CONCEPTUAL DESIGN OF A NOVEL SCAPE UNDULATOR *

Y. Ivanyushenkov†, J. Fuerst, Q. Hasse, M. Kasa, Y. Shiroyanagi, E. Trakhtenberg, and E. Gluskin,
Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA

Abstract

The concept of a novel SuperConducting Arbitrarily Polarizing Emitter, or SCAPE, has recently been suggested at the Advanced Photon Source (APS). It consists of two pairs – both vertical and horizontal – of superconducting planar magnets assembled around a beam vacuum chamber. Such a device will be capable of generating either planar or circularly polarized photons, depending on which pair of magnets is energized. The magnetic simulation suggests that due to the use of superconducting technology, the expected magnetic field is higher than that of the APPLE undulators. The SCAPE undulators introduce a viable alternative to PM undulators for the fourth generation of storage rings with a multi-bend achromat lattice, as well as for the FELs where utilization of round beam vacuum chambers becomes possible. The mechanical simplicity and higher magnetic field will make SCAPE-type undulator a supe-rior source of polarized x-rays. The results of magnetic modelling, as well as the design concept of the SCAPE, are presented.

INTRODUCTION

Superconducting undulators are electromagnetic undulators that employ superconducting coils for generating magnetic field. This technology offers the flexibility of winding undulator coils in various shapes, thus allowing for the realization of various types of undulator magnets. For instance, both planar and helical superconducting undulators can be fabricated [1].

It is quite typical that users of polarized x-rays would like to have a source, which can generate both circular and planar polarized photons. To answer this challenging request, a concept of a novel superconducting undulator – SCAPE, has been developed.

SCAPE CONCEPT

The SCAPE undulator consists of two pairs of planar-like magnetic cores arranged around a beam vacuum chamber, as shown in Fig. 1. Each core contains two sets of superconducting coils with the currents flowing in the opposite directions. One pair of cores is also longitudinally shifted against the other pair by a quarter of the undulator's period length. Such a structure generates a planar undulator field when one of the core pairs – either vertical or horizontal – is energized. Helical magnetic field is generated when all cores are energized. As a result, a SCAPE can produce either planar or circular (as well as elliptical) polarized radiation. A similar concept was realized with warm electromagnetic coils in [2]. In a

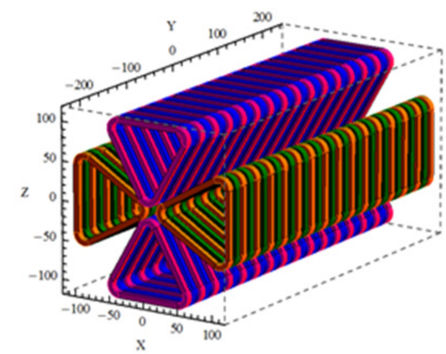

Figure 1: Concept of SCAPE— a universal SCU with four planar superconducting coil structures. A round beam chamber is not shown.

SCAPE, the magnetic field value depends on the coil currents and can be varied without any mechanical movement of the undulator cores, unlike in APPLE undulators.

It should be noted that the SCAPE magnetic field is maximized when a small-diameter round beam chamber is used. Such beam chambers become possible at the synchrotron light sources with multi-bend achromat lattices, including the APS Upgrade storage ring [3], as well as at FELs.

MAGNETIC SIMULATION

The magnetic modelling of the SCAPE is being performed in the Radia software package [4]. A typical simulated magnetic field profile (without end effects correction) is shown in Fig. 2.

