DESIGN STUDY OF A SUPERCONDUCTIVE IN-VACUO UNDULATOR FOR STORAGE RINGS WITH AN ELECTRICAL TUNABILITY BETWEEN K=0 AND 2

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Abstract

After the first successful tests of a superconductive in-vacuo undulator by a Karlsruhe-Mainz group [1] with beam the design study of a superconductive in-vacuo undulator for a storage ring is presented in this paper. The period length of the undulator will be 14 mm and the electrical tunability is between K=0 and 2. The idea is to build first a short version of the undulator, perform first tests and afterwards build a device which can be installed and tested in ANKA [2]. The undulator is foreseen for a beam line where rapid changes of the wavelength of the X-ray radiation are required.

1 OVERVIEW OF THE TEST RESULTS

The undulator tested with an 855 MeV beam consists mainly of a superconductive wire coiled around an iron core. The coiling technique is shown in fig. 1.

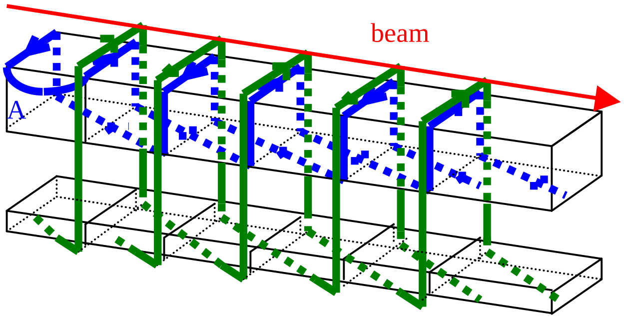

Figure 1: Coiling technique for a short period undulator

The coiling begins at the upper left-hand part of the undulator (A). The wire forming the loop is fixed and both wire ends are coiled together around the first bar. Afterwards the second bar is attached and the wiring is continued around the first and the second bar. This coiling technique allows to obtain short period undulators (in this case 3.8 mm period length) and stacks of wires with the same current direction close to the beam.

The short period length requires a small gap. In order to keep the undulator field high the gap width should not exceed one third of the period length. During the experiments the gap width for this undulator was 2 mm. The undulator worked without any technical problems. A beam of 50 µA cw did not cause any quench. On the other hand the field was not very high (0.15 T) limited by the room temperature conductors between power supply and undulator. The cables were only able to transport 300 A.

2 THE STORAGE RING COMPATIBLE SUPERCONDUCTIVE UNDULATOR

2.1 Specification

After the first successful beam tests an experiment of the new undulator device in a storage ring is foreseen. A short outline of the specification is shown in Table 1.

Table 1: Undulator specification

Period length λ_u	mm	14
Nominal gap	mm	5
Gap width variation	mm	1-15
Number of periods		100
Max. field strength in the center of the gap (5 mm gap width)	T	≥1.5
Max field error within a horizontal range of ± 30 mm from the axis	T	≤ 0.01
Long-term stability of the field		$\leq 10^{-4}$

The period length was chosen to provide the optimum spectra for the ANKA energy (2.5 GeV) without reducing the gap width (5 mm nominal) too much. If a gap width of 5 mm would interfere with the operation of the storage ring it could be increased mechanically up to 15 mm.

2.2 Technical layout

The inner part of the undulator (without compensation of the end fields and correction coils) is shown in fig.2.

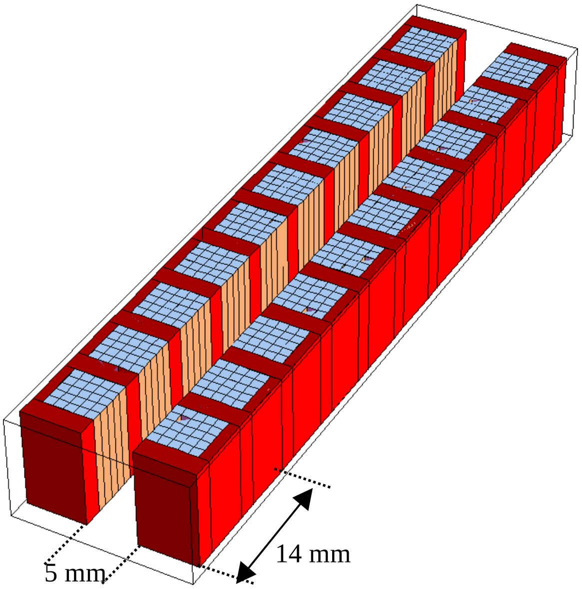

Figure 2: Central part of the undulator (red=iron). The current direction alternates from one coil package to the next.

