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POSSIBILITY FOR QUASI-PERIODIC KNOT-APPLE UNDULATOR

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Abstract

An intense on-axis radiation power from an undulator is a serious problem especially for a low-photon-energy beamline in a facility with high or medium energy storage ring. This problem may be solved by using a Figure-8, or a Knot undulator configuration. However, original configurations of these undulators are useless for changing polarization state. The APPLE undulator and other similar variations are capable for reducing on-axis power density in the elliptical modes but not capable in the linear modes. In these circumstances, we made a conceptual magnet design of Knot-APPLE undulator which is capable to generate elliptically polarized radiation as well as linearly polarized radiation with reduced on-axis power density. We present a possibility to introduce a quasi-periodicity in this type of undulators is in order to achieve further reduction of integral harmonics.

INTRODUCTION

In order to generate radiation in the region in VUV or soft X-ray at a medium or high energy storage ring facility, the undulator should have a very long period and a high K-value. Especially for a linear undulator, unwanted high power radiation from higher harmonics concentrates on the radiation beam axis, and hence it give a heave heat load on optical components in a photon-beamline. To reduce the on-axis heat load, the Figure-8 undulator was proposed [1], and has been used in several synchrotron radiation facilities. Also, similar ideas 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 are capable for generating various polarization states such as the right/left circular polarizations and tilted linear polarizations. However, in the linear polarization modes, on-axis high power radiation form higher harmonics is remaining as a serious problem.

In order to solve all problems described above, we proposed a new scheme which is called a Knot-APPLE undulator or an APPLE-Knot undulator to reduce on-axis radiation power in every polarization mode [5]. Furthermore, we investigate a possibility for the quasi-peroidization of Knot-APPLE undulator in order to achieve further reduction of integral harmonics such as second and third harmonics.

KNOT-APPLE UNDULATOR

Figure 1 shows a partial view of magnetic structure for Knot undulator. This structure, similar to the Figure-8 undulator, the Halbach type 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. 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 structures.

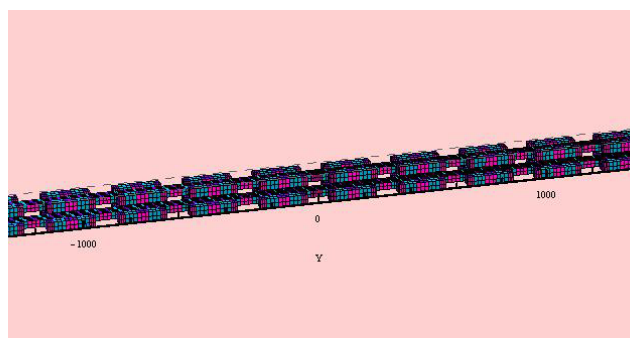

Figure 1: RADIA model of magnet structure for a Knot undulator (partial).

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 that of vertical field. Figure 2 shows the magnetic field distribution of Knot undulator under consideration.

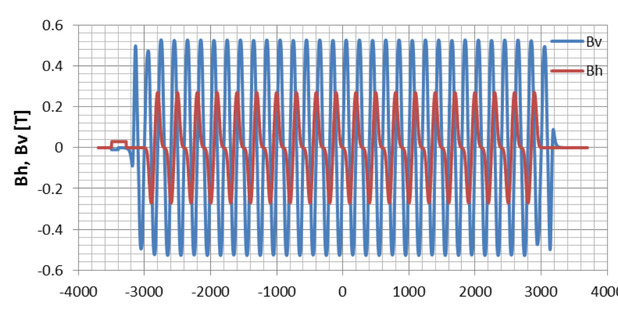

Figure 2: Field distribution of Knot undulator.

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In Figure 2, blue line represents the vertical field and red line represents the horizontal field. The period lengths are 200 mm and 300 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.

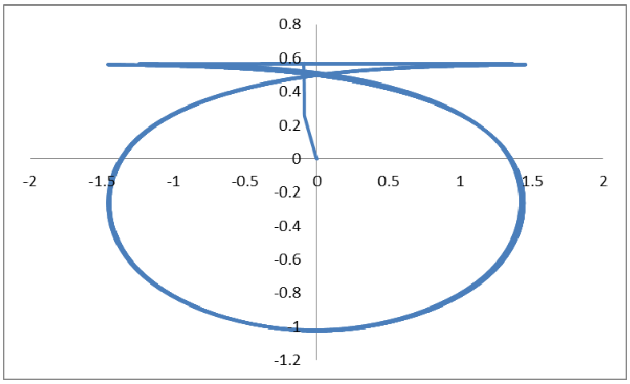


Figure 3: Kick-angle [mrad] of Knot undulator.

