The 20th International Magnetic Measurement Workhop

Programme Booklet

4th - 9th June 2017

Diamond Light Source

diamond

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Welcome

Dear IMMW20 delegate,

It is with great pleasure that I welcome you to Diamond Light Source for the 20th International Magnetic Measurement Workshop.
We have a packed programme of talks covering a wide range of activities from laboratories across the world, and in addition, we have three excursions planned to the largest scientific facilities based in the UK; the Joint European Torus (JET), the ISIS Spallation Neutron Source, and of course Diamond itself.

Following the successful trial of the tutorial day in Taiwan for IMMW19, we are pleased to once again be able to offer the opportunity of learning the fundamentals of magnetic measurement, before witnessing a measurement demonstration of both insertion devices and multipole accelerator magnets.

Despite the packed programme we hope that you find some time to explore the local environment. Diamond is located in some of southern England's best countryside, beneath The Ridgeway – a path that has been in constant use for over 5000 years and is described as Britain's oldest road. We also look forward to showing you around the historic city of Oxford before perhaps sharing a tale or two over a pint of real ale (or even a glass of English wine)!

The quality of the event has been assured by the support of our sponsors MetroLab, Kyma, Faraday Motion Control and Vacuumschmelze, who will also be exhibiting on Monday and Tuesday.

Once again, welcome to the 20th International Magnetic Measurement Workshop, and I hope you have an informative, productive, and enjoyable week with us.

Ed Rial

On behalf of the IMMW20 Local Organising Committee

Committees

International Programme Committee

- Stephane Sanfilippo, PSI
- Animesh Jain, ANL
- Joel Chavanne, ESRF
- Marco Buzio, CERN
- Josep Campmany, ALBA
- Joseph DiMarco, FNAL
- Zack Wolf, SLAC
- Heiner Brueck, DESY
- Ching-Shiang Hwang, NSRRC

Local Organising Committee

- Ed Rial (Chair), Diamond Light Source
- Stephen Milward, Diamond Light Source
- Abolfazl Shahveh, Diamond Light Source
- Zena Patel, Diamond Light Source
- Emma Clarke (Event Manager), Diamond Light Source

Sponsors and Supporting Organisations

We would like to extend our thanks to the following organisations for their generous sponsorship and support for IMMW20

Exhibition

On the 5th & 6th June the following companies will be exhibiting in the Diamond Atrium.

Metrolab

Metrolab is the global market leader for precision magnetometers, used to very precisely measure strong magnetic fields. Over the past 30 years, they have won the trust of MRI manufacturers and physics laboratories across the world.

Metrolab's offer incorporates mastery of precision magnetic field measurement, understanding of magnet systems applications, a passion for industrial quality, and the responsiveness of a small company.

Kyma Undulators

Kyma is the only company in the world whose unique business is design, manufacturing and characterization of insertion devices. Part of Kyma's activities are dedicated to modelling and prototype development, thus enabling the company to participate in the development and construction of complex devices and measurement systems.

Products
- Pure Permanent Magnet Insertion Devices
- Hybrid Undulators and Wigglers
- In-vacuum Undulators
- Equipment for magnetic measurements

Engineering services
- Co-design and co-development with Customers
- Design and consultancy services
- Design and supply of mechanical structures and components
- Refurbishment and upgrade of existing insertion devices
- Magnetic measurements and magnet characterization

Faraday Motion Controls

Faraday Motion Controls specialise in ultra-high performance motion control technology. Every day of our lives, we probably use some form of product that has been manufactured using precision motion control.
Often imitated but never equalled, DELTA TAU ‘s unique ” MACRO” communications protocol, unrivalled flexibility and nanometre accuracy means it can handle the most demanding motion applications on earth – or even space.
DELTA TAU Motion Partners offer much, much more than just high performance controllers. OEMs and manufacturers can choose from an extensive menu of products and services ranging from individual components, such as motors, amplifiers and controllers, to complete turnkey motion solutions.
Whatever your motion control requirement, from the supply of a simple, single axis controller to the design and installation of a complex multi-axis system, DELTA TAU can meet it.

VACUUMSCHMELZE

VACUUMSCHMELZE GmbH & Co. KG is a leading global manufacturer of advanced magnetic materials and related products.

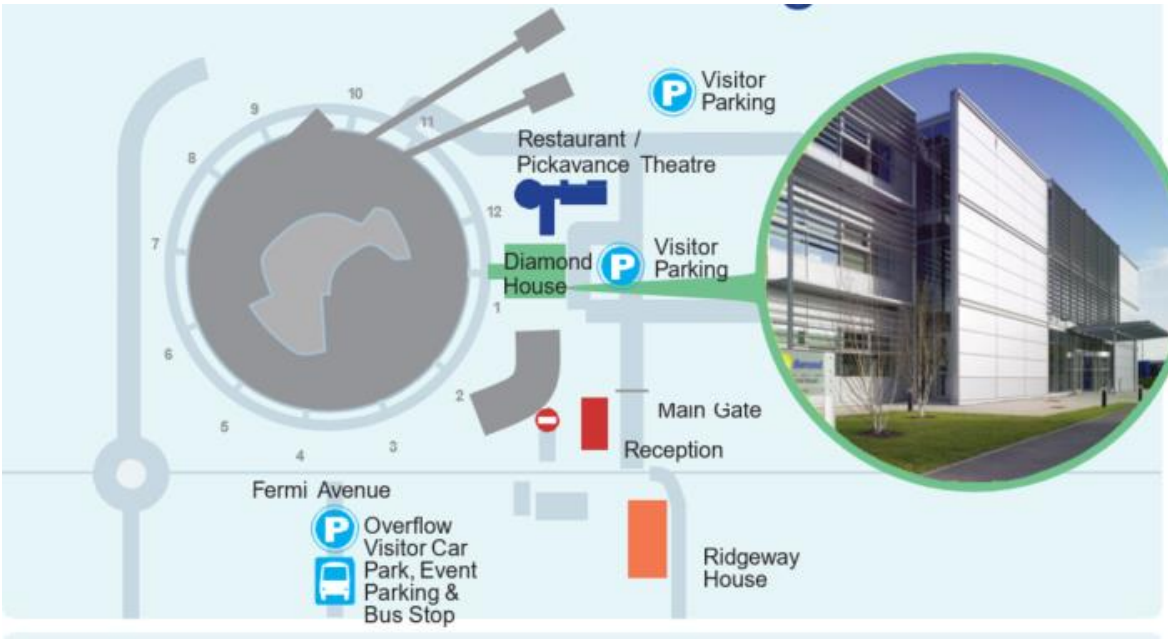
In 1914, the first vacuum melting furnace laid the foundation for today's VACUUMSCHMELZE. Then in 1923, melting alloys in a vacuum went into production on an industrial scale. This initial operation was located in Hanau, Germany and later grew into a company that operates on a worldwide basis:

- with 4.300 employees
- in more than 50 countries
- with annual sales of about approx. 380 million Euro

Today, VACUUMSCHMELZE’s range of products comprises a broad array of advanced semi-finished materials and parts, inductive components for the electronics, magnets and magnet assemblies for use in a wide variety of fields and industries spanning watch-making and medical technology, renewable energies, shipbuilding, automotive and aviation. The use of VACUUMSCHMELZE products is so extensive that we all use them every day - without knowing it.

