SUPERCONDUCTIVE UNDULATORS WITH VARIABLE POLARIZATION DIRECTION

B. Kostka, R. Rossmanith*,
Institute for Synchrotron Radiation /ANKA, Research Center Karlsruhe, Germany
A. Bernhard, U. Schindler, E. Steffens, University of Erlangen, Germany

Abstract
For certain applications there is a need for undulators which can produce circularly polarized light (EUV or X-rays) with variable polarization directions. In this paper a novel idea for such an undulator is described which is based on the recently developed concept for building high field superconductive undulators. The polarization direction in this new design is changed simply by altering the strength and the direction of currents in part of the windings.

INTRODUCTION

Most undulators in synchrotron light sources are planar (large horizontal and small vertical gap) undulators with a vertical field. The electrons (or positrons) are forced by these devices to oscillate in the horizontal plane. The light in the forward direction of the electrons is horizontally polarized. In addition to these commonly used undulators a few so-called helical or elliptical undulators exist which are designed to produce circularly or elliptically polarized radiation (for a detailed overview of these devices see for instance [1]).

For most of the applications a planar design (large horizontal and small vertical gap) has advantages over a circular shaped gap: the planar design is more compatible with storage rings beams, the gap is easier to pump etc.

Conventional helical undulators with switchable helicity are built with permanent magnets or electromagnets. In order to change the helicity, arrays of permanent magnets have to be moved mechanically. Conventional electromagnetic helical undulators have the advantage that no mechanically movement is necessary but the disadvantage that the period length is very long (e. g. 12 cm for the Duke undulator [2]).

This paper describes a new technique whereby a helical planar undulator with variable helicity can be built with superconductive wires. The polarization direction of these new devices can be altered by changing the current in parts of the wires without mechanically moving any parts of the undulator [3].

* Corresponding author: rossmanith@anka.fzk.de, Forschungszentrum Karlsruhe, Synchrotron Light Source ANKA, PO Box 3640, Karlsruhe Germany, Tel +49 7247-82-6179

THE ELEMENTS OF AN UNDULATOR WITH ELECTRICALLY ADJUSTABLE POLARIZATION

The required field for producing circular radiation is sketched in fig. 1. The particle first experiences a vertical field. As the particle moves along, the field vector rotates into the horizontal direction and afterwards further into the negative vertical direction. The field vector performs a continuous rotation, either clockwise (left picture) or anti-clockwise (right picture). As a result the particle performs a helical motion around its otherwise unperturbed trajectory. Should both the maximum horizontal and the maximum vertical magnetic field strength be equal, the generated synchrotron radiation is circularly polarized. Should the two field strengths not be equal, the synchrotron radiation is elliptically polarized.

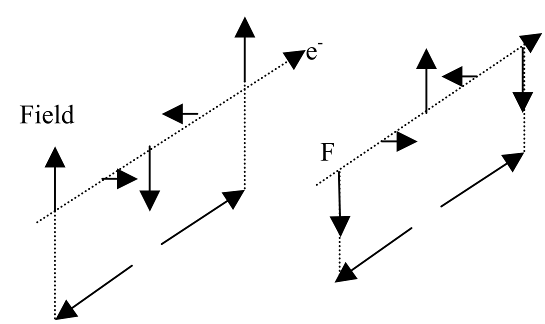

Figure 1: Field directions in a helical undulator. The field rotates either clockwise (left diagram) or anti-clockwise (right diagram) around the particle trajectory. Electrons following this field emit either right-handed or left-handed synchrotron radiation.

The field shown in fig. 1 is produced in the following way. Starting point for the explanation is a planar undulator built with superconductive wires as shown in fig. 2 [3]. The directions of the current flow is indicated by arrows. The current produces a magnetic field around the wires described by the law of Biot-Savart. When only the region around the beam axis is taken into account all magnetic fields in the direction of the field axis disappear. A vertical field is only to be found between two adjacent pairs of wires.

After the results of a beam test with a superconductive undulator had been published in 1999 [4], R. P. Walker [5] pointed out that this concept could be easily modified to obtain a helical undulator for fixed helicity. Later this idea was worked out in more detail by S. Sasaki [6] in several papers.

