IWAA 2024

Monday, 7 October 2024 - Friday, 11 October 2024

SLAC

Book of Abstracts

Contents

5

Introduction to SLAC

Author: John Schmerge[1]

[1] *SLAC*

Corresponding Author: schmerge@slac.stanford.edu

6

IWAA2024 Organizational Announcements

Author: Georg Gassner[1]

[1] *SLAC*

Corresponding Author: gassner@slac.stanford.edu

Survey and Alignment I / 8

SLAC Metrology Department

Author: Georg Gassner[1]

Co-authors: Bryan Rutledge [1]; Francis Gaudreault [1]; Hans Imfeld [1]; Michael Gaydosh [1]; Michael Rogers [1]

[1] *SLAC*

Corresponding Author: gassner@slac.stanford.edu

This presentation will provide an overview of the SLAC Metrology organization, focusing on Alignment group activities. The presentation will also cover the instrumentation used for everyday work and projects we recently worked on such as the LCLS-HE undulator upgrade, the Rubin Observatory LSST Camera, and the Super CDMS project.

Survey and Alignment I / 9

Petra IV Alignment Overview

Author: Jana Barker[1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: jana.barker@desy.de

PETRA IV requires stringent alignment accuracies for close to 300 girders and over 3000 magnets, despite pervasive space constraints. This paper summarizes the alignment progress of the project's current prototype
(pre-project) phase, as well as future plans. Under development are two novel multipole magnet referencing concepts photogrammetric and laser tracker measurements. Each concept utilizing laser

optical micrometers on a vertical rotary stage axially traversed by a vibrating wire. Also Custom stable floor-mounted instrument pillars are under prototype-phase development. These will be applied to multiple alignment and magnet fiducialization work stations for PETRA IV.

Survey and Alignment I / 10

High Precision Spatial Measurement Method of Accelerator Cell Pre-alignment Based on Multiple Total Station

Author: Yubo Xing[1]

Co-authors: Bo Li [1]; Jing Liang [1]; Lan Dong [1]; Liang Lu [1]; Lingling Men [1]; Na Ma [1]; Tong Wang [1]; Xiaolong Wang [1]; Zhen Yang [1]; Zhenqiang He [1]; Zhiyong Ke [1]

[1] *Sun Yat-sen University*

Corresponding Author: xingyb3@mail2.sysu.edu.cn

For stable operation of accelerators, high-precision alignment, positioning, and installation are crucial. Installing all equipment individually inside the tunnel poses safety risks as personnel may be exposed to enclosed and potentially radiative environments for extended periods. To address the challenges of long adjustment times and prolonged maintenance within the tunnel, most accelerator equipment under construction or in research consists of pre-aligned units. The magnets within each unit are pre-aligned with high precision in the laboratory before being transported to the tunnel. Aligning the entire magnet support frame can significantly improve installation efficiency within the tunnel. To meet the requirement of 10 μm transverse and vertical pre-alignment accuracy for the magnet units in the HEPS storage ring, this study designed a high-precision pre-alignment measurement system for accelerator units using four total stations for angle observations. Only angle measurements are used. By employing different instrument layout configurations and incorporating reliable distance benchmarks, high-precision pre-alignment of the magnet units are achieved. Theoretical analysis and simulation calculations reveal that when three total stations are arranged in an equilateral triangle in the plane, the measurement accuracy of the circumcircle center point is the highest, with the highest elevation measurement accuracy observed during horizontal total station observations. By arranging ceramic balls and utilizing image recognition for automatic targeting, real-time point calculations during pre-alignment enhance efficiency. Subsequently, based on this system, pre-alignment simulation calculations and experimental verification of eight magnet units in the HEPS storage ring are conducted, achieving high-precision online adjustment of individual points and ultimately realizing the 10μm lateral and vertical pre-alignment accuracy target within the cells. This method, based on high-precision measurements in a small-scale space, reduces the time and activity required for personnel on-site, mitigates radiation exposure risks, and facilitates laboratory-scale batch pre-alignment unit adjustments. It also provides a reference for pre-alignment of multiple magnet units in large accelerators such as the CEPC.

Survey and Alignment I / 11

Geodetic and Alignment Aspects for Proton Improvement Plan-II at Fermilab

Author: Virgil Bocean[1]

[1] *Fermilab*

Corresponding Author: bocean@fnal.gov

Proton Improvement Plan-II (PIP-II) is Fermilab's plan for upgrading the accelerator complex with the goal of providing proton beam power of 1.2 MW on target at the start of operations of the Long

Baseline Neutrino Facility (LBNF). It will also create a platform for long term development to multi-MW capabilities to support a broader Fermilab research program.
The presentation summarizes the concepts, methodology, implementation, and current results of the geodetic and alignment procedures to support the PIP-II development and its associated R&D programs, and an update on the progress.

Survey Concepts and strategy I / 12

Towards a European community on Accelerators, detectors and beamline alignment

Author: Hélène Mainaud Durand[1]

Co-author: David Martin [2]

[1] *CERN*

[2] *ESRF*

Corresponding Authors: martin@esrf.fr, helene.mainaud.durand@cern.ch

Following on from the International Workshop on Accelerator Alignment IWAA 2022, an alignment seminar was organized at the ESRF in June 2023. Four European laboratories: CERN, ALBA, SOLEIL and ESRF participated in this event. It was a very successful one-day event, divided into 7 sessions of 1h each dedicated to specific topics of mutual interest. These topics included: application of uncertainty, programs and applications, alignment techniques, permanent monitoring system, the use of external company support and approaches to adjustment and least squares calculations. Each topic was followed by a roundtable discussion.
Despite the success of the seminar, it was clear we had only scratched the surface of common topics for discussion. Furthermore, it was obvious that participation from other European labs would make such an event even more interesting. A second alignment seminar was therefore organized in April 2024, this time over two days at CERN, with representatives from 5 additional laboratories: DESY, MAXIV, GSI, DIAMOND and GANIL.
This presentation will detail the context and content of these seminars and present their outcomes and a summary of actions."

Survey Concepts and strategy I / 13

Towards an Expression of Uncertainty in Accelerator Alignment

Author: David Martin[1]

Co-author: Gilles Gatta [1]

[1] *ESRF*

Corresponding Author: martin@esrf.fr

When we are asked to align something in an accelerator, on a beamline or in a detector, there is always a desired tolerance associated with the alignment. Generally, this tolerance describes how well the something, for example a quadrupole magnet, should be aligned with respect to something else, for example, the adjacent quadrupole magnet.
The problem is that often the person giving the alignment tolerance isn't talking about the same things as the person who is receiving the tolerance information and expected to do the alignment. This can lead to misunderstandings. The problem of speaking a common language to define tolerances so there is no ambiguity in how they are interpreted is addressed by Geometrical Product Specification (GPS), for example ISO 14638:2015.

