

MONDAY 19th

Status of the magnet and of the undulator activities for the X ray Free Electron Laser SwissFEL at the Paul Scherrer Institute

S. Sanfilippo, Paul Scherrer Institut, Villigen, Switzerland

An overview of the magnet measurement activities at the Paul Scherrer institute is presented. The talk will mainly focus on the magnets needed for the X-ray free electron laser (SwissFEL), the next large scale facility in preparation at the Paul Scherrer Institute. Based on a normal-conducting 5.8 GeV linear accelerator, the SwissFEL will cover a spectral range of 0.1-10 nm wavelength. An amount of typically 300 magnets of 4 different types (solenoids, quadrupoles, dipoles and correctors) is required. In order to preserve the high brightness and the low emittance of the femto-second electron pulses, these magnets have to fulfill severe tolerances in the field quality and in the magnet positioning. An overview of the status of the magnetic elements will be presented. The magnetic measurements strategy, the development of magnetic measurements systems and a summary of the main test results will be reviewed.

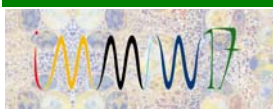
Measurement Devices for Magnetic Fields of Superconducting Undulator Coils at ANKA

A. Grau, T. Baumbach, S. Casalbuoni, S. Gerstl, M. Hagelstein, T. Holubek, D. Saez de Jauregui, ANKA, Karlsruhe Institute of Technology, Karlsruhe, Germany

At ANKA there is an ongoing R&D program to develop superconducting insertion devices (IDs). The performance of superconducting IDs depends strongly on their magnetic field quality and it is therefore of fundamental importance to characterize their magnetic field properties accurately before installation in synchrotron light sources.

At ANKA a vertical helium bath cryostat to characterize the magnetic field of undulator mockup coils up to a length of 35cm was built and is in operation. A new horizontal measuring system for superconducting undulator coils up to 2 m was delivered in July 2011 and is currently under commissioning. It will allow field mapping with Hall probes and field integral measurements in a 4.2K cryogen-free environment.

In this contribution we present the main characteristics of the measurement systems, the status, as well as some results.



Overall of the magnet measurement system at NSRRC

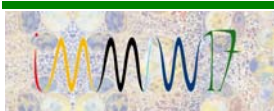
C. S. Hwang, J. C. Jan, F. Y. Lin, C. K. Yang, C. H. Chang, NSRRC, 101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30076, Taiwan

Several magnet measurement systems were developed at NSRRC to characterize the lattice magnets and the insertion devices of the TPS project. For the lattice magnets, a high-precision harmonic magnetic-field measurement system [1] by using a fixed-angle Hall probes method was developed. This system is not only used to measure and analyze the bending magnet but also for the quadrupole and sextupole magnets. The precision is within 0.01% for the multipole components. In addition, a high precision rotating-coil system [2] and a stretch wire system [3] or flip-coil system [4] were used to measure and analyze the multipole magnets, i.e. quadrupole and sextupole magnets. The measurement precision of the multipole component and the positioning of the rotating-coil system are better than 0.01% and 5 μm , respectively. The mechanical offset in horizontal and vertical axis of the rotating-coil system is 30 μm and 10 μm , respectively. However, the horizontal offset can be compensated to be within few μm . The fixed-angle Hall probes system should be associated with a precise three-orthogonal axes x-y-z table and various algorithms mapping trajectory to suit for different kinds of magnets. The PSD method with precision of 2 μm was fixed and used to align the center and level between magnet and the measurement system.

For the insertion device magnets, a three-orthogonal axes Hall probe [4] is developed to characterize the electron trajectory and spectrum performance of the insertion devices, especially for the elliptically polarized undulator and the adjustable phase undulator (APU). However, the magnetic field strength, the accurate position and the planar-Hall effect of the three-orthogonal Hall probes should be calibrated and adjusted carefully. In addition, the stretch-wire systems were used to measure the magnetic field distribution of the first and second field integral. For the magnet block sorting, there is a highly automatic measurement system for three-orthogonal magnetic moment of the permanent magnet block measurement [6]. Meanwhile, a pulse-wire system [7] is being developed for the measurement of the point field, first and second field integral of the mini-pole undulator. The main error source of pulse-wire system is the rigidity of the Be-Cu wire that will distort the magnetic field wave front. Therefore, a Fourier Transform algorithm can be used to compensate the distortion wave front to obtain the real magnetic field distribution. The pulse-wire system can also be used for the magnet center calibration of the quadrupole and sextupole magnet. Recently, we develop the in-situ field measurement system for the cryogenic in-vacuum undulator. This presentation will report the current status and the technical issue of the various measurement systems.