The red parts represent iron, the brighter parts are superconductors. In this example the superconductive wires have a cross section of 1 x 1mm^2. In reality a smaller wire size is more advantageous in order to reduce the current and to minimize the technical problems at the current feed-through.

The coiling technique shown in fig. 1 has to be modified. One possible modification is shown in fig. 3.

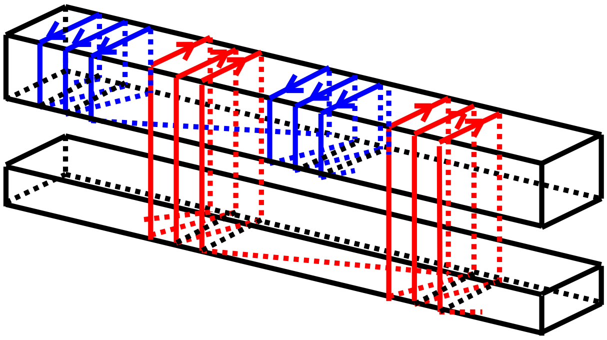

Figure 3 Coiling technique for a 14 mm period gap undulator. The second, lower bar is much smaller than the first so that the residual solenoid field is negligible

In a first step the wire is coiled around the central part as before. Afterwards the second bar is attached and the coiling continued.

In order to obtain several layers the coiling techniques shown in fig.1 and 2 can be combined.

2.3 End Field Compensation and Trajectory Optimization

The end regions of the undulator can deflect the incoming particle and slightly bend the trajectory. It is therefore very important to compensate the end fields of the undulator. One possibility of compensation is shown in fig. 4. Again the darker parts are iron, the lighter parts the superconductive wire stacks. In the figure only a short undulator is shown. The real undulator is 100 periods long.

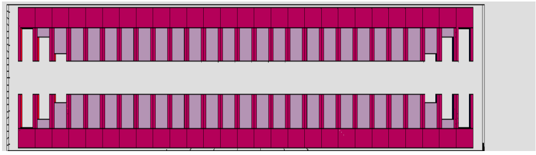

Figure 4: Compensation of end field effects by reducing the number of wires per groove

The calculated field for this device at a current density of 1 kA/mm^2 is shown in fig. 5 and the calculated particle trajectory in fig. 6. The calculations were performed with the code RADIA from ESRF [3].

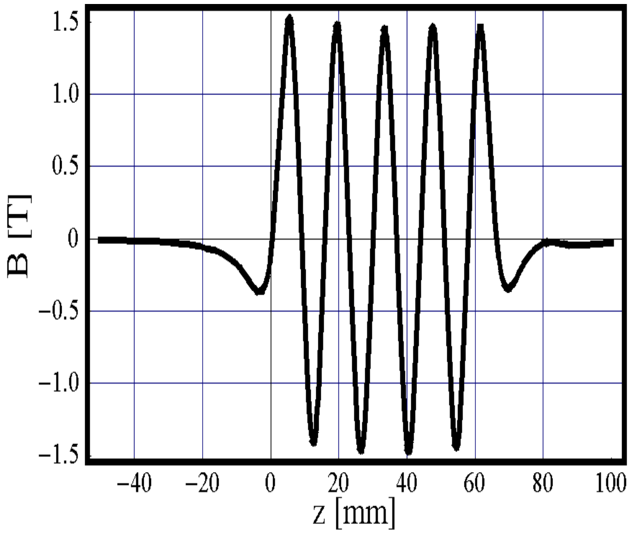

Figure 5: Field in the center of the 5 mm gap in Tesla at a current density of 1 kA/mm^2

