THE SECOND GENERATION OF SUPERCONDUCTING INSERTION DEVICES FOR ANKA*

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Abstract

After the superconducting undulator SCU14 was installed and successfully started operation at ANKA in spring 2005, a second generation of superconducting insertion devices for ANKA is under development. The ANKA soft X-ray analytics beamline WERA is planned to be equipped with a superconducting elliptically polarising undulator (SCEPU) with electrically tunable polarisation, and a superconducing combined undulator/wiggler (SCUW) capable of period tripling will serve as the source for the planned ANKA imaging beamline.

In this paper the studies on the ANKA superconducting EPU and the status of the SCUW-project will be reviewed.

INTRODUCTION

Superconductive undulators (SCUs) have the potential to overcome fundamental limits of state of the art permanent magnet undulators in terms of the ratio of field amplitude to period length and thereby to considerably extend the spectral range of the synchrotron radiation accessible at a given electron beam energy [1, 2, 3, 4, 5].

Apart from this general property, the superconductive undulator technique provides the opportunity of purely electrically adjusting not only the field strength, but a whole set of parameters determining the characteristics of the emitted light such as field helicity and direction field quality or the undulator period length.

In spring 2005 the first cold-bore superconducting undulator, built by ACCEL Instruments, Germany, was installed at ANKA and for more than one year has shown to be reliability operable [6, 7]. In the next step a second generation of superconducting insertion devices for ANKA is under development. This development follows three major lines:

- *electrical shimming*: Based on the analysis of the field data of the ANKA-SCU an electrical shimming concept for superconducting undulators was studied theoretically and will be tested experimentally [8, 9, 10].
- *electrical polarisation control*: A superconducting elliptically polarising undulator employing a combination of a helical and a planar SCU for the ANKA soft X-ray analytics beamline was designed and several prototypes were fabricated and experimentally investigated
- *electrical period length switching*: By employing two or more independent sets of coil packs the period length of a superconducting undulator may be multiplied. A hybrid undulator/wiggler matching the experimental needs of the planned ANKA-IMAGE beamline relying on this concept is currently in the design phase.

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THE SUPERCONDUCTING ELLIPTICALLY POLARISING UNDULATOR

The general requirement for generating elliptically polarised undulator radiation is a magnetic field along the beam axis consisting of two phase-shifted sinusoidal transversal components. In particular, if the phase shift equals $\pm\frac{\pi}{2}$ and both components have equal amplitudes, the field will be ideally helical and the photons produced will be circularly polarised. A superconductive undulator generating a helical magnetic field can be realized by tilting the coil packs around the vertical axis as shown in fig. 1 ("helical coil packs"). However, such a simple arrangement

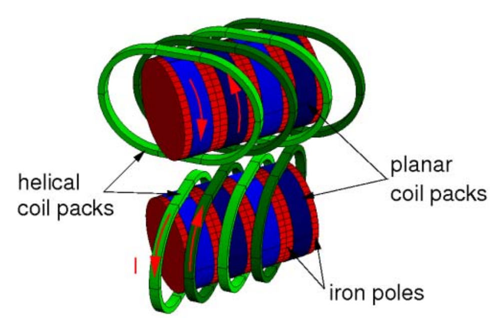

Figure 1: Coiling scheme for a superconductive EPU (2 periods) consisting of two nested independently powered SCUs. The outer SCU with tilted coil packs generates a helical magnetic field, the inner SCU a purely vertical field employed for electrically tuning the field helicity.

