LOCAL AND INTEGRAL FIELD MEASUREMENT SETUP FOR 2M LONG SUPERCONDUCTING UNDULATOR COILS

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Abstract

The performance of superconducting insertion devices (IDs) depends strongly on their magnetic field quality. It is of fundamental importance to characterize the magnetic properties of IDs accurately before installation in synchrotron light sources. Measurements of the field properties of conventional, i.e. permanent magnet based IDs made huge progress during the last years and initiated a new era in synchrotron light sources. For superconducting IDs similar major improvements are now necessary and a part of our R & D program for superconducting insertion devices is to perform quality assessment of their magnetic field properties.

This contribution describes the equipment to perform magnetic measurements of the local field and of the field integrals of superconducting undulator coils in a cold in vacuum (cryogen free) environment with a focus on the results of the factory acceptance test.

INTRODUCTION

Undulators are used in synchrotron light sources to produce high brilliance photon beams [1]. Important figures of merit for an undulator are the phase error and the field integrals. The phase error, which should ideally be zero, is related to the quality of the emitted radiation. The photons emitted along the electron sinusoidal trajectory interfere constructively if the phase advance between successive poles is equal to π. The phase advance and the wavelength are determined by the period length, field strength and the beam energy. Emitted photons can not interfere constructively if the period length and/or the field strength deviates in one, or several periods. The field integrals along the beam axis should ideally be zero so that there is no effect on the electron beam orbit.

There is a well established research and development program going on at the synchrotron ANKA (ANgströmquelle KArlsruhe), situated at the Karlsruhe Institute of Technology (KIT), to develop superconducting insertion devices (IDs) [2]. Of high relevance for our R&D program are the tools that we have developed, and that are under development, to perform quality management of the magnetic field properties of superconducting IDs. Adapting the tools used for permanent magnet undulators to superconducting IDs is our challenge.

The device CASPER I (**C**h**A**racterization **S**etu**P** for field **E**rror **R**eduction) was built in 2007 and it is an operating facility where small mock-ups (max. length 350 mm, max. diameter 300 mm), winding schemes, superconducting materials and wires, and field correction techniques can be tested in a liquid helium bath [3].

In this contribution we describe the final measurement setup of CASPER II, a device to qualify the magnetic field properties of coils up to 2 m long [4], and the factory acceptance test of the cryostat.

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CRYOSTAT DESIGN

The cryostat was build by the company CryoVac (Troisdorf, Germany) and was delivered in July 2011 to ANKA.

The inner part of the cryostat is in vacuum, to perform tests with conduction cooled superconducting coils like in final IDs and to be as flexible as possible for using various measuring techniques such a Hall samples and the stretched wire technique. As shown in Fig. 1 the cryostat has a shell-like structure with 3 plates at 300 K, 80 K and 4 K, with respective shields to facilitate the exchange of the coils.

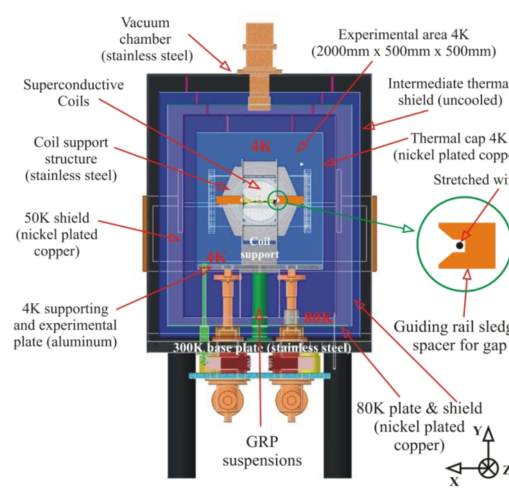

Figure 1: Sectional view from the front of the cryostat showing the different temperature regions.

