SUPERCONDUCTIVE 14 MM PERIOD UNDULATORS FOR SINGLE PASS ACCELERATORS (FELS) AND STORAGE RINGS

R. Rossmanith, Forschungszentrum Karlsruhe, Germany and National University of Singapore
H. O. Moser, Singapore Synchrotron Light Source, National University of Singapore
A. Geisler, A. Hobl, D. Krischel, M. Schillo, ACCEL Instruments, Germany

Abstract

Two superconductive undulators with a period length of 14 mm are under construction for ANKA (2.5 GeV storage ring) and the 100 MeV microtron beam of the National University of Singapore after a first successful beam test of a superconductive undulator with a period length of 3.8 mm at the Mainz Microtron MAMI [1] In order to test the production techniques a 10 period long prototype was built. In this paper the measurements of the field and the field errors are described

1 INTRODUCTION

Conventional undulators use permanent magnets (especially for short periods) or electro-magnets. With permanent magnets the properties of the magnetic material limit the magnetic field. Therefore numerous efforts exist to replace the permanent magnets by other elements: e.g. crystals [2] or superconductors [3]. Several years ago a novel superconductive undulator was built [1] which combined the advantages of superconductivity and in-vacuo design [4]. It was demonstrated that the field strength with superconductive undulators is significantly higher in comparison with permanent magnet undulators.

Both ANKA [5] and the National University of Singapore (NUS) [6] recently independently showed interest in an undulator whose radiation can be tuned electrically over a wide wavelength range.

The wavelength λ of the emitted light is (λ_u is the period length)

$$\lambda = \frac{\lambda_u}{2n\gamma^2}\left(1+\frac{k^2}{2}\right)$$

k=0.934. λ_u [cm]. B[T]

In order to cover a wide wavelength range the wavelengths between the first (n=1) and the third harmonics (n=3) have to overlap. As a result k has to be 2 at minimum. Simulations [7] show that a gap of 4 to 5 mm leads to k=2 when the period length is 14 to 15 mm.

Finally it was decided to build together with ACCEL as industrial partner a superconductive undulator with a period length of 14 mm (50 periods for NUS and 100 periods for ANKA) in three steps:

a.) Construction of a small prototype of the undulator body (10 periods long) without the cryostat

b.) Construction and test of a precise Hall-probe device to measure the field and the field errors.

c.) Design and construction of a cryostat suitable for in-vacuo operation which fulfills the stringent requirements for being incorporated in a storage ring vacuum.

In the following the results obtained in the steps a.) and b.) are described. The design of the cryostat will be different for both undulators. For ANKA the stringent requirements for a storage ring vacuum requires several modifications which can be avoided when the undulator is installed in a single pass machine.

2 THE MECHANICAL DESIGN OF THE 10 PERIOD TEST DEVICE

The technical concept was already introduced in a previous paper [8]. Here only a short summary is given. The body of the undulator consists of two cylinders shown in fig. 1. The superconductive wires are fixed in grooves. The grooves next to the beam are perpendicular to the beam, the grooves opposite to the beam have a helical form. The large holes in the middle of each cylinder are foreseen for LHe.

The arrangement of the superconductive wires close to the beam are shown in fig. 2 with the matching sections at the begin and the end of the undulator.

A photograph of the coiled undulator with the four layers is shown in fig.3. The picture shows the part which is close to the beam.

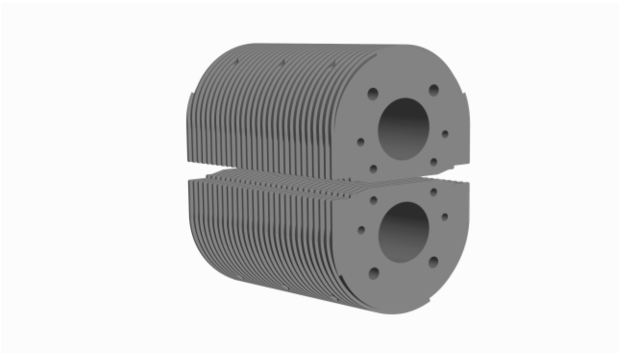

Fig. 1 The iron body of the undulator with the grooves for the superconductive wire. The beam travels along the gap. Through the big holes in the lower and upper part flows LHe

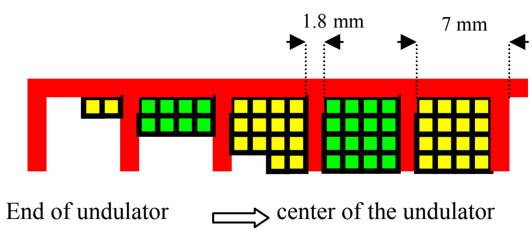

Fig. 2 For a period length of 14 mm and a k-value close to 2 each groove is filled with 16 wires. Towards the end of the undulator the number of the wires is reduced. The cross-section of one wire is about 1 mm^2. Wires with the same color (or grey values) have identical current directions.