Workshop Locations

Site overview



Diamond House Ground Floor

Locations
Tutorial Day Talks
G59 (Diamond House

Workshop Talks (Mon – Fri)
Pickavance Lecture Theatre
Registration Desk
Diamond Atrium

Exhibition
Diamond Atrium

Catering
Diamond Atrium

Delegate Information

Refreshments and Lunch
Lunch, Tea and coffee will be served in the atrium of Diamond House on the 4th, 5th, 7th and 8th June.

Lunch on the 6th and 9th will be served in R22, the on-site restaurant situated out of the doors at the front of the Atrium and to the left (in the same building as the main lecture theatre). You will be provided with a voucher to make your lunch purchase from the daily selection on offer.

Wi-Fi Access
Wi-Fi Access is available within Diamond House through the Diamond Visitor Network. No Network Key is required.

Emergency Procedure and Information
In case of emergency within Diamond House, please call the RAL emergency line on 2222 from any internal phone.

In case of hearing the fire alarm, please make your way as quickly as possible to the assembly point located in the car park in front of Diamond House.

For non-emergency assistance, please call Emma Clarke on 07471 026060.

Medical Assistance
If you require emergency medical assistance, please call 999 from any phone. You should call the NHS 111 service if you need medical help fast, but it is not a 999 emergency. Calls to 999 and NHS 111 are free from landlines and mobile phones.

Travel and Transport

Local transport links to and from Didcot Parkway can be found at the bus station (located in the Fermi Avenue Event Parking). Didcot can also be reached by taxi in around 20 minutes from Diamond. Local taxi companies are:

Pryors ☎ (+44) 1235 812345 Go Green Taxis ☎ (+44) 1235 811100

For train timetables see – www.nationalrail.co.uk

Didcot Parkway to Oxford – approx 15mins
Didcot Parkway to London Paddington – approx 45mins

Smoking
Please note smoking is not permitted within 5 metres of any building on site.

ATM Machine
An ATM machine is located in the coffee room adjacent to the Pickavance Lecture Theatre.

Tutorial Programme – Sunday 4th June 2017

Session Chair – Zack Wolf, SLAC

10:00	**Registration and Welcome Refreshments**
10:30	Introduction to Magnetic Measurements **Maro Buzio, CERN**
11:30	Coffee Break
12:00	Hall Sensor Devices **Radivoje Popovic, EPFL**
13:00	Lunch
13:45	Hall Probe Measurements in Insertion Devices **Marco Calvi, PSI**
14:45	Coffee Break
15:00	Lab Demonstration
17:00	Close

Monday 5th June 2017

Session Chair am – Josep Campmany, ALBA/
Session Chair pm – Joseph DiMarco, FNAL

08:30	**Registration and Welcome Refreshments**
09:00	Welcome – **Richard Walker, Diamond Light Source** Introduction – **Stéphane Sanfilippo, PSI**
	Overview of Activities
09:25	Challenges for the magnet projects at the Paul Scherrer Institute **Stéphane Sanfilippo, PSI**
09:50	Magnetic measurements at Budker INP on behalf of BINP magnetic measurement team **Ivan Okunev, BINP**
10:15	Measurement facility and test results for FRIB superconducting magnets at IMP **Wenjie Yang, IMP**
10:35	Coffee Break
	Overview of Activities
11:05	Status of insertion devices and magnetic measurement systems at MAX IV Laboratory **Hamed Tarawneh, MAX IV Laboratory**
11:30	Overview of magnetic measurement activities at the ESRF **Gaël Le Bec, ESRF**
11:55	Magnetic measurements at ALBA. General status and recent activities **Jordi Marcos Ruzafa, ALBA**
12:20	Lunch
	Overview of Activities
13:20	The ZEPTO project: Tunable permanent magnets for the next generation of high energy accelerators **Alex Bainbridge, STFC**
13:45	Overview of magnetic measurements for the Advanced Photon Source Upgrade **Animesh Jain, ANL**
14:10	Sigmaphi magnetic measurements on FAIR magnets (HESR dipole and quadrupole) and Tsinghua synchrotron dipole magnets **Marie-Julie Leray Pereira, SigmaPhi**
14:30	Coffee Break
	Magnetic Alignment
15:00	Precise magnet alignment for the SPring-8 Upgrade **Kenji Fukami, SPring-8**
15:25	Precise mechanics for the magnetic measurement setup **Ivan Morozov**
15:50	Performance of rotating wire magnetic alignment systems for the Advanced Photon Source Upgrade **Charles Doose, ANL**
16:30	**Facility Tour of Diamond**
18:30	**Welcome BBQ Reception**

Tuesday 6th June 2017

Session Chair – Marco Buzio, CERN

	Hall Probes
09:00	Magnetic performance of new Hall probe bench for measuring closed devices **Josep Campmany, ALBA**
09:25	Calibration of a Hall Probe Array **Jan Henry Hetzel, FZ Juelich**
09:50	Novel magnetic field mapping technology for small and closed aperture superconducting undulators **Erik Wallen, Advanced Light Source, Lawrence Berkley Laboratory**
10:15	Hallcube: from prototype to product **Christina Wouters, ETH Zurich**
10:35	Coffee Break
	Hardware and Software
11:05	Development of new measurement capabilities at Kyma **Mirko Kokole, Kyma**
11:30	Installation and use of magnetic measurement benches **Loïc Lefebvre, ESRF**
11:55	Stretched-wire system measurement applied in CPMU of HEPS-TF **Zhiqiang Li, IHEP**
12:20	Lunch
13:30	**Free Afternoon** **Optional Excursion to Oxford City Centre – Departing outside Diamond House at 13:45**

Wednesday 7th June 2017

Session Chair AM & PM – Ching-Shiang Hwang, NSRRC

	Hardware and Software
09:00	A multi-purpose 3D-Helmholtz-Coil for high accuracy measurements and calibration, **Olaf Dunkel, CERN**
09:25	A Laser-Compass Magnet Probe for Solenoid measurements **Thomas Zickler, CERN**
09:50	Influence of instrumentation noise in magnetic measurements by induction method **Anton Pavlenko, BINP**
10:15	1)Low noise amplifiers for inductive magnetic measurements. 2) Sorting of the magnets for a hybrid undulator structure **MarkusTischner (on behalf of Pavel Vagin, DESY**)
10:35	Coffee Break
	Hardware and Software
11:05	Field Mapper for Superconducting Torus Magnet for the Jefferson Lab 12GeV Upgrade **Renuka Rhajput-Ghoshal, JLAB**
11:30	Magnetic measurement of ITER Toroidal Field Coils **Marco Buzio, CERN**
11:50	An embedded 6DOF/3-axis hall probe device to map the magnetic field of a Toroidal Field Coil Winding Pack of the ITER Project **Matteo Bargiacchi, ASG-Superconductors**
12:10	Lunch
	Applications and Techniques
13:10	Rotating- and Translating-Coil Magnetometers for Extracting Pseudo-Multipoles in Accelerator Magnets **Stephan Russenschuck, CERN**
13:35	NMR magnetometry with single-chip integrated transceivers **Giovanni Boero, EPFL**
14:00	Talks close for the day
14:05	Travel to JET
14:30	**Facility Tour of JET, Culham Centre for Fusion Energy**
16:30	Bus returns to Diamond.

