LOW EMITTANCE RECONSTRUCTION OF THE ARC SECTION OF THE PHOTON FACTORY

K. Harada†, Y. Kobayashi, N. Nakamura, K. Oide, H. R. Sakai, S. Sakanaka
Accelerator Laboratory, KEK

Abstract

The present horizontal emittance of the Photon Factory (PF) ring is about 35.4 nm·rad. By the reconstruction of the normal cells at the arc section, the emittance can be reduced to about 8 nm·rad. In this proceedings, the design, optimization and simulation results for the low emittance lattice are shown.

INTRODUCTION

PF ring began the user operation in 1982 with the horizontal emittance about 400 nm·rad [1],[2]. The emittance reduced to about 37 nm·rad by the low emittance configuration in 1986 [3], and about 37 nm·rad by the high brilliance reconstruction in 1997 [4]. Before the reconstruction, the normal cell consists of two bending magnets. After the high brilliance reconstruction, the normal cell consists of only one bending magnet. The number of the quadrupoles, sextupoles and the normal cells were doubled in order to reduce emittance largely. By the straight sections upgrade in 2005, the lengths of the existing straight sections were extended and new four straight sections for the in-vacuum insertion device were installed. At present, the insertion devices were installed to the all available straight sections. In this proceeding, we show the low emittance reconstruction of the arc section of the PF ring which enables to reduce the emittance to about 8 nm·rad.

NEW CONFIGURATION

New Normal Cell

Fig. 1 shows the section of the lattice for the reconstruction. While the straight sections are unchanged, the only arc sections are reconstructed. Similar to the reconstruction in 1997, the numbers of the normal cells are doubled by replacing present one 1.9m length bending magnet used from 1981 to the new two short combined function magnets of 65 cm length. While the horizontal emittance of the present normal cell is about 41 nm·rad, it reduces to 4.6 nm·rad for the new normal cell. The parameter of the ring is shown in Table 1 and Fig.2 shows the optics. Although the chromaticity is not largely increased, the strong chromatic sextupoles by about ten times are required due to the small dispersion function. In order to realize them, the diameter of the magnetic poles of the sextupoles are reduced from 9 cm to about 4 cm.

† email address kentaro harada@kek jp

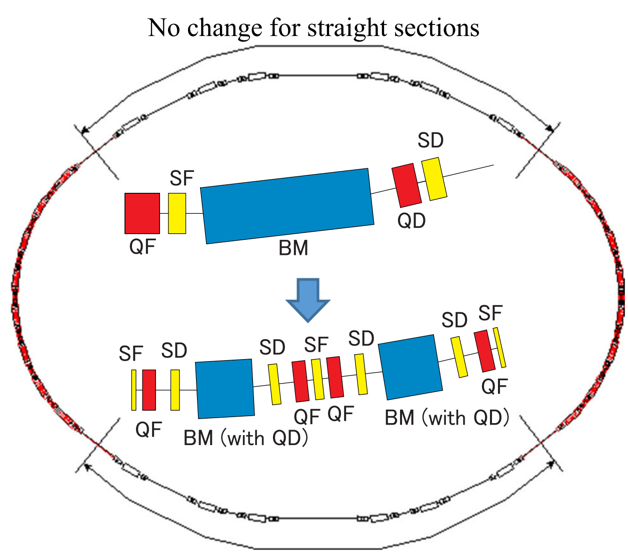

Figure 1: The arc sections for the reconstruction.

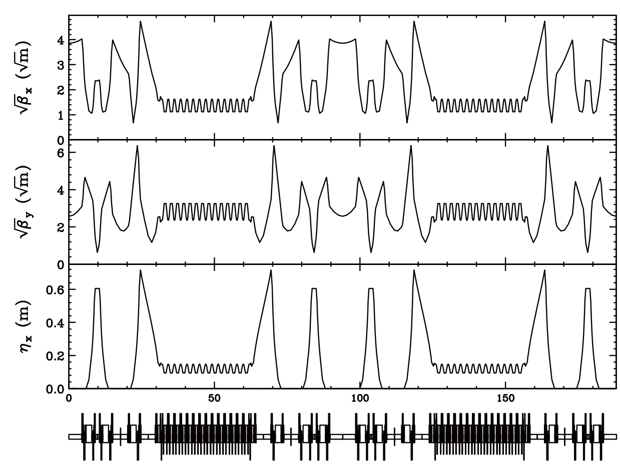

Figure 2: The new optics of the ring.