Once tolerances are explicitly defined, the object can be measured and compared to the theoretical design tolerances. When we have several objects, like magnets on girders, or if we manipulate an object like a magnet several times, we will get several independent comparisons to the theoretical design tolerances. Ultimately, we will be confronted with how to determine how well the tolerances are respected using several independent measurement results.
This is done using the estimation of uncertainty in measurement. This paper outlines a proposal for how to establish a statement of alignment uncertainty following rules outlined in the Guide to Uncertainty in Measurement (the GUM). The GUM and its supplements published by the Joint Committee for Guides in Metrology are generally accepted as providing best practice for the establishment of a statement of uncertainty in measurement.

Survey Concepts and strategy I / 14

From Engineering to Alignment: on the use of installation specifications based on an extended use of ISO GPS situation features at the European Spallation Source

Author: Fabien Rey[1]

Co-author: Bertrand Nicquevert [2]

[1] *European Spallation Source*

[2] *Ecole Normale Supérieure de Paris Saclay (+ LBNL + CERN on special leave)*

Corresponding Author: fabien.rey@ess.eu

Over the last years , the European Spallation Source has gone through an intense phase of installation of critical equipments requiring accurate positioning. All previous efforts invested to express geometrical requirements using technical drawings and ISO GPS language have been pursued and largely applied to produce installation drawings based on a generic template. An extended use of ISO GPS situation features enabled us to carry over initial functional requirements onto alignment objectives on the field. Practical examples will be presented.

Survey and Alignment II / 15

Design of the PIP-II Tunnel Geodetic Control Network

Author: David Krawczuk[1]

[1] *Fermilab*

Corresponding Author: krawczuk@fnal.gov

Fermilab's PIP-II project will result in a new beamline approximately 510 meters long. A geodetic control network will need to be established to precisely align the beamline components in the tunnel. This design focused on the tunnel network, as the surface network had already been considered. After selecting the geometry, instrumentation, and methodology, a pre-analysis was performed to estimate the global network uncertainties. Local errors were also estimated by considering alignment procedures and instrument noise. The global and local errors were then combined to estimate the total alignment uncertainty, which was compared against the project's alignment accuracy requirements.

Survey and Alignment II / 16

The Measurement of the ESRF Storage Ring

Author: David Martin[1]

Co-authors: Cristina Gonzalez-Torres [1]; Gilles Gatta [1]

[1] *ESRF*

Corresponding Author: martin@esrf.fr

The European Synchrotron Radiation Facility (ESRF) was established in 1988 as the world's first 3rd generation light source. Alignment was critically important. The quadrupole and sextupole magnet alignment tolerances were 100 μm in both the horizontal and vertical directions perpendicular to the beam.
The vertical tolerance was achievable with high precision levelling, but in the late 1980's only very specialised instruments could achieve precision like this in the horizontal plane. Two instruments that could achieve these tolerances under specialised conditions were the distinvar and ecartometer, which were the instruments used to install and measure the initial Storage Ring in 1992.
Things have evolved considerably since 1992. In 1992 it took 57-man days to do a survey with 2700 observations. Uncertainty in the horizontal direction perpendicular to the beam was 220 μm. In 2024, 8 man-days (i.e. 4 teams of 2 people in one 8-hour shift) can make a survey with 9600 observations and uncertainty in the horizontal direction perpendicular to the beam is 50 μm.
This paper follows the evolution in the techniques, instrumentation, software and particularly the quality of the measurement results achieved at the ESRF over the past 32 years.

Survey and Alignment II / 17

Geographic Information System (GIS) at SLAC

Author: Brian Fuss[1]

[1] *SLAC*

Corresponding Author: fuss@slac.stanford.edu

The Metrology Department at SLAC develops and hosts numerous GIS (Geographic Information System) websites for most departments at the laboratory. In addition, the department creates large format maps for SLAC users and departments that are displayed throughout the lab. This presentation will outline some of the GIS work that SLAC Metrology provides, such as for environmental protection soil sample positioning, vegetation control using LiDAR for the 8km 230kV SLAC main powerline easement, SLAC site-wide utilities including power and water systems, building occupant space management with GIS Python update programs, and more.

Survey Concepts and strategy II / 20

A Survey of Accelerator Alignment Concepts for Professional Development

Author: Peter Manwiller[1]

[1] *Facility for Rare Isotope Beams (FRIB) at Michigan State University*

Corresponding Author: manwille@frib.msu.edu

Research laboratory engineering departments encourage employees to pursue professional development in their field. Within the accelerator alignment community, limited introductory resources address the unique considerations of this specialized discipline. This paper aims to cover important

alignment concepts in an engaging and exploratory manner utilizing a multiple-choice quiz format to help newer alignment engineers review key professional concepts. The desired outcome is for group leaders to use the concepts presented here to aid in the professional development of newer members. The included answer key and brief explanations after each question are designed to inspire further learning and research of the topics. Topics covered include network survey planning, geometric impacts on measurement accuracy, fiducialization techniques, and alignment smoothing.

Instrumentation / 21

An IR Photonic Type HLS system developed at NSRRC

Author: Tse-Chuan Tseng[1]

[1] *NSRRC*

Corresponding Author: tctseng@nsrrc.org.tw

A simplified hydraulic levelling system (HLS) developing project has been carried out to monitor the ground settlement of TPS tunnel within 10 um resolution in these years. An IR photonic type integration was proposed to meet the requirement. This design consists of simple circuits with separated IR led and phototransistor to sense the water surface variation inside a small chamber installed on the ground. Through different sensing combinations assembled with several chamber types, a series of tests had been performed to examine the measurement range, linearity, resolution, etc. Eventually, an improved model consists of a chamber with three measuring cells is able to expand the sensing range to 10mm with 1um passible resolution. This system is under data communication test and will be manufactured next year. This paper presents the system design and testing results.

Instrumentation / 22

Sub-millimetric field measurements over kilometres using Arpent two-wavelength ADM

Author: Joffray Guillory[1]

Co-authors: B. Weyer [2]; D. Próchniewicz [3]; D. Truong [1]; Dominique Missiaen [2]; García-Asenjo García-Asenjo [4]; J-P. Wallerand [1]; Jean-Frederic Fuchs [2]; K. Wezka [5]; M Wisniewski [6]; R. Luján [4]; S. Baselga [4]

[1] *Conservatoire national des arts et métiers (CNAM)*

[2] *CERN*

[3] *Warsaw University of Technology (WUT)*

[4] *Universitat Politècnica de València (UPV)*

[5] *: Warsaw University of Technology (WUT)*

[6] *Główny Urząd Miar (GUM), Warsaw, Poland*

Corresponding Author: joffray.guillory@cnam.fr

Cnam has developed Arpent, a two-wavelength ADM where the distances do not depend on the air refractive index, but only on the dispersion. By simultaneously measuring two optical path lengths at two different wavelengths, it is no longer necessary to determine the air temperature and pressure. Arpent measures distances consistent with the SI-metre definition and achieves uncertainties better than 1 mm over 8 km (k=1), which can be of great interest for the surveying of large structures such as particle accelerators. This article describes the operating principle and performance of Arpent. Firstly, compensation for changes in the air refractive index when measuring a fixed distance of 2.6 km or 5.4 km over several days showed standard deviations lower than 0.3 mm. Secondly, distances were compared with those of the GNSS-based distance meter (GBDM+) developed by UPV, for nine baselines ranging from 1.0 km to 6.5 km and located at two reference sites: EURO5000 and CERN. The

distances provided by Arpent and GBDM+ proved compatible within their uncertainties (k=1) for seven baselines, and the differences had a standard deviation of 1.8 mm. Finally, Arpent was tested over 8 km. The two-wavelength ADM and GBDM+ will soon be used to transfer absolute scale to the new INTA1000 calibration baseline at the Spanish National Institute of Aerospace Technology (INTA).