Thursday 8th June 2017

Session Chair – Animesh Jain, ANL

	Measurement Reports
09:00	Magnetic field measurements of the XFEL 5m undulator segments with different hall probes **Uwe Englisch, XFEL**
09:25	Some recent developments for undulators at PETRA **Markus Tischer, DESY**
09:50	Study on the discrepancy between the prediction from magnetic measurement and the result from beam based measurement/spectral measurement for NSLS-II insertion devices. **Toshi Tanabe, BNL**
10:15	Magnetic field measurement systems for SuperKEKB **Ueki Ryuichi, KEK**
10:35	Coffee Break
	Measurement Reports
11:05	Results from the Double Double Bend Achromat Installation: Accelerator Magnets and Insertion Device measurements **Abolfazl Shahveh, DLS**
11:30	Magnetic measurement system for superconducting final focus quadrupoles for SuperKEKB **Yasushi Arimoto, KEK**
11:55	Magnetic measurement results in R&D magnets for the Advanced Photon Source Upgrade **Roger Dejus, ANL**
12:20	Lunch
	Measurement Reports
13:20	AC magnetic field measurement by a small flip coil system **Jianxin Zhou, IHEP**
13:45	Overview of magnetic field measurement for various magnets in NSRRC **Ching-Shiang Hwang, NSRRC**
14:10	Delta undulator measurements For LCLS-II **Zack Wolf, SLAC**
14:30	Coffee Break
15:00 – 16:00	**Facility Tour of ISIS, Rutherford Appleton Laboratory**
19:00 – 22:00	**Workshop Dinner – Ashmolean Rooftop Restaurant, Oxford**

Friday 9th June 2017

Session Chair – Stéphane Sanfilippo, PSI

	Rotating Coils
09:00	Rotating coil probe activities at Fermilab **Joseph DiMarco, FNAL**
09:25	Design of an ISO-Perimetric Coil for a Transversal Field Scanner **Gianni Caiafa, CERN**
09:50	Harmonic coil measurement system using a PCB coil **Andrew Lees, STFC**
10:15	Coffee Break
	Conclusions and Final Remarks
10:45	Round table discussion To cover: (1) Overview and General activities in magnetic measurement, (2) Hall probe, (3) Wire based measurement, (4) NMR devices, (5) New technique & development of field measurement, (6) ID magnet measurement
11:55	Conclusion and final remarks
12:20	Workshop close and Lunch

Abstracts

Monday 5th – Overview of Activities - 09:25

Challenges for the magnet projects at the Paul Scherrer Institute

S. Sanfilippo, Paul Scherrer Institut

The talk concerns the strategy and the projects of the magnet section for the next five years. Special focus will be put on the development of the infrastructure and the magnetic measurements systems for the magnets of the second SwissFEL beam line and for superconducting magnets in the proposed upgrade of the Swiss Light Source and the next generation of light and compact gantries. The PSI contribution to the design and the production of a 16 T demonstrator at 4.5 K with a Canted-Cosine-Theta geometry for the Future Circular Collider will be also overviewed.

Monday 5th – Overview of Activities - 09:50

Magnetic measurements at Budker INP

I. Okunev, BINP

Every year INP carries out a large number of contracts for the production of various types of accelerators magnetic elements. The paper describes the use of three basic methods of magnetic measurements: the induction method, measurements with the help of Hall sensors and the NMR method. The report presents examples of precision measurements of various types of magnetic elements: dipole, quadrupole, sextupole, pulsed magnets, undulators and wigglers. Brief characteristics of electronic devices are given, software features are described.

Monday 5th – Overview of Activities - 10:15

Measurement facility and test results for FRIB superconducting magnets at IMP

W.Yang, IMP

The Facility of Rate Isotope Beams (FRIB) superconducting magnets are used to focus and steer the heavy ion beams of the FRIB driver linac. All the angers are designed as solenoid with bucking coils to suppress the stray field and have superconducting dipole correctors to steer both horizontal and vertical field. Two types of magnets are manufactured in China and some of them have been tested at The Institute of Modern Physics (IMP). This paper describes the measurement facilities and magnetic axis measurement method. We also present a summary of the measurement process and test results of the magnetic performance for the magnets.

Monday 5th – Overview of Activities - 11:05

Status of Insertion Devices and Magnetic Measurement Systems at MAX IV Laboratory

H. Tarawneh, Max IV Laboratory

An overview of the insertion devices activities at MAX IV Laboratory will be presented. The talk will focus on the new set up of magnetic measurement systems, Hall probe bench and two wire systems, at MAX IV. Two EPUs, each of 4 m long, were built in-house using this set up of measurement system that satisfied the required field quality and installed in the 3 GeV ring. I will report on the production of 4 undulators, 2 EPUs and 2 quasi-EPUs, for both MAX IV rings which is currently in progress.
I will also briefly present the first commissioning results of the first 5 insertion devices, 2 EPUs, 2 In-vacuum undulators and one in-vacuum wiggler, which has been installed in the 3 GeV ring so far.

Monday 5th – Overview of Activities - 11:30

Overview of magnetic measurement activities at the ESRF

G. Le Bec, ESRF

The on-going magnetic measurement activities at the ESRF will be reviewed. The ESRF has started a major upgrade of its accelerator complex. The new, low-emittance storage ring will be installed in 2019. Most of the 1000 magnets of the new storage ring are being measured with stretched wire benches developed and built in-house, and installed at suppliers premises. The first outcomes of this project will be presented. Local field measurements of various magnetic devices are performed in the lab. Hall probe benches are developed and used for cryogenic undulator, dipole and combined dipole-quadrupole measurements. Measurement methods and results will be shown. Other R&D topics will be introduced, including the development of new stretched wire measurement sequences, and a variant of the vibrating wire measurement method.

Monday 5th – Overview of Activities - 11:55

Magnetic measurements at ALBA. General status and recent activities

J. Marcos, V. Massana, L. García, and J. Campmany

ALBA synchrotron – CELLS, Consorci per a la construcció, equipament i explotació del Laboratori de llum de sincrotró. Ctra. BP 1413, de Cerdanyola del Vallès a Sant Cugat del Vallès, Km. 3,3, 08290 Cerdanyola del Vallès, Barcelona, Catalonia (Spain)

During the last two years ALBA magnetic measurements laboratory has been involved in the measurement of magnets for a number of facilities that are being built over the world. The measured magnets had different characteristics and requirements, and their

characterization has been a challenge in terms of improving the methodologies of fiducialization and data analysis.
Especially relevant has been the measurement of structures without lateral access using a conventional Hall probe bench, making the measurement in two steps and relying on alignment accuracy to merge both measurements. We have also improved the methodology to fiducialice the rotation axis of the measuring coil in our rotating coil system. All these methodological improvements will be described in the first part of the contribution.
In the second part of the contribution we will summarize the different measurement campaigns that have been undertaken. These campaigns include the measurement of (i) all the dipoles and quadrupoles for ThomX Compton Backscattering facility; (ii) two window-frame corrector magnets for the extraction to the new beamline dedicated to research being built at CNAO ; (iii) the four dipoles for the bunch compressor of CLARA linear accelerator. The challenges posed by each campaign will be presented, highlighting the most relevant results
The contribution will conclude with a presentation of the upgrade activities of the different measurement systems that are currently being carried out.

