MAGNETIC MEASUREMENT SYSTEM FOR SUPERCONDUCTIVE COILS*

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Abstract

A device for precise magnetic measurements of superconductive coils was designed, built and installed at the synchrotron radiation source ANKA, Forschungszentrum Karlsruhe. Accurate magnetic field measurements are a prerequisite for the characterization and optimization of insertion devices. The new device allows measuring the magnetic field magnitude of test coils with a longitudinal precision of 3 μm using a 2D Hall probe bench. The cylindrical liquid He cryostat allows mounting coils of maximum dimensions 35 cm in length and 30 cm in diameter. The set-up is computer controlled.

In this contribution we present the new device as well as the results obtained.

INTRODUCTION

Compared to the permanent magnet devices, superconductive undulators represent a challenge in magnetic measurements due to the very low operation temperature [1, 2].

For an undulator, an important figure of merit is the optical phase errors which determine the X-ray spectrum quality on the high harmonics and therefore the usable photon energy range. To determine the phase error, a scanning Hall probe bench with a high longitudinal precision and appropriate level of Hall probe calibration was constructed.

In this report we present the description of the measuring system and the results of the tests carried out on a superconductive mock-up produced by ACCEL.

MAGNETIC FIELD MEASUREMENT FACILITY FOR SHORT UNDULATOR COILS

Fig. 1 presents a schematic view of the main components of the magnetic measurement setup installed at the synchrotron radiation source ANKA, Forschungszentrum Karlsruhe [3]. A similar device was build by a group from Brookhaven National Laboratory [4].

The cryostat has an external diameter of 550 mm and a height of 1825 mm. The inner diameter of 370 mm allows to host superconductive coils of maximum dimensions 35 cm in length and 30 cm in diameter. On the bottom of the LHe vessel (vacuum side) an electric heating plate together with a temperature sensor is installed in order to evaporate the liquid helium. The coils, probe assembly, current leads etc. are all pre-assembled and then lowered by a crane in the cryostat. The probe is fixed to the intermediate supporting plate of the cryostat and moved by the stepper motor. The evaporated helium is collected and recovered by a pipe system. The stainless steel helium-vessel of the cryostat is surrounded by a vacuum chamber and a nitrogen-vessel.

Two pairs of vapour-cooled current leads for maximum 1500 A and 500 A are installed. The current leads consist of copper rods in temperature section from 300 K to 60 K and high temperature superconductors in between the 60 K to 4.2 K section.

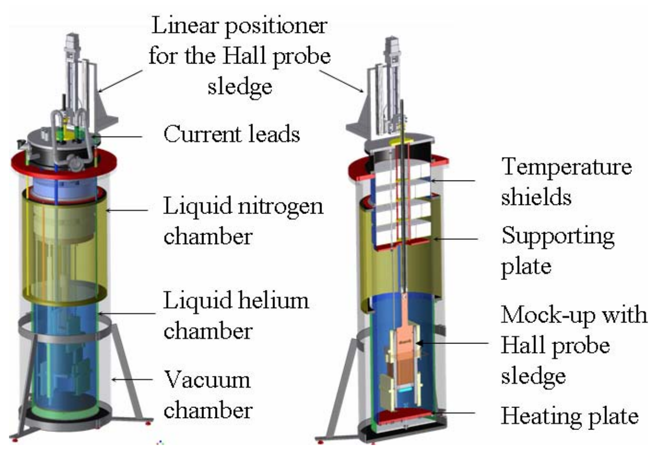

Figure 1: The cryostat assembly together with mock-up coils and Hall probe sledge. On the sledge several Hall probes are mounted for mapping the magnetic field.

MECHANICAL LAYOUT OF THE MOCK-UP

The assembly of the mock-up and Hall probe sledge is shown in Fig.2

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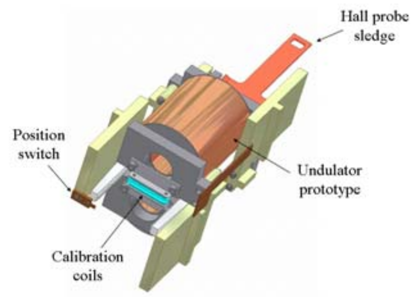

Figure 2: Assembly of the mock-up coils and Hall probe sledge. On the sledge three Hall probes are mounted for mapping the magnetic field.

The undulator prototype is equipped with a position switch which determines the zero position for the Hall probe sledge to mark the zero point of the magnetic field scan, with *(a)* a Hall probe sledge and *(b)* with calibration coils to calibrate the Hall probes *in-situ* at liquid helium temperatures.

(a) In the field-mapping instrument three Hall sensors and the temperature sensor are attached to a brass sledge supported at the corners by four pins (Fig. 3). These pins slide over two precision bars mounted inside the mock-up gap. Three Hall probes are distant from each other by 20 mm. The commercially available Hall probes have an active area of 0.0025 mm². The Hall probes are calibrated for the operation at 4 K. The measuring range is ± 7 T at temperatures between 1.5 and 350 K. The linear accuracy of the Hall probes is 0.5 %, this allows to measure the phase errors with resolution of ± 1.2°.