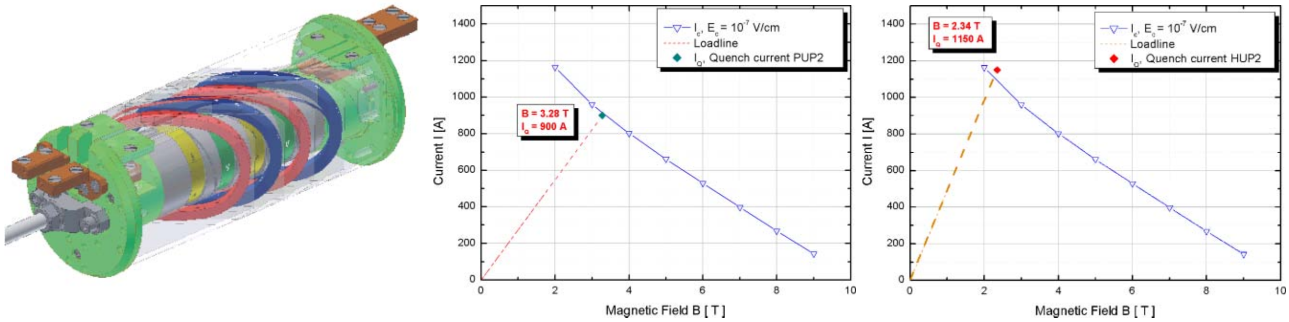

Figure 3: Quench test of the SCEPU prototype "P2" in liquid He at 4.2 K. The picture shows the prototype, the graphs show the loadlines and theoretical limits for the planar and the helical coil, respectively

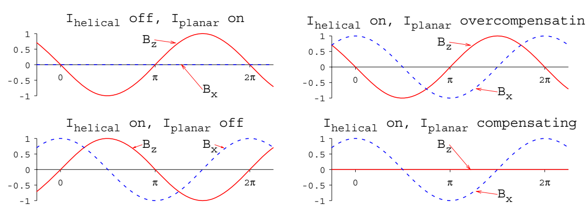

Figure 2: Field directions along beam axis for the four operation modes of a planar-helical SCEPU

does not provide any possiblilty to change the polarisation of the light as required for applications utilizing elliptically polarized X-rays like e.g. circular magnetic dichroism. Polarisation control can be achieved by combining the helical with a planar undulator (fig. 1, "planar coil packs") which is capable of over-compensating the vertical field component generated by the helical undulator. A combined planar-helical SCU can be operated in four modes corresponding to two linear and two circular polarization states of the radiation generated as shown in figure 2 [11, 12].

Several prototypes of combined planar-helical undulator coils were built at the Institute for Technical Physics of the Forschungszentrum Karlsruhe. Quench tests in liquid He and tentative magnetic field measurements were carried out, the coiling technique was optimised and particularly a technique for coiling 2 m long helical undulators was developed. For the prototype "P2" investigated at 4.2 K the short sample value for the critical current density was reached for both the helical and the planar coil, as shown in figure 3.

Apart from these tests showing the concept to work, a SCEPU relying on this concept was designed for the soft X-ray analytics beamline WERA at ANKA. The basic design parameters are summarised in table 1. The first harmonic of this insertion device covers a range from 400 to 1300 eV, i.e. the $2p$ absorption edges of the transition metals and the $3d$ absorption edges of the Lanthanides up to Tb. The estimated tuning curve is shown in figure 4.

Table 1: Basic design parameters for the SCEPU for the WERA-beamline at ANKA

Period length [mm]	45
Gap width (warm bore) [mm]	15
Number of periods	44
Helical field $B_{x,y\,\mathrm{max}}$ [T]	0.35
$K_{\mathrm{helical,max}} = K_{hx}^2 + K_{hy}^2$	2.06
Purely horizontal field $B_{x\,\mathrm{max}}$ [T]	0.37
$K_{x\,\mathrm{max}}$	1.53
Purely vertical field $B_{y\,\mathrm{max}}$ [T]	0.87
$K_{y\,\mathrm{max}}$	3.66

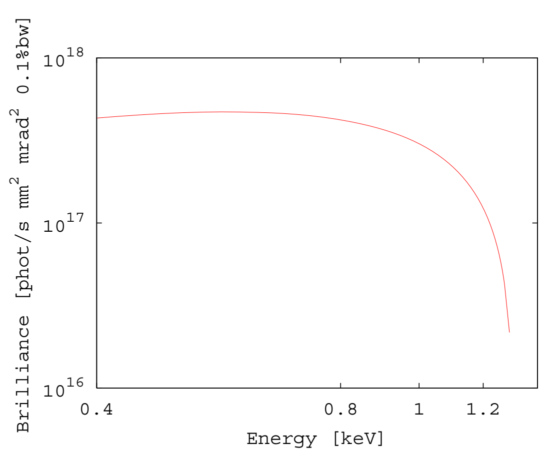

Figure 4: Tuning curve (1st. harmonic, circular polarisation) of the superconducting EPU for the soft X-ray analytics beamline WERA at ANKA, calculated with XTC (XOP) [13], assuming the design parameters listed in table 1 and ANKA electron beam parameters.