Monday 5th – Overview of Activities - 13:20

The ZEPTO project: Tuneable permanent magnets for the next generation of high energy accelerators.

A. Bainbridge, STFC

Permanent magnet (PM) based systems offer a potential solution to one of the key issues in designing and running modern particle accelerators; the power draw from conventional electromagnet systems. STFC and CERN are investigating the feasibility of using tuneable PM systems to reduce high electricity and water-cooling costs; plus the associated large scale infrastructure burden in the proposed CLIC accelerator.
This collaboration has resulted in the development of two tuneable PM Quadrupole systems, and is currently proceeding with the construction and analysis of a PM C-Dipole with a tuning range of over 50%. A prototype has been extensively simulated by finite element modelling and is being constructed using a large 500x400x200 mm block of NdFeB which slides horizontally to provide tuning.
We outline the design, construction and measurement of both the quadrupoles and the prototype dipole and discuss their suitability as replacements for electromagnetic systems. Issues including field homogeneity over a large tuning range and the management of high magnetic forces are addressed. Particular attention is paid to comparisons between the magnetic properties predicted by simulation and those actually recorded in the magnet test laboratory at STFC Daresbury, using Hall probes, stretched wire benches and rotating coils.

Monday 5th – Overview of Activities - 13:45

Overview of magnetic measurements for the Advanced Photon Source Upgrade

A. Jain, Argonne National Laboratory

The new storage ring for the proposed upgrade of the Advanced Photon Source (APS-U) at Argonne National Laboratory will require 1320 magnets. A group of several magnets will be assembled on a common support structure with magnet-to-magnet alignment tolerance of 30 microns RMS. Magnetic measurements will be used to ensure that the individual magnets meet the field quality specifications and the required alignment is achieved in the magnet assemblies. In addition to regular dipoles, quadrupoles and sextupoles similar to the existing machine, the APS-U lattice consists of several combined function magnets with strong dipole and quadrupole components. Several of these combined function magnets are also slightly curved, which makes measurement of field quality and alignment difficult using conventional rotating coil and wire based methods. This talk will describe the plans for magnetic measurements, and methods developed to measure the curved combined function magnets. * Work supported by the US Department of Energy under contract DE-AC02-06CH11357

Monday 5th – Overview of Activities - 14:10

Sigmaphi magnetic measurements on FAIR magnets (HESR dipole and quadrupole) and Tsinghua synchrotron dipole magnets.

M.J Leray Pereira, SIGMAPHI

Sigmaphi designs, makes and measures magnetic systems and beam transport lines for particle accelerators. After years of development and fruitful collaborations with some major labs, Sigmaphi offers a complete range of solutions for measuring any magnetic systems: hall probe, rotating coil and search coil. This contribution proposes: - recent developments at Sigmaphi - recent measurements on FAIR serial magnets (HESR dipole and quadrupole magnets) - measurement setup in progress (Tsinghua project).

Monday 5th – Magnetic Alignment - 15:00

Precise Magnet Alignment for the SPring-8 Upgrade

K. Fukami [1,2], N. Azumi [1,2] T. Kai [3], H. Kimura [1,2], J. Kiuchi [3], S. Matsui [2], S. Takano [1,2], T. Watanabe [1,2] and C. Zhang [1]

1 Japan Synchrotron Radiation Research Institute, 2 RIKEN SPring-8 Centre, 3. SPring-8 Service Co., Ltd.

For the SPring-8 major upgrade, SPring-8-II, multi-pole magnets need to be aligned within 25 micro-meters on a common girder. The value is required goals from beam dynamics, but we aim to achieve even better precision to pursue better light source performances. For the purpose, we have developed a magnet alignment procedure based on a vibrating wire method (VWM), a laser tracker, and auxiliary schemes. In demonstrating the VWM, a 'resolution' of the magnetic centre measurement for each individual magnet has achieved better than 1 micro-meter, but the imperfection of physical linearity of wire, including a wire sag, may significantly deteriorates the overall precision of the on-girder alignment. The linearity of wire has been precisely measured by a wire position sensing deck developed for the purpose, and the effect on the alignment precision has been evaluated. The wire position precisely placed at the centre of each magnet is transferred to a fiducial point of the magnet. The girder-to-girder alignment as well as BPM alignment are all implemented using these fiducial points. The overall scenario of the precise alignments and critical factors that determine the precision will be summarized, and key points to improve the precision will be discussed.

Monday 5th – Magnetic Alignment - 15:25
The stability of the quadrupole magnet axis.

A. Batrakov, I. Morozov, I. Okunev, Budker Institute of Nuclear Physics, Novosibirsk State

For creations of magnetic system of the free electron laser XFEL it was nessesary to have the device capable to focus electron beam with high stability of magnet axis. The main requirements for the magnet are as follows: max gradient 100 T/m, aperture diameter 16 mm, length of the iron yoke 0.1 m, admissible shift of a magnetic axis is less than 5 mkm. The magnet design was done in collaboration between DESY and BINP and the lenses are produced by BINP. The report presents the design of magnet measurements stand and results of the acceptance tests for magnetic field measurements. The special attention is paid to measurement of a magnetic axis shift within 1 mkm precision.
The magnetic field measurements of the magnet XQA is done with the rotating coil method. The rotation coil consists of a ceramic shaft of 15 mm diameter. On this shaft sits the main coil which has 20 turns and a length of 250 mm. Two additional coils of 125 mm length each sit symmetrically to the center of the main coil. The main coil is used to determine the integral of the magnetic field and the shift of the magnetic center at different excitation currents. The two short ones are used to find the initial magnetic axis at a given current value of the magnet.

Monday 5th – Magnetic Alignment - 15:50

Performance of rotating wire magnetic alignment systems for the Advanced Photon Source Upgrade

C. Doose, Argonne National Laboratory

Charles Doose, Argonne National Laboratory, Argonne, IL 60439, USA. Abstract The proposed upgrade to the Advanced Photon Source Storage-ring requires alignment of the magnetic centers of the quadrupole and sextupole magnets to 30 microns rms. Two rotating wire alignment systems have been developed and tested in order to achieve this tolerance. One of the alignment systems, with a wire length of 3.5 meters, was used to align a system of five prototype magnets. The other alignment system, with wire lengths ranging from 1 to 2 meters, was tested using individual magnets. A description of the system tests, performance of the alignment measurement systems and survey techniques using a Laser Tracker will be presented.