Instrumentation / 24

Improvements in handling of orient-to-gravity (OTG) data for Leica Absolute Trackers

Author: Matthias Saure[1]

[1] *Leica Geosystems AG*

Corresponding Author: matthias.saure@hexagon.com

During IWAA2022 at CERN in Geneva a discussion was raised by laser tracker users about the differences in the handling of orient-to-gravity (OTG) measurements between Leica Absolute Tracker AT403 and AT9x0/AT500.
The talk will present a new approach for AT9x0 and AT500 in Spatial Analyzer to provide gravity referenced coordinates in the instrument frame to overcome this issue.

Tools & Monitoring I / 25

Layer Beams and their prospect for long-range alignment

Author: Martin Dušek[1]

Co-authors: Jean-Christophe Gayde [1]; Miroslav Šulc [1]; Sebastian Figura [1]

[1] *CERN*

Corresponding Authors: jean-christophe.gayde@cern.ch, martin.dusek@cern.ch

As part of the study on using structured laser light for alignment, an innovative technique is proposed for generating symmetrical pseudo-non-diffracting layers of caustic optical beams, known as Layer Beams (LB). The state of the art for producing similar beams consists of using spatial light modulators. Our approach is based on the design of a generator with a specific arrangement of cylindrical lenses that shapes the wavefront to create an LB. The intensity distribution of the LB in a plane transverse to the direction of propagation, shows parallel lines whose number varies with the distance from the generator. Our experiments, conducted in a 140-meter-long optical laboratory facility, demonstrated successful propagation over the entire available distance, with the thickness of the transverse lines in the order of a millimetre. This approach considerably reduces the complexity and cost of such a system compared to LBs generated using spatial light modulators. This paper summarises the main aspects of this research, highlighting the potential of using LBs for aligning accelerator components over long distances.

Tools & Monitoring I / 26

An Overview of Progress with the Study of a Structured Laser Beam for Alignment

Author: Witold Niewiem[1]

Co-authors: Dirk Mergelkuhl [1]; Jean-Christophe Gayde [1]

[1] *CERN*

Corresponding Author: witold.niewiem@cern.ch

The Structured Laser Beam (SLB) is a pseudo-non-diffractive optical beam characterized by the low divergence of the Inner Core (IC), down to 10 μrad, and the presence of concentric rings, with the most prominent being the Outer Ring (OR). The size of the IC and OR can vary depending on the SLB generator setup. SLBs have the potential to serve as straight reference lines for long-distance alignment systems due to the small diameter of their IC and their theoretically infinite propagation distance, which has been experimentally verified up to 900 meters. However, the straightness of a light beam propagating in the atmosphere can be affected by refraction. Optical alignment systems often use a vacuum to mitigate this refraction effect. While the vacuum system provides a propagation space for the laser beam, it imposes constraints on space availability, access, and the operation of the alignment system. In the case of an SLB passing through a vacuum pipe, its intensity distribution may be modified, resulting in an apparent shift of the IC and disrupting the straight reference line. Additionally, light reflected from the vacuum pipe complicates the measurement of the IC position. This paper discusses the prospects of SLB alignment systems, including recent advancements and remaining challenges.

Tools & Monitoring I / 27

A new laser-based monitoring method for the cryomodule components alignment in CSNS II

Author: Zhenqiang He[1]

Co-authors: Tong Wang [1]; Xiaolong Wang [1]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences (IHEP CAS)*

Corresponding Author: hezq@ihep.ac.cn

Alignment of superconducting cavities is a critical concern for the China Spallation Neutron Source Phase II (CSNS II) linac. To measure cavity displacement during the cooling process to liquid helium temperature, a new laser-based Poisson Spot Monitor (PSM) system was introduced. This system utilizes the diffraction spot captured on a CMOS camera when a parallel laser beam passes through a spherical target to track cavity positions. The Poisson spot center coordinates are determined through image processing. In the initial stages, we monitored the position changes of the double-spoke superconducting cavity prototype during cooling and reheating, comparing the results with those from micro-telescope measurements, which yielded positive outcomes.

Tools & Monitoring I / 28

Internal monitoring of the HL-LHC components

Author: Vivien Rude[1]

Co-authors: Carlo Petrone [1]; Clara Cala [1]; Hélène Mainaud Durand [1]; Julia Calmels [1]; Patrick Bestmann [1]; Vincent Barbarroux [1]

[1] *CERN*

Corresponding Authors: helene.mainaud.durand@cern.ch, vivien.rude@cern.ch

The High-Luminosity Large Hadron Collider (HL-LHC) project at CERN aims to enhance the LHC's performance and expand its potential for discoveries beyond 2029. New components will be installed within the 220 meters before the collision points of the ATLAS and CMS experiments, including 16 NB3Sn quadrupoles to focus the beam before collision and 8 radio frequency crab cavities to allow beam tilting, thereby increasing number of collisions within experiments. Whether for quadrupoles or for crab cavities, the element consists of two distinct elements: the visible outer envelope (called the vacuum vessel for quadrupoles and the cryomodule for crab cavities) and the active element installed inside (called the cold mass for quadrupoles, and cavity for crab cavities).
The HL-LHC project requires the determination of the position of the inner element within the outer envelope with an accuracy of 0.1 mm (1σ). Until now, the position of the cold mass in a quadrupole was determined during construction and considered stable afterward in warm conditions and with a thermal contraction model in cryogenic conditions. However, due to the stringent HL-LHC requirements, the previous assumption is no longer be considered valid. To determine the position of the inner element inside the outer envelope in real time with 0.1 mm accuracy, the absolute distances between the two elements will be measured using multi-target Frequency Scanning Interferometry. CERN has conducted tests on the first HL-LHC quadrupoles and crab cavities under both warm and cold conditions. For the crab cavities, the positions of the two cavities were monitored during the cool down. For quadrupoles, the positions of the mechanical axis of the cold mass in both conditions were compared with the behavior of the magnetic axis. This paper will describe the monitoring system and report on the results from these initial measurements.

