PLANAR AND PLANAR HELICAL SUPERCONDUCTIVE UNDULATORS FOR STORAGE RINGS: STATE OF THE ART *

A. Bernhard, B. Kostka, R. Rossmanith#, Institute for Synchrotron Radiation, T. Schneider, Institute for Technical Physics, Forschungszentrum Karlsruhe, Germany
D. Dölling, A. Hobl, D.Krischel, S. Kubsky, ACCEL Instr. GmbH, Bergisch Gladbach, Germany
U. Schindler, E. Steffens, University of Erlangen-Nürnberg, Germany

Abstract

In the past planar superconductive undulators for single pass operation were built and successfully tested with beam [1]. As a next step devices suitable for storage rings are in preparation. Experiments will be conducted with the aim to clarify various open questions concerning the operation of a cold bore undulator in a storage ring, the heat load generated by the beam in the cold bore, phase error compensation etc. The beam tests will be performed in the ANKA storage ring in Karlsruhe. After completion of these tests the interest will focus on a next generation of superconductive undulators with electrically adjustable period length and variable polarization direction. The first steps in this direction are mentioned at the end this paper.

THE SUPERCONDUCTIVE UNDULATOR FOR ANKA

The basic design concept for superconductive undulators has been described in several papers [2,3,7]. The parameters of the ANKA undulator are as follows:

Period length: 14 mm
Gap variable in steps: 5, 8, 12 and 16 mm
Length: 100 periods
The coils are shown in fig. 1 before final assembly.

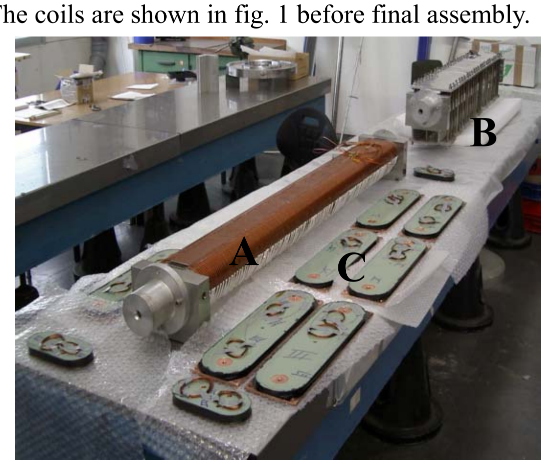


Fig. 1 The coils of the ANKA undulator before final assembly. A und B are the undulator coils during different construction phases. After coiling the wire is temporarily kept under tension in a metal container (B). After fixation the container is removed (A). C are the correction coils.

Fig. 2 Vacuum vessel (insulation vacuum) for each of the coils. The correction coils are also inside the vacuum vessel

The technique used to construct osuperconductive undulator coils is in the meantime well established. For storage ring operation each of these two coils together with the correction coils is enclosed in a separate vacuum vessel (fig. 2).

The barrier between the beam and the undulator coil is a thin foil with a 50 µm copper coating. In order to minimize resistive wall heating the RRR factor of the copper foil is better than 100.

The two parts of the undulator are surrounded by a vacuum vessel cooled to about 60 K (fig.3). The whole cooling system is cryogen-free (with cryo-coolers).

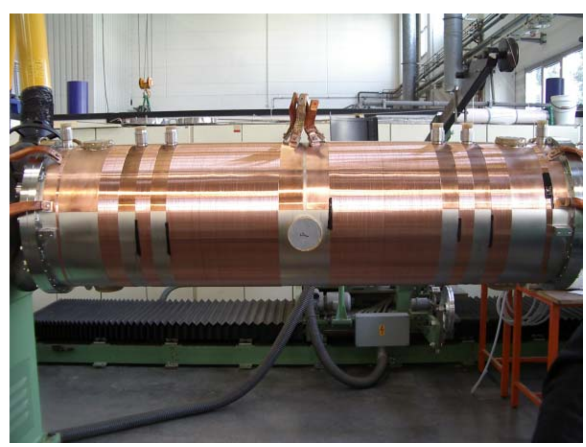


Fig. 3 The inner vacuum vessel of the undulator during assembly

*Work supported by the German BMBF Research grant ESAN05013603 and the 6th European Framework Program
#Corresponding author, rossmanith@anka.fzk.de

FIELD MEASUREMENTS

Field measurements in superconductive undulators with Hall probes [6] and stretched wire techniques for field integrals have now become become a standard technique. Nevertheless, Hall probe measurements are difficult to interpret [4] and are subject to various controversal discussions. In this paper we only point out the limits of the present field measurements. The measurements were performed for the first time in a cryostat suitable for operation in a storage ring (fig. 2). The data were measured with a set of five Hall probes at a gap of 8 mm in a vertical Dewar (Fig. 4).

