DESIGN STUDY OF KNOT-APPLE UNDULATOR FOR PES-BEAMLINE AT SSRF

Shigemi Sasaki#, Atsushi Miyamoto,
Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima, Japan
Shan Qiao
Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, People's Republic of China

Abstract

An intense on-axis radiation power from a linear undulator is a serious problem for a VUV/soft-X-ray beamline at medium or high energy light source facility. This problem may be solved by using a specially designed linear undulator such as the Figure-8, Pera, or Knot undulators. However, a permanent magnet undulator of such kind is not capable of changing polarization state. On the other hand, an APPLE undulator is able to generate variable polarization, but is not capable to reduce on-axis power density in linear modes. To solve these problems, we investigated various magnetic structures and found that the combination of Knot and APPLE undulator scheme works to generate low on-axis power density in every polarization mode.

INTRODUCTION

In order to generate the undulator radiation in VUV region at a medium energy storage ring facility, the undulator should have a very long period and a high K-value. In this case, especially for a linear undulator, unwanted high radiation power for higher harmonics concentrates on the radiation beam axis, and hence it give a heave heat load on optical components such as a mirror and a monochromator. To reduce the on-axis heat load, the Figure-8 undulator was proposed [1] and have been used in several synchrotron radiation facilities. Also, similar ides for the same purpose were proposed [2-4]. However, all those ideas except the Figure-8 were not realized may be due to the complicated structure and the advantages are not so significant compared with Figure-8. More importantly, all those exotic devices including the Figure-8 are not capable of varying polarization states. On the other hand, the APPLE-type undulators can generate various polarization states such as the right/left circular polarization, tilted linear polarization, and horizontal/vertical linear polarization. However, in the linear polarization modes, on-axis high power problem form higher harmonics is remaining as a serious problem.

In order to solve all problems described above, we propose a new scheme which is called a Knot-APPLE undulator to reduce on-axis radiation power in every polarization mode.

KNOT UNDULATOR

Figure 1 shows the magnetic structure of Knot undulator. This structure, similar to the Figure-8 undulator, the Halbach structure permanent magnet arrays locate above and below the beam axis, and magnet rows for generating horizontal magnetic field on the beam axis locate at both sides of central magnet rows. As shown in Figure 1, the dimension in the direction of beam axis of each magnet block in the horizontal row is the same with that in the vertical rows except the end structure.

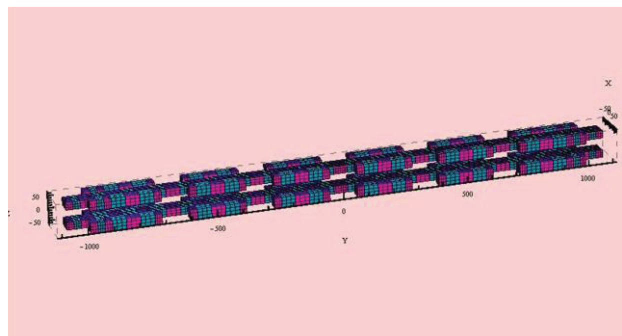

Figure 1: RADIA model of magnet structure for a Knot undulator.

As is seen in Figure 1, there is an empty space between segments in the horizontal structure in order to create the zero-field region. With this structure, the period length of horizontal field is one and a half of vertical field. Figure 2 shows the magnetic field distribution of Knot undulator having the structure of Figure 1.

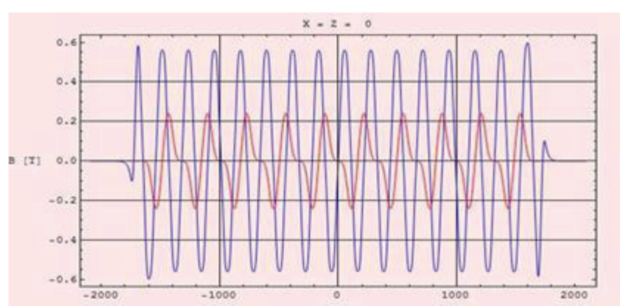

Figure 2: Field distribution of Knot undulator.

In Figure 2, blue line represents the vertical field and red line represents the horizontal field. The period lengths are 220 mm and 330 mm for vertical and horizontal, respectively. The magnet gap to generate the field in this figure is 40 mm.