References

- [1] C. S. Hwang, F. Y. Lin, G. J. Jan, and P. K. Tseng, *Rev. Sci. Instrum.*, **65**(8), 1994, 2548-2555.
- [2] J. C. Jan, C. H. Chang, C. S. Hwang, and F.Y. Lin, "*Precise Rotating Coil System for Characterizing the TPS Magnets*", Particle Accelerator Conference (PAC09), Vancouver, Canada, p. 199 (2009).
- [3] C. S. Hwang, C.H. Hong, F.Y. Lin and S.L. Yang, "Stretch-wire system for the integral magnetic field measurement", *Nucl. Instrum. Meth. A* 467 (2001) 194-197.
- [4] C.S. Hwang, F.Y. Lin, T. C. Fan, 2003, "Integral magnetic field measurement using an automatic fast long-loop-flip coil system", *IEEE Trans. on Instrum. and Meas.*, Vol. 52, NO. 3, (2003) 865-870.
- [5] C. S. Hwang, T.C. Fan, F.Y. Lin, Shuting Yeh, C.H. Chang, H.H. Chen, P. K. Tseng, *J. Synchrotron Rad.* 5, 1998, 471-474.
- [6] C. S. Hwang, Shuting Yeh, P. K. Tseng, and T. M. Uen, *Rev. Sci. Instrum.* 67(4), 1996 1741-1747.
- [7] T. C. Fan, C. S. Hwang, C. H. Chang, Ian C. Hsu, "A systematic study on pulse wire system for magnetic field measurement on long undulator with high field", *Rev. Sci. Instrum.*, 73, 1430 (2002).



Measurement challenges for the magnet projects at CERN

S. Russenschuck, L. Walckiers, et al., CERN

We present the measurement needs for the upcoming projects at CERN. These include field measurements in magnets for HIE-Isolde, LINAC4, CLIC, MedAustron, as well as superconducting magnets for LHC upgrade and consolidation. Moreover, on-line field measurements for accelerator controls are important recurrent activities. The measurement activities and technologies are influenced by fast-ramp cycles, small and large apertures compared to the LHC magnet apertures, three-dimensional and dynamic effects, and small radius of curvature.

Overview of Magnetic Measurements at SLAC National Accelerator Lab (SLAC)

Scott D. Anderson, Yuri Levashov, Zachary Wolf, SLAC National Accelerator Lab (SLAC), Menlo Park, CA, USA

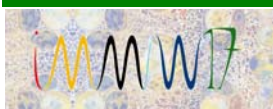
The Magnetic Measurements Group at SLAC measures all beamline, insertion, klystron and experimental magnets for use at SLAC. The techniques and instruments used for measuring the above devices will be discussed. These techniques include stretched wire, rotating coil, vibrating wire and hall probe measurements.

Production Measurements of Magnets for the NSLS-II Storage Ring*

Animesh Jain, Brookhaven National Laboratory, Upton, New York 11973-5000.

The National Synchrotron Light Source-II (NSLS-II) is a new light source under construction at Brookhaven National Laboratory (BNL). In order to deliver the design performance of this machine, the field quality of all magnets in the storage ring must meet very demanding specifications. Multipole magnets (quadrupoles and sextupoles), dipole correctors and the main bending dipoles, representing a total of 15 different magnet types, are currently being produced by various manufacturers distributed worldwide. All magnet vendors are responsible for the field quality in their magnets, and carry out magnetic measurements to ensure compliance with the requirements. So far, nearly all magnets received are also undergoing magnetic testing at Brookhaven National Laboratory (BNL) as part of validation of manufacturers' data quality. A significant effort has also been made at BNL to study reproducibility of field quality in all the early magnets to ensure that the demanding field quality will be preserved when the magnets are split and reassembled to install the vacuum chamber. Modifications to magnet designs and construction methods were proposed, wherever necessary, based on these studies. The measurement results obtained so far will be described, along with a comparison of measurement data taken at BNL and by magnet manufacturers.

* Work supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH1-886



Insertion device magnetic measurement facility at the NSLS-II

Toshi Tanabe and the member of NSLS-II insertion device group. Photon Science Directorate, Brookhaven National Laboratory, Upton, NY 11973, U.S.A.

National Synchrotron Light Source-II (NSLS-II) project at Brookhaven National Laboratory is currently in the construction stage. A new insertion device (ID) magnetic measurement facility (MMF) is being set up in order to satisfy the stringent requirement on the magnetic field measurement of IDs. ISO-Class7 temperature stabilized clean room is being constructed for this purpose. A state-of-the-art Hall probe bench and integrated field measurement system will be installed therein.