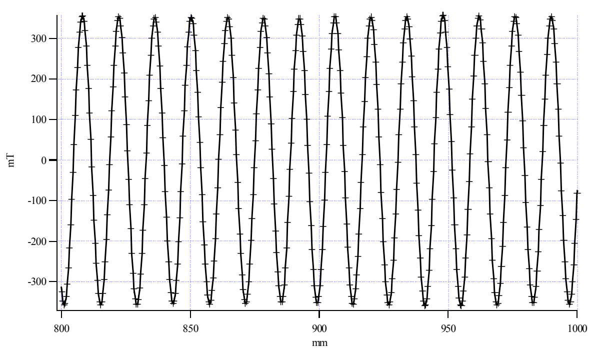


Fig. 4 Arbitrary selected undulator section (14 periods out of 100) close to the middle of the undulator. The current is 500 A and the gap is 8 mm. The points at which the measurement is performed are marked by a cross. The measured points are connected by a fit curve.

The measurement at discrete points (as shown in fig. 4) limits the accuracy of the measurement. The average period length calculated from fig. 4 (averaged over 14 periods) is 13.995 mm as compared to the design period length of 14 mm. The relative deviation is 5. 10^{-3}. A more detailed analysis shows that the period length averaged over the whole undulator is 14.008 mm.

Due to the discrete measuring points (the measuring points are 431,6 µm apart) the individual period length error can only be evaluated up to a certain limit: the period length seems to oscillate due to the fixed measuring points in fig. 4 around 14 mm as shown in fig. 5. This uncertainty can only be improved by choosing more measuring points per period which leads to an extremely time-consuming measurement. The uncertainty shown in fig. 5 corresponds to about ± 1.7 %.

From a technical point of view the measurement of the longitudinal position of the Hall probe is somewhat difficult since the Hall probe has to be positioned very accurately in the LHe path. There are two different ways of measuring the position: firstly, by a position sensor attached to the stepper motor moving the Hall probe and secondly by an optical interferometer. Only the stepper motor positioning system was used for the measurement.

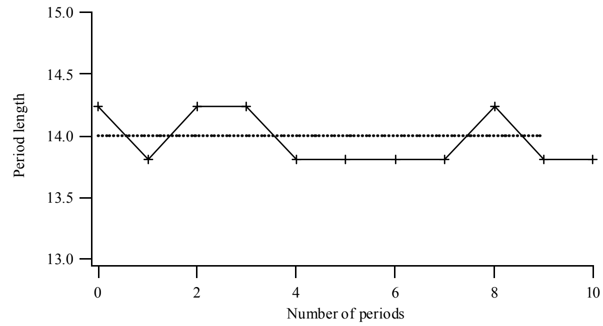


Fig. 5 Uncertainty in evaluating the period length due to the finite step width of 431.6 µm of the measured points. The measured period length (solid line) oscillates around the nominal period length of 14 mm. The uncertainty is about ± 1.7 %.

Before the field measurements were performed the field in the undulator was measured with zero current. The measurement showed that the zero effect is negligible. The absolute maxima of the field from fig. 4 are shown in fig. 6 (two values for each period).

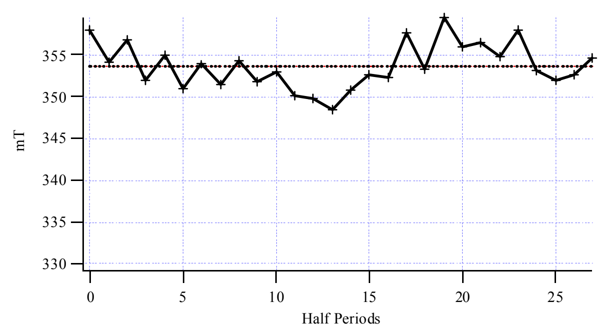
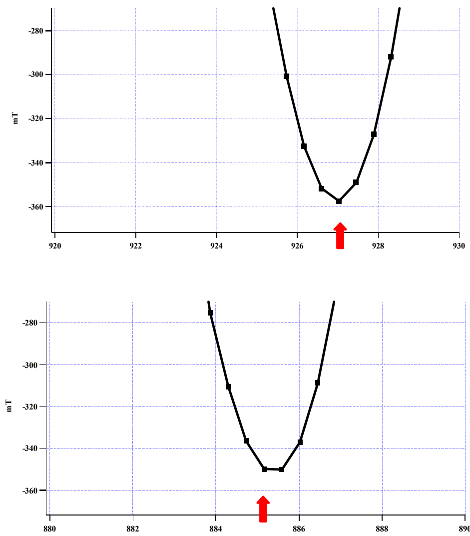


Fig. 6 Fluctuations of the maxima from fig. 4. The fluctuations are ≤ ± 1.2 %

The amplitude fluctuations are the same for the negative and the positive field values: ± 1.2 %. This demonstrates that there is no systematic error, neither from a zero current field nor from the Hall probe itself. Fig. 5 and fig. 6 show that the field errors are not correlated to the period length errors.