*Work supported by the US Department of Energy under contract DE-AC02-06CH11357

Tuesday 6th – Hall Probes – 09:00

Magnetic performance of new Hall probe bench for measuring closed devices

J.Campmany, ALBA

ALBA has designed and built a new magnetic measurement bench for closed structures, presented elsewhere.
This bench has been fully built in-house and has been mechanically characterized at ALBA, showing excellent performance in terms of repeatability and accuracy, as was presented at IMWW19.
Now we present its magnetic characterization carried out at ALBA. It was done along 2016 using as reference a pure permanent magnet dipole, to characterize the bench accuracy for homogeneous fields, and an undulator segment, to charecterize it for inhomogeneous fields.
Results are very promising, and for the first the repeatability reached 40μTesla.
In the case of undulator characterization, the repeatability reaches 50μTesla, with a period determination accuracy of 0.5 microns.
As a conclusion, we consider that the concept of this bench has been fully proofed, fulfilling all the requirements of magnetic measurement benches for ID and accelerator magnets characterization.
After this characterization, the bench has been moved to CIEMAT premises, and has been used to magnetically characterize a superconducting cyclotron that is being built there.
In this contribution we present the results of magnetic characterization of the bench as well as the first results of cyclotron measurements.
In the near future, the bench will be moved to ALBA in order to measure the SCU15 undulator build by Babcock-Noël for ANKA at liquid helium temperatures and high vacuum. In order to do this, we will present the modifications and improvements needed to be implemented.

Tuesday 6th – Hall Probes – 09:25

Calibration of a Hall Probe Array

J, Hetzel, HEDI[1]

One accelerator of the Facility for Antiproton and Ion Research FAIR in Darmstadt (Germany) will be the High Energy Storage Ring HESR. For the measurement of multipole components of the magnetic elements of the HESR an arrangement of eight 3D-Hall Probes is going to be used. All eight probes are located in the transverse plane at one radius with respect to a central axis and with an angular distance of _=4. A piezo motor allows the rotation around the cental axis. The gain factors of the Hall probes as well as small angular and translational displacements are a priori unknown. By analysis and comparison of multi-pole measurements in quadrupole and dipole magnets these calibration quantities are estimated.
We would like to thank the magnetic measurement group of CERN and especially Marco Buzio

[1]HEDI (measurements of the HEsr DIpoles): U. Bechstedt, J. Boeker, C. Ehrlich, I. Engin, J. Hetzel, S.Quilitzsch, H. Soltner, P. Tripathi (Forschungszentrum J• ulich IKP-4 and ZEA-1)

Tuesday 6th – Hall Probes – 09:50

Novel Magnetic Field Mapping Technology for Small and Closed Aperture Undulators

E, Wallen, Advanced Light Source, Lawrence Berkley Laboratory

Lawrence Berkeley National Laboratory (LBNL) is currently developing a prototype noninvasive magnetic measurement technique that will enable the characterization of novel undulator geometries where access exists only via a small-dimension circular vacuum tube through the undulator along its magnetic axis. This technique will facilitate the tuning characterization of optimized insertion devices for multibend achromat storage rings and free electron lasers, where closed small-bore devices are appropriate. LBNL is planning to upgrade the Advanced Light Source (ALS) to become a diffraction limited light source (ALS-U), that will allow the use of ultra-compact, short-period, small-gap, closed-aperture superconducting undulators to generate highly coherent tunable synchrotron radiation. To realize this measurement technology, three key system components have been developed: an ultra-compact magnetic field sensor package, a position acquisition system using laser technology, and a magnetic sensor transport system. This paper describes the development of the novel magnetic field measurement system and summarizes the magnetic field measurement tests carried out with a 0.2425 T dipole magnet and a short 10 period undulator at LBNL.

Tuesday 6th – Hall Probes – 10:15

Hallcube – from prototype to product

C. Wouters, ETH

The Hallcube project envisages a new type of three---axis Hall sensor with an unprecedented accuracy of <100 ppm at the 1 T level for any field direction. The sensor is comprised of six uniaxial Hall sensors that are arranged in such a way that they form a sub---mm active volume. Due to its unique configuration, the sensor addresses the accuracy limitations that current three---axis Hall sensors face. The first prototype demonstrated the feasibility of the proposed design with an active volume of (200 µm)3 and overall dimensions of (4 mm)3. It provides a high spatial resolution of 30 µm x 30 µm x 1 µm for each field component; full field vector measurements practically at a single point in space and time; and a reduction of the planar Hall effect by a factor of 35. A 3D characterization and calibration scheme was implemented to accurately translate the Hall voltages into the magnetic field vector. Because of the success of the 3D Hall sensor prototype, it is being improved and further developed with the goal that it can be used by whoever requires knowledge of the full magnetic field vector to a high---accuracy. The objective and results of the continued project will be presented.

Tuesday 6th – Hardware Software – 11:05

Development of new measurement capabilities at Kyma

M. Kokole, Kyma

Kyma is designing and manufacturing state of the art insertion devices for light-sources around the world. To keep up with increasingly more stringent specifications for these devices we are constantly developing and improving our test and measurement capabilities.
Here we present recent developments in measurement capabilities which include hall probe system for closed gap IDs specifically designed for the Cornell Compact Undulator. Pulsed wire bench acquired from Colorado State University. And a universal insertion device measurement bench control system intended to be a flexible and extendable system applicable to different hardware and measurement techniques.

Tuesday 6th – Hardware Software – 11:30

Installation and use of magnetic measurement benches

L. Lefebvre, G. Le Bec, P. Arnoux, C Benabderrahmane, F. Revol, J. Chavanne, C. Penel, ESRF – The European Synchrotron, Grenoble, France

In 2019, the European Synchrotron Radiation Facility (ESRF) will renew the magnetic structure of the storage ring for the Extremely Brilliant Source upgrade (EBS). For that purpose, a thousand new magnets are currently being built. The ESRF decided to harmonize the magnetic measurements with the various suppliers. Eight stretched-wire magnetic measurement bench were built by the ESRF and are in use in supplier premises plus on-site for the quality control and for the production of permanent magnet dipoles. A feedback from the installation of magnetic measurement benches will be given with the encountered issues and solutions to these issues.

The alignment of the magnets on the girders and the magnetic structure are essential to guide the beam accurately through the storage ring. An overview of the measuring process used to control the delivered magnetic field and to align the magnets will be presented.
The results of pre-series and first batches obtained in this way will be discussed and compared between the suppliers' premises and the ESRF measurements to get a feedback from quality control.

Tuesday 6th – Hardware Software – 11:55

Stretched-wire system measurement applied in CPMU of HEPS-TF

Z. Li, Institute of High Energy Physics, Chinese Academy of Sciences

The field integral measurement of the magnetic measurement system are important to evaluate and optimize the magnetic performance of the undulator of advanced photon source.Stretched-wire systems are built for a cryogenic permanent magnet undulator in High Energy Photon Source-Testing Facility. The fixed structure of stretched-wire is designed to measuring 2-meters long undulator in cryogenic-vaccum chamber.The special wire material is applied to reduce the deflection of the wire, and constant tension is maintained along the wire. The moving stages and nanovoltmeter are combined to acquire field integral data,integration time is set to fit the stages moving time. Long repeatability measurement of 1st field integral and standard deviation are the key performances,which depend on the stability of wire and less noise.Strategy of improving the measurement accuracy and stability is discussed.

Wednesday 7th – Hardware Software – 09:00

A multi-purpose 3D-Helmholtz-Coil for high accuracy measurements and calibration

O. Dunkel, V. Remondino, S. Russenschuck, CERN

An increasing use of permanent magnets at CERN and a growing park of measuring instruments require new qualification devices and improved calibration procedures for this equipment. As a part of this development a highly sensitive and accurate Helmholtz-Coil has been built at CERN.
The talk describes the design of the 3D construction, gives an overview of the coil parameters as well as of the initial characterization and finally resumes the first measurements carried out with this new device.