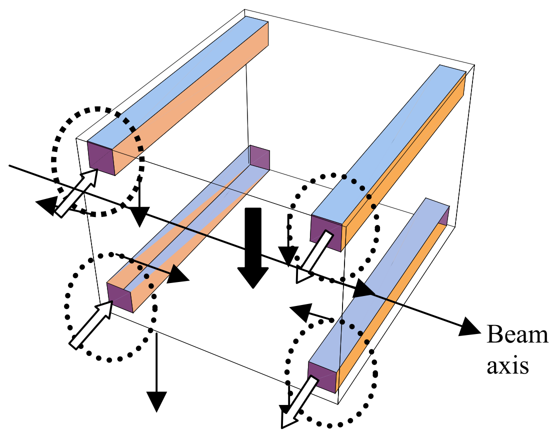

Figure 2: Principle of a planar superconductive undulator. The current flows in the directions marked by the arrows. The resulting field at the beam axis is vertical.

A residual horizontal field is generated when all the wires above the beam axis are rotated by a certain angle around the vertical axis and all the wires below the beam trajectory are rotated by the same angle but into the opposite direction as shown in fig. 3. The field components in the beam direction cancel each other out as in the previous case (fig. 4).

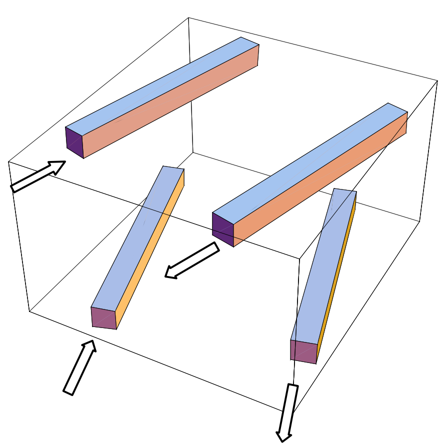

Figure 3: Wire arrangment in a superconductive undulator producing both vertical and horizontal field components. The horizontal field component results from the tilting of the wires.

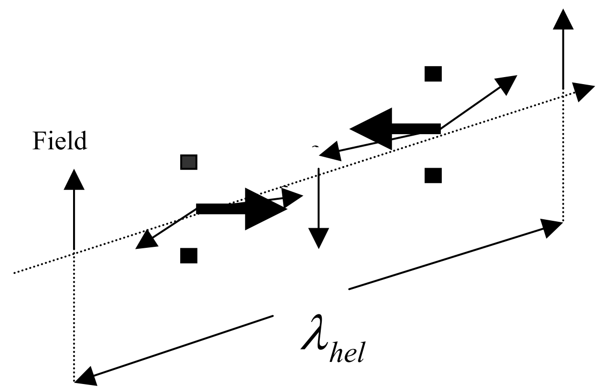

Figure 4: The field components produced by a wire arrangement shown in fig. 3. The inclination of the wires generates a residual horizontal component in between the wires along the beam axis. The thick arrows show the residual horizontal field.

THE UNDULATOR WITH ELECTRICALLY ADJUSTABLE POLARIZATION

The design is based on a very simple idea: a combination of a planar undulator (explained in fig. 2) and an undulator with tilted wires shown in fig. 3. Fig. 5 shows how the two undulators are combined. The inner undulator is the undulator shown in fig. 3 and produces both a horizontal and a vertical field. The ratio of the strength between the two fields depends on the rotation angle of the wires. Both components are in general not equal. The outer undulator is a conventional planar undulator generating a vertical field. The inner undulator and the outer undulator are connected to separate power supplies.

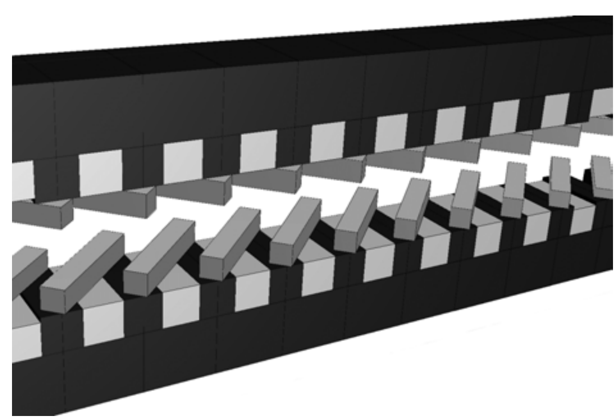

Figure 5: A possible layout of a planar helical undulator with electrically switchable helicity direction. The dark parts consist of magnetic iron, the brighter parts are superconductive wires.

The manner in which the undulator works is demonstrated with the help of fig. 6. In 6a the current through the outer undulator is adjusted so that the horizontal and vertical field are equally strong. By changing the polarity of the power supply and reversing the field of the outer undulator, the vertical field of the inner undulator is reduced until the horizontal and the absolute value of the vertical field are equal again (fig. 6b). The sign of the vertical field direction is now opposite and the helicity of the emitted light has changed sign.