Cooling the 80 K plate and pre-cooling the 4 K plate will be done via heat exchangers. To reach the final 4 K on that plate four 2-stage cryocoolers are installed. To power the main coils and/or additional correction coils 8 current leads with 500 A each are mounted (Fig. 2). To reduce the thermal heat load on the 80 K shield caused by radiation, there is one uncooled high emissivity shield fixed with GRP (glass reinforced plastic) suspensions at

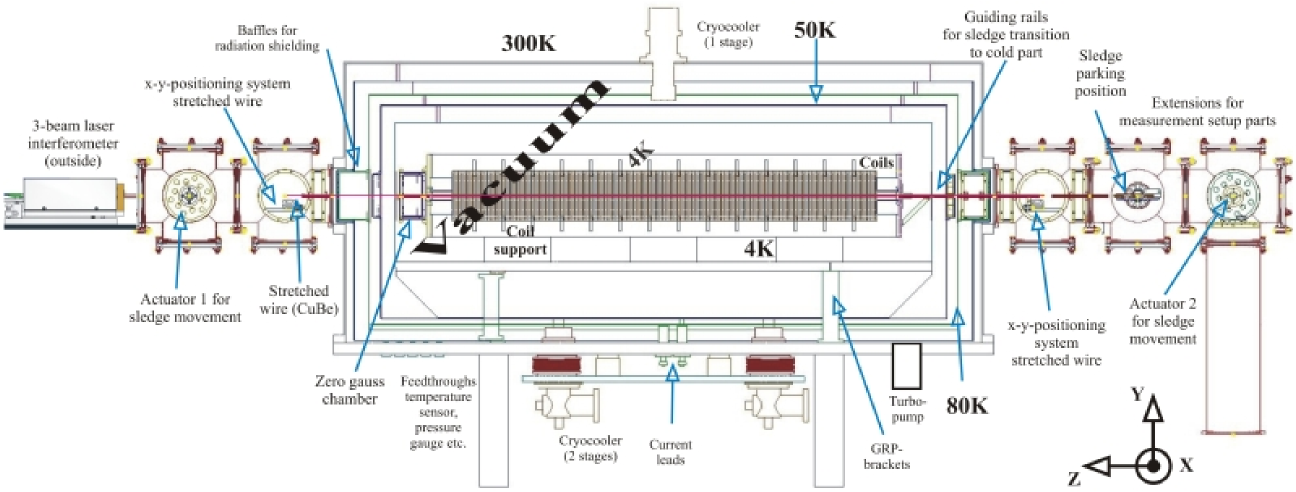

Figure 2: Drawing of the cryostat CASPER II with equipment for local and integral field measurements.

the outer stainless steel vacuum chamber. This shield reduces the thermal load on the 80 K one. The 80 K shield is cooled by a single stage cryocooler (Fig. 2). Additional technical details are given in [4].

MEASUREMENT SETUP

To measure the magnetic field properties of the coils two measurement techniques will be applied: Hall sensors for local field measurements and the stretched wire method to measure field integrals and multipole components. The coils are mounted in a stiff stainless steel support structure which takes the force resulting from the magnetic field, and are arranged horizontally as in the final ID. The mechanical accuracies required for the measurements are described in detail in [4].

Local Field Measurements

For local field measurements three Hall sensors are placed on a brass sledge which will be pulled through the gap along the undulator.

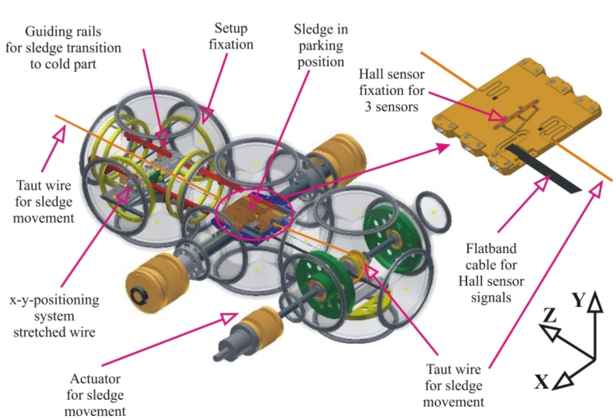

Figure 3: Drawing of the measurement parts for local field measurements.

On each side of the sledge, a wire is attached to enforce the movement in both directions by two stepper motors located on both sides of the cryostat (Fig. 2).

The motors work synchronous and coil the wire on a bobbin (Fig. 3). The precise position of the sledge and of the Hall samples along the moving direction is measured by a laser interferometer SIOS SP-2000-TR within 1µm. In order to measure the field in the middle of the gap the sledge is guided by sliding rails (Fig. 1 and 2), which are part of the coils support structure and a have extensions to guide the sledge to the room temperature region (Fig. 3), where it has to be parked while measuring with the stretched wire.

To check the calibration of the Hall sensors it is planned a µ-metal zero gauss chamber. To shield the sensors from all stray fields, it will be mounted at the end of the support structure (Fig. 2). On the other side, to test the field dependence of the Hall samples at values up to 1 T, a pair of racetrack coils is foreseen.

