PORTABLE MAGNETIC MEASUREMENT SYSTEM

Joe Kulesza, Dave Waterman, Alex Deyhim, Eric Van Every, ADC, NY 14882, U.S.A
K. Ingvar Blomqvist, Sweden

Abstract

This portable magnetic field measurement system is a very sophisticated and sensitive machine for the measurement of magnetic fields in undulators (Planer, EPU, and Apple II), wigglers, and in-vacuum ID units. The magnetic fields are measured using 3 axis hall-effect probes, mounted orthogonally to a thin wand. The wand is mounted to a carriage that rides on vacuum air bearings. The measurement system base is a solid piece of granite. A flip coil is provided on two vertical towers with X, Y, and Theta axes. Special software is provided to assist in homing, movement, and data collection. A similar system to this was constructed for use at APS [1].

CONTROL ARCHITECTURE

The control architecture is based on a Kontron rack mount PC running Windows XP Office. The PC provides a means to communicate with the various components of the system while providing an operator graphical interface and connection to host or internet via Ethernet LAN. The PC runs a program called IGOR which provides the graphical interface as well as communication to system components

There are 2 motion controllers: A Parker ACR9000-4, a 4 axis controller which controls the Hall Probe, and a Parker ACR9000-6, a 6 axis controller which controls the Flip Coil. Both are made by Parker-Hannifin. These devices communicate with the PC via RS232 - one port for each controller (COM 1 -> ACR9000-4 Hall Probe, COM 2 -> ACR9000-5 Flip Coil). The Parker controllers run independently of the PC and of each other. Each has an operating system program called Acro-View that runs specific programs developed by ADC. This relieves the PC of the motion control burden. Three Keithley 2701 DVMs and one Keithley 6220 constant current source are used to control and collect data from the Hall Probe and Flip Coil. Other control system such as Tango based for 3D measurement are developed at ALBA [2].

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 are 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 rotary servo motor on a traction drive. This is located on a hinged plate at the back of the carriage.

The carriage is supported on NewWay Precision vacuum-air bearings, 3 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 to the front guiding surface by the traction motor on the back of the carriage.

The vertical and horizontal axes are supported and guided on steel cross roller bearing rails. Total travel is 250 mm less limit region. Preloaded ball-screws have 1 mm lead per turn and are servo motor driven. All servo motors have rotary encoders with 8000 counts per revolution. The vertical axis on the hall probe carriage is provided with a brake that is applied with Servo Off and disengaged with Servo On.

Cables for encoders, motors, and limits, and hoses for air and vacuum are fed thru an Igus flexible wire-way for low friction and cable life. An aluminum "I" beam is mounted to the back of the granite to support the cable wire-way. Controls are located in a 19 inch cabinet near the middle of the beam. Cables have connectors at the side of the cabinet and at the back of the carriage.

A facilities plate is provided with an air micron filter, coalescing filter, desiccant dryer, and regulator. A vacuum pump is provided that can produce 12.5 In-Hg. In addition, vacuum and air pressure are monitored by 2 sensors with displays and programmable set-points. The set-points must be met for the servos to be enabled.

The flip coil consists of two mirror-image towers with X,Y, and Theta axes. A coil is strung between the theta axes of each tower. Typically, 25 turn of 41 AWG beryllium copper wire is used. One tower has a manual lead screw to tension the coil. This is the Master tower which contains the X,Y,L axes, the other tower is the Slave tower and contains the A,B,R axes. The Slave follows the Master on all moves. All axes are servo driven. The towers are filled with sand to dampen vibrations and to increase mass. Levelers are provided on the feet. Cables connect from panels on the towers to the side panel on the controller.

ELECTRICAL DESCRIPTION

The motion controls are based on two Parker ACR 9000 servo controllers. These reside in the control cabinet. The ACR 9000-4 supports the Hall Probe carriage long axis servo (Z), the vertical servo (Y), and the horizontal servo (X). This controller also produces the triggers for the Hall Probe measurements. The ACR 9000-

6 supports 6 servo axes for the Flip Coil, 2 each of X, Y and Theta. One set of 3 axes (X, Y, Theta) forms the master and the other 3 form the slave. Hall Probe and Flip Coil can function independently. All servo motors are driven by Parker Aries servo drives located in the control cabinet.

The long axis (Z) position feedback is derived from the Renishaw HS10 laser. This laser is mounted on one end of the beam on a mount that provides adjustment for pitch, roll, yaw, and lateral offset. The laser is compensated for temperature and barometric pressure with a Renishaw RCU-10 unit.

The laser output signals are incremental (A Qaud B, quadrature) and differentially driven to a custom Differential receiver card made by ADC. The differential receiver card merges the home reference sensor and laser A Quad B signals and re-drives these to the Parker 9000-4

The position feedback for the vertical (Y) and horizontal (X) servo axes are provided by Renishaw incremental glass scales. All feedback is A Qaud B (quadrature) and differentially driven. These encoder signals are received directly by the ACR 9000-4.

The magnetic field is measured by 3 orthogonal axes of Hall effect probes. These probes are also mounted on a custom circuit card designed by ADC. The hall probes are wired in series so they all receive the same excitation current. The excitation current is provided by a Keithley 6220 constant current source. This source must be set to 5 ma and 12 v compliance manually, before measurements can begin.

The output of the each of the hall sensors are received by a dedicated Keithley 2701 Digital Volt Meter (DVM). These are automatically programmed to sample the data on an external trigger pulse generated by the ACR 9000-4. The X axis Keithley is special because it has a 20 channel input adapter. This is used to multiplex X axis Hall sensor, flip coil, and Hall Probe RTD signals. The Other two Keithley DVMs are dedicated to Y and Z hall sensor data exclusively. The Hall sensors require calibration for temperature and output variance, as well as orthogonal mis-alignment and spacing. This compensation is performed in the PC, but the user is required to select the proper compensation files.