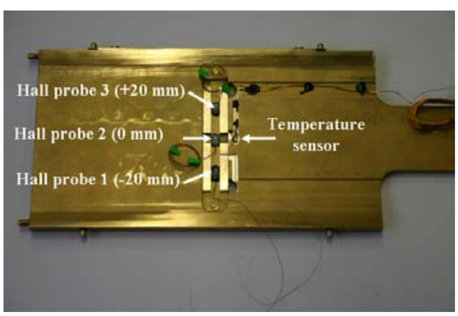

Figure 3: Hall probe sledge with three Hall probes and temperature sensor.

The Hall probe array is driven by a computer controlled stepper motor. The speed is variable from 0 to 600 mm/min and the spatial resolution is 3 µm at 300 K.

Measurements were performed when the sledge moved upwards only.

(b) The measuring system is equipped with Helmholtz calibration coils which are attached directly to the mock-up assembly (Fig. 4). The coils are powered by a 500 Ampere power supply. The calibration coils are designed such that the Hall probes on the sledge fit into the homogeneity region of the magnetic field of the coils. The magnetic field distribution in the calibration coils was analysed with different currents. As an example, Fig. 5 shows relatively large homogeneity area (up to 0.15 mm^2) of the magnetic field measured at 300 A.

Figure 4: Calibration coils. The coils are made by a 54 filaments NbTi wire. The dimensions of the rectangular wire are 0.46 × 0.72 mm. Each coil has 8 × 8 layers.

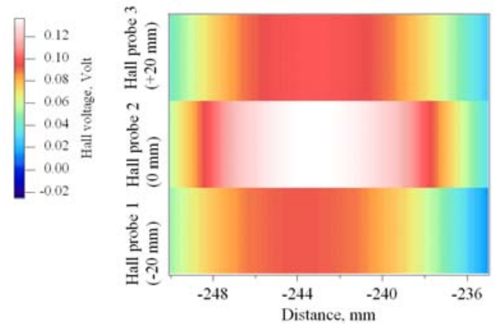

Figure 5: Magnetic field distribution produced by the calibration coils at 300 A. The Hall voltage responds as a function of the distance was measured with three Hall probes. The spatial resolution is 100 µm.

The magnetic measurement setup is computer controlled. Data acquisition and storage are performed by a PC. The computer system for the magnetic test facility is based on a UNIX system. The program SPEC is used for the positioning of the motor, signal counts and scanning of the magnetic field map.

TEST FIELD MEASUREMENTS

In the following the test measurements of the existing mock-up were performed to demonstrate the functionality of the measuring system.

The magnetic field measurements were carried out at different currents (Fig. 6) and different spatial resolution. A comparison of successive scans reveals that the repeatability error in probe positioning is typically no larger than 3 µm.

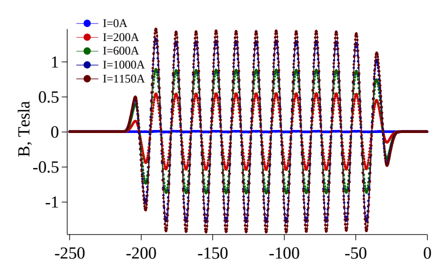

Figure 6: Measured magnetic field along the beam axes with Hall probe at different current.

The angle and the trajectory deviations for the electron beam have been calculated and the result suggests that magnetic field corrections are required. This is in a good agreement with already published data [5].

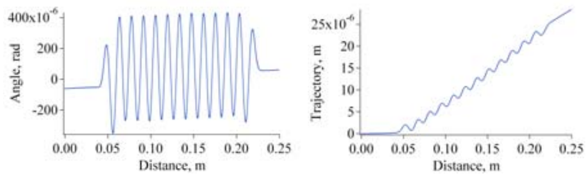

Figure 7: Angle and trajectory of the electron beam calculated for the data measured at 1000 A with the spatial resolution of 20 µm.

OUTLOOK

A horizontal setup for superconducting coils up to 1.5 m long is under construction. The cryostat will have an outer vacuum chamber at 300 K, a 77 K chamber which will be pre-cooled by liquid nitrogen and a 4.2 K chamber which will be cooled by the cryocoolers. The whole system will be under insulation vacuum. Access to the gap will be provided by the support flange that allows to measure the field integrals with the stretched-wire technique and by a linear stage with which the Hall probes can be moved along the main coils axis allowing to measure the local magnetic field. The Hall probe XYZ stage will be placed on the 77 K plate (Fig. 8), [6].

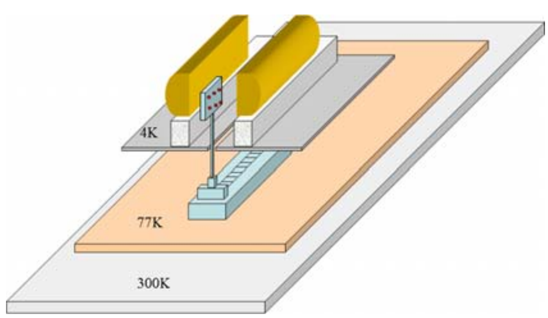

Figure 8: Technical sketch of the measurement setup for the undulators up to 1.5 meters long.

CONCLUSION

A new test facility for the short mock-ups has been successfully developed and a first experimental validation of the cryostat at cryogenic conditions was performed. The magnetic measurement system was tested with the existing mock-up coils. The results show a good reproducibility and agreement with already published data.

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