Wednesday 7th – Hardware Software – 09:25

A Laser-Compass Magnet Probe for Solenoid measurements

T. Zickler, CERN

In the past, magnetic measurements of solenoids at CERN have been performed using Hall probes. In view of the advanced requirements for characterizing electron-cooler solenoids, a new measurement system has been developed. This system features a laser-compass based probe, which can detect small transversal field components in the range of 1 x 10-4 in the shadow of the axial main field. A first prove-of-principle shows promising results and clearly highlights the advantages of this technology.

This presentation gives an overview of the concept, demonstrated the sensitivity of the system and provides an outlook about planned extensions towards an industrial standard system.

Wednesday 7th – Hardware Software – 09:50

Influence of instrumentation noise in magnetic measurement by induction method

A. Pavlenko, A. Batrakov, BINP

The instrumentation noise in magnetic measurements using digital integrations is the main factor, limiting resolution and repeatability of measurements. Based on the example of electronics the instrumentation noise are considered. The contribution of noise for the times of digital integration from microseconds to tens of seconds is analysed. Methods for improving the signal-to-noise ratio realised in practice are described. For integration time of 10 μs the proposed methods made possible to obtain an integral noise of about 10-11 V·s, and for the integration time 100 s the noise was 10-7 V·s. The report concludes by analysing the contribution of the noise of the digital integration path, power supply and the angle encoder in rotating coil systems. Comparison of these limiting factors for real systems is presented.

Wednesday 7th – Hardware Software – 10:15

1)Low noise amplifiers for inductive magnetic measurements. 2) Sorting of the magnets for a hybrid undulator structure

P. Vagin, Deutsches Elektronen Synchrotron

Low noise amplifiers for inductive magnetic measurements. In the inductive magnetic measurements based on Faraday's law, the induced voltage in the coil is proportional to the magnetic flux derivative over time. In order to get the magnetic field, the integral of the measured voltage should be found. Integration time varies from microseconds for pulsed magnets to hundreds of seconds for a search coil field mapping. At long integration times, the noise of the measurement system is limited by "pink" noise with 1/f noise density that grows towards lower frequency. The proposed amplifier is built by chopper-stabilized ADA4528 operational amplifiers, connected in parallel to reduce the noise down to 2nV/sqrt(Hz) at frequencies below 0.1Hz. Based on earlier work, a comparison of different voltmeters with different integration time is presented. Sorting of the magnets for a hybrid undulator structure. Permanent magnet blocks for undulators usually have different errors, such as magnetization direction, amplitude, North-South error, and other non-uniformities in the magnetization. By sorting the magnets and combining them to compensate each other errors', the total trajectory, phase and multipole errors of the undulator could be significantly reduced. For the proper characterization of magnet errors, a Helmholtz coil that measures the total magnetization amplitude and direction is not enough, especially for a hybrid undulator magnet structure, where the presence of high permeability poles completely changes the distribution of magnetic errors and its effect on the on-axis field amplitude. The proposed method uses an array of 3D Hall probes to measure the magnetic fieldmap of the individual magnets, in order to recalculate a proper model of the magnet errors, and then uses this model to determine the effect on the on-axis field amplitude.

Wednesday 7th – Hardware Software – 11:05

Field Mapper for Superconducting Torus Magnet for the Jefferson Lab 12GeV Upgrade

R. Rajput-Ghoshal[1], R. Fair[1], J. Meyers[1], M. Beck[1], D. Brakman[2], M. Mestayer[1], M. Taylor[1]
1. Jefferson Lab, Newport News, Virginia USA 2. University of Richmond, Richmond, Virginia, USA

As part of the Jefferson Lab 12 GeV upgrade, the Hall B magnet system requires two conduction cooled superconducting magnets – a Torus and a Solenoid. The Torus consists of 6 trapezoidal coils connected in series with an operating current of 3770 A. During commissioning of the torus magnet, field mapping was carried out at different levels of operating current in order to determine the field profile and field error table. In order to meet the physics requirement of the field accuracy we need magnetic field strength measurements which are accurate at the 0.1% level, and we need to know radius and azimuth to 0.1 mm and z to 0.5 mm. The center line of the torus magnet is approximately 6 m from ground level and the overall height of the torus magnet is

approximately 8.5 m. There is also limited space around the magnet and in between the coils. Field mapping had to be carried out along the Z axis (i.e. along the bore) and at 4 radial locations between each coil. These restrictions provided certain challenges for the magnetic field mapping task. The mapper prototype was built and tested prior to use on the Torus itself. In this presentation the field mapper design, prototyping and actual data collection procedure will be presented.

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Wednesday 7th – Hardware Software – 11:30

Magnetic measurement of ITER Toroidal Field Coils

M. Buzio, CERN

Large D-shaped Nb3Sn coils are currently being produced for the ITER tokamak in construction at Cadarache, France. This talk describes the equipment, developed jointly by CERN and PSI, that is being used to map their magnetic field at room temperature and the least-squares inverse problem of reconstructing an equivalent current filament from the measurements.

Wednesday 7th – Hardware Software – 11:50

An embedded 6DOF/3-axis hall probe device to map the magnetic field of a Toroidal Field Coil Winding Pack of the ITER Project

M. Bargiacchi, ASG-Superconductors

Fabrication and assembly errors might generate significant deviations of the magnetic field generated by the ITER Toroidal Field Coils Winding Packs (TFWP) with respect to the nominal field. The insertion of the impregnated TFWP inside the steel case is driven by the definition of the Current Centre Line (CCL). The CCL is defined at each cross section of the D-shape of the TFWP as the geometrical barycenter of the conductors' coordinates. In order to reconstruct the CCL once the WP is assembled, the field is mapped around each section with a specially designed device. A 3-axis Hall Probe is mounted on a 6DOF portable CMM. The 6 degrees of freedom of the Hall Probe are characterized with respect to the portable CMM with a constant calibration matrix. The relative coordinate of the portable CMM are then transferred to the absolute CMM reference to obtain the point of application and components of the B-field in a fixed point. The whole procedure is carried out on the fly granting a fast way to map the B-field around the TFWP in arbitrary points. The device's performances are tested against a reference field in order to assess the uncertainty related to the measure.

Wednesday 7th – Applications of Techniques – 13:10

Rotating- and Translating-Coil Magnetometers for Extracting Pseudo-Multipoles in Accelerator Magnets

S. Russenschuck, CERN

A classical method for describing the magnetic flux density in accelerator magnets is to develop the (measured or computed) magnetic flux density at a given reference radius into the eigenfunctions of the 2D Laplace equation. This method works well for long, straight magnets and is perfectly in line with magnetic field measurements using rotating-coil magnetometers. The Fourier coefficients of the field solution, known in the accelerator community as field harmonics, serve for the integrated field reconstruction and are the direct interface between the magnet designers and the beam physicists.