Figure 3 shows the kick-angle map in an undulator having the field shown in Figure 2 for an electron beam with the energy of 3.5 GeV.

#sasakis@hiroshima-u.ac.jp

ISBN 978-3-95450-138-0

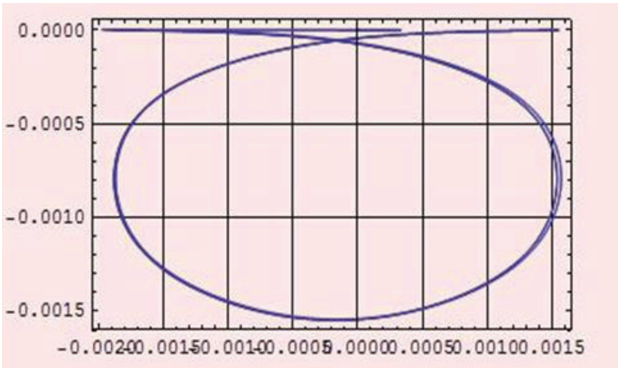

Figure 3: Kick map of Knot undulator.

The on-axis angular flux density spectrum is shown in Figure 4. At 6.2 eV peak position, the horizontal linear polarization with $P_L > 99$ % is achieved. For the calculation, parameters of the storage ring at Shanghai Synchrotron Radiation Facility (SSRF) are used which are E=3.5 GeV, I=200 mA, and ε_0=11.2 nmrad.

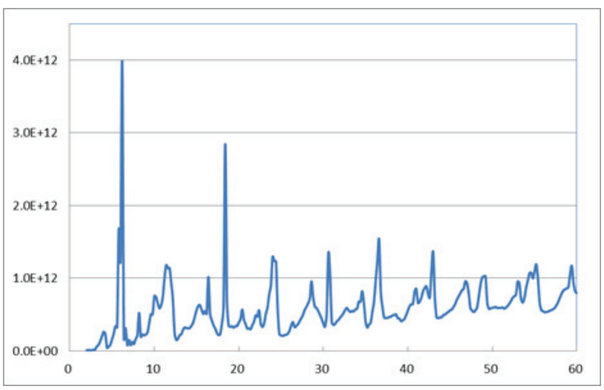

Figure 4: On-axis spatial flux density of the horizontal polarization mode.

KNOT-APPLE UNDULATOR

The Knot-APPLE undulator can be made by dividing central magnet rows into two parts in the same manner for creating the APPLE device. To create a magnet row in one quadrant, one has to combine the vertical row and horizontal row in a fixed position in the same magnet holder. Then, one has to introduce the same motion mechanism with that of APPLE undulator.

Vertical Polarization Mode

To reach to the vertical polarization mode, the magnet row phase has to be moved $\pm\pi$ ($\pm$110 mm) in anti-parallel direction. The antiparallel motion causes tilt of linear polarization which is different form the parallel motion that generates elliptical polarization.

Figure 5 shows the magnet row positions for the vertical polarization mode.

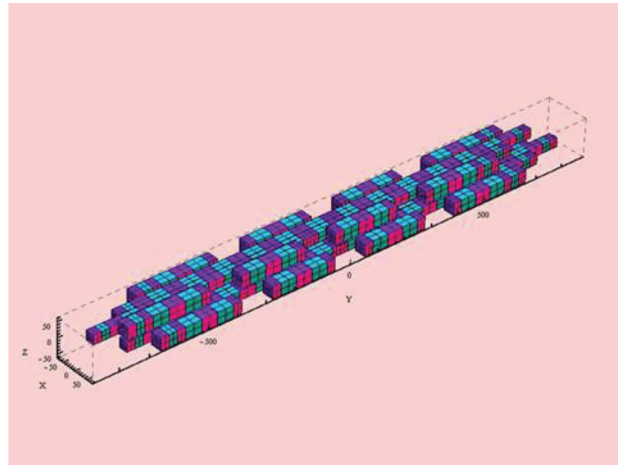

Figure 5: Magnet Structure of Knot-APPLE undulator in the vertical polarization mode.