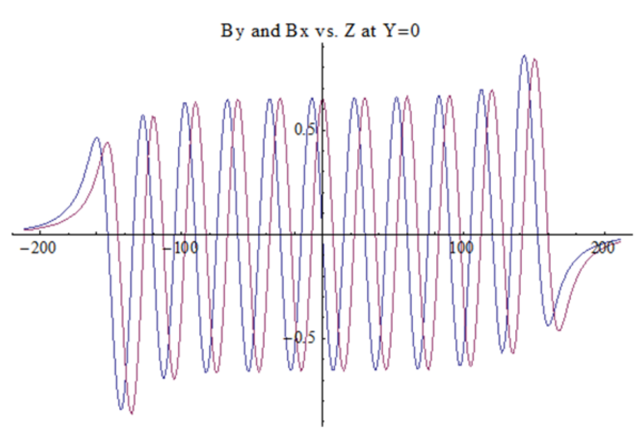

Figure 2: Simulated SCAPE magnetic field profiles in vertical plane (blue) and horizontal plane (red). Vertical axis is in T, and horizontal axis is in mm.

* Work supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357.
† yury@aps.anl.gov

The SCAPE coils could be realized in a variety of shapes including triangular coils, racetrack coils (see Fig. 3), or even circular coils. The triangular coils have been

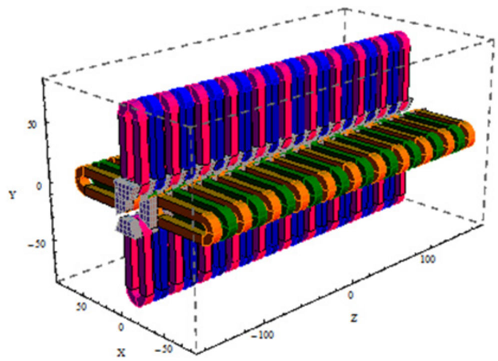

Figure 3: Possible SCAPE configuration with racetrack coils and magnetic poles.

chosen for a further analysis since they allow more room at the core back side for superconducting wire turns, similar to planar undulator cores.

The magnetic simulation shows that the magnetic field on the undulator's axis can be increased by about 30% when magnetic poles are added to superconducting coils. Also, to allow room for mechanical spacers between the cores, superconducting coils could be recessed, as shown in Fig. 4.

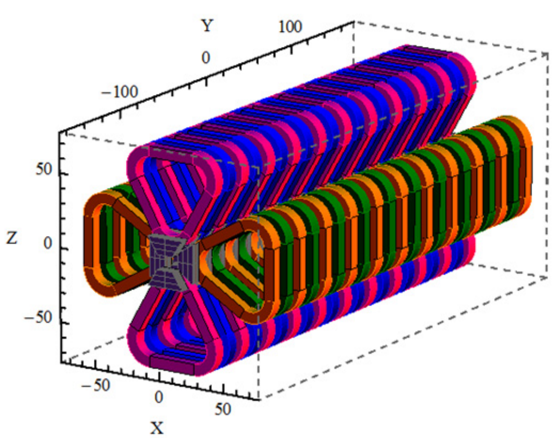

Figure 4: SCAPE configuration with recessed triangular coils and magnetic poles.

The APS Upgrade lattice enables a round beam chamber with the internal diameter of 6 mm. As a result, the gap between the magnetic poles could be as small as 10 mm. The simulation using the above Radia model, with the parameters listed in Table 1, predicts the field on axis of 1.03 T. The period length of 30 mm is chosen to satisfy the users' requirement to lower the energy of the 1st harmonic down to 2.75 keV with 6 GeV electron beam of the APS Upgrade.

Table 1: SCAPE Model Parameters and Simulated Field

Parameter	Value
Undulator period length, mm	30
Beam chamber ID, mm	6
Beam chamber OD, mm	9
Magnetic gap (pole-to-pole), mm	10
Coil recess, mm	2
Coil-to-coil gap, mm	14
Coil cross sectional dimensions, mm × mm	7.5 × 7.5
Coil current density, A/mm^2	1200
Undulator peak field, T	1.03

CONCEPTUAL DESIGN

The mechanical design of the SCAPE follows the concept developed during the magnetic simulation phase. It is also based on the APS's experience of fabricating superconducting planar undulator cores, as well as the experience of machining extruded Al beam chambers. The design model of the SCAPE magnet's components, showing four cores with magnetic poles and a beam chamber, is presented in Fig. 5.