Tools & Monitoring II / 29

LGC open-source: a strategy to share adjustment software and algorithmic development

Author: Guillaume Kautzmann[1]

Co-authors: F. Klumb [1]; J Gutekunst, [1]; P Elson [1]

[1] *CERN*

Corresponding Author: guillaume.kautzmann@cern.ch

LGC (Logiciel Général de Compensation) is a software that computes position estimates and associated statistics based on observations obtained by CERN surveyors. Since the mid-1980s, LGC has been a crucial tool to perform geodetic computations in various contexts - from simple levelling campaigns to advanced monitoring projects. The CERN Geodetic Metrology group continues to maintain, improve, and modernize LGC. Over time, LGC has achieved maturity and stability thanks to extensive testing and continuous improvements.
Up to now, LGC has been a proprietary software, with its use restricted to CERN and rarely licensed to outside entities. Driven by growing interest from external partners, this paper details the beginnings of the journey for transitioning LGC to an open-source platform. By open-sourcing LGC, we aim to ensure its long-term viability and quality, encourage contributions from a wider user/developer base, and foster community mutual assistance around accelerator alignment problems. We detail the motivation behind this initiative and the role played by the newly established Open Source Project Office (OSPO) at CERN for facilitating open-source licensing and distribution.

Tools & Monitoring II / 30

CoToLiP, a new tool to handle each of the six degrees of mutual situation between any two integral features.

Author: Bertrand Nicquevert[1]

[1] *Ecole Normale Supérieure de Paris Saclay (+ LBNL + CERN on special leave)*

Corresponding Author: bertrand.nicquevert@ens-paris-saclay.fr

ToLiP, or minimum set of situation features made of (at most) a poinT On a Line In a Plane, has been introduced as an intermediate object between any integral feature's geometry and the coordinate system representing its situation (location and orientation). CoToLiP is the tool to deal with the composition of two ToLiPs. The paper gives background on how this is built and used to encode complex geometrical specifications using ISO GPS extended tools, and to support the whole "engineering to alignment" cycle, including assembly, fiducialization and installation phases.

Tools and Monitoring III / 31

Full Remote Alignment System (FRAS) for HL-LHC project

Author: Hélène Mainaud Durand[1]

Co-authors: Anne-Valérie Naegely [1]; Antje Behrens [1]; Dirk Mergelkuhl [1]; Francis Klumb [1]; Guillaume Kautzmann [1]; Jean-Christophe Gayde [1]; Jean-Frederic Fuchs [1]; Mateusz Sosin [1]; Patrick Bestmann [1]; Vincent Barbarroux [1]; Vivien Rude [1]

[1] *CERN*

Corresponding Author: helene.mainaud.durand@cern.ch

The High Luminosity Large Hadron Collider (HL-LHC) project is an upgrade of the LHC to enable continuous operation at instantaneous luminosities over double that of the current LHC value. To do so, nearly 1.2 km of accelerator components of the present LHC machine will be replaced, applying new, innovative technologies. This includes a Full Remote Alignment System (FRAS) to continuously and accurately monitor the position of components and to perform remote adjustment. This paper will present the alignment solutions currently being finalized and their qualification plan. It will then review the alignment strategy, from the dismantling of old elements to the first years of operation of FRAS using the newly installed components.

Tools and Monitoring III / 32

A next generation survey train for future accelerators

Author: Florian Barcet[1]

Co-authors: Dirk Mergelkuhl [1]; Patrick Bestmann [1]

[1] *CERN*

Corresponding Author: florian.barcet@cern.ch

The increasing dimensions and constraints for next-generation accelerators are driving the development of new methods and strategies for automated alignment measurements. While the existing LHC collimator survey train has demonstrated significant potential, it also revealed the drawbacks and shortcomings of such a system.
A next generation survey train is therefore under development, taking into account all the lessons learnt from the previous version. At present, the focus is on developing the measurement system. Computer vision metrology stands out as the most promising technology for rapid, non-contact measurements, reducing the risk of interference with the accelerator installations. A prototype has been built and will be fully qualified on a test setup in 2025.
This paper describes the general considerations for such a system along with the studies and implementation of the measurement solution. The results of first measurements will be compared to those from classical measurement methods.

Survey Concepts and strategy III / 33

The overview of the storage ring alignment of HEPS

Author: Tong Wang[1]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences (IHEP CAS)*

Corresponding Author: wangt@ihep.ac.cn

The High Energy Photon Source(HEPS) was a first fourth-generation synchrotron light source in China, it has an energy of 6 GeV and a circumference of 1360m. Construction began in 2019, and beam commissioning started on July 23,2024. The first beam circulation was achieved on the first day, proving the success of the alignment. This report will introduce the alignment strategy, and the method of the pre-alignment in experiment hall and the final alignment in tunnel.

Survey Concepts and strategy III / 34

Development of a new levelling process integrated into a 3D global calculation

Author: Jean-Frederic Fuchs[1]

Co-authors: Camille Vendeuvre [1]; Jean-Francois Segers [1]

[1] *CERN*

Corresponding Authors: guillaume.kautzmann@cern.ch, jean-frederic.fuchs@cern.ch

CERN surveyors have been performing the smoothing of beamlines for decades using the 2D + 1 measurement and calculation process, where computing the planimetric (XY) and altimetric (H) data is performed independently and separately. Direct leveling (1D) is still recognized today as the most efficient method to allows accurate vertical determination over long distances.
CERN practices are continuously reviewed and optimized to adapt to new constraints and technological developments. With the High Luminosity upgrade of the Large Hadron Collider scheduled to take place from 2026-2029, data from hundreds of new sensors will be available in 3D. A new strategy is therefore needed to integrate the leveling measurements into a global 3D calculation.
A new leveling observation model, named *DLEV, has been developed for the CERN in-house least squares adjustment software, LGC (Logiciel Général de Compensation).
This new function integrates a geoid model and geo-referenced leveling stations that must be well determined especially in the longitudinal direction. It can also estimate the collimation error. The positions of digital leveling stations must be determined through multilateration measurements with a robust adjustment method and specific initial values due to the linear geometry of the network. Optical leveling stations require the new observations to be geo-referenced, and alternative input to be provided. This paper will review the new leveling process and compare the results of 3D and 2D+1 calculations using a practical case study.