The Kiethely's receive the same external trigger generated by the ACR 9000-4 which synchronizes the data. The Kiethley'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.

The trigger is generated at the ACR 9000-4 using a special gearing function. This function tracks the laser position and produces one output trigger pulse based on a programmable gearing option. This function also buffers back-counts which must be counted out again to produce the trigger. This feature eliminates trigger distance errors caused by vibration.

The flip coil towers are controlled by the ACR 9000-6. The right tower (as you face the back of the granite) is the Master and the other tower is the Slave. The slave follows the master's position axis for axis. That is, the Horizontal axis slave (A) follows the master X axis (X), the vertical axis slave (B) follows the master axis (Y), and the theta axis slave (R) follows the master axis (L).

Several loops of a light (41 AWG) beryllium copper wire is stretched between the two towers rotary axes. The master tower has a tensioner. Typically, 25 loops are strung between the two towers. The flip coil is revolved in the magnetic field and produces a voltage that is received by the X axis Keithley DVM. The coil is revolved in a sequence of 45 degree steps both forward and backward to reduce errors. The flip coil only measures the field integral. The coil can be twisted 180 degrees to measure second integrals.

Serial communication (RS232) is provided between the PC and each of the 3 Kiethley's, and the 2 ACR 9000s. A 6th com port is also provided for occasional communication with the Parker Aries drives and Renishaw laser. All but the 6th port are permanently cabled. The PC is a Kontron industrial rack mount with a Pentium III 2.4 GHz CPU, 80M hard drive, Floppy, 4 USB ports (in the back), CDrom reader, flat panel display, keyboard and mouse. Two USB ports are used for COM-1 and COM-2 which connect to the ACR 9000-4 and 9000-6 respectively. . One PCI card slot is used for an EasySync 4 port RS232 card which provides COM 3, 4, 5, and 6. A panel is located in the left side of the controller to connect the display signal, display power, mouse, and keyboard.

Required software is the Parker ACR-VIEW to program and control the ACR 9000 units, Parker Aries Support Tool to program the Aries drives, Renishaw RCU-CS to setup the laser, and IGOR Pro to communicate with the Kiethley's, transfer and compensate the sample data, and produce plots of the magnetic fields.

AXIS HALL PROBE

ADC has developed a magnetic measurement hall probe with 3 orthogonal axes to complement our line of magnetic measurement systems as shown in figure 1. This probe uses three FW Bell GH-700 hall sensors with the addition of an on board RTD for temperature measurement. ADC has designed this probe using 4 layer board technology. All signals lines are embedded between two layers of copper to reduce noise. While the 4 layer board is the same thickness, the extra layers make it mechanically stiffer. The fit and form factor is the same as the ESRF probe so that existing mounting and calibration fixtures can be used in retrofit applications. The 10 pin, 2.5 mm pin spacing connector has been replaced with a 12 pin 1.5 mm connector. An adapter cable is used to interface to existing cable connections. The board thickness is 1.5 mm, making it useful for In-Vacuum undulator characterization. It should be noted that while this Hall probe can be calibrated up to +/-1 T in Y and Z directions, the X direction is limited to +/-.707 T. This is because the di-pole field generator is limited to 1T and the probe length is such that it can only be inserted in the di-pole field magnet at a 45 degree angle. The readings are then resolved to perpendicular.

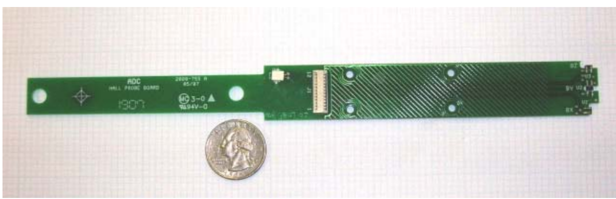

Figure 1: ADC Hall Probe

FLIP COIL

The flip coil consists of two towers each with 3 degrees of freedom, X, Y and Theta shown in figure 2. They are named left and right and identified as you face the granite beam. The Master is on the right the Slave on the left. The master is identified by the manual tensioner and cable connection to the flip coil.

The cables attach to the controller at the connector panel and at the connector panel on each tower. The cables are labeled with the connector identifier. The flip coil towers are roughly aligned with the beam line of an undulator by manual positioning of the towers but then fine adjustment is provided in the software.

The coil is strung from one theta axis to the other starting from the right tower. The right tower provides a means to connect the coil to a cable that then runs to the top Keithley DMM. A light set of twisted pair wires (with a weight) is provided at the master tower. A spool on the Theta axis accommodates several turns on the theta axis although only one is turn is needed. A set of gold pins are mounted in the spool to provide connection to the flip coil wires. The flip coil wires are soldered to these pins to reduce noise and resistance because the flip coil signal is small. The flip coil then runs back to the top Keithley, channel 2. The Keithley DMM can be used to measure the resistance of the flip coil indicating good or open connections.

Typically, 25 turns are used. The number of turns must be entered on the IGOR display for an accurate measurement. Beryllium copper wire, 40-41 AWG, is used for the flip coil's winding. The tensioning screw is provided on the master tower that is used to re-tension the coil as it will stretch.

Figure 2: Flip Coil Towers

REFERENCES

[1] Yu.Eidelman, B.Deriy,O.Makarov,I.Vasserman, APS Argonne, IL 60439, 2001 International Conference on Accelerator and Large Experimental Physics Control Systems.

[2] D. Beltran, F.Becheri, R.Butzbach, D. Fernandez-Carreiras, J.Klora, P.Readman, E,Taurel, 2005, ICALEPCS International Conference on Accelerator and Large Experimental Physics Control Systems.