NSLS-II MAGNETIC MEASUREMENT SYSTEM FACILITY*

M. Musardo#, T. Corwin, D. Harder, P. He, C. A. Kitegi,
W. Licciardi, G. Rakowsky, J. Rank, C. Rhein and T. Tanabe,
National Synchrotron Light Source II, Brookhaven National Laboratory, Upton, NY 11793, USA

Abstract

The National Synchrotron Light Source II at Brookhaven National Laboratory (BNL) is a storage ring of 3 GeV electron beam energy that will provide ultra high brightness and flux and exceptional beam stability using advanced insertion devices (IDs). The magnetic characterization of these devices is important to achieve these performances. In order to perform precise and accurate measurements of the NSLS-II IDs, several recent improvements on actual magnetic measurement system have been developed. The system includes a flipping coil bench to measure the first and second magnetic field integrals and a Hall probe bench to perform magnetic field measurements of different types of IDs.

The main features of the hardware system, control program and the recent improvements in the magnetic measurements system are presented.

INTRODUCTION

All insertion devices for NSLS-II have been bought from different vendors. It is planned to measure these devices at NSLS-II in order to confirm vendors. Our magnetic measurements are the final verification of the complex design and fabrication process, so that proper certification of device can be made. The magnetic measurement system facility at BNL consists in a Hall probe bench MMB-6500, built by Kugler, GmbH and an Integrated Field Measurement System (IFMS), provided by ADC [1].

HALL PROBE BENCH

The Hall probe mapping bench has an ultra-precision granite guide beam. There are nine conrolled axes. The air-ride Z axis has a travel distance of 6.5 meters. The trajectory deviation for the Z axis carriage is ± 7 µm and the positioning accuracy is ± 1 µm. The X and Y axes are high precision stages. Mounted to the Y stage carriage is a rotary stage. Mounted to the rotary stage is a small X-Y stage. Mounted to that is a pair of goniometers. Thus the extended Hall probe can be positioned in any orientation and then translated (see Fig. 1). The Z' axis is used as a follower stage for transporting the cables, so that cable loading does not affect the Z axis trajectory. Instrumentation is also carried on the follower stage (see Fig. 2).

The Z axis has two encoders. A linear scale encoder is used for the motion control and a laser interferometric encoder is used for generating triggers. A Delta Tau controller is used for motion control. A Senis 3D probe is used as the Hall sensor.

Each Hall sensor, arranged along X-axis, has been accurately calibrated to provide a calibration curve of its response to the strength of the magnetic field up 1.9 Tesla. The magnetic field sensitive volume for each sensor is 150x150x1 µm and the angular accuracy of axes with respect to the reference surface is about of ± 2°.

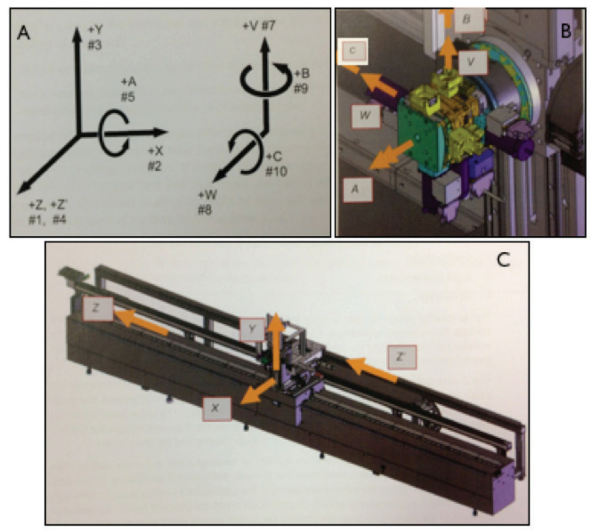

Figure 1: A: Machine coordinate system. Axis movements viewed from undulator towards granite. B: Arrangement of the goniometer head axes V, W, A, B and C. C: Arrangement of the three main linear axes X, Y, Z and auxiliary axis Z'.

In order to improve the accuracy and the repeatability of the Hall probe measurements, the electronics of the data acquisition have been upgraded. In particular a new time synchronization system has been developed in order to optimize the first integral repeatability and the precision of magnetic field measurements. Figure 3 shows the vertical field of a Damping Wiggler with period length of 100 mm at the minimum gap of 15 mm (blue line) and the field difference between two consecutive Hall scans (red line), which represents an absolute error of the magnetic field, measured with the initial triggering method. This error is a periodic and systematic curve with precise harmonic frequencies (see Fig. 4). The peak-to-peak amplitude is about of 30 G and occurs around the magnetic field gradient. It is a strong indication of a small jitter in the start trigger of the Hall probe measurements. This trigger jitter was reduced by changing from a motion controller generated trigger to a trigger generated by external Hardware, the parallel digital signal from the laser encoder is processed in external logic which feeds a trigger signal into an FPGA aboard a National Instruments CompactRIO real-time PAC. The

CompacRIO also houses the digital-to-analog convertor which is used for data acquisition. In this fashion trigger latency for data capture is reduced to less the 1 μs.