Recently, magnetic measurement requests have arisen from new accelerator projects, that require more than the integrated bending strength or harmonic content of the magnets. A well-established measurement method consists of mapping the field with a 3D Hall sensor, which is, however, inaccurate compared to the rotating-coil magnetometers and very time consuming. For fast-cycling magnets the field is often measured only on the mid-plane using a stationary fluxmeter, which is expensive to fabricate in printed-circuit board (PCB) technology. While fluxmeter measurements yield a relatively fast feedback on the magnet-to-magnet reproducibility, the measurements are of limited relevance for beam simulations because they require ramping the magnet and deliver only the integrated field strength. However, for storage rings, the highest precision of the magnet measurements is required at steady state, i.e., injection and/or high-energy plateau of the beam.
For the study of the beam envelope and long-term stability in synchrotrons (in particular for low energies), as well as light sources employing wigglers and undulators, the higher order imperfections in the magnetic field play an essential role.
Consequently, tolerance limits for these higher field harmonics must be established. They will depend on the beam size, the required storage time and the particle species (electrons, protons, heavy ions). Tracking codes are used for this purpose, where the effect of a higher multipole field on the particle dynamics is described explicitly by the Lorentz-force acting on the particle. The description of the magnet elements must be symplectic, that is, the integral operators acting on these elements must preserve the particle density in the phase space of all possible values of position and momentum variables. This is automatically the case as long as the magnetic field in a magnet can be described by a series of thin lenses with an equivalent kick.

As long as the design orbit is not deviating too much from the central orbit, and the multipole field expansion is valid, the calculation of these fields is straightforward. This is, however, not the case in the magnet extremities, where highly nonlinear field distributions are encountered and the multipole coefficients do not constitute a complete orthogonal function set for the field solution.
We have therefore developed measurement methods based on moving induction-coil arrays, longitudinal and transversal rotating-coil scanners, and induction-coil transducers for solenoidal magnets. These methods require, however, a sophisticated post-processing step based on the regularity conditions of electromagnetic fields in simply connected, source-free domains. The measurement raw data are in all cases induced voltages that are integrated using a digital integrator, which is triggered by linear or angular encoder stages. The results are convolution signals of spatial flux distributions. At this stage it is also possible to use an array of search-coils in order to compensate the main signal und thus to increase the signal-to-noise ratio in the voltage signals.

The numerical methods used in the post-processing step include the expansion of the field solution into bipolar (for curved magnets) and plane elliptic coordinates (for magnets with narrow gaps), the local description of field errors, and the post-processing of measurement data using numerical field computation methods.
Calculating the transversal field harmonics as a function of z, or measuring these harmonics with a very short, rotating induction-coil scanner, allows the extraction of the coefficients of a Fourier-Bessel series (aka pseudo-multipoles or generalized gradients), which can then be used in the thin lens approximation of the end regions of accelerator magnets. These pseudo-multipoles establish the theoretical foundation for the treatment of data acquired from the transversal field scanner (aka toy train), the moving fluxmeter, and the solenoidal field transducer.

Wednesday 7th – Application of Techniques – 13:35

NMR magnetometry with single-chip integrated transceivers

G. Boero, Ecole Polytechnique Federale de Lausanne (EPFL)

We present the design and performance of broad-band single-chip integrated transceivers specifically conceived for NMR magnetometry. The single-chip transceivers are realized using a standard silicon CMOS integrated circuit technology. An RF transmit amplifier, a transmit/receive switch, a low noise RF receive amplifier, an IQ-mixer, and an IF amplifier are integrated on a single silicon chip of about 1 mm2. The advantages and problematic aspects with respect to conventional discrete electronic approaches are discussed. We show the results of magnetic field measurements performed at 1.4 and 7 T. Particular attention is devoted to the comparison of the experimentally achieved magnetic field resolution with respect to the thermal noise limit. A magnetic field resolution of 3 nT/Hz1/2 at 7 T (i.e., about 0.4 ppb/Hz1/2) is achieved, with a projected thermal noise limit of 3 pT/Hz1/2. The choice of the sample material, the possible sequences and algorithms to compute the magnetic field value, the effect of field gradients, the ambient field fluctuations, and the time resolution are also discussed.

Thursday 7th – Measurement Reports – 09:00

Magnetic field measurements of the XFEL 5m undulator segments with different hall probes

U. Englisch[1], F. Wolff-Fabris[1], P. Li [1,2], T. Wei [1,2], Y. Li1, J. Pflueger[1]
1 European XFEL GmbH, 2. Chinese Academy of Engineering Physics

For the European XFEL 91 5m long undulator segments are needed. As part of the production process, all segments were measured and tuned on the three magnetic benches at the European XFEL using identical Bell Sypris Hall probe systems. Motivated by small inconsistencies due to the gaussmeters, which were seen in the calibration and limited the overall accuracy, it was decided in late 2014 to repeat and cross check all undulator segments in a so-called Re-measurements Campaign using three identical Senis H3A-0YJ02F-B02KT0K5K Hall-probe systems. This was only possible because of the overall delay of the whole project. The Re-measurement Campaign was performed in a quite compact fashion and thus permitted measurement prior to installation eliminating changes caused by the intermediate storage. In this contribution a comparison between the first measurements and Re-measurement Campaign is presented.

Thursday 7th – Measurement Reports – 09:25

Some recent developments for undulators at PETRA

M. Tischer, DESY

The talk reports on two different developments for undulators which were recently installed in the storage ring PETRA III at DESY.
The first topic relates to a phase shifter scheme which has been integrated in a permanent magnet hybrid undulator structure in order to suppress the emission of higher harmonics at integer multiples of the fundamental wavelength. The magnetic properties of this adjustable structure will be discussed. The second part describes a simple magnetic shimming method that was tested and applied for correction of systematic phase errors which are usually tedious to straighten out. Such errors can be induced for example by a non-uniform girder deformation as function of undulator gap or other deficiencies. By appropriate selection of the shim parameters, its gap-dependent strength can be adapted or the signature zeroed at some particular gap.

Thursday 7th – Measurement Reports – 09:50

Study on the discrepancy between the prediction from magnetic measurement and the result from beam based measurement/spectral measurement for NSLS-II insertion devices.

T.Tanabe, BNL

All the insertion devices (IDs) installed at the National Synchrotron Light Source-II storage ring have been rigorously certified for their magnetic characteristics. Our ID-Magnetic Measurement Facility (MMF) has state-of-the-art equipment which has been cross-calibrated with measurement systems at other facilities. The magnetic axes are carefully determined with respect to the mechanical fiducials whose locations are precisely measured by a laser tracker. However, certain IDs exhibit larger multipole values measured by electron beam than those predicted from magnetic measurement. Additional adjustment was needed for some IDs to achieve predicted spectral performance from the magnetic measurement. This paper shows some results of our investigation into the cause of these discrepancies.

Thursday 7th – Measurement Reports – 10:15

Magnetic Field Measurement Systems for SuperKEKB

U. Ryuichi, KEK

SuperKEKB is an electron-positron double ring collider, which aims to achieve a peak luminosity of 8Ã—1035 cm-2s-1. The magnetic properties of all magnets were evaluated using several types of magnetic field measurement systems at KEK. Magnetic field strength and uniformity of the dipole magnet were evaluated using a flip coil system. There are three types of flip coil systems, which are equipped with 2.0 m, 3.5 m and 6.5 m probe. Two harmonic coil systems were used to measure quadrupole, sextupole and wiggler magnets. The multipole components and magnetic axes were evaluated by using long and short coils. Effective lengths and longitudinal field profiles were measured using a small flip coil, which moves along the beam direction. Magnetic coupling adjacent magnets, such

as between quadrupole magnet and steering magnet, were measured with a flip-flop system. All magnets were found to satisfy the required tolerance for multipole field errors. Our magnetic field measurement systems are presented in detail in this report.