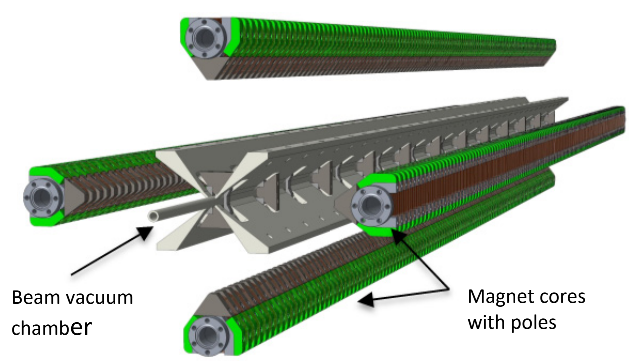

Figure 5: Exploded view of SCAPE magnet with a beam chamber.

The Al round beam chamber is integrated with longitudinal fins that are used to extract heat from the beam chamber. Preliminary estimations suggest that in the APS Upgrade lattice, the heating of a small aperture round beam chamber by synchrotron radiation from the upstream magnets could be as high as 300 W/m. With the chosen shape, a large amount of heat can be extracted from the Al beam chamber without overheating it. The magnet's core structures are similar to the planar SCU

ISBN 978-3-95450-182-3

cores, differing only in shape. The SCAPE cores are cooled by LHe passing through the channels in the cores. The nonmagnetic spacers that are reacting attractive forces between cores are also visible in Fig. 5. These spacers connect the cores through the openings in the beam chamber fins. A design model of the magnet assembly

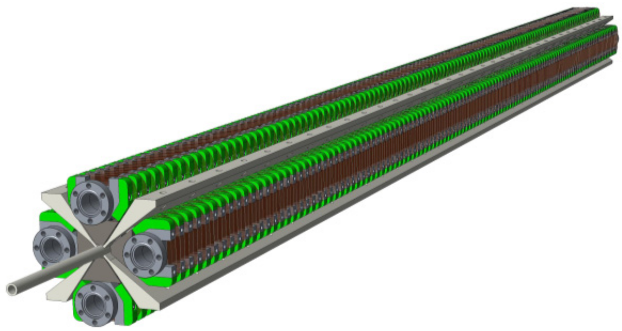

Figure 6: SCAPE magnet assembly with the beam chamber.

with the beam chamber is shown in Fig. 6.

The APS SCU team is currently working on a detailed design of the SCAPE, and is planning to build a short prototype in 2017.

CONCLUSION

The concept of a novel SuperConducting Arbitrarily Polarizing Emitter, or SCAPE, has recently been suggested at the Advanced Photon Source. This undulator employs two pairs of cores with superconducting coils for generating either planar or circularly polarized photons, depending on which pair of cores is energized. The undulator's magnetic field can be regulated by changing the currents in the coils. There is no mechanical movement of any parts of the undulator structure which is involved in the control of the magnetic field. Such an undulator would expand the existing family of x-ray polarized sources with noticeable advantages for FELs and synchrotron light sources with multi-bend achromat lattices.

REFERENCES

[1] Y. Ivanyushenkov *et al.*, "Status of Development of Superconducting Undulators at the Advanced Photon Source", presented at the 8th International Particle Accelerator Conf. (IPAC17), Copenhagen, Denmark, this conference, paper WEOCA3, May 2017.

[2] L. Nahon *et al., Nucl. Instrum. and Meth.,* vol. A396, pp. 237-250, 1997.

[3] S. Henderson, "Status of the APS Upgrade Project," in *Proc. IPAC15*, Richmond, VA, USA, paper TUPJE067, pp. 1791-1793, May 2015.

[4] http://www.esrf.eu/Accelerators/Groups/InsertionDevices/Software/Radia