STUDY OF A MODIFIED QUASI-PERIODIC UNDULATOR

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Abstract

To suppress high-order harmonic radiation effectively while maintain comparatively higher fundamental radiation intensity, a modified quasi-periodic undulator (QPU) which the magnet blocks have different size is studied in this paper. Then the paper also compares the radiation spectrum of various structural schemes. It is shown that the higher harmonic radiation of this modified scheme will be suppressed more effectively than the conventional QPU.

INTRODUCTION

In order to improve the signal-to-noise ratio which decreased by the mixing of high harmonics, Shigemi Sasaki,et al designed an undulator with intentional phase error in periodic structure [1].Then B.Diviacco,et al proposed the suppress effect could be achieved by adding a horizontal magnetic field[2] .Based on this principle, J.Chavanne,et al constructed a QPU in ESRF and a suppression ratio of 8.3 and11.3 on harmonics 3 and 5 have been observed [3].C.H.Chang,et al build a QPU with a hybrid magnetic structure [4].

In this paper, we present a modified QPU which the magnet blocks have different size and give a result of the detailed comparative study. The performance of schemes is simulated by RADIA and SPECTRA[5-6].

MAGNETIC FIELD

For the quasi-periodic undulator in ESRF,with the characteristics of simple structure, easy fabrication, this common basic structure is used in our scheme. The H-magnets (blocks magnetized horizontally) in specific location are displaced vertically by a value δ.The following Fibioacci sequence of X_n is the longtitudinal coordinate which represents the n-th position of the magnet array [3].

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$$X_n = n + (1/\eta - 1)[n/(\eta + 1) + 1] \qquad (1)$$

Where n is an integer, [y] denotes the maximum integer less than the number in the bracket. If $X_n - X_{n-1}$ is equal to 1, the n-th H-magnet is untouched. If it is equal to $1/\eta$, the n-th H-magnet is vertically displaced by δ. We select the irrational number $\eta=\sqrt{5}$ and δ=5mm.

For a pure permanent magnet undulator, when the width of magnet blocks is much longer than the gap and every period consists of four magnet blocks, the magnetic field in two dimensional approximate is given by[7-8]:

$$B_y(y,z) = \sum_{j=0}^{\infty} B_n ch(nk_u y)\sin(nk_u z)\sin(\frac{n\pi}{2}) \qquad (2)$$

$$B_n = \frac{4\sqrt{2}B_r}{n\pi}(1-e^{-nk_u h})e^{-nk_u g/2}\cos(n\pi\frac{l_v}{\lambda_u} - \frac{\pi}{4}) \qquad (3)$$

Where B_n is the peak value of n-th harmonic magnetic field, λ_u is the period length, g is the magnet gap, h is height of magnet blocks, k_u=$2\pi/\lambda_u$, B_r is the remanence of magnet, l_v is the length of the vertical magnetized magnet blocks. Through the adjustment of the l_v/λ_u value, the higher harmonic emission could be suppressed or enhanced for the higher harmonic field has same or opposite sign to the fundamental.

According to the above theory, the length of the H-magnet blocks and two V-magnet blocks (blocks magnetized vertically) on either side is adjusted at the quasi-periodic place. This modified QPU structure which the length of H-magnet blocks is 14mm and the length V-magnet blocks is 28mm is shown by Figure 1.

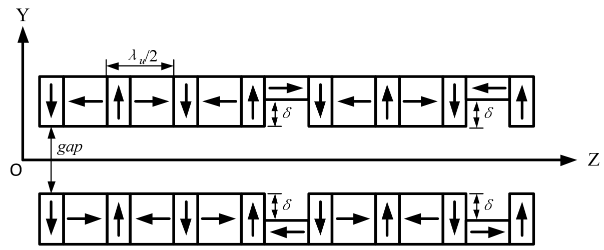

Figure 1: 2D view of the modified QPU.

After a lot of calculation and repeated comparisons about different undulator structures, we select the main parameters of the modified QPU are shown in Table 1.The modified QPU structure is simulated by RADIA [5]. Figure 2 presents the vertical field distribution. For the displacement of the H-magnets, the peak field oscillates between 0.635T and 0.575T.

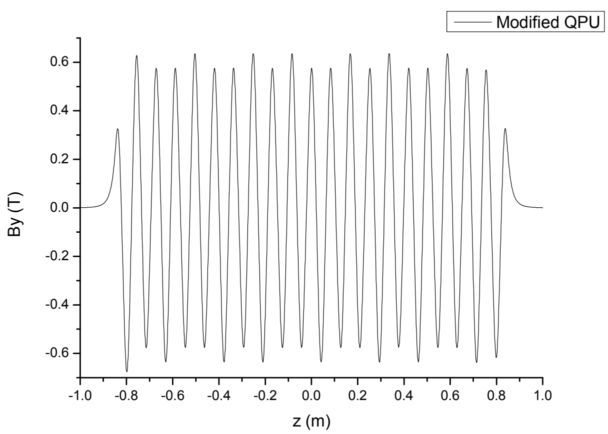

Figure 2: Simulated vertical field of the modified QPU as a function of the longitudinal coordinate.