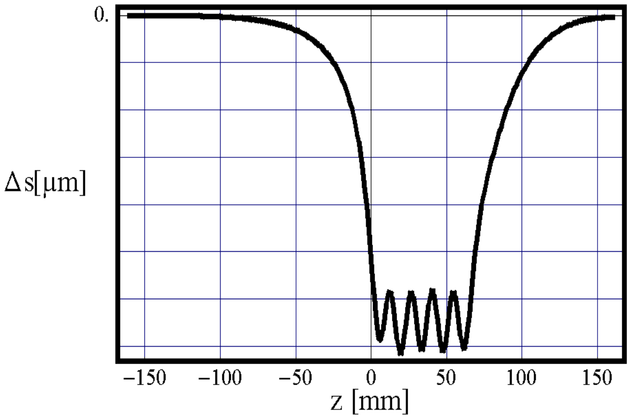

Figure 6: Calculated particle trajectory for the field shown in fig. 5. The particle displacement is shown in μm

The iron bars between the coil packages act as flux concentrators and as mechanical stabilizers for the coils. The highest field is concentrated in the iron bars outside the superconductor. Fig. 7 shows the field distribution inside the undulator. The field is calculated in the center of one of the undulator coils where it is higher compared to the center of the gap. The black bars in the drawing mark the position of the iron bars. The flux saturates the iron.

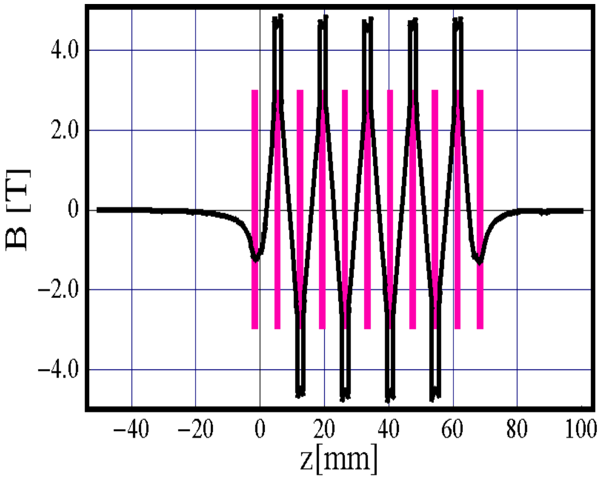

Figure 7: Calculated field inside one of the undulator coils. The red bars show the iron. The iron acts as flux concentrator.

In order to compensate the particle trajectory a couple of correction coils will be installed in the undulator. The correction coils are connected to individual power supplies. The correction coils allow to trim the undulator electrically during operation.

3 THE SPECTRA

The spectral range which can be accessed by ANKA with the undulator is shown in fig. 8. In this graph the tunability range for the 1st, 3rd, 5th and 7th harmonics is shown. The spectra are calculated with the program SRW from the ESRF [4].

The parameter list for the calculation of these spectra is shown in Table 2. It is assumed, that the undulator is installed in one of the straight sections of ANKA and, by introducing additional quadrupoles, the beta functions are small in both directions.

Table 2: Parameters for the spectra calculated in fig. 8

Beam		
Energy	GeV	2.5
Current	mA	400
ε_x	nm.rad	84
ε_y	nm.rad	1.7
β_x	m	0.9
β_y	m	0.9
Undulator		
Period length	mm	14
K_{max}		1.96

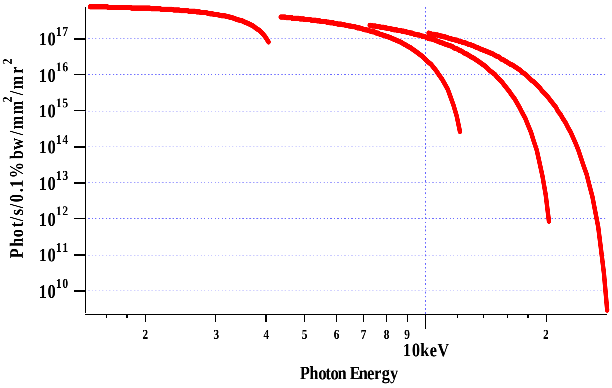

Fig. 8 Tunability of the 14 mm undulator for ANKA. Beam parameters shown in Table 2.

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