Optimization of the Optics

For the large dynamic aperture, the linear optics of the straight sections are designed to be transparent for the sextupoles. The matching section at the end of the normal cell only consists of one bending magnet and no sextupole and The identical 14 normal cells form the arc section. For the large dynamic aperture, the tune advance of the straight section with the matching sections are adjusted to be integer or the half integer. If the sextupoles are installed to the dispersive section of the long straight section, the total strength of the sextupoles can

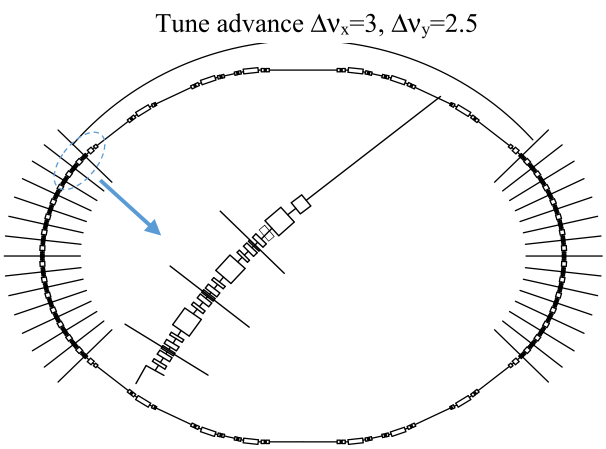

Figure 3: The new lattice of the ring.

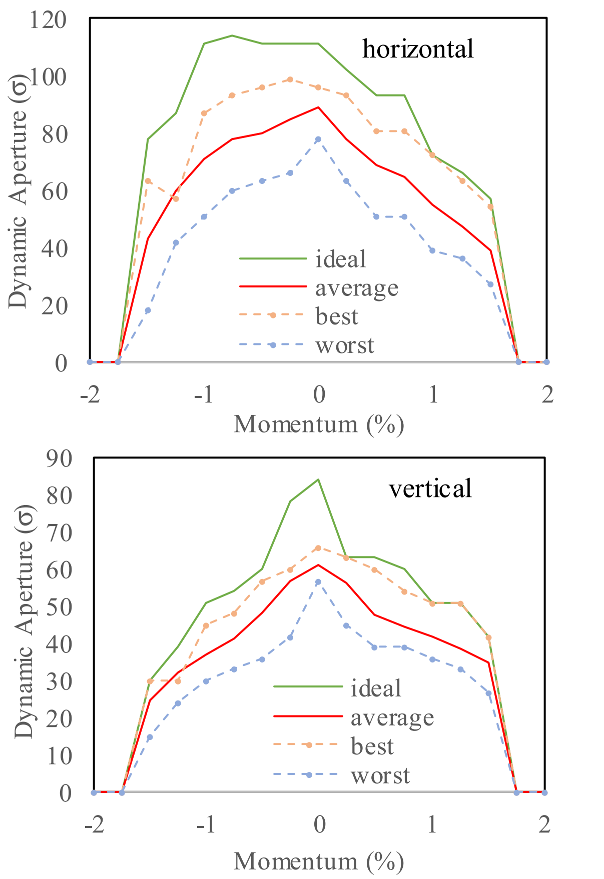

Figure 4: The dynamic aperture of the ring. The average, the worst and the best cases are calculated from 50 samples of random magnetic errors.

be largely reduced. The dynamic aperture, however, also largely reduced. Although the error of the tune advance for the transparency is acceptable for some extent, the sextupole component at the long straight sections are unacceptable for the large aperture.

Table 1: Parameters of the PF Ring

		present	new
Energy	E [GeV]	2.5	
Circumference	C [m]	187.0	
Emittance	ε_0 [nm·rad]	35.370	8.073
Normal cell emittance	ε_{nc} [nm·rad]	40.722	4.561
Energy spread	σ_E/E	7.29E-04	1.64E-03
Momentum compaction	α	6.56E-03	4.39E-03
Betatron tune			
Horizontal	ν_x	9.60	12.1
Vertical	ν_y	5.28	6.2
Chromaticity			
Horizontal	ξ_x	-13.432	-17.573
Vertical	ξ_y	-17.314	-25.117
Energy loss	U_0 [MeV/rev.]	0.399	0.513
Damping time			
Horizontal	τ_x [msec]	7.777	3.040
Vertical	τ_y [msec]	7.815	6.109
Longitudinal	τ_z [msec]	3.918	6.171
Revolution freq.	f_{rev} [MHz]	1.60253	
RF frequency	f_{RF} [MHz]	500.100	
Harmonic number	h	312	
RF voltage	V_{RF} [MV]	1.70	
Synchrotron tune	ν_s	-0.015	-0.009
Bunch length	σ_z [mm]	9.700	10.475
Bucket height	$(\Delta E/E)_{RF}$	0.012	0.017

The Dynamic Aperture

Figure 4 shows the simulated dynamic aperture after the COD correction with the random magnetic errors of the alignment errors of 50 µm, field fluctuation of 0.05% and rotation of 0.1 mrad. Even with these errors, the dynamic aperture is as wide as that of the present PF ring. At the injection point, the present dynamic aperture is about 24 mm for the ideal case. For the new lattice, β_x is 10.25 m and rhe horizontal dynamic aperture is about 23 mm with 80 σ aperture. With the worst case of the simulation, it may be about 17 mm with 60σ aperture.