Survey Concepts and strategy III / 35

Overview of the alignment strategy for SOLEIL II machine

Author: Sebastien Ducourtieux[1]

Co-authors: Alain Lestrade [1]; Bruno Leluan [1]; Cedric Bourgoin [1]; Emma Lazarowicz [1]; Mourad Sebdaoui [1]; Youen Delalande [1]

[1] *Synchrotron SOLEIL*

Corresponding Author: sebastien.ducourtieux@synchrotron-soleil.fr

Located in the heart of the Paris-Saclay university and technology park, SOLEIL is preparing a major upgrade of its machine and beamlines. This project known as SOLEIL II aims to provide a 4th generation synchrotron light source by the end of 2030. The new storage ring will have an emittance of 85 pm.rad which will naturally arise challenging questions about the solutions to be chosen for its alignment. Indeed, simulations carried out by the Accelerator Physics group have shown that the storage ring girders and most of the magnets on a girder must be aligned transversally with a tolerance of +/- 50 µm (normal distribution with 25 µm standard deviation and truncated at 2 sigmas). For more specific components such as magnets on matching straight section girders, the tolerances are decreased to +/- 20 µm (normal distribution with 10 µm standard deviation and truncated at 2 sigmas). Finally, the 354 m circumference of the machine must be maintained to its nominal value at better than +/- 2 mm (normal distribution with 1 mm standard deviation and truncated at 2 sigmas).
Concerning the positioning of the new machine with respect to the actual one, the SOLEIL II project try to minimize as far as possible the modification of the beamline position and orientation that would require beamline realignment. But due to the compacity of the future machine and the technical choices made for the lattice (still under development), some concessions had to be made. Five to six beamlines over the 29 installed at SOLEIL will be relocated around the machine. Dipole-based beamlines will suffer from substantial changes in position and orientation (1° shift in the horizontal plane) and will require a realignment but without modifying the hutch position. Finally, concerning the 13 beamlines based on insertion devices, everything is done to limit their transverse realignment and orientation (less than 1 mm transversally and less than 50 µrad in direction).
The given presentation will provide an overview of the alignment strategy under development at SOLEIL to position the new machine with respect to the actual one and to keep certain beamlines in position. The objective is to avoid any deformation of the theoretical machine. It will also be an opportunity to present current metrological development to better control laser tracker measurement and to keep as low as possible the component alignment uncertainty.

Survey Concepts and strategy III / 36

ALS Historical Circumference analysis

Author: Hongyan Zhu[1]

Co-authors: Chris Hernikl [1]; Katherine Ray [1]

[1] *Lawrence Berkeley National Lab*

Corresponding Author: hongyanzhu@lbl.gov

The Advanced Light Source (ALS) achieved first light in 1993. 30 years later, a major effort is taking place to upgrade it to 4th generation light source. There will be two accelerators reside in the same tunnel, one is Accumulator Ring which is hung on the inner wall, another one is Storage Ring which will replace the current ALS Storage Ring. RF system will be shared by the two Accelerators. A concern is raised by physicists, which is if the RF system can be tuned to accommodate the circumference changes of both accelerators, especially because they are differently supported. With historical data and new survey campaign, how the circumferences change and the difference of the changes are analyzed.

Survey and Alignment III / 37

Survey and Alignment for the APS Upgrade Storage Ring

Author: William G. Jansma[1]

Co-authors: Animesh Jain [1]; Charles Doose [1]; Jeremy Nudell [1]; Joshua Downey [1]; Rolando Gwekoh [1]; Samuel P. Jarvis

[1] *Argonne National Laboratory*

Corresponding Author: jansma@anl.gov

The Advanced Photon Source (APS) is a synchrotron X-ray facility located at Argonne National Laboratory, in operation since 1996. The APS recently completed an extensive upgrade, replacing the original APS electron storage ring with a state-of-the-art multi-bend achromat machine. The upgraded storage ring generates X-rays up to 500 times brighter than the original ring.
After more than 25 years of operation, the original APS storage ring was shut down on April 24, 2023, disassembled and removed. New, pre-assembled storage ring modules were installed, and electrons were injected into the new ring on April 13, 2024, less than one year later. The first stored electron beam was achieved on April 20, 2024.
In this paper we summarize the years of planning and preparation needed to successfully accomplish the goal replacing the 1,104-meter circumference storage ring within a one-year window. Magnet fiducialization, module assembly, survey control, and module installation and alignment will be presented.

Survey and Alignment III / 38

ALS-U Accumulator Ring Alignment progress

Author: Hongyan Zhu[1]

Co-authors: Bertrand Nicquevert [2]; Katherine Ray [1]

[1] *Lawrence Berkeley National Lab*

[2] *Ecole Normale Supérieure de Paris Saclay (+ LBNL + CERN on special leave)*

Corresponding Author: hongyanzhu@lbl.gov

The ALS-U project is upgrading the existing Lawrence Berkeley National Laboratory Advanced Light Source to a diffraction-limited soft x-ray light source. There will be two accelerators residing in the existing tunnel, the Accumulator Ring (AR) and the Storage Ring (SR). AR pre-staging (assembly of magnets on rafts) and their installation in the tunnel are currently taking place. This talk will cover the pre-staging alignment budget breakdown and the survey and alignment work progress.

Survey and Alignment III / 39

Closeout

Author: Georg Gassner[1]

[1] *SLAC*

Corresponding Author: gassner@slac.stanford.edu

Poster session and Coffee @ B053 / 42

Using local gravity observations for network calculations in spatial analyzer

Author: Martin Joska[1]

Co-authors: Fabien Rey [1]; Igor Vilin [1]; Jordan Rattle [1]; Pawel Garsztka [1]; Tomasz Zawierucha [1]

[1] *European Spallation Source*

Corresponding Authors: fabien.rey@ess.eu, martin.joska@ess.eu

At the European Spallation Source (ESS), we extensively use Spatial Analyzer (SA) for a variety of applications, including network calculations. A significant challenge has been to involve local gravity observations during the network calculation in SA. To address this, we have developed a solution to represent the local geoid within SA. In this poster we will present our methodology and implementation.

Poster session and Coffee @ B053 / 43

A new process for calculating beam offsets during alignment

Author: Camille Vendeuvre[1]

Co-author: Léa Hadj Kaci [1]

[1] *CERN*

Corresponding Author: camille.vendeuvre@cern.ch

Accurate alignment of beam components in particle accelerators is crucial to optimize machine performance and enhance precision measurement in the experiments. CERN is developing a new process for calculating beam position offsets directly in the field during the alignment stage.
This process benefits from recent developments within CERN's adjustment software, LGC (Logiciel Général de Compensation), which allows the use of geometrical data of the equipment, and roll angle measurements, directly into compensation calculations. This allows in-field calculation and adjustment of components at the beam position level, which becomes inaccessible once the component is installed. This streamlined sequence minimises beam point offsets and enhances overall alignment quality. Significant effort has been put into ensuring the process is flexible and user-friendly. This allows field teams to utilize it efficiently with limited time and calculation tools, without requiring extensive knowledge of the machine and its operational history.
This paper presents an overview of the calculation process, emphasizing input data quality and provides a comparison with existing calculations to evaluate the potential benefits of this new method.