Table 1: Main Parameters of the Modified QPU

Parameters	Value
Period length	84mm
Period number	20
Overall length	1680mm
Remanence	1.22T
gap	30mm
Height of magnetic blocks	40mm
Width of magnetic blocks	80mm

Table 2: Electron Beam Parameters in NSRL

Parameters	Value
Beam Energy	800MeV
Current	300Ma
Energy spread	0.0005
Emittance	x:36.4mm-mrad y:1.82 mm-mrad coupling coefficient:5%
Ring circumference	66m
Number of bunches	45
Longitudinal length	10mm
Beta function	x:3.28m y:1.81m
Dispersion function	0.87m
Beam radius	x:0.5326mm y:0.0607mm

RADIATION SPECTRUM

Figure 3 illustrates the angular spectral on axis (10m from the source) for three structures computed by SPECTRA [6]. The electron beam parameters in NSRL are given in Table 2 and Table 3 shows the angular spectral flux values of three structures at the position of first, third and fifth harmonics.

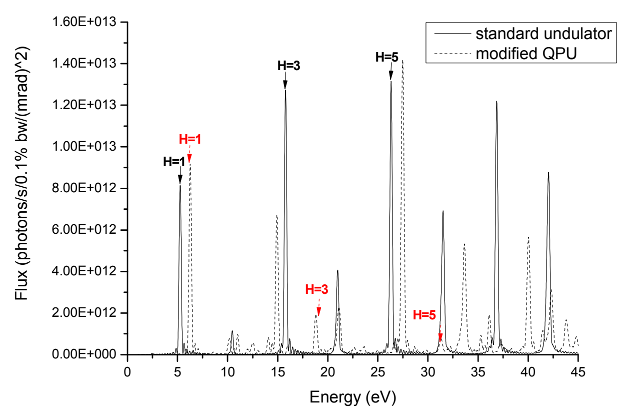

Figure 3: Angular spectral flux versus photon energy for the standard undulator and modified QPU.

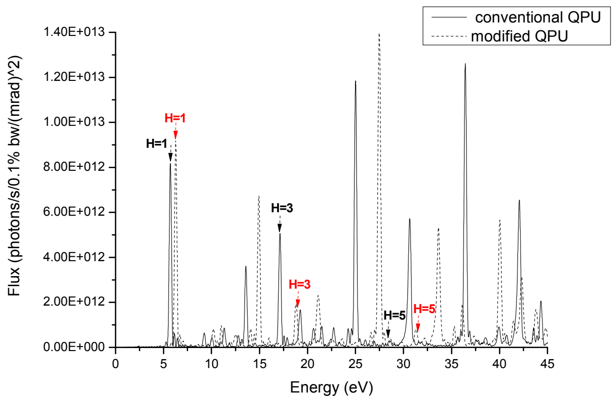

Figure 4: Angular spectral flux versus photon energy for the conventional QPU and modified QPU.

Table3: Comparisons the Harmonic Spectrum Flux of Three Schemes at the Position of First, Third and Fifth Harmonics

Type	**Standard undulator**	**Conventional QPU**	**Modified QPU**
1st energy [eV]	5.27	5.71	6.27
1st flux 10^{13} [ph/s/mm2/0.1%]	0.8164	0.8179	0.9178
3rd energy [eV]	15.81	17.13	18.81
3rd flux 10^{13} [ph/s/mm2/0.1%]	1.244	0.5069	0.1921
3rd relative to 1st flux	1.5238	0.620	0.2093
5th energy [eV]	26.35	28.55	31.35
5th flux 10^{13} [ph/s/mm2/0.1%]	1.278	2.789e-2	7.654e-2
5th relative to 1st flux	1.5654	0.0341	0.0834

In Figure 3, the solid line and dash dotted line represent the standard undulator and modified QPU respectively. Figure 4 shows angular spectral flux versus photon energy for the conventional QPU (solid line) and modified QPU (dashed line). The 3rd and 5th harmonic flux of the standard undulator, convention QPU and modified QPU are marked with black solid arrows, black dotted arrows and red dotted arrows at the photon energies equal to 3 and 5 times as the energy of fundamental. It is easy to find the modified QPU presents higher angular flux on the fundamental radiation than the standard undulator. Compare with standard undulator, the 3rd and 5rd harmonic flux of the modified QPU is lower 84.6% and 95%. In particular, the 3rd harmonic of the modified QPU is less 62.1% than that the conventional QPU.

CONCLUSION

According to the calculated results in previous section, it seems that the modified QPU gives a better performance than conventional QPU. There might be further possibilities for applying this structure to avoid the mixing higher harmonics in many users' experiments. We will do more research about the parameters of the modified QPU in the future.

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