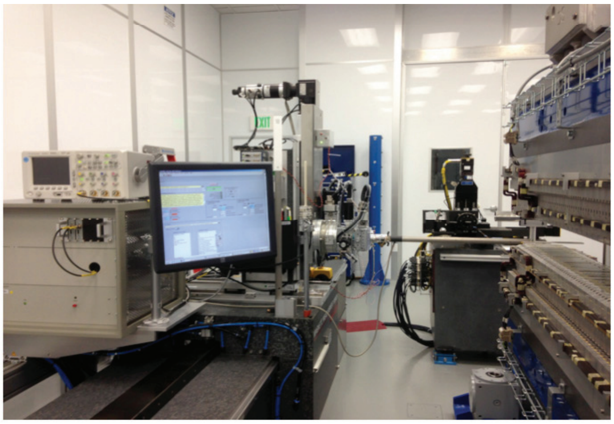

Figure 2: Hall probe measurement bench.

The magnetic measurements made with the new triggering system were carried out with a step of 1 mm and a scan speed of 24 mm/s.

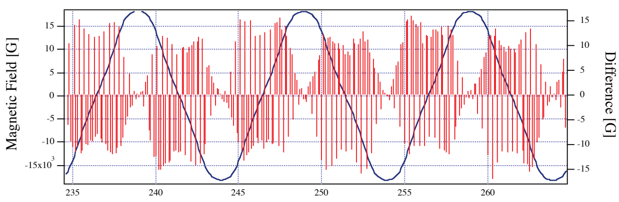

Figure 3: Magnetic field (blue line), difference of consecutive Hall measurements (red line).

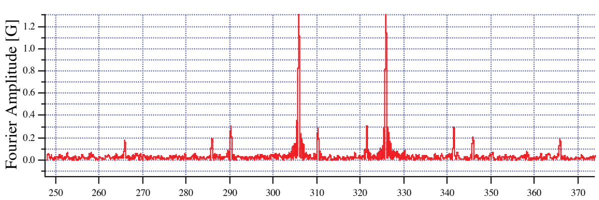

Figure 4: Spectral analysis of the difference.

Using this new system the error peak-to-peak is decreased to 5 G. (see Fig. 5), and also a improvement of the field integral repeatability was achieved.

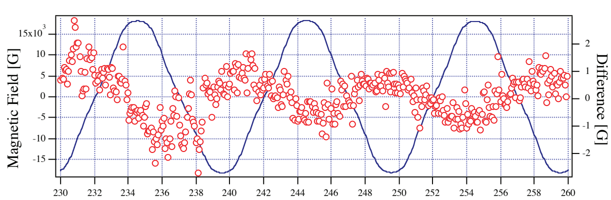

Figure 5: Magnetic field (blue line), the difference of consecutive Hall measurements (red dot).

The standard deviation for first field integral measurement of four consecutive scans is of 0.10 G m and for the second field integral is about 0.15 G m^2.

Figure 6 shows the horizontal electron trajectory of a Damping Wiggler obtained from four consecutive Hall probe measurements. The maximum absolute deviation is of few μm.

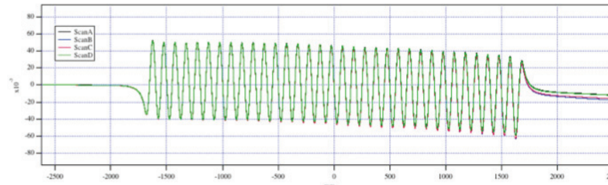

Figure 6: Horizontal electron trajectory of Damping Wiggler with period length of 100 mm at gap of 15 mm.

FLIPPING COIL BENCH

The flipping coil bench is typically used to characterise the integrated field of long insertion devices [2,3,4]. A long coil is stretched between the two ends of the device. The bench consists of two supports located at each end of an ID. The pedestals are made from granite with extremely flat ±10 μm tolerance on the top surface. Each pedestal has 3 leveling feet that also provide ±10 mm adjustment in the Z (longitudinal) and X (transverse) directions and 50 mm in the vertical direction. The six linear stages have Renishaw RELM linear encoder feedback with 0.1 μm resolution and ±1 μm accuracy. 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. Two rotary direct drive servos are used to achieve 1 revolution per second with an angular accuracy of 40 arc-sec and encoder resolution of about 0.005 deg. These eight servomotors are controlled by a Delta Tau GeoBrick PMAC-2. A Keithley DVM 2701 integrator is used for data acquisition with a custom switching card to select the measurement source. A Stretched 38 AWG beryllium copper wire is used to support the flip coil given to it mechanical rigidity and to reduce its sag. Coil rigidity is desired to attenuate its vibrations, swings and curvature.