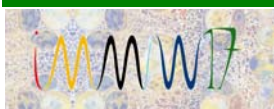
IDs in the project baseline scope include six damping wigglers, two elliptically polarizing undulators (EPUs), three 3.0m long in-vacuum undulators (IVUs) and one 1.5m long IVU. Three-pole wigglers with peak field over 1 Tesla will be utilized to accommodate the users of bending magnet radiation at the NSLS. Besides those project beam lines, the nine additional ID beam lines are being designed with various funding sources.

Future IMMF activities include: 1) an in-vacuum magnetic measurement system for PrFeB cryo-undulators, 2) development of a closed loop He gas refrigerator for improved vertical test facility (VTF), 3) development of a horizontal superconducting undulator measurement bench

Overview of Magnetic Measurement Activities at Shanghai Synchrotron Radiation Facility

Hongfei Wang, Jidong Zhang, Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800

Shanghai Light Source (SSRF) is a third generation synchrotron radiation facility with the intermediate energy of 3.5 GeV. Two wigglers W80 and W140, one elliptically polarizing undulator EPU100 of the APPLE-II type with 4.3 meters long and two in-vacuum undulators IVU25-1,2 with 2 meters long have been built in the phase-I of SSRF project. In order to characterize the undulators, we have built several sets of magnetic field measurement systems in our laboratory whose temperature stability is 0.1 degree. One is the flipping coil magnetic field integral measurement system for the measurement of both first and second magnetic field integral distributions and integrated multipole errors in Undulators. One is Hall probe system used to measure mapping of magnetic field. Another is Helmholtz coil system used to characterize magnetic blocks. In addition, we have built a rotating coil and a translation coil system to measure the magnetic field of conventional magnets used to SSRF. A lot of experimental results prove that these magnetic field measurement systems are efficient enough to carry out the accurate magnetic field measurements. In future, we will develop some new systems to measure the magnets used to free electron laser. In this paper, we will report the details of the development of these magnetic field measurement systems.



Overview of Recent Fermilab Magnetic Measurements Activities

Joe Di Marco, **Fermi National Laboratory**, Upton, New York 11973-5000

As the Tevatron shuts down, there are several other projects at Fermilab that represent the lab future. The current magnetic measurement activities for these are highlighted.

JLAB 12GeV Upgrade Measurement Overview

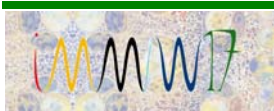
Kenneth Baggett, **Jefferson National Lab**, Newport News, VA, USA

Jefferson Lab is currently working to double the power of its nuclear accelerator from 6GeV to 12GeV. This requires the existing accelerator dipoles to be removed from the tunnel, refurbished, additional steel added, and re-mapped. Setting up the final 6GeV experiment would allow for approximately 3 months to begin the upgrade. A plan was developed to map the seven arc dipole strings totaling 176 two and three meter dipole magnets. Specifications for matching along an arc were established at 0.03%. Processes and measurement techniques used to complete the refurbishment project and meet the matching specification requirement will be discussed. Results will be presented.

Design, manufacturing and measurement of the magnets for MedAustron

Thomas Zickler, **CERN**, Geneva, Switzerland.

MedAustron, a future center for ion-therapy and research in Austria, will comprise an accelerator facility based on a synchrotron for the delivery of protons and light ions for cancer treatment and for clinical and non-clinical research. The facility requires a large number of electro-magnets, more than 300 in total, to be designed at CERN and produced in industry. To validate the electro-magnetic design and to verify their performance, in particular the field quality and the dynamic behavior, all magnets have to be carefully measured. In this presentation, we will highlight the challenges in the design, the manufacturing and the magnetic measurements.



TUESDAY 20th

A Rotating Coil Array in “Mono-Bloc” Printed Circuit Technology for Small Scale Harmonic Measurements at CERN.

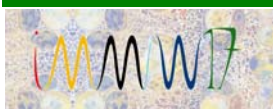
Olaf Dunkel, Rui de Oliveira, Lucette Gaborit, Ricardo Beltron-Mercadillo, CERN, Geneva (Switzerland).