Poster session and Coffee @ B053 / 44

Recent survey results of the SuperKEKB MR and the study of the ATL application

Author: Mika Masuzawa[1]

Co-authors: R. Ueki [1]; S. Nakamura [1]

[1] *KEK*

Corresponding Author: mika.masuzawa@kek.jp

SuperKEKB is a double ring collider consisting of a 7 GeV electron ring (HER) and a 4 GeV positron ring (LER) with a circumference of 3 km.
SuperKEKB was constructed by reusing the KEKB tunnel that was shut down in 2010. The KEKB beamline magnets were aligned in the same plane at the time of construction. SuperKEKB utilizes "nano-beam scheme,"where two low emittance beams collide with a large crossing angle at the interaction point (IP) and therefore it is more sensitive to machine errors such as misalignment than KEKB. To achieve higher luminosity than KEKB, it is necessary to compensate for the distortion of the closed orbit and optical function caused by tunnel subsidence.

The rate of the tunnel subsidence varies from year to year. There are some structures in the subsidence variations along the tunnel, possibly due to excavation work done in the vicinity of the tunnel between 2013 and 2014. Tunnel level surveys are performed every summer to confirm that there are no problems to SuperKEKB's high luminosity operation with the optics group.
An empirical ATL law was applied to describe the complicated structural level variations of the SuperKEKB tunnel, using the level data from 2005 to 2023. The new survey results and the study on the ATL application will be reported.

Poster session and Coffee @ B053 / **45**

Attempt to measure building deformation using crack displacement gauges

Author: Yuichi Okayasu[1]

[1] *KEK*

Corresponding Author: okayasu@post.kek.jp

Since 2020, we have been continuing to conduct control surveys of the KEK electron-positron accelerator using a laser tracker and digital level. Since analysis has confirmed a trend in beamline fluctuations, we introduce an attempt to experimentally introduce a crack displacement meter to confirm the trend in fluctuations.

Poster session and Coffee @ B053 / **46**

Survey and Alignment Design for the Shenzhen Superconducting Soft-X-ray Free Electron Laser

Author: Wenjie Cheng[1]

Co-author: Wei Wang [1]

[1] *Institute of Advanced Science Facilities, Shenzhen*

Corresponding Author: chengwenjie@mail.iasf.ac.cn

The objective of the Shenzhen Superconducting Soft-X-ray Free Electron Laser (S^3FEL) is to develop a free electron laser source utilizing a superconducting linear accelerator operating at an electron energy of 2.5GeV. The facility has a length of approximately 1.8km and features a wavelength range of 1 to 30nm for its Free Electron Laser, aimed at advancing cutting-edge scientific research and development. High-precision control network data is essential as a reference benchmark for aligning the S^3FEL components installed in four main areas: linac, LTU, undulator, beamline and experimental station (BL & ES). This ensures smooth particle trajectories and the generation of high-quality beams. This poster focuses on the design indicators for alignment accuracy, control network types, measurement schemes, data processing methods, and accuracy evaluation of key components within S^3FEL.

Poster session and Coffee @ B053 / **48**

Alignment System Tests on the CERN HL-LHC Remote Alignment System Mock-Up

Author: Mateusz Sosin[1]

Co-authors: Clara Cala [1]; J. Falcao Machado [1]; Julia Calmels [1]; M Dandekar [1]; P. Biedrawa [1]; R. Fernandez Bautista [1]; Vincent Barbarroux [1]

[1] *CERN*

Corresponding Authors: helene.mainaud.durand@cern.ch, mateusz.sosin@cern.ch

The High Luminosity upgrade of the Large Hadron Collider (HL-LHC) aims to enable continuous operation at instantaneous luminosities over double the current LHC value. To meet this goal, components installed in the Long Straight Sections around the ATLAS and CMS experiments must be aligned to within a tolerance of 0.45 mm vertically and 0.2 mm radially over a length of 420 meters. This precise alignment necessitated the development of a range of novel interferometric and capacitive sensor solutions, their acquisition systems, and micrometric resolution adjustment mechanics. This all falls under the scope of a new Full Remote Alignment System (FRAS) framework. To validate the FRAS sensors and adjustment mechanisms and confirm positioning strategies, a dedicated test bench known as the Single Component Test (SCT) was deployed at CERN. The SCT comprises a real magnet equipped with the full set of FRAS sensors and actuators, integrated into a tunnel-like configuration. This setup allows for the validation of all components under real operational conditions and serves as a rehearsal platform to crosscheck the integration of all systems before their final deployment in the LHC tunnel.
This paper describes the SCT setup, the integration of FRAS systems, the tests conducted, and summarizes the test results and lessons learnt.

Poster session and Coffee @ B053 / 49

Status on geodetic studies and alignment perspectives for the CERN Future Circular Collider

Author: Benjamin Weyer[1]

Co-authors: Léonard Watrelot [1]; Witold Niewiem [1]

[1] *CERN*

Corresponding Authors: witold.niewiem@cern.ch, benjamin.weyer@cern.ch

The ongoing feasibility study for the Future Circular Collider (FCC-ee) planned to be built at CERN raises survey and geodetic challenges. Developing an alignment strategy for the 8832 magnets within the 91.2 km circular tunnel, associated transfer lines, and the 2 or 4 experiments is critical. A robust geodetic infrastructure, including the definition of coordinate reference systems and the implementation of associated reference frames must be created together with the development of a local geoid model. Concurrently, automated methods for the fiducialisation of equipment and their precise alignment in the tunnel and experimental caverns must be devised. Furthermore, the maintenance of the alignment must be anticipated over the 20 years of foreseen operation with permanent or periodic monitoring and readjustment systems. The new methods will have to respect strict alignment tolerances for the different parts of the accelerator, such as the straight sections, interaction regions, and machine-detector interfaces. Given the size of the machine, these methods should also enable survey operations to be completed within a reasonable timeframe and with minimal human workforce.
This paper presents the current status of the study and gives perspectives and plans for additional research and development that will be carried out in the coming years to prepare the final feasibility study report and the technical design report.