QUASI-PERIODIC KNOT-APPLE

To create a quasi-periodicity in a Knot-APPLE undulator, it is necessary to retract each magnet which is horizontally magnetized at a certain longitudinal position predicted by the 1-D quasi-periodicity criterion [6]. An example of retracted magnet is shown in Fig. 4.

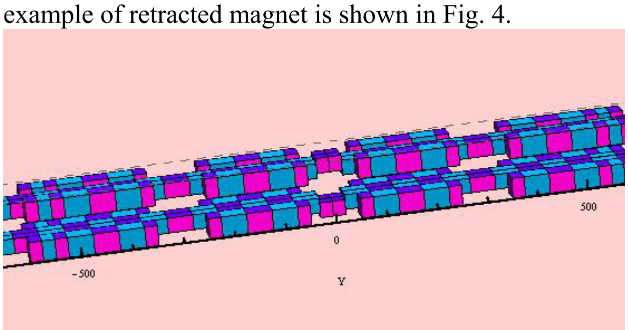


Figure 4: RADIA model of retracted magnet at a certain quasi-periodic position in a Knot undulator.

Figure 5 shows the magnetic field distribution of a quasi-periodic Knot undulator.

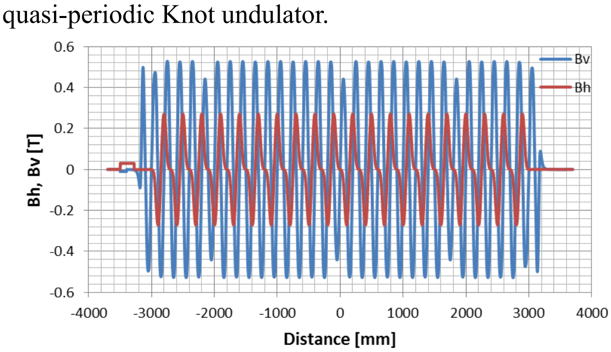
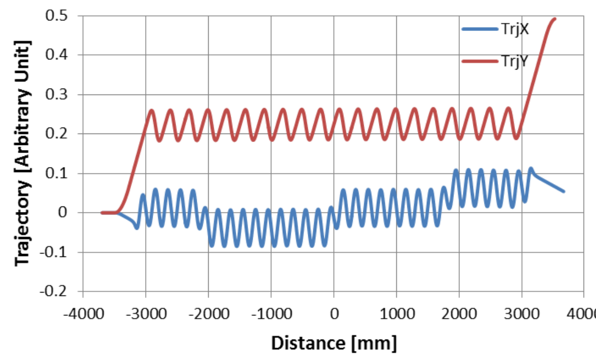


Figure 5: Field distribution of a Quasi-Periodic Knot undulator.

The quasi-periodic positions are determined with the same manner in reference 6. However in the present case, the period length is 600 mm, and therefore the number of period is only 10 for a 6-m-long undulator. Due to these restrictions, we can place only three retracted magnets at quasi-periodic positions in each jaw. The trajectory and kick-angle map in this QP-Knot undulator are shown in Fig. 6 and Fig. 7.



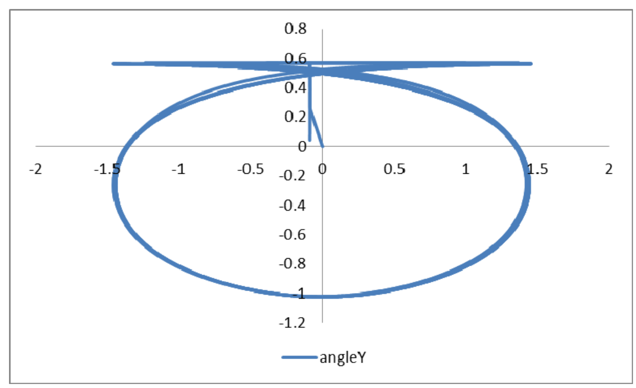


Figure 6: Beam trajectory in the QP-Knot undulator.

Figure 7: Kick-angle [mrad] of QP-Knot undulator.

As one can see in Fig. 7, the shape of off-axis radiation power distribution is almost the same with that for a periodic Knot undulator as shown in Fig. 3.

RADIATION SPECTRA

In this section, comparisons of radiation spectra among three different undulators which are a periodic Knot undulator, a quasi-periodic undulator, and a conventional planar undulator.