New accelerator projects, such as CLIC, the Compact Linear Collider, require harmonic measurements of small magnets with apertures of 10 mm and less. For these applications the mechanical precision of traditional winding techniques for rotating coil arrays is not sufficient to achieve a measurement accuracy of the order of 10^{-4} . As rotating or fixed racetrack coils remain the most reliable devices for accurate harmonics measurements, other techniques must be applied to manufacture such small diameter coils with the required precision. In this frame, CERN develops a harmonic coil array with three rotating coils based on a mono-bloc printed circuit technology for the measurements of the CLIC final-focus quadrupole hybrids with an aperture of 8 mm. The presentation covers the design and manufacturing particularities and first results achieved with this device. A tentative comparison with well known winding techniques and other measurement methods might open the discussion for future applications of this technique..

The new Fast Digital Integrator with increased throughput and upgraded self-calibration

P. Arpaia, B. Celano, M. Buzio, P. Cimmino, L. Fiscarelli, C. Giaccio, L. Walckiers, CERN, Geneva (Switzerland).

In recent years, the cooperation between CERN and University of Sannio led to the development of a flexible platform for data acquisition and analysis, integrating new specific hardware and software, as well as including new test and real-time analysis facilities. This platform has been consolidated by adding further features to its main hardware component, the Fast Digital Integrator (FDI). Metrolab, a Swiss company leader in magnetic measurements for particle accelerators, acquired the license for marketing FDI. At CERN, critical new applications were deployed quickly and effectively through the FDI. Magnetic measurements campaigns aimed at (i) validating the model underlying FiDel highlighted the need for improving the harmonic compensation of the third-harmonic (b3) component of the main LHC dipoles, and (ii) characterizing permanent and fast-pulsed iron-dominated magnets to be used on the Linac 4 series tests and to analyse the field of the entire acceleration line will contribute to the beam brightness. These successful applications, together with emerging new applications in cable testing, highlighted the need for enhanced performance in FDI. In particular, high-field and fast-cycling magnet tests pointed out the need for increasing further the throughput, by adding direct memory access features, as well as by increasing the on-board acquisition RAM. High-bandwidth challenging tracking tests requested on-line data validation by automatic error detection and simplified self-calibration procedure. In the talk, the requirements, the concept design, and the specific solutions for enhancing the performance of the new instrument are highlighted.



In situ calibration of rotating shafts; accuracy obtained for the 15-m-long shaft for LHC and the 18 mm aperture shaft for Linac4

P. Arpaia, L. Fiscarelli, C. Petrone, L. Walckiers, O. Dunkel, G. Gollucio, CERN, Geneva (Switzerland).

In magnet testing, coil based measurement systems are widely exploited. The calibration of coil sensors is an important step for the minimization of measurement errors. Usually specific benches are built and maintained on purpose. Currently at CERN, new techniques for "in situ calibration" of rotating shaft, carried out directly on the magnet under test without using specific reference benches, are under development. The presentation shows the results obtained by means of new calibration procedures for two case studies: LHC-dipole 15-m-long shaft and small-aperture shaft for Linac4 magnets.

An Encapsulated Rotating-coil Test System at Fermilab

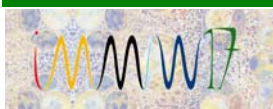
Joe Di Marco, Fermi National Laboratory, Upton, New York 11973-5000

A portable "mole-type" rotating coil has been built and tested at Fermilab. The probe includes an encoder and gravity sensor, and capability to accommodate rotating coils of various radii. The design is intended to be simple, and features an external rotating-coil drive via non-magnetic flexible shaft.

Towards the Next Generation Magnetic Measurement System

Jerzy M. Nogiec, Fermi National Accelerator Laboratory, Batavia, IL 60134, USA

With Fermilab's conventional magnet measurement system approaching the end of its lifecycle, there arose a need to develop its replacement, a next generation measurement system. The new system will allow for leveraging the relative strengths of languages and platforms to create a comprehensive solution to measure and analyze accelerator components and manage test-related data. The emphasis is on the completeness of the solution capturing the full lifecycle of the measurement, starting from entering test subject information through configuring a required measurement, conducting the measurement, saving the results and raw data, and, finally, reviewing and analyzing these results. The system will also allow for associating and storing any documents pertaining to the test, such as test plans, screen snapshots, comments, analysis reports, etc. The system will be extensible, allowing for new measurements or analyses to be added, as well as new DAQ instruments and subsystems. The automation of measurements will be accomplished by scripting that will provide the necessary flexibility in changing measurement sequences.



Design of a new measurement system for closed insertion devices and magnets

J. Campmany, J. Marcos, V. Massana, C. Colldelram, L. Ribó, F. Becheri, J. V. Gigante and D. Einfeld, Insertion Devices and magnetic measurements section, ALBA-CELLS, Barcelona, Catalonia (Spain).

