RECONSTRUCTION OF PHOTON FACTORY STORAGE RING FOR THE STRAIGHT-SECTIONS UPGRADE PROJECT

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Abstract

At the 2.5-GeV ring of the Photon Factory, a large-scale reconstruction of its lattice is in progress. The objects of the reconstruction are an increase in number and extensions of the straight sections for insertion devices. Four new straight sections will be created and all existing straight sections will be largely extended. As a result, the number of straight sections for insertion devices will be increased from the currently available seven to thirteen. The newly created straight sections are short in length but will have low beta functions and will be suitable for housing short-period narrow-gap undulators. An in-vacuum undulator, which has a sufficiently high brilliance within a spectral range for the x-ray research field, is being developed and will be installled. The shutdown for the upgrade project is scheduled for the period from March to September, 2005.

INTRODUCTION

The Photon Factory (PF) of KEK administers two light sources, the 2.5-GeV PF ring and the 6.5-GeV PF-AR [1]. The PF ring is practically full of 70 experimental stations, and the available 7 straight sections are occupied by a various type of insertion devices. The PF-AR is now also a dedicated X-ray source, but it originates from the booster ring for the TRISTAN collider, so the capacity of its experimental hall is limited. There are 10 experimental stations with 4 undulators at the PF-AR.

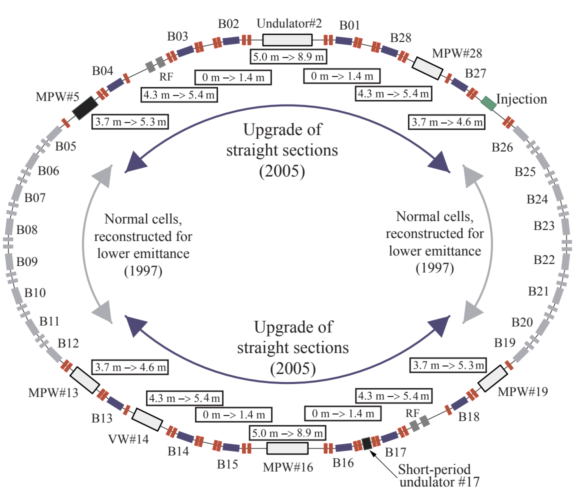

Figure 1: Straight-sections area to be reconstructed for the upgrade project.

The first commissioning of the PF ring was in 1982 as a second-generation synchrotron light source with the original emittance 450 nm rad. In the two decades after then, the usual emittance has been reduced to 36 nm rad through twice upgrades in 1986 and 1997. In 1997, we accomplished a major reconstruction around the normal cells as shown in figure 1. The number of quadrupoles and the sextupoles were doubled at those sections [2]. According to the decrease in the bore radius, most beam ducts in the normal cells were replaced by new ones. Combined with the installation of the damped RF cavities [3], the ring has continued a stable operation over 5000 hours a year after the reconstruction. It has recovered a merit of long beam lifetime in spite of the lowered emittance in a few years. The typical lifetime has reached over 60 hours for the normal stored current 400 mA.

In order to satisfy increasing needs for the undulator radiation in the x-ray range and demands for various types of new devices, we have proceeded with another large-scale upgrade project for the straight sections [4, 5]. The whole reconstruction of the ring started in March, 2005, with a scheduled half-year shutdown.

Table 1: Principal beam parameters after the upgrade

		New optics
Beam Energy	E (GeV)	2.5 (3.0)
Circumference	C (m)	187
Length and number of straight sections	8.93 m	2
	5.41 m	4
	5.29 m	2
	4.63 m	2
	1.41 m*1)	4
Superperiodicity		2
Bending Radius	ρ	8.66 m
Energy Loss/turn	U_0 (keV)	399
Natural emittance	ε_x (nm rad)	27
X-Y coupling	κ	<0.01
Momentum compaction factor	α	0.005
Betatron tune	ν_x/ν_y	10.22/5.28
Damping time	$\tau_x/\tau_y/\tau_z$ (ms)	7.8/7.8/3.9
Number of bending magnet		28

*1) new straight sections

LATTICE MODIFICATION AND THE NEW OPTICAL FUNCTIONS

The main purpose of the straight-sections upgrade project is to produce new short straight sections and to extend existing straight sections. The lattice around the straight sections shown in the figure 1 will be modified by replacing existing quadrupoles with new ones having shorter length and higher field gradient. The new quadrupoles will be placed closer to the adjoining bending magnets. Forty six quadrupoles have been newly manufactured for the project. The existing insertion devices will not be changed for the time being.

The length and the number of straight sections are summarized in table 1, together with the principal beam parameters after the modification. The longest straight section of presently 5.0 m long will be extended to 8.93 m. Four short straight sections of 1.41 m will be created by replacing a triplet of quadrupoles with two pairs of doublets.

Figure 2 shows the new optical functions to be operated after the reconstruction. The dispersion (η_x) and the beta functions (β_x, β_y) are optimized to be as low as possible for the insertion devices and the RF cavities. As shown in figure 3, the new short straight sections will have a low beta function (β_y) of 0.4 m and be suitable for housing short-period narrow-gap undulators. In-vacuum undulators, which have a sufficiently high brilliance within a spectral range from 8 to 16 keV, are being developed. The first in-vacuum model for the PF ring will be installed in the beamline #17 which is being reconstructed for the structural biology experiment.