Poster session and Coffee @ B053 / 50

Modelling and optimization of SOLEIL II survey and uncertainty

assessment of the measurement process using Monte Carlo approach

Author: Youen Delalande[1]

Co-authors: Alain Lestrade [1]; Bruno Leluan [1]; Cedric Bourgoin [1]; Joffray Guillory [2]; Mourad Sebdaoui [1]; Sebastien Ducourtieux [1]; Stephane Durand [3]

[1] *Synchrotron SOLEIL*

[2] *Conservatoire national des arts et métiers (CNAM)*

[3] *Laboratoire Geomatique et Foncier, CNAM*

Corresponding Authors: sebastien.ducourtieux@synchrotron-soleil.fr, joffray.guillory@cnam.fr, youen.delalande@synchrotron-soleil.fr

Located in the heart of the Paris-Saclay university and technology park, SOLEIL is preparing a major upgrade of its machine and beamlines. This project known as SOLEIL II aims to provide a 4th generation synchrotron light source by the end of 2030. The new storage ring will have an emittance of 85 pm.rad which will naturally arise challenging questions about the solutions to be chosen for its alignment. Indeed, simulations carried out by the Accelerator Physics group have shown that the storage ring girders and most of the magnets on a girder must be aligned transversally with a tolerance of ± 50 µm (normal distribution with 25 µm standard deviation and truncated at 2σ). For more specific components such as magnets on matching straight section girders, the tolerances are decreased to ± 20 µm (normal distribution with 10 µm standard deviation and truncated at 2σ). Finally, the 354 m circumference of the machine must be maintained to its nominal value at better than ± 2 mm (normal distribution with 1 mm standard deviation and truncated at 2σ).
The SOLEIL II alignment will be mainly carried out using laser trackers whose commonly accepted instrumental uncertainty is 7 µm + 3 µm/m, making the required 25 µm tolerances only achievable under very specific conditions. However, for the 10 µm tolerance needed for the most sensitive components, the limits of the instruments must be pushed back.
All the parameters having a strong influence on the measurement process during a survey must be perfectly controlled and optimized to maintain a low level of uncertainty. This includes the instruments'metrological performance, the environment in which they are used, how the operators use them, the dimensional and geometrical stability of the machine, and finally the methodology used.
Although an experimental approach is possible for this optimisation, it remains difficult to implement due to the number of scenarios that need to be tested directly on the machine to draw conclusions on the large number of variables that influence the results.
For this reason, the approach envisaged here is to model the measurement process which involves defining its input parameters such as uncertainty components. This model will be fed with experimental data. It will be used to perform simulations and thus identify the best measurement strategy for the future machine. We will optimise a selection of parameters such as the number of laser trackers used, the number of fixed points on the walls and their positions, the number of stations and their position, the measurement range, the number of times these measurements need to be repeated, and the duration of the measurement process, etc...
To evaluate the performance of the different tested scenarios, probabilistic techniques such as Monte Carlo approach will be used. This consists in carrying out random draws in compliance with the conditions of each of the input parameters. The whole of this approach will enable us to identify the uncertainty components having the greatest contributions during a machine survey, to optimise the measurement process and to establish the best geodetic network before installation of the future machine.
The poster will explain how the model is built, what are the main parameters and uncertainty components considered and finally will present the very first results obtained.

Poster session and Coffee @ B053 / 52

Overview of the Installation & Alignment of HEPS SR

Author: Chunhua Li[1]

Co-authors: Han Yuanying [1]; Lan Dong [1]; Li Minxian [1]; Liu Xiaoyang [1]; Shang Lu [1]; Shu Yang [1]; Siyu Chen [1]; Wang Haijing [1]; Wu Lei [1]; Yafeng Wu [1]; Yan Luping [1]; Yang Shu [1]; Yuandi Xu [1]; Zhou Ningchuang [1]; Zihao Wang [1]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences (IHEP CAS)*

Corresponding Author: lichunhua@ihep.ac.cn

The High Energy Photon Source (HEPS) has been under construction since 2019. It is designed to be the first high-energy diffraction-limited synchrotron light source in China. To achieve an ultra-low emittance of less than 60pm.rad, substantial efforts have been invested in the alignment process of the SR. This involves thousands of elements being arranged in a very tight space. To fulfill such a heavy task, not only the accuracy, but also the efficiency has been taken into account. A mockup experiment has been performed firstly to verify the installation process and resolve the emerging and potential issues, paving the way of the mass installation. The progress of the accelerator commissioning indicates the satisfactory achievement of the alignment work.

Poster session and Coffee @ B053 / 53

Direct Wire Offset Measurements by Photogrammetry Including Gravity Link

Author: Florian Barcet[1]

Co-authors: Dirk Mergelkuhl [1]; Patrick Bestmann [1]

[1] *CERN*

Corresponding Author: florian.barcet@cern.ch

This paper presents a novel method for direct wire offset measurements using photogrammetry, with a focus on integrating a link to gravity. This development is motivated by the High Luminosity Large Hadron Collider (HL-LHC) project, where increased radiation in the Long Straight Section (LSS) necessitates automating the wire measurement process with a Full Remote Alignment System (FRAS). To integrate this system with the rest of the machine, a new process had to be developed.
A prototype has been developed based on a support frame on which four high-resolution cameras and four inclinometers are mounted. Although the prototype currently operates manually, it was designed with future automation in mind, particularly for integration into CERN's Monorail Inspection Train (TIM).
The methodology begins with an acquisition interface that defines trigger parameters for synchronized data capture, enhancing accuracy and reliability. The key to the process is the identification and measurement of targets and the stretched wire using advanced machine vision techniques. The relative orientation of each camera is calculated using specialized software tools, such as Hexagon DPA-studio and MicMac. Additionally, a custom calibration process of the inclinometer's block is performed, to link the photogrammetry measurements to gravity. The acquired data is processed to calculate the horizontal and vertical offsets.
The comprehensive integration of these components results in a robust and precise method for wire offset measurements, with accuracy expected to meet the stringent requirements of particle accelerator applications. Initial results are extremely promising, showing that the prototype reaches the demanded precision of less than 50µm, making it an excellent solution for the HL-LHC's challenging environment."

Survey and Alignment I / 54

CEPC alignment and installation

Author: Xiaolong Wang[1]

[1] *IHEP*

Corresponding Author: wxl@ihep.ac.cn

The Circular Electron Positron Collider (CEPC) is a next-generation particle collider planned for construction in China, with the aim of conducting precision studies of the Higgs boson. The main ring of the CEPC has a circumference of 100km, the total number of components to be aligned is about 60000, and the alignment accuracy requirement between adjacent components is better than 0.1mm. The immense scale and high-accuracy requirement pose significant challenges to the alignment and installation work. This report will introduce the strategies for CEPC alignment and installation, as well as the new technologies will be adopted and the research progress.

Survey Concepts and strategy II / 55

Alignment Strategy for HALF and Some Research Process on Alignment Technologies at NSRL

Author: Xiaoye He[1]

Co-authors: Enchen Wu [1]; Qiuyu Zhang [1]; Ting Ding [1]; Wei Wang [1]

[1] *National Synchrotron Radiation Laboratory*

Corresponding Author: xyhe@ustc.edu.cn

Hefei Advanced Light Facility (HALF), a key mega-science facility, has started civil construction since June 2023 in Hefei, China, and National Synchrotron Radiation Laboratory (NSRL) is responsible for the construction. HALF is a 4th generation diffraction limited synchrotron radiation light source which includes a 192 m injector, a 138.4 m transport line, and a storage ring with a circumference of 480 m. Comparing to the 3rd and earlier generation light source, it requires more stringent alignment accuracy. This paper instructs the alignment strategy for it, including alignment accuracy requirements for different parts, alignment procedures and techniques for different stages of the project from civil engineering, the installation of components in the machine to the deformation monitoring system. At the same time, this paper elaborates on the scientific research work aimed at improving accuracy and efficiency in each sub stage of control network establishment, pre-alignment stage, smoothing and other alignment stages, such as automation simulation and measurement methods of control network based on measurement plan, four laser tracker pre-alignment system and its accuracy improvement algorithms, comparison of multiple self-developed smoothing methods, control network deformation prediction algorithm with machine learning. The above scientific research will be further deepened in the future to further assist in the alignment work of HALF and other large scientific devices.

