontal - 290 mm
Position Feedback	Long Axis -79.25 nm per count , Optodyne Laser; Vertical Axis – 50 nm per count, Renishaw Tape Scale; Horizontal Axis – 50 nm per count, Renishaw Tape Scale
Magnetic Filed Measurement	.1 Gauss to 1 Tesla, 20 bit range, as output by the FW Bell uncompensated port
Data Conversion	22 bit range At the Kiethly DVM
Trigger Distance	Programmable

PERFORMANCE

Data was taken on this system by SLAC metrology lab before shipment. Details of this data is available on request. The data consists of the position deviations of the probe in X and Y axis along the travel, the effect of pitch on the probe height over the travel, and the effect of carriage yaw on the probe position. Instruments used were an auto collimator and a stretched wire probe. The following are excerpts from that report.

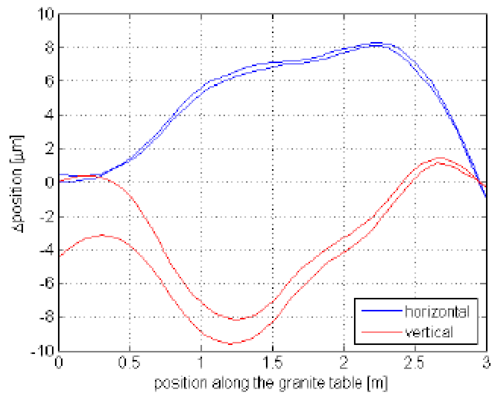

Figure 3: Position deviations of the probe along the granite table (WPS and AC data)

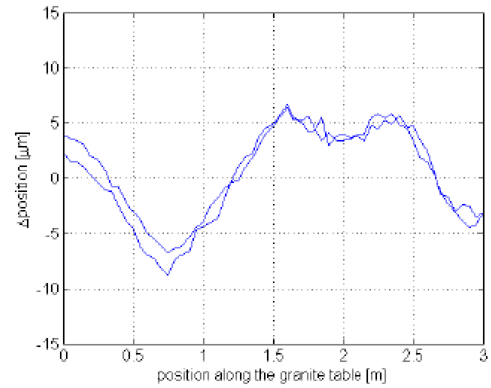

Figure 5: Effect of carriage pitch on probe z-position in 0.5 m height difference

FLIP COIL

The left flip coil tower is used to hold a device for referencing the measurement system to the ID unit. This is done by first finding the X,Y,Z locations of the mount shown below in the Hall Probe bench coordinate system. The tower and mount are moved until they are in alignment with the hall probe bench. A threaded hole is provided in the hall probe break-away mount to install a long rod for an indicator. Next a magnet is used with a magnetic field focusing element to find the location of the focusing element in the hall probe bench coordinate system.

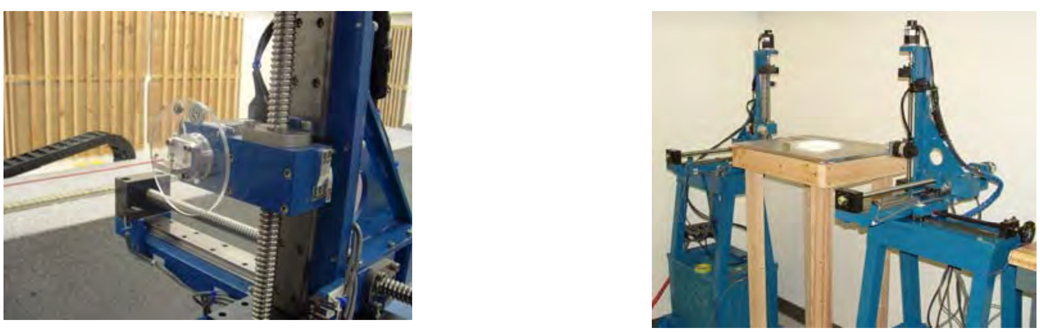

FIGURE 4. Flip Coil Field Integrator

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