The fluctuations in fig. 6 can be explained in the following way. Figs. 7 a and b show two maxima and the points where the measurements are performed. Due to the chosen distance between the measuring points the amplitude appears different for each maximum. This explains the amplitude fluctuations which are in reality obviously smaller than the 1.2 %.

These two examples demonstrate that a precise measurement of the distributed errors is time consuming and will be presented in a future paper.



Figs.7 a and b Explanation of the amplitude variation in fig. 6. Due to equidistant measuring points an artificial amplitude error is generated which has to be corrected before the quality of the field is evaluated.

POSSIBLE NEXT GENERATION OF SUPERCONDUCTIVE UNDULATORS: SUPERCONDUCTIVE PLANAR-HELICAL UNDULATORS

Superconductive undulators make it possible to change the emitted wavelength electrically without any mechanical motions. Recently it was discussed whether this principle could be extended to other undulator parameters, e.g. light polarization. First ideas on an undulator with an electrically changeable polarization direction are briefly summarized in the following [5].

The principal layout of the undulator is shown in fig. 8. The undulator consists of two planar undulators: the coils of the inner undulator are tilted by 45 degrees. The tilted wires produce a horizontal and vertical field , the untilted ones a vertical field. By changing the currents through the wires the polarization direction can be changed.

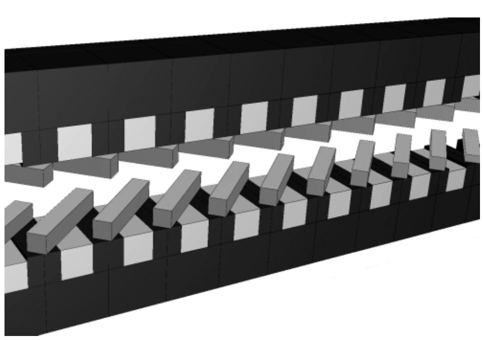


Fig. 8 A possible layout of a planar helical undulator with electrically switchable helicity direction. The dark parts consist of magnetic iron, the brighter parts are superconductive wires.

Fig. 9 shows as an example of how the directions of the polarization can be changed electrically.

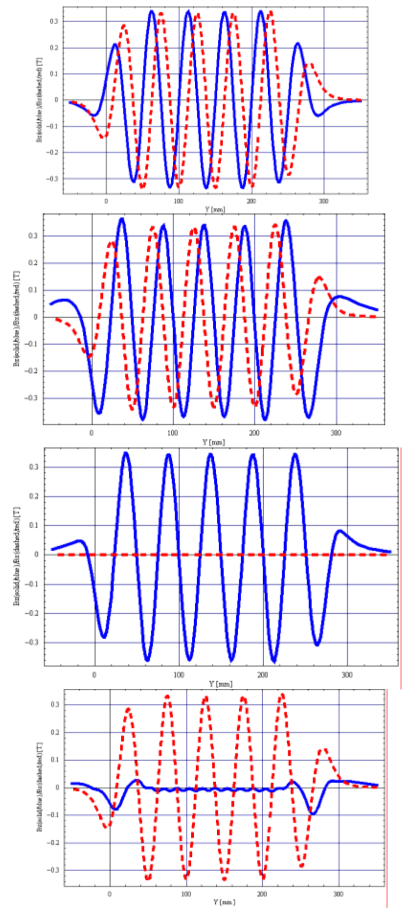


Fig. 9 The direction of the light polarization can be changed (from top to bottom: both helicities, vertical and horizontal) purely electrically without moving mechanical parts. Blue (solid line) is the vertical field, red (dotted line) the horizontal field.

REFERENCES

[1] T. Hezel et al., PAC 1999, New York, http://accelconf.web.cern.ch/accelconf/

[2] R. Rossmanith, H. O. Moser, EPAC 2000, Vienna http://accelconf.web.cern.ch/accelconf/

[3] S. Kubsky et al., Proc. SRI 03, San Francisco 2003

[4] J.Chavanne, P. Elleaume, Processing of the Magnetic Measurements of the ACCEL NUS superconducting unduator, ESRF internal note, private communication

[5] B. Kostka et al., APAC 03, Gyeongju, Korea http://accelconf.web.cern.ch/accelconf/

[6] R. Rossmanith et al., EPAC 2002, Paris APAC 03, http://accelconf.web.cern.ch/accelconf/
S. H. Kim et al., APAC 03, Gyeongju, Korea http://accelconf.web.cern.ch/accelconf/

[7] I. Ben-Zvi et al., Nucl. Instr. Meth. A vol. 297 (1990) 301