Fieldmap measurements of magnetic structures are one of the best and complete characterization data that can be provided for accelerator models. From fieldmap data, it is possible to compute electron beam characteristics with a high degree of precision. However, measurement of big “closed” magnetic systems, as H bending magnets, in-vacuum undulators, cryoundulators or superconducting insertion devices is still a challenge. Integrated field measurements with coils have been used to some extent, but they cannot characterize internal and local variations of field. Some Hall probes assembled in the tip of long arms have sometimes been used too, but the accuracy of positioning is poor. Some methods have been used at SLS and SOLEIL, based on pulsed wire, and special measurement systems with dedicated vacuum chambers have been built at Spring8 and ESRF. Here we present a design of a small holder containing 3 Hall probes that slides on strong carbon fibers attached to pedestals. Longitudinal position is measured with a laser interferometer, and row and pitch angles are controlled also using laser positioner. According calculations, spatial accuracy of this device can reach ± 30 μm and ± 50 μm . A prototype is currently being constructed at ALBA-CELLS. Main features and the first detailed designs will be discussed.

Rotating Printed-Circuit-Board Probe Measurements

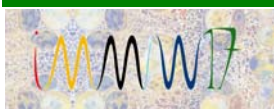
Joe Di Marco, Fermi National Laboratory, Upton, New York 11973-5000

Features and performance of pcb-based probes that have been fabricated and tested in the past couple of years at Fermilab are presented.

Magnetic measurement instrument with Printed Circuit Board coils for the MedAustron synchrotron main bending magnets

A. Beaumont, M. Buzio, O. Dunkel, R. De Oliveira, M. Stockner, T. Zickler, CERN, Geneva, Switzerland.

MedAustron, a future center for ion-therapy and research in Austria, will comprise an accelerator facility based on a synchrotron for the delivery of protons and light ions for cancer treatment and for clinical and non-clinical research. In the synchrotron, sixteen curved, H-type bending magnets will be used, which are presently under construction. These magnets will be systematically measured at CERN using an array of coils that follow the curvature of the magnet yokes (fluxmeter). Printed Circuit Board (PCB) coils mounted on a light-weight sandwich structure support will be used instead of classical coils wound from wire. This presentation describes the measurement principle, explains the motivation for using PCB coils combined with a sandwich structure, and presents the manufacturing status.



Use of ferrimagnetic resonance probes for field markers in pulsed and non-homogeneous fields

P. Arpaia, M. Buzio, F. Caspers, D. Giloteaux, G. Golluccio, D. Oberson, L. Walckiers, CERN, Geneva, Switzerland.

At CERN we are currently looking for a new field marker for the combined-function magnets for the Proton Synchrotron, able to generate a trigger pulse whenever the dipole component crosses a predefined threshold. The most promising option is a Ferri-Magnetic Resonance (FMR) resonator, based on a commercial RF filter, working in the GHz range. In this talk we review the specifications of the project, discuss the characterization of the sensors tested so far, and illustrate how the machine operation could benefit from this new kind of device.

Plans for Measurement of Field Straightness in the Solenoids for the Electron Lens System for RHIC*

Animesh Jain, Brookhaven National Laboratory, Upton, New York 11973-5000.

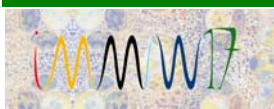
As a part of the proposed electron lens system for the Relativistic Heavy Ion Collider (RHIC), two 6 T, 200 mm aperture, 2.5 meter long superconducting solenoids are being designed and built at Brookhaven National Laboratory. For efficient operation, the electron beam must be aligned to the proton beam within 50 microns. This places a similar requirement on the straightness of field lines in the solenoids. Since such a degree of straightness is not achievable by manufacturing tolerances alone, a set of five short dipole correctors per axis is included as an integral part of the magnet system. However, precise measurements of the field straightness are necessary in order to determine the settings of these correctors. Traditionally, such measurements are made using a magnetic needle and a mirror system. It is planned to measure the field straightness in the RHIC electron lens solenoid also using this technique. A new measurement system is being developed to carry out these measurements. In addition, we intend to also develop the vibrating wire technique to carry out field straightness measurements in a solenoid as a simpler and perhaps more reliable alternative to the magnetic needle. The measurement system under development will have provision to do measurements using either of the two methods. The measurement system will be described, along with potential difficulties in using the vibrating wire technique for such measurements.