If only the outer undulator is on, the field is purely vertical (fig. 6c). If the outer undulator compensates the vertical field of the inner undulator, the field direction is purely horizontal (fig. 6 d).

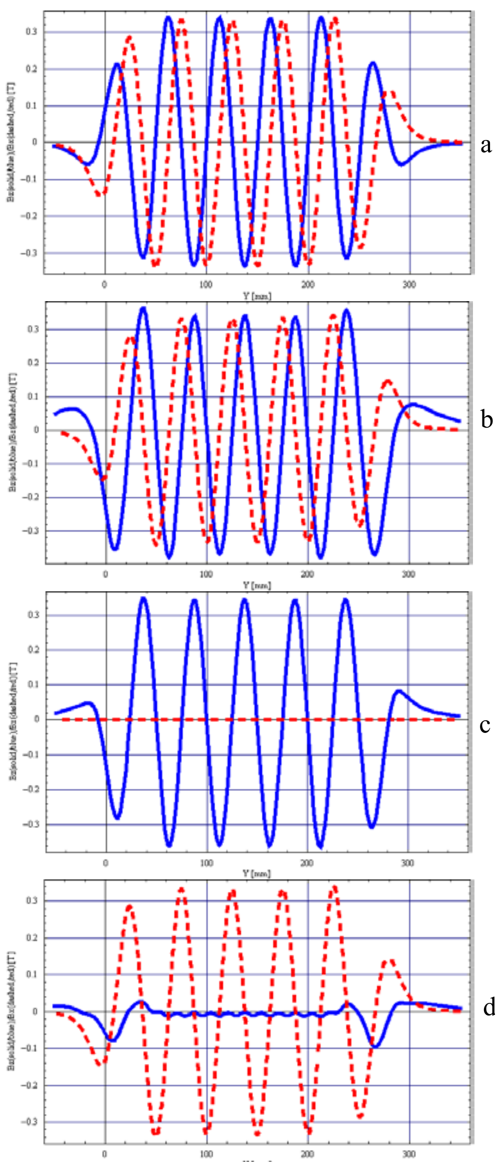

Figure 6: Field of the planar helical undulator shown in fig. 5. The currents are summarized in Table I. a: helicity, one direction. b: helicity other direction, c: purely vertical field , d: purely horizontal field.

The parameters of the undulator shown in fig. 6 are:
gap: 17 mm,
period length: 50 mm.

The wires of the inner undulator are tilted by 45 degrees relative to the outer undulator. For the sake of simplicity only 6 periods are shown. The end fields are not yet matched. This task will be dealt with in the future. The assumed wire thickness in the given example is 1.25 x 0.8 mm^2. Undulator A consists of 9 x 6 wires, the undulator B of 15 x 10 wires.

The field were calculated with the program RADIA [7]. The required currents are summarized in Table 1.

Table 1: Currents through the undulator of fig.6

	Current density through inner undulator in A/mm^2	Current density through outer undulator in A/mm^2
Right handed helicity	460	-115
Left handed helicity	460	-1000
Vertical field	0	-300
Horizontal field	460	-458

REFERENCES

[1] H. Onuki and P. Elleaume (Editors), Undulators, Wigglers and their Applications, Taylor and Francis, 2003

[2] V. N. Litvinenko et al., Nucl. Instr. Meth. A 475 (407) 2001

[3] R. Rossmanith, U. Schindler, German Patent Application DE 10358225.8

[4] T. Hezel et al., 1999 PAC, New York, http://accelconf.web.cern.ch/AccelConf/p99/

[5] R.P. Walker, New concept for a planar superconducting helical undulator, Oct. 18th 2000, ELETTRA internal report, private communication see also: Nagai Ryoji, Circular, elliptical or variable polarization type flat hybrid undulator, Japanese Patent Office, Patent Abstracts of Japan, Publication Number 10302999 A, 13. 11. 1998

[6] S. Sasaki, Design of a superconducting planar helical undulator, Proc. Workshop on Superconducting Wigglers and Undulators, ESRF, June, 2003, http://www.esrf.fr/Accelerators/Conferences/ID_Workshop

[7] P. Elleaume, O. Chubar and J. Chavanne, Proc. PAC97, Vancouver 1997, http://accelconf.web.cern.ch/accelconf/pac97/papers/pdf/9P027.PDF