Figure 6 shows the magnetic field distribution and Figure 7 shows the kick-angle map for vertical polarization mode. As it is obvious by comparing the field distribution for the horizontal polarization mode in Figure 2, the period length of vertical field component is one and a half larger than that of horizontal polarization.

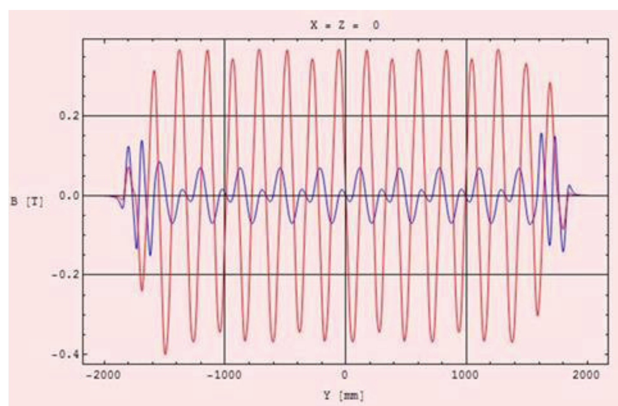

Figure 6: Field distribution of Knot-APPLE undulator in the vertical polarization mode.

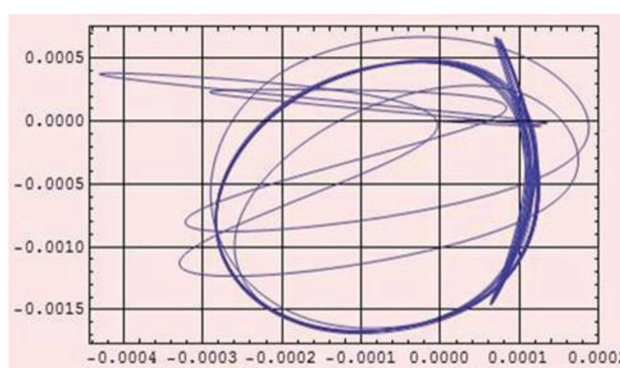

Figure 7: Kick map in the vertical polarization mode.

The on-axis flux density spectrum for the vertical polarization mode is shown in Figure 8. For the calculation, the ring parameters are assumed to be the same with those of horizontal polarization mode. The degree of vertical linear polarization in this mode is above 97 % at the fundamental (17.4 eV) peak position.

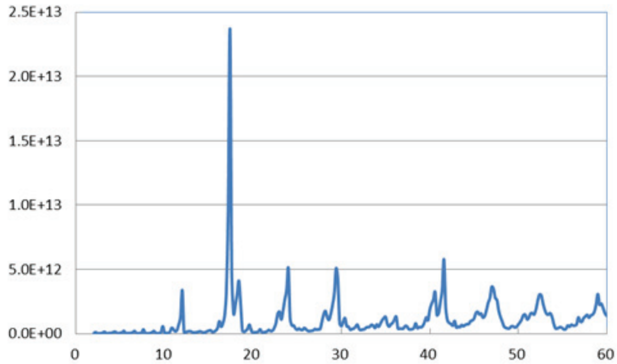

Figure 8: On-axis spatial flux density of the vertical polarization mode.

Elliptical Polarization Mode

To realize the elliptical polarization, different form the antiparallel motion for tilting linear polarization, the parallel motion is required. Figure 9 shows the magnet structure for the elliptical mode.

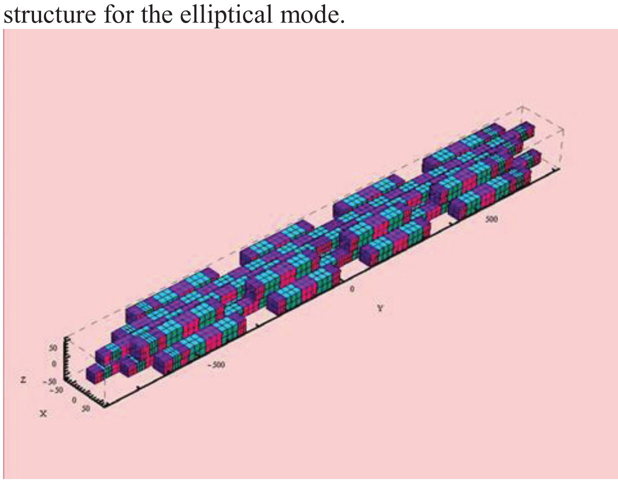

Figure 9: Magnet Structure of Knot-APPLE undulator in the elliptical polarization mode.