* Work supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH1-886

Measuring eddy current contributions in normal conducting magnets

M. Buzio, R. Chritin, D. Giloteaux, G. Golluccio, CERN, Geneva (Switzerland)

In recent years there have been demands at CERN to measure precisely the extent and duration of eddy current effects in many different types of magnets. We review first the measurement method that is based on the fast acquisition of the transient behavior of magnet current and field. Then we summarize the results obtained on magnets of widely different geometry and characteristics. Finally, we attempt to derive a simple predictive scaling law based on a simplified model and the available data.



WEDNESDAY 21st

Comparison of Arepoc and Sentron Hall Sensors using Undulator A at the APS magnetic measurement facility*

Isaac Vasserman, Melike Abliz, Joseph Xu, APS, Argonne National Laboratory, Illinois, USA

The calibration of Hall sensors from Arepoc s.r.o. (self-regulatory organization) indicates that their sensitivity is strongly dependent on temperatures above 250 deg K. The sensor's temperature, on the other hand, is a function of the magnetic field, because the sensor's resistance depends on the strength of the magnetic field. Therefore calibration results can be directly applied only if the calibration and operation environments are identical. But during ID magnetic measurements a Hall sensor is exposed to rapidly changing strengths of the magnetic field, while calibration process utilizes static fields and therefore stable temperatures. Some Hall sensors, such as a Sentron probe, are integrated with a circuit that compensates for the variation of the Hall voltage signal from the temperature variation. Therefore, the Sentron probe could be used as a temperature-independent standard for non-compensated probes.

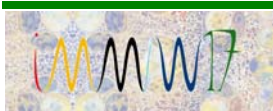
Magnetic measurements of the APS Undulator A with Arepoc and Sentron probes have been performed and results have been compared. The errors associated with the temperature variation of the Arepoc sensor during these measurements have been evaluated.

* Work supported by U.S. Department of Energy Office of Science, Office of Basic Energy Sciences, under contract No. DE-AC02-06CH11357.

Influence of an ambient field on an undulator with iron support structure

U. Englisch, A. Liebram, J. Pflueger, European XFEL GmbH, Germany

In order to investigate the influence of an ambient field onto a magnetic structure external helmholtz coils were installed in our laboratory: one creates a vertical and one a horizontal field component. Via the application of a current we can simulate an ambient field in the range of -175 uT up to 125 uT for the vertical and -68 uT up to 51 uT for the horizontal component. By applying the strongest produced ambient fields the magnetic field of an undulator was measured for different gaps. In case of the vertical field we see a low amplification of the ambient field inside the magnetic structure whereas the horizontal ambient field component disappear for low gap. It rises up to the applied value if the gap will be opened. The amplification of the vertical ambient field show nearly no gap dependency. These effects can be explained with the iron support structure of the undulator. Furthermore we did not observe any magnetic hysteresis effect of the external fields.



Comparative study between mechanic and magnetic measurements of gap dependent hysteresis

A. Liebram, U. Englisch, J. Pflüger; European XFEL GmbH, Germany

The gap dependence of the magnetic field of the first U48 prototype for the XFEL was measured with high precision.

The built in encoder system was compared with an external mounted encoder system as a reference and has shown to be accurate to some microns, showing a mechanical hysteresis between open and close movement.

The gap dependence of the magnetic field showed a clear hysteresis-like behavior which depends on the previous history of the gap.

Thus for the precise adjustment of the field of a planar undulator the measured gap value is not sufficient. In addition the details of the path and history have to be taken into account.

Characterization of ALBA out-vacuum undulators and wiggler using Hall probe system. Some remarks.

J. Marcos, J. Campmany, V. Massana, Insertion Devices and magnetic measurements section, ALBA-CELLS, Barcelona, Catalonia (Spain).

Between August 2009 and February 2010 the three out-of-vacuum Insertion Devices (IDs) included in Phase I of ALBA were characterized at the Magnetic Measurements Laboratory of ALBA-CELLS as a part of the Site Acceptance Tests (SAT) campaign.

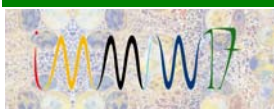
The analyzed devices were two elliptical APPLE II-type undulators (EU61 and EU71 devices) manufactured by ELETTRA (Italy) and a hybrid technology multipole wiggler (MPW80 device) manufactured by ADC (USA).

Performed tests included extensive measurements using a Hall probe bench equipped with a 3-axis probe and flipping coil measurements.

Obtained results were used to determine the magnetic axis and to analyze the features of all three components of the magnetic field for different mechanical settings (gap, phase and/or taper) of the devices.

The mapping of the magnetic field also made it possible to check the accuracy of the magnetic assembly for each device.

The most remarkable results obtained throughout this set of tests will be presented.