Survey Concepts and strategy II / 56

Design and alignment accuracy of HEPS magnet girder adjustment mechanism

Author: Zihao Wang[1]

[1] *IHEP*

Corresponding Author: wangzihao@ihep.ac.cn

The Very low emittance of High Energy Photon Source (HEPS) demands high stability and adjusting performance of the magnet support. The alignment error between girders should be less than 50 μm. Based on that, the adjusting resolution of the girder are required to be less than 5 μm in both transverse and vertical directions. Besides, the natural frequency of magnet support assembly should be higher than 54 Hz to avoid the amplification of ground vibrations. To meet the requirements, during the development of the prototype, the structure of the prototype was designed through topology optimization, static analysis, grouting experiments, dynamic stiffness test and modal analysis, and

the rationality of the structure was verified through prototype experiments. During the field installation, the performance of the magnet support was again verified to be better than the design requirements through test work after installation.

Tools and Monitoring III / 57

Magnetic Fiducialization of HEPS Insertion Devices

Author: Lingling Men[1]

[1] *IHEP*

Corresponding Author: menll@ihep.ac.cn

Precision in fiducialization and alignment of insertion devices (IDs). Conventional sensor systems utilizing Hall probes for high-precision magnetic field measurements face limitations in determining the absolute position of the magnetic center of IDs. In this paper, the Magnetic Landmark (MLK), a novel solution based on a magnetized block structure, is designed to address this challenge. The MLK serves as an intermediary, establishing contact between the magnetic center of insertion devices and their externally accessible fiducials, thus enabling high-precision alignment. Through analysis of magnetic field distribution, self-calibration precision, and practical application of the magnetic landmark.

Tools & Monitoring II / 58

Calibration of a New Generation of High Speed and High Precision Measuring Instrument - Vision Measuring Instrument

Author: Luyan Zhang[1]

[1] *IHEP*

Corresponding Author: zhangluyan@ihep.ac.cn

CEPC, the next generation of particle colliders which is in planning. The storage ring of CEPC is 100 km long, and the collimation accuracy between adjacent precollimation units is better than 0.1mm. The measurement speed of traditional laser tracker measurement method can not meet the requirements of construction period. This report presents a new measuring instrument based on photogrammetric system, the vision measuring instrument, and presents experiments for its calibration method and verification properties.

Tools & Monitoring II / 59

Multilateration Method for Pre-Alignment of High Energy Photon Source Storage Ring

Author: Shang Lu[1]

[1] *IHEP*

Corresponding Author: lushang@ihep.ac.cn

In order to achieve 10μm pre-alignment accuracy of high energy photon source (HEPS) storage ring in transverse and vertical, four laser trackers were used for set up a four-station multilateration measurement system. Experiment results show that the absolute position measurement accuracy is within 7.1μm. Three pre-alignment standard workstations have been established. And the laser multilateration measurement method is adopted to the pre-alignment of the three, five and eight magnet girders in the storage ring of HEPS. Currently, all 288 girders of the storage ring have been pre-aligned. This report will introduce the detailed steps and results of pre-alignment.

Poster session and Coffee @ B053 / **60**

Designment of alignment support for high energy photon source (HEPS) storage ring vacuum tubes

Author: Ningchuang Zhou[1]

[1] *IHEP*

Corresponding Author: zhounc@ihep.ac.cn

The storage ring of high energy photon source (HEPS) has about 1536 vacuum tubes, which need different supports to align them to the desired position and keep their stability. According to the operational requirements of the storage ring vacuum tubes, this article introduces several types support structure of vacuum tubes. And finite element thermal-stress analysis was conducted on the vacuum box and vacuum box bracket. The result of the analysis provides a reliable theoretical basis for the design of the vacuum tubes support.

Poster session and Coffee @ B053 / **61**

Alignment scheme of sextupole and Mover in the pre-alignment MP unit of HEPS

Author: Lei Wu[1]

[1] *IHEP*

Corresponding Author: wulei@ihep.ac.cn

The HEPS storage ring consists of 48 7BA cells, with multipole magnets in each cell supported by several multipole girders. A set of alignment adjustment mechanism is present between each multipole magnet and the girder to fine-tune the magnet's six degrees of freedom position. The majority of magnet adjustment mechanism structures utilize vertical wedge blocks and horizontal and longitudinal push-pull bolts. But all sextupoles are installed on Movers that can be remotely adjusted both horizontally and vertically. Due to the Mover's inability to adjust angular orientation, the pre-alignment of the sextupole magnet is different from other multipole magnets. This article will introduce the alignment requirements of sextupole and Mover, error analysis and control measures, as well as the alignment scheme and process.

63

Optional - Visit to David Rumsey Map Center

Survey and Alignment III / 64

Several Recent Monitoring Efforts in NSLS-II

Corresponding Author: cyu@bnl.gov

Monitor the changes of accelerator components and tunnels are one of the major efforts when the machine is running. Several recent monitoring efforts will be discussed.
Long term measurements above truck tunnel will be updated. Besides, a new wire position system is installed. The system, data processing and results will be shown.
The circumference changes of storage ring in one year are also measured in month long intervals and are compared with beam data. This is a topic that didn't get covered a lot. The approach and results will also be reported.

Survey Concepts and strategy II / 65

Automated quadrupole magnet positioning for enhanced harmonic coil measurement

Author: Xudong Zhang[1]

Co-author: Wenjun Chen [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: xdzhang@impcas.ac.cn

The accurate placement of magnets is essential for accurate magnetic field measurements. The current positioning technique employed for harmonic coil measurement is inefficient due to its labor-intensive and time-consuming nature. Therefore, we use four cameras to monitor the position of the magnet due to its non-contact feature, and an electrically driven Stewart platform is utilized to manipulate the magnet. The experiments indicate that the efficiency of the quadrupole magnet positioning has increased significantly by at least 5 times, and the final positioning accuracy was verified by the laser tracker.

Poster session and Coffee @ B053 / 66

Recent progress of the SHINE(Shanghai Hard X-ray FEL Facility)

Author: Zhiqiang Jiang[1]

[1] *Shanghai Hard X-ray FEL Facility*

Corresponding Author: jiangzq@sari.ac.cn

Recent progress of the SHINE(Shanghai Hard X-ray FEL Facility)