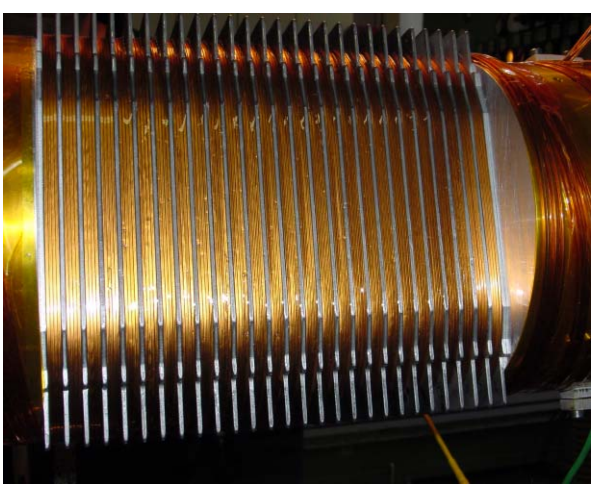

Fig. 3 Photo of the undulator showing the section close to the beam (see fig. 1). The dimensions are defined in fig. 2

3 FIELD MEASUREMENTS

The field measurements were performed in a vertical Dewar. The field was measured with calibrated Micro-Hall probes (active area 0.1 x 0.1 mm) in the center of the gap.

The micro-Hall probes were mounted on a sledge which could be moved along the center of the gap. The measurements were only performed when the sledge was moved into the upward direction.

Fig. 4 shows the measured field for a current of 1000 A (almost identical with a current density of 1000 A/mm^2). Fig. 5 shows the measured field at 500 A.

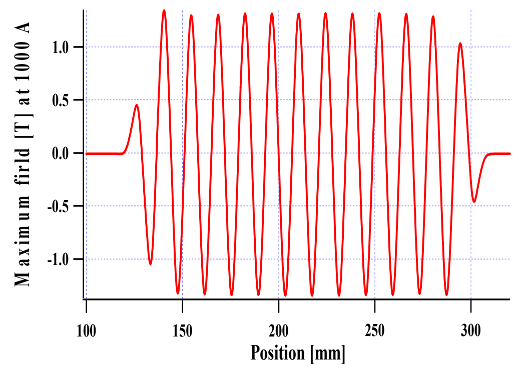

Fig. 4 Measured field along the trajectory with a current of 1000 A (almost identical with 1000 A/mm^2). The gap is 5 mm.

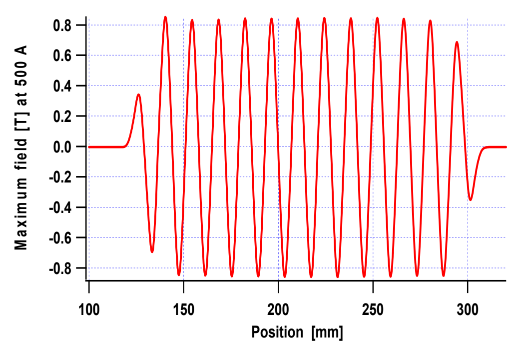

Fig. 5 Measured field along the trajectory with a current of 500 A (almost identical with 500 A/mm^2). The gap is 5 mm.

Fig. 6 shows the measured influence of the saturation of the iron on the maximum magnetic field. Above 150 A/mm^2 the saturation effects reduce the slope of the field curve. Above 200 A/mm^2 the slope again is linear.

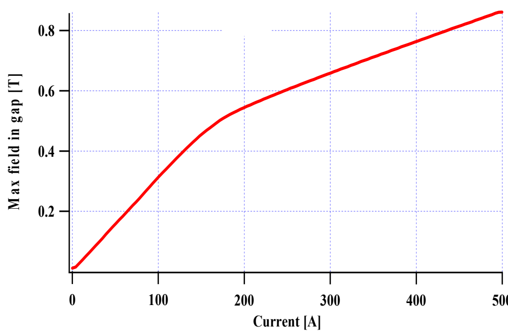

Fig. 6 The measured influence of the saturation of the iron on the maximum magnetic field.

The measured uncorrected first and the second integral are shown in fig. 7 and 8 (1000 A).