Measurements of permanent magnet blocks for undulators and modellization of their homogeneities

V. Massana, J. Marcos, J. Campmany, Insertion Devices and magnetic measurements section, ALBA-CELLS, Barcelona, Catalonia (Spain).

At the Insertion Devices Laboratory at Alba, we have built and commissioned a fixed stretched wire bench (FSW) to measure magnetic elements; in our case, magnet blocks mounted on holders (modules). We have evaluated the accuracy and repeatability of this bench and have developed a methodology of measurement capable to compensate main positioning errors, leading to a highly repetitive performance.

In order to check the performance of the bench we assembled a short undulator array. The assembly of the blocks was previously simulated using the field integrals measured with the stretched wire. Principle of superposition is not fulfilled for individual integrals in some stages of the assembly because susceptibility is different from one, thus the modelling of the blocks is useful to simulate all the steps of array building.

A model of the blocks, taking into account magnetic inhomogeneities has been developed to simulate the magnetic characteristics of each module. The process of assembly was experimentally controlled by measuring with a flipping coil bench each step, and we related these measurements to the simulated model.

High level of agreement (within few G-cm) between calculated and measured magnetic structure is observed.

Magnetic measurement at Sigmaphi

Marie Julie Leray, Sigma-Phi

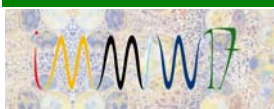
Sigmaphidesigns, makes and measures magnetic systems and beam transport lines for particle accelerators. After years of development and fruitful collaborations with some major labs, Sigmaphioffers a complete range of solutions for measuring any magnetic systems: hall probe, rotating coil, search coil. This contribution proposes:

- recent developments at Sigmaphi
- a brief overview of magnetic measurement activities at Sigmaphi
- recent measurements and comparison with TOSCA
- measurement setup in progress (Medaustronproject)

Magnetic measurements and Faraday's law; have we understood the paradoxes?

S. Russenschuck, S. Kurz, B. Auchmann, CERN, Geneva (Switzerland).

Have we really understood Faraday's law, which is so fundamental in magnetic measurements? Thinking for a while about the Hering "paradox" may cast this in doubt. The problem arises from the usual (engineering) textbook structure of presenting transformer electromotive force (EMF) and motion induced EMF as two independent phenomena. We will try to present the role of the Lie derivative and the Galilean transformation to arrive at network equations to calculate the terminal voltage of devices such as the railgun, the homopolar generator, the stretch wire measurement system, and the Hering experiment.



THURSDAY 22nd

Stretched wire measurements of multipole magnets at the ESRF

Gaël Le Bec, *ESRF, Grenoble (France)*.

New quadrupole and sextupole magnets have been built in the context of the ESRF upgrade. A stretched wire (SW) measurement bench was developed for the characterization of these magnets.

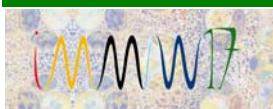
Theoretical aspects of SW measurements were investigated. A least square approach has been developed for processing the measured signals. This approach can be used for any SW trajectory: it allows correcting numerically the position errors of the SW. Moreover, SW trajectories which are not sensitive to one field multipole were designed: it can be seen as a SW equivalent of the “bucked” rotating coils. The sensitivity of this approach to the SW position errors and to the voltmeter errors has been studied.

The SW bench and the processing method have been tested with various magnets and the results obtained from different SW trajectories were compared. It has been demonstrated that an accuracy of a few 10^{-4} of the main multipole can be obtained.

Experiences with the single stretched vibrating wire test stand at PSI

C.Wouters, V. Vrankovic, S.Sidorov, R.Deckardt, P. Chevtsov, M.Calvi, S.Sanfilippo, **Paul Scherrer Institut, Villigen, Switzerland**

The measurements of the PSI SwissFEL quadrupole magnets are planned to include a single stretched vibrating wire method for determining the location of the magnetic axis. A test stand has been set up to investigate all the aspects and influences of the environment and our equipment that can affect the accuracy of such measurements. We have acquired a PLL equipped digital lock-in amplifier with 2 independent units from Zurich Instrument and a precise measurement arm from FARO. Additionally we have designed a new vibration detection system and tested it against the classical laser to photo diode combination. The new detector which is based on the electromagnetic induction is a set of two orthogonal pairs of coils positioned closely around the wire. Here we present the results from the test stand and plans for the automatized measurement necessary for measuring hundreds of quadrupole magnets in 2012.



Measuring axis and multipoles of small aperture quadrupoles with vibrating wires

Pasquale Arpaia, Marco Buzio, Juan Jose Garcia Perez, Carlo Petrone, Louis Walckiers, CERN, Geneva, Switzerland.

