STATUS OF INSERTION DEVICE MEASUREMENT SYSTEMS AT MAX IV LABORATORY

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Abstract

An insertion device lab was setup at MAX IV Laboratory and the production of insertion devices, mainly out-of-vacuum is ongoing and aided by new magnetic measurement systems. A new 5.5 m long Hall probe bench is used for field map measurements and a new hybrid flip coil and stretch wire system will be used for field integrals of full devices as well as individual magnet blocks characterisation. This paper describes these magnetic measurement systems and their achieved and expected performance.

INTRODUCTION

MAX IV Laboratory is the next step in the natural evolution of MAX I, II and III machines which were shutdown in December 2015. The new machine will be inaugurated in June 2016[1].

In order to meet the strict demands of the accelerators and have control over the Insertion Device (ID) performance, a dedicated ID lab was established. Currently all out-of-vacuum insertion devices at the facility are being built in-house.

The lab is located in the experimental hall and occupies a space of 180 m^2. No special enclosure surrounds the lab, only movable walls to stop moving air. Air temperature is continuously recorded and the deviation didn't exceeds 1.1 ºC between October 2015 and April 2016.

A Hall probe mapper and a flip coil bench are used for magnetic measurements at the lab.

All heavy loads are moved around the lab using air cushions and a 1.5Ton fixed crane aids the assembly process.

HALL-PROBE BENCH

A new Hall probe bench was setup at the lab. It allows measuring the longitudinal profile of the magnetic field and generate field maps which provides information about the electron's orbit, angle and phase. This information is crucial for the shimming process of an ID. It is also the main tool used for fiducialization. The system consists of three main components: Motion, Acquisition and Software (see Figure 1).

Motion System

The motion system was purchased from Kugler GmbH, it consists of 3 main axis and 6 secondary ones. The main axis performs the horizontal, vertical and longitudinal motions. The longitudinal axis is sliding on air bearings and driven by a linear motor and driver. A secondary longitudinal axis which follows the main is used to carry the cables and acquisition electronics, there is no mechanical coupling between the two to prevent vibrations from transmitting.

Acquisition System

The acquisition of field values is performed on-the-fly while the Hall probe is moving. A 1.5mm thick 3D hall-probe is used from SENIS AG. The analog signals are then digitized and stored by Keithley voltmeters at specific locations whenever a trigger pulse is received from the motion system. The Acquisition system is placed on the auxiliary axis to reduce analogue cable length. A 15m USB cable transmits the digital data to the operator PC.

Software

Igor Pro is used to control all the mentioned systems and provide a user-friendly interface for the operator and also performs the data analysis and plotting required for the shimming process. B2E [2] codes developed by ESRF are used in the analysis as well.

Figure 1: Hall probe bench (left) measuring EPU53 undulator at MAX IV laboratory.

Specifications

The main system specifications are mentioned in Table 1, these values are collected from manufacturer's datasheets and were verified during the acceptance tests after the procurement of the subsystems.

Performance

Measurements are taken at maximum speed allowed by the motion system of 150mm/s during the undulator shimming. No major improvement to phase or orbit results were detected when using lower speeds. Forward and backward scans are performed and averaged to suppress acquisition delay effects if needed.

ISBN 978-3-95450-147-2

Table 1: Hall-probe Bench Main Specifications [3], [4]

Property	Value	Unit
Motion system specs:		
Longitudinal travel distance	5500	mm
Horizontal travel distance	300	mm
Vertical travel distance	300	mm
Longitudinal max. speed	150	mm/s
Longitudinal speed error	≤ ±0.5	%
Absolute positioning error	≤ ±5	µm
Axis straightness error	≤ ±10	µm
Pitch / roll errors	≤ ±8	µRad
Acquisition system specs:		
Max field strength	±2	T
Resolution	2	µT
Offset fluctuation (drift)	< 3	µT
Temperature coefficient	< ±25	ppm/ºC
Planar Hall voltage	< 0.05	%
Probe dimensions	1.4 x 10 x 10	mm

Figures 2, 3 & 4 investigate the effect of the scan speed on the repeatability of the system's results. The data was collected repeatedly during the shimming process of the 4 m long EPU53 for the 3 GeV ring.