Thursday 7th – Measurement Reports – 11:05

Results from the Double Double Bend Achromat Installation: Accelerator Magnets and Insertion Device measurements

A. Shahveh, Z. Patel, E. Rial, Diamond Light Source

Three girders of one Double Bend Achromat (DBA) cell in the Diamond storage ring have been replaced by a newly designed Double Double Bend Achromat (DDBA) cell including two girders and a straight section to house an Insertion Device (ID). This talk reports the magnetic measurement and alignment of the magnets designed to use in the DDBA cell using a single stretched wire bench as well as magnetic measurements and alignment of the combined function dipole magnets and the ID using a Hall probe and flipping coil bench.

Thursday 7th – Measurement Reports – 11:30

Magnetic measurement system for superconducting final focus quadrupoles for SuperKEKB

Y.Arimoto, KEK

SuperKEKB is a high luminosity e+/e- collider with a design luminosity of 8 x 10^35 cm^-2 s^-1. The design of SuperKEKB is based on the “nano-beam scheme”. The beam size at a colliding point is expected to be 50 nm in vertical direction. The beam is squeezed with superconducting final focus quadrupole magnets. The magnet system consists of eight quadrupole magnets, 43 cancel/corrector magnets, and four compensation solenoids. We use harmonic coil system to measure field quality of the quadrupoles and correctors and a single stretched wire system to measure magnet center of the quadrupoles. Here, I will introduce our magnetic measurement system.

Thursday 7th – Measurement Reports – 11:55

Magnetic measurement results in R&D magnets for the Advanced Photon Source Upgrade

R. Dejus, ANL

The new storage ring for the proposed upgrade of the Advanced Photon Source (APS-U) at Argonne National Laboratory will require magnets delivering good field quality, with many of them operating at high field strengths. R&D versions of some of the magnet types have been built and studied in detail using a rotating coil and Hall probes. This talk will describe the magnetic measurements performed, and the results obtained, in four R&D quadrupoles and one R&D sextupole. These measurements have contributed to the development of the final magnet designs.

** Work supported by the US Department of Energy under contract DE-AC02-06CH11357*

Thursday 7th – Measurement Reports – 13:20

AC magnetic field measurement by a small flip coil system

J. Zhou, Institute of High Energy Physics, China

The China Spallation Neutron Source (CSNS) accelerator system consists of a linear accelerator and a rapid cycling synchrotron (RCS). The main magnets of the RCS accelerator are excited by AC current with DC bias. The magnetic field quality is very important for the RCS accelerator operation, since it has been used to guide and focus a circulating beam. In order to characterize the AC magnets, a small flip coil measurement system has been developed and each type of AC magnet has been studied. After magnetic field measurements, some interesting measurements are obtained. For example, the integration field increases as the core temperature increases, the eddy current causes the integral field to decrease and the phase difference between the magnetic field and the exciting current is constant in the middle region of the magnet pole, but the phase difference becomes bigger while out of the magnet end region. These discoveries are very important and meaningful for the RCS accelerator operation, with these findings, the parameters of the RCS accelerator has been further optimized.

Thursday 7th – Measurement Reports – 13:45

Overview of magnetic field measurement for various magnets in NSRRC

C. Y. Kuo, C. K. Yang, J. C. Jan, F. Y. Lin, J. C. Huang, T. Y. Chung, Cheng-Hsing Chang, Cheng-Hsiang Chang, C. S. Hwang

Several field measurement methods were developed for various lattice magnets, pulse magnets and insertion devices in NSRRC. The measurement methods and the system precision were reported that include (1) 1-D fixed-angle Hall probe with elliptical mapping trajectory is used for the measurement of point field and integral field of lattice dipole magnet, (2) 1-D fixed-angle Hall probe with circular mapping trajectory is used for the point field mapping and integral field measurement of lattice quadrupole and sextupole magnets, (3) 1-D (2-D) on-axis fixed-angle Hall probe is used for the spectrum shimming of insertion devices, (4) Rotating coil without bucking coil was used to measure the integral field of quadrupole and sextupole magnets, (5) Stretch wire was used for lattice quadrupole and sextupole magnet as well as the insertion devices, (6) In-situ field measurement in the UHV environment for in-vacuum or cryogenic undulator, (7) Cryogenic Hall probe measurement is used for superconducting magnet, (8) Search coil and loop coil for the pulse magnet. The field measurement results of various magnet and the relative issues are also discussed herein.

Thursday 7th – Measurement Reports – 14:10

Delta Undulator Measurements For LCLS-II

Z.Wolf, SLAC

The soft x-ray undulator line of LCLS-II is planned to have three Delta undulators placed at the end. They will produce intense coherent x-rays of any desired polarization using the microbunched beam from the planar undulators of LCLS-II. In order to produce coherent light, the three Delta undulators must be tuned to produce straight beam trajectories with small phase errors, and the three must be accurately matched in field strength, and matched to be resonant to the microbunched beam. This will present many challenges since the Delta undulators can't be tuned after they are assembled, and accurate measurements must be made of a non-uniform field in a long, small diameter beam tube. I will discuss the measurements we made on the Delta undulator for LCLS-I, and the improvements we would like to make for LCLS-II.

Friday 7th – Rotating Coils – 09:00

Rotating coil probe activities at Fermilab

J. DiMarco

Recent rotating-coil activities at Fermilab are presented, focusing on Printed Circuit Board (PCB) probes for magnetic measurements. New designs and developments are discussed along with recent calibration studies.

Friday 7th – Rotating Coils – 09:25

Design of an ISO-Perimetric Coil for a Transversal Field Scanner

G. Caiafa, CERN

A new design of rotating coil transducer for local, transversal field measurements is proposed. The goal of this research is to design and validate a sensor suitable to be used in the magnet extremities where the multipole coefficients do not constitute a complete orthogonal function set for the field solution. The proposed sensor has been designed to be produced as a flexible, printed-circuit board.

Friday 7th – Rotating Coils – 09:50

Harmonic coil measurement system using a PCB coil

A. Lees, STFC

The harmonic coil method allows for accurate measurement of the field quality of axisymmetric accelerator magnets. While the principle behind this method is relatively simple, building a machine to get the most accurate measurements can be both difficult and expensive. Through a research and development project, a prototype harmonic coil system is built on a small budget to explore the potential of developing a suitable machine using a printed circuit board for the coil. Using a PCB offers some advantages as the coil can be created easily and cheaply; it is also simple to add additional coils such as bucking coils. Some of the problems encountered in testing the prototype system are explained along with how they were overcome. A comparison with an industrial harmonic coil system is also carried out to estimate the accuracy of the prototype machine.

Delegate List

First Name	Last Name	Organisation
Anton	Ahl	Scanditronix Magnet
Emilia Simona	Apostol	INCDIE ICPE-CA
Yasushi	Arimoto	KEK
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Ching-Shiang	Hwang	NSRRC
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Stephen	Jago	STFC
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Stephane	Sanfilippo	Paul Scherrer Institut
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