The optics of the straight sections are almost unchanged. The injection scheme and the minimum gap of the in-vacuum undulators can be kept unchanged. The brilliances of the insertion devices are improved by 7~8 times [6] and shown in Figure 5.

Position of the Beam Lines

While the positions of the insertion device beam lines from the straight sections are unchanged, the light source point of the bending magnet beam lines of the arc sections moves to the upstream by about 55 cm. It causes the inward parallel shift of the photon beam axis as shown in Figure 6. In order to recover this shifts, the lattice of the arc section is required to be moved by 2 cm

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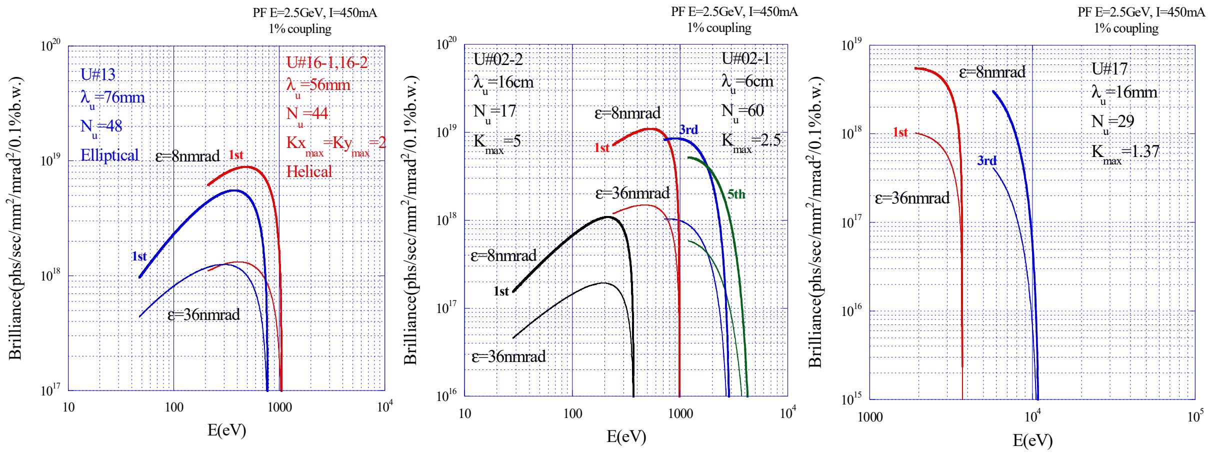

Figure 5: The estimation of the improvement of the brilliance by the emittance improvement [6].

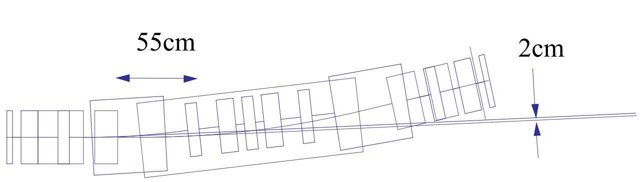

Figure 6: Change of the photon axis without lattice adjustment.

outward by changing the position of the bending magnet at the matching section by about 9 cm nearer to the arc section as shown in Figure 7. Even with this change, the circumference of the ring is reduced by about 3 cm and the frequency of the RF is required to be increased by about 100 kHz.

SUMMARY

The present horizontal emittance of the Photon Factory (PF) ring is about 35.4 nm·rad. By the reconstruction of the normal cells at the arc section, the emittance can be reduced to about 8 nm·rad. The double number of the combined function short bending magnets are adopted and one present normal cell become two new normal cells. Although the lattice of the straight sections is not changed, the optics are optimized to reduce the non-linear effects of the sextupoles of the arc sections. By keeping the phase advance of the straight section as 3π for the horizontal direction and 2.5π for the vertical, the dynamic aperture as large as that of the present ring can be achieved with the magnetic errors. The difference of the optics of the straight sections are so little that the beam injection and the operation of the in-vacuum short-gap undulators can be maintained.

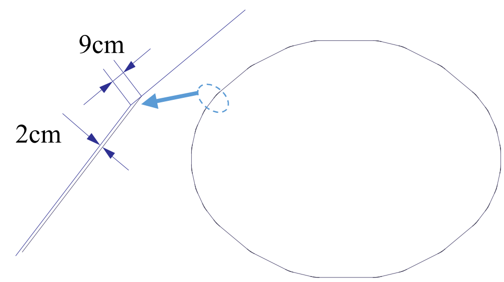

Figure 7: The lattice adjustment to fix the photon axis.

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