STUDIES ON A HYBRID SUPERCONDUCTING UNDULATOR/WIGGLER

In order to match the demands of the planned IMAGE-beamline for highly brilliant X-rays in the 10-20 keV en-

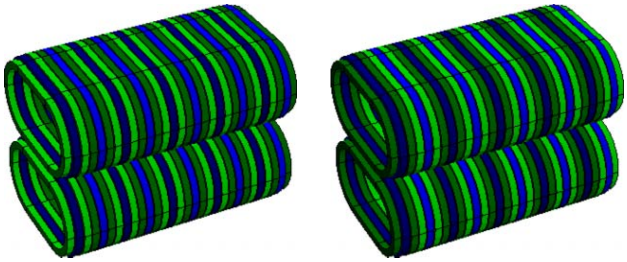

Figure 5: Coiling scheme for a superconducting undulator/wiggler (SCUW) capable of period tripling

Table 2: Basic design paramters for the ANKA SCUW

	Und.	Wiggler
Period length [mm]	15	45
Gap width (cold bore) [mm]	5	5
Number of Periods	99	33
Max. Field Amplitude [T]	1.5	3.5
$K_{\max}$	2	14.5

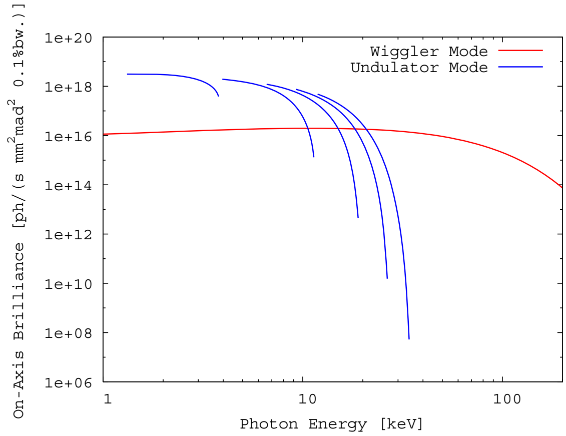

Figure 6: Tuning curve and spectrum of the radiation of the SCUW in undulator and wiggler operation mode, respectively.

ergy range on the one hand and a high flux in the hard X-ray regime up to 100 keV on the other hand, a concept for a superconductive insertion device capable of period length switching has been studied.

Electrically varying the period length of a superconductive insertion device requires coiling schemes with two or more sets of individually powerable coil packs. For the ANKA-IMAGE beamline a hybrid superconducting undulator/wiggler (SCUW) capable of period tripling is under study. The coiling scheme is illustrated in figure 5. The device consists of two individually powerable sets of coil packs, indicated in the figure by the colours green and blue. The current directions are indicated by the lighter and darker colours. Reverting the current direction in one of the coil sets changes the period length of the magnet structure by a factor of three.

Table 2 summarises basic design parameters chosen for the ANKA-SCUW. The device can be operated in an undulator mode with 15 mm period length and a wiggler mode with 45 mm period length. Estimated tuning curves/spectra for both operation modes are shown in figure 6.

CONCLUSIONS

Superconductive undulator technology provides the opportunity to control electrically characteristic parameters of the undulator field. In particular, superconducting coil arrangements can be realised which allow to electrically adjust the field helicity or field direction, respectively, and thereby the polarisation state of the emitted light. On the other hand, by properly arranging two or more independent sets of coil packs in one undulator coil, a period length multiplication may be achieved. At the Forschungszentrum Karlsruhe, two novel superconducting insertion devices making use of these concepts are under study and are planned to be built in the next years.

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