Figure 10 shows the magnetic field distribution for the elliptical polarization mode at the magnet row phase of 65 mm, and Figure 11 shows the kick-angle map of this mode.

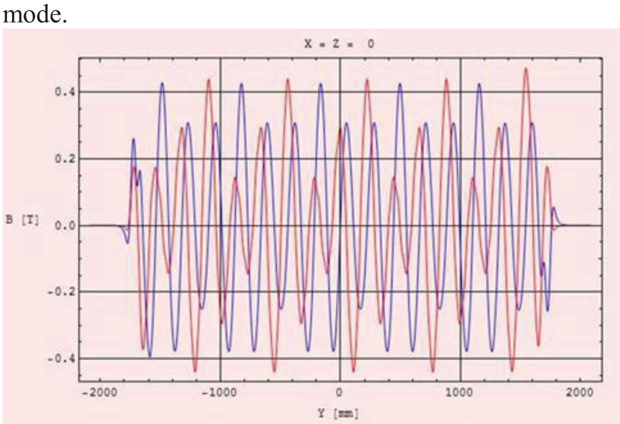

Figure 10: Field distribution of the elliptical mode at magnet row phase $D = 65$ mm.

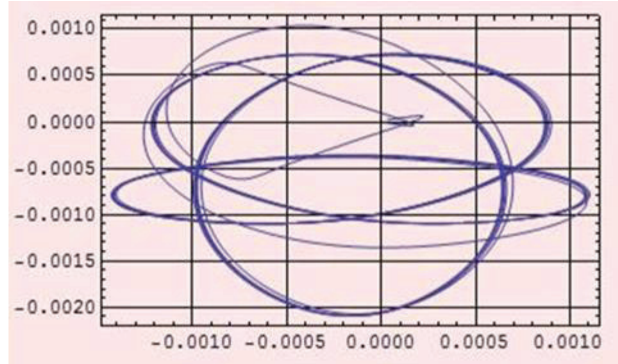

Figure 11: Kick map in the elliptical mode.

The on-axis flux density spectrum of elliptical polarization mode is shown in Figure 12. For the calculation, the ring parameters and the undulator gap were assumed to be the same with previous two cases. The degree of circular polarization in this mode is above 90 % at 9.8 eV peak position.

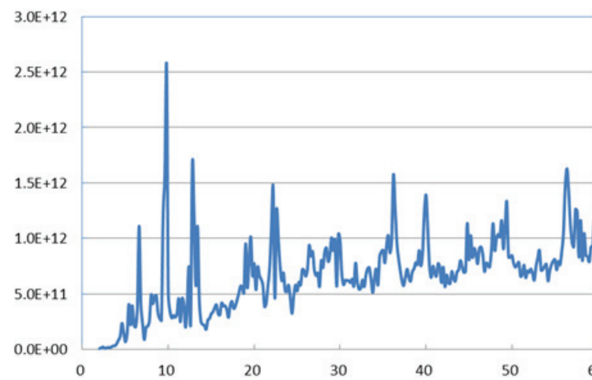

Figure 12: On-axis spatial flux density of elliptical polarization mode.

SUMMARY

In this paper, the Knot-APPLE undulator that is capable to vary polarization states with low on-axis power density at every polarization mode is proposed. This new device can be useful for synchrotron radiation users who use relatively low photon energies at medium/high energy ring facilities.

REFERENCES

[1] T. Tanaka and H. Kitamura, Nucl. Instrum. Meth. A 364 (1995) 368.
[2] S. Sasaki, *Undulators, wigglers and their applications*, pp. 237-243 (Ed. by H. Onuki and P. Elleaume, Taylor & Francis Inc, New York, 2003).
[3] S. Qiao et. Al., Rev. Sci. Instrum. 80 (2009) 085108.
[4] J. Yan and S. Qiao, Rev. Sci. Instrum. 81 (2010) 056101.