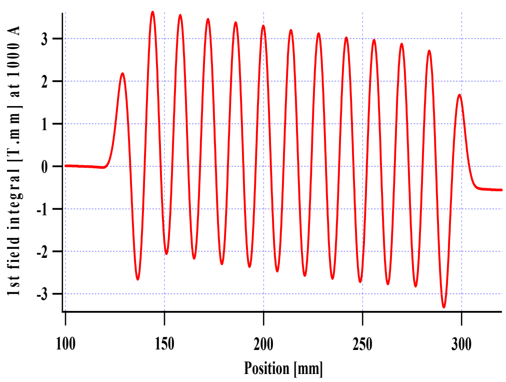

Fig. 7 The measured 1st field integral at a current of 1000 A/mm^2. The residual error is about -0.6 T.mm

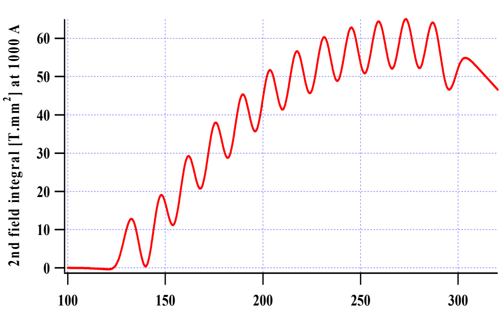

Fig. 8 The measured 2nd field integral at a current of 1000 A/mm^2

The field deviations in fig. 7 and 8 show that similar to conventional undulators correction coils are required. The correction coils could be two coils at the beginning and the end (1st and 2nd integral) and an added dipole field with a field strength of about 0.006 T.

The deviation of the period length from the specified value of 14 mm was carefully measured and is shown in fig. 9. Fig. 10 shows the measured phase error in degrees.

The maximum current through the undulator was 1060 A after 3 training steps. Below 900 A the ramping speed was 500 A/2min without a quench (limited by the power supply).

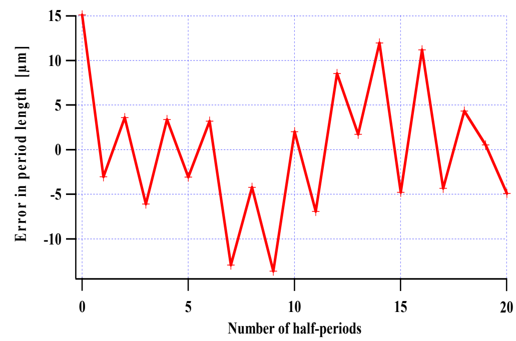

Fig.9 Measured deviation of the half-period length from the value of 7 mm. The specification asked for a maximum deviation of 20 µm, the measured value is significantly smaller.

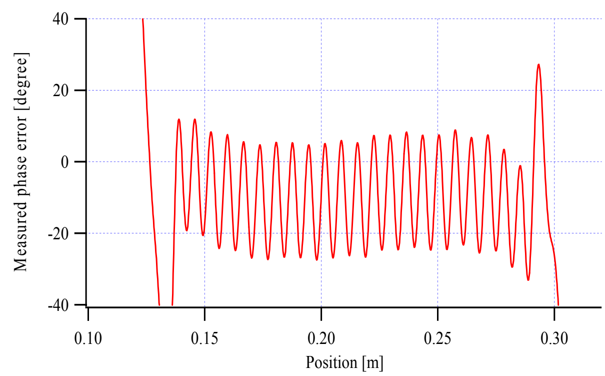

Fig. 10 Measured phase error in degrees

4 OUTLOOK

After these successful tests the 50 and the 100 period undulator are now under construction. Due to the gained experience the design of the two undulators will be slightly different

5 REFERENCES

[1] T. Hezel et al., Proc. PAC 1999, New York
[2] A. Korol et al., J. Phys. G: Nucl. Part. Phys. 24 (May 1998) L45-L53
[3] H. Moser et al., Germ. Patent P101 094.9-33
I. Ben-Zvi et al., Nucl. Instr. Meth. A297 (1990) 301
[4] H. Kitamura et al., Nucl. Instr. Meth. A467 (2001) 110
[5] H. Moser et al., Proc. EPAC 2000, Vienna
[6] H. Moser et al., Proc. APAC'01, Beijing
[7] H. Moser, R. Rossmanith, Magnetic field of superconductive in-vacuo undulators in comparison with permanent magnet undulators, Nucl. Instr. Meth. A, in press and electronic preprint:
http://lanl.arxiv.org/abs/physics/0204037
[8] A. Geisler et al., Proc. PAC-2001- Chicago