Some recent upgrades have been carried out to improve the accuracy and the repeatability of the field integrals at high measurement speed. In particular a new control software has been developed to perform "on-the-flight" measurements of both horizontal and vertical field integrals. The "on-the-fly" measurements are faster than the traditional "step-by-step" measurement, shortening significantly the measurement time of an ID. The measurement of the two field integral components in a range of 60 mm, with a measurement step of 1 mm and a scan speed of 55 mm/s is of 90 seconds against the 91 minutes using the old method "step-by-step".

Lot of measurements with different integration time and velocity were carried out in order to optimize the accuracy and the reproducibility of the field integral measurement. A maximum velocity of 55 mm/s and an integration time of 16.67 msec provide the best compromise between higher sensitivity (large step) and better spatial resolution (small step). These settings also ensure a good signal/noise ratio and a good repeatability.

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The integration time affects the amount of reading noise, as well as the reading rate of the instrument. So a digital filter has been used to stabilize noisy measurements. The digital filter places a specified number of A/D conversions into a memory stack. These A/D conversions occur consecutively within a selected reading window. The readings in the stack are then averaged to yield a single filtered reading. The stack has be filled using the "repeating average filters". To further reduce the high frequency electrical noise, created primarily from the several motors of the system, a capacitor of 1µF has been used (see Fig. 7, left).

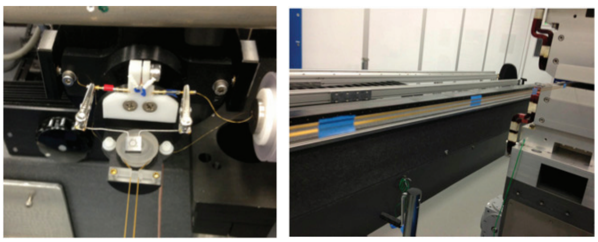

Figure 7: (Left) Electrical noise reduced by fitting a capacitor of 1 µF. (Right) Adhesive tape.

The function of the capacitor is to dampen random electrical noise, which causes small voltage fluctuation. In addition the capacitor helps to filter and remove the alternating currents caused by ripple voltage.

The disadvantage of an "on-the-fly" measurement is the vibration induced by the acceleration/deceleration at beginning and end of each movement. Electromechanical resonance was detected in the motors during the coil acceleration, causing small coil vibrations. To reduce this undesired effect, some pieces of adhesive tape were applied on the coil (see Fig. 7, right), it's a very simple and cheap solution, but efficient.

Figure 8 shows the horizontal (red line) and the vertical (blue line) field integrals as function of the transverse position. The standard deviation of five measurements is 7 G cm for the vertical field integral and of 3 G cm for the horizontal component. The repeatability of the measurement using just the coil rotation mode (Fig. 9) is 3.5 G cm for the vertical field integral and 2.5 G cm for the horizontal component.

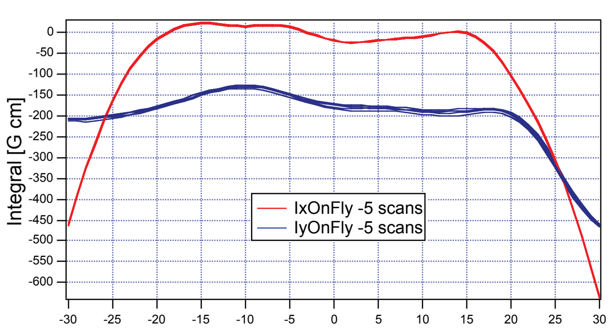

Figure 8: Horizontal field integral (red line), vertical field integral (blue line).

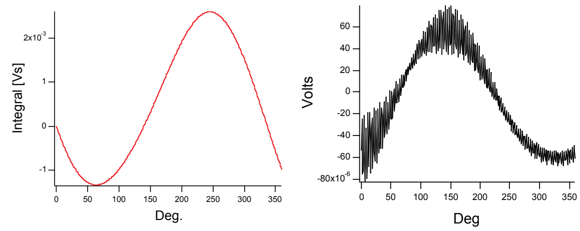

Figure 9: Voltage integrated (red line). Voltage readings (black line).

CONCLUSION

Replacing actual power supplies of the converter with DC batteries is an additional improvement of the Hall probe bench. The accuracy shall be increased as the use of DC batteries will eliminate time varying interference coupled into the converter via the power lines.

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