Field Integral Measurements

The change in angle and position of the electron beam at the undulator exit caused by the undulator are proportional to the first and second field integral, respectively. It is important to keep the field integrals as small as possible to keep the undulator transparent for the electron beam.

To measure the field integrals we will make use of the stretched wire technique: a thin wire stretched along the ID is moved in the gap of the undulator perpendicular to the main beam motion. The voltage induced by the movement of the wire is proportional to the field integrals values.

In this setup a Copper Beryllium wire with 125 µm diameter is used. The tension to keep the wire straight is applied by a 500 g weight fixed at one wire end and put on a deviation roll (Fig. 4). The movement will be performed by an x-y-positioning system on each side with encoders with 1 µm resolution. The units can move 130 mm in x-direction and ± 20 mm in y-direction

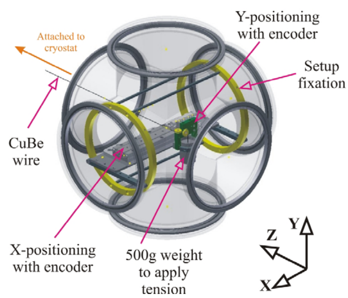

Figure 4: Measurement components for integral field measurements.

synchronous or in opposite direction (for further details see [3]).

FACTORY ACCEPTANCE TEST

The factory acceptance test (FAT) of the cryostat has been performed. The functionality of all electrical and mechanical parts has been proved.

In table 1 are summarize selected results of the FAT. Specific attention was paid to the temperatures in the 4 K region because of their crucial importance to cool the superconducting coils.

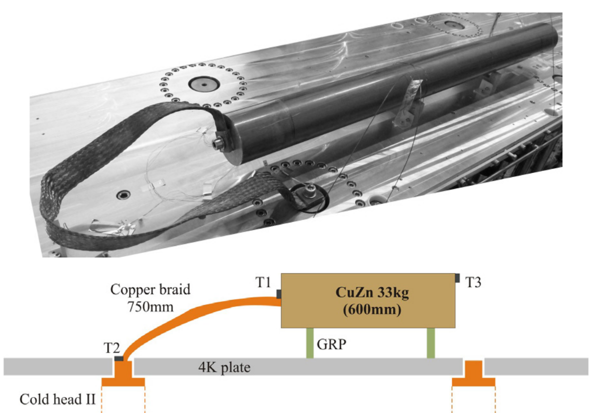

Figure 5: Picture and schematic side view of the 4K plate with FAT temperature test setup.

The superconducting coils assembled in the support structure will be directly connected with copper braids to the cryocooler cold heads and will be thermally isolated from the 4 K plate. To simulate the final temperatures reachable by the superconducting coils we arranged a 60 cm long brass block thermally disconnected from the 4 K plate, placed in the middle of it (Fig. 5) and cooled via a 750 mm copper braid (cross section ~50 mm²) to one cryocooler cold head. Three CERNOX temperature sensors were clamped to this setup.

The final temperatures reached after cool down and other specified parameters are shown in Table 1. Temperatures except T1 to T3 are averaged temperatures (sign ∅) because of several measurement points on the same cryostat element.

Table 1: Summary of Factory Acceptance Test

Component	Specified value	Reached value
Recipient pressure before starting turbo pump	p ~ 0.5 mbar	1 mbar
Time to reach this pressure	t < 1 h	35 min.
Base pressure before start cooling	p ~ 10^{-4} mbar	$5*10^{-4}$ mbar
Time to reach base pressure	t < 2 h	55 min.
Final pressure while operation	p < $5*10^{-6}$ mbar	< 10^{-6} mbar
Temperature 80K-plate	T < 85 K	∅ 83 K
Temperature 80K-shield	T < 100 K	∅ 85 K
Temperature 50K-shield	T < 60 K	∅ 50 K
Temperature 4K-shield	T < 10 K	∅ 6.2 K
Temperature 4K-plate	T < 4.5 K	∅ 4.5 K
T1	targeted < 4 K	3.6 K
T2	"	3.4 K
T3	"	3.7 K

CONCLUSION

In order to perform magnetic field measurements of superconducting IDs a horizontal, helium-free, in-vacuum measurement system is currently at the end of the construction phase. The cryostat is manufactured, has passed the factory acceptance test and has been delivered to ANKA. The system will allow to measure coils up to a length of 2 m. Applied measurement techniques will be integral field measurements via stretched wire and local field mapping with Hall sensors.

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