Resonances in measured field data were found at lower scan speeds. Further investigations are needed to pinpoint the cause and fully characterize the Hall bench performance.

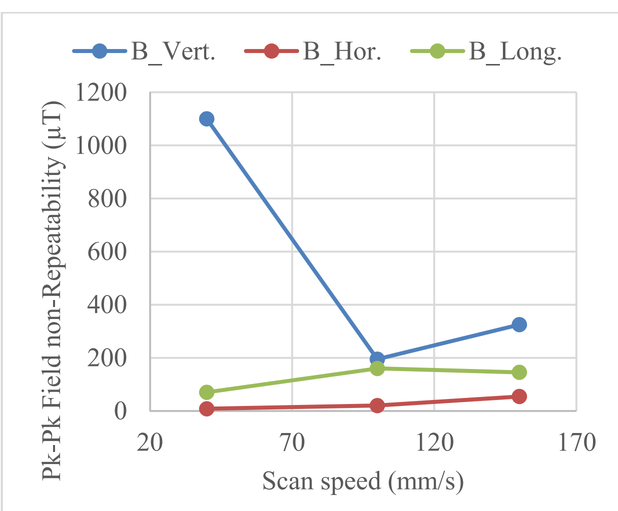

Figure 2: Field repeatability vs scan speed test results along a full undulator. Three field components are shown in different colours, vertical field amplitude = 0.9T.

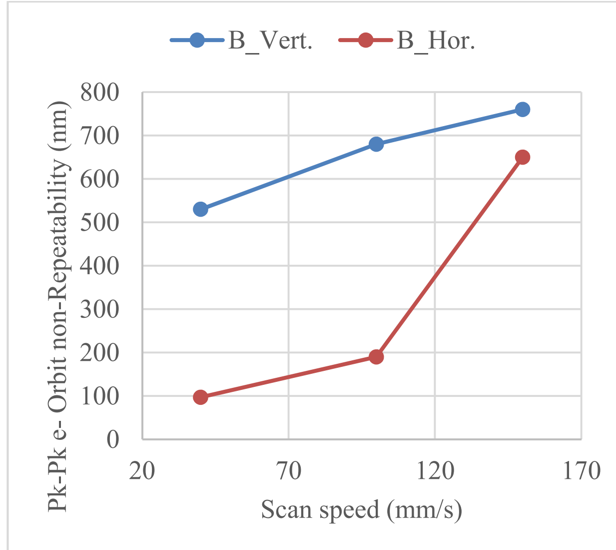

Figure 3: Electron orbit repeatability vs scan speed test results. Horizontal orbit (B_Vert) / Vertical orbit (B_Hor) magnitude is around 30 / 14 µm.

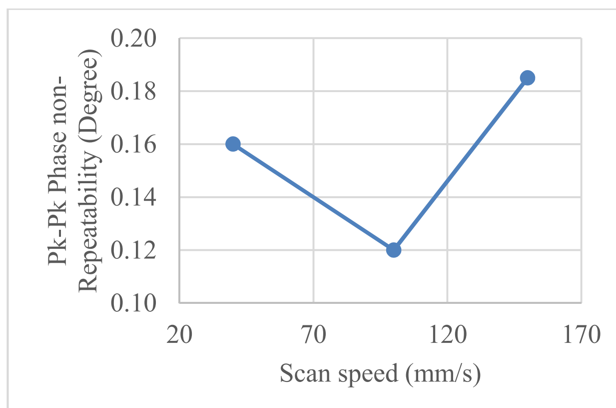

Figure 4: EPU53 phase error repeatability measurement in HP mode vs scan speed test results.