Parameters of Shanghai Synchrotron Radiation Facility (SSRF) storage ring are used for the spectral calculations. These main parameters are: the electron energy of 3.5 GeV, the beam current of 200 mA, and the natural emittance of 11.2 nmrad for the normal operation mode.

Figures 8, 9, and 10 show on-axis radiation spectra from the Knot undulator, the QP-Knot undulator, and the planar undulator with the period length of 200 mm, respectively.

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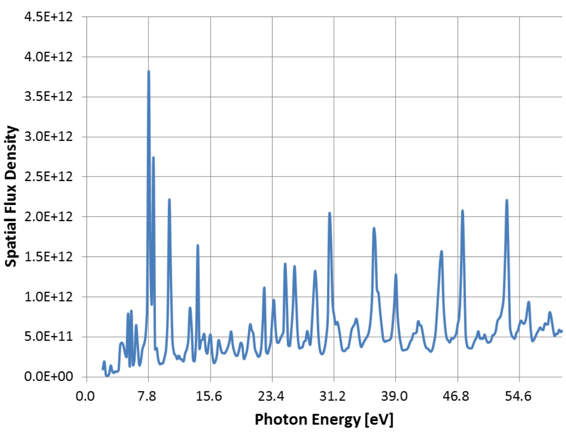

Figure 8: On-axis spatial flux density of Knot undulator with 200/300 mm period.

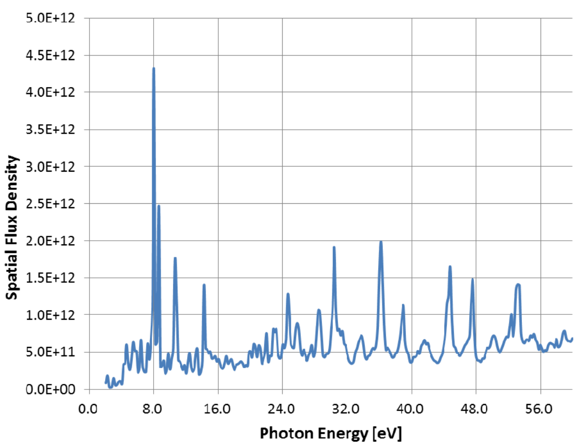

Figure 9: On-axis spatial flux density of QP-Knot undulator with 200/300 mm period.

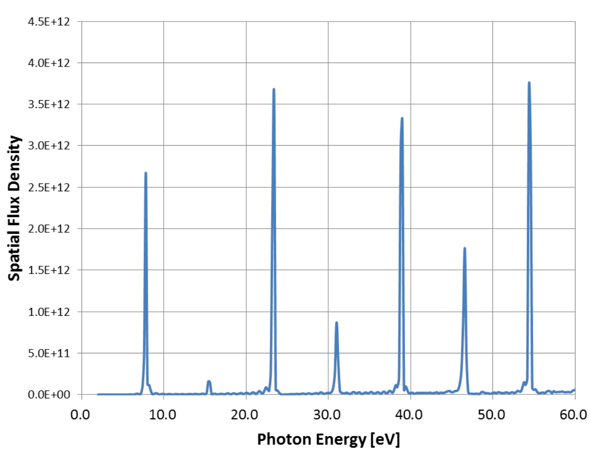

Figure 10: On-axis spatial flux density of planar undulator with 200 mm period.

For the fair comparison, the undulator gap of each undulator was set so that the fundamental photon energy becomes around 8 eV. By comparing Figure 8 and 9, peak intensities of 2nd, 3rd, 4th, and 5th harmonics are found to be smaller in the quasi-periodic Knot undulator. Also, it should be noted that the fundamental intensity form a Knot or a QP-Knot undulator is stronger than that from a planar undulator.

DISCUSSIONS AND SUMMARY

The quasi-periodic Knot-APPLE undulator can be made by dividing central magnet rows into two parts in the same manner for creating the APPLE or periodic Knot-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. However, it should be noted that a pure quasi-periodic structure may be distorted by moving magnet rows to achieve the vertical polarization. To solve this problem, further improvement is needed.

In this paper, a possibility of the quasi-periodic Knot-APPLE undulator was considered. This new scheme may be used for further peak intensity reduction of low order integral harmonics. The QP-Knot APPLE undulator 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.

[5] S. Sasaki, *et al.*, Proc. PAC'13, pp1043, published in JaCoW Conference Proceedings Webpage (accelconf.web.cern.ch/AccelConf/pac2013).

[6] S. Sasaki, *et al.*, J. of Physics : Conference Series **425** (2013) 032009.