A new multipole measurement method based on vibrating wire is presented. The magnet multipoles are assessed by positioning the wire in different points on a circle inside the magnet aperture and measuring the amplitude of wire vibrations. Then, an analytical model relates vibration amplitudes to multipoles. Results aimed at analyzing the model performance are reported. Also experimental results of tests carried out at European Center for Nuclear Research (CERN) on small permanent magnets for the new linear accelerator show the effectiveness of the proposed technique.

A study of undulator magnets characterization using the vibrating wire technique

*A. Temnykh,^{a)} Y. Levashov,^{b)} Z. Wolf,^{b)} (a) **Cornell University, Laboratory for Elem-Particle Physics, Ithaca, NY 14850, USA**, (b) **SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA***

The vibrating wire technique employs a stretched wire as a magnetic field sensor. Because of a small diameter of the wire and that the wire can be supported at distances less than 1 meter away from the ends of the magnet, this technique is very appealing for measurements of magnetic field in small gap/bore undulators and with limited access to tested field. Also, it could be an independent method to verify and supplement Hall probe measurements.

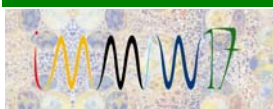
An LCLS undulator was used as a test bench to study the potential of the vibrating wire technique for measurements of magnetic field errors and prediction of beam trajectories. A calibrated magnetic field distortion was introduced at various locations. Sensitivity and spatial resolution of the method were tested. The field errors found with vibrating wire technique agreed with Hall probe measurements.

Precision Alignment of Multipoles on a Girder for NSLS-II*

*Animesh Jain, **Brookhaven National Laboratory, Upton, New York 11973-5000.***

The National Synchrotron Light Source-II (NSLS-II) is a new light source under construction at Brookhaven National Laboratory (BNL). Up to seven quadrupoles and sextupoles in the NSLS-II storage ring will be mounted on a common girder (~5m long). These magnets must be aligned precisely to each other. The vibrating wire technique, first developed at Cornell, is being used to align the multipoles with a targeted precision of ± 10 microns, well within the required tolerance of ± 30 microns for the finally installed girder in the ring. Extensive R&D was carried out earlier to study sources of measurement errors and to improve accuracy. A fully automated system is now in use for production measurements and three fully assembled girders have been measured and aligned so far. The procedures used for alignment, and the problems encountered will be discussed along with the results.

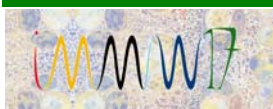
* Work supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH1-886



Measurements of small aperture quadrupoles for the Linac4 and CLIC projects

C. Petrone, J. Garcia Perez, L. Walckiers, **CERN**, Geneva (Switzerland).

Measurements of small aperture quadrupoles for Linac4 and CLIC CERN projects are a challenge. Using the Single Stretched Vibrating Wire to measure the harmonics as well as magnetic axis is a possibility that we have explored with success. Results of several measurements of these magnets and comparison with alternative methods results when available will be shown. In particular measurements of series permanent quadrupole magnets with 50 and 20 mm aperture for the Linac4 and the 8 mm aperture CLIC prototype will be detailed.



FRIDAY 22nd

Fast Digital Integrator Upgrade

*Jacques Tinembart, **Metrolab** (Switzerland).*

As announced at the last workshop, Metrolab have licensed the Fast Digital Integrator from CERN. In the meantime, we, the CERN and our customers have discovered a number of issues and limitations of this instrument. While the CERN are working on a completely new design, Metrolab have focused on ways to fix existing instruments. We will review the issues and the proposed improvements.

Three-axis Hall Magnetometer Evolution

*Philip Keller, **Metrolab** (Switzerland).*

Metrolab have presented their ultra-compact, USB-based Three-Axis Hall Magnetometer at preceding workshops. We will present the latest developments for this instrument: new sensors, upgraded firmware, upgraded software, improved calibration, and proposed new electronics.

Hall Teslameter with NMR-like Accuracy

*S. Dimitrijevic, R.S. Popovic, **SENIS**, Switzerland.*

We are about to finish the development of a novel Hall digital teslameter with the accuracy approaching that of NMR teslameters. The analog front-end part of the teslameter is based on our Hall transducer with 1ppm resolution. The DC accuracy of the teslameter is about 10ppm. This is achieved by a careful digital correction of residual offset, sensitivity variations, and nonlinearity. Available will be 1, 2, or 3-axis teslameters for the field ranges between 20mT and 20T and the frequency ranges from DC to several kilo-hertz.