WIRE BENCH DESCRIPTIONS

Wires and coils are fast, flexible and precise methods for measuring first and second field integrals along accelerator magnets. A new wire bench is under construction at the lab. It is planned to be used as both a stretch wire and flip-coil system by only changing the wire or coil attachment points.

Mechanics and Motion

Two towers facing each other hold and move the wire. Each tower consists of a horizontal stage, vertical stage and rotating stage. The rotating stage is used in flip-coil mode only (see Figure 5). Wire tensioning is done by longitudinal motion of the two towers away from each other.

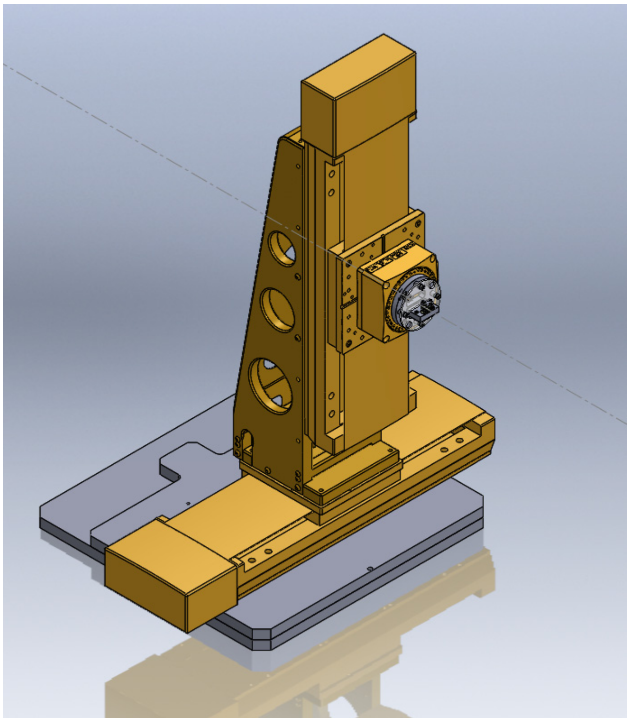

Figure 5: CAD model of one of the towers of the wire bench.

Data Acquisitions and Software

A Keysight nano-voltmeter is used for integrating the induced voltage on the wire. Integration periods of multiples of power line cycle shall be used to suppress 50Hz noise.

Slip rings are used to allow the coil to continuously rotate and transmit the signals. A precise load cell is attached to the coil holder for monitoring the coil tension. Igor Pro is used again for motion control and data analysis. Table 2 below summarizes the required parameters of the new bench.

Table 2: Wire Bench Main Requirements [5], [6]

Property	Value	Unit
Hor/Ver travel distance	300	mm
Hor/Ver travel max. speed	200	mm/s
Rotating stage max. speed	720	°/s
Nominal coil width	5	mm
Nominal coil length	5.5	m
Linear stages total error	$\leq \pm 4$	µm
Rotating stages total error	$\leq \pm 0.005$	°
Nano-voltmeter resolution	1	nV
Required repeatability error	$< \pm 2.5$	g.cm

CONCLUSION

The magnetic measurement systems at MAX IV Laboratory are still work in progress and there are still aspects which aren't fully explored or developed. The Hall probe bench is mature enough to be used for ID shimming while the wire bench is still under construction.

ACKNOWLEDGEMENT

Many thanks go to Morten Boettcher for his work on ID assembly and shimming, his many input on measurement systems are highly appreciated. And Lena Brunnacker for her work on the wire bench design, procurement and scheduling.

REFERENCES

[1] MAX IV Laboratory, `https://www.maxiv.se/`

[2] ESRF, http://www.esrf.eu/

[3] MMB-5500 Instruction Manual, Kugler GmbH.

[4] H3A Datasheet, SENIS AG.

[5] Newport, `http://www.newport.com/`

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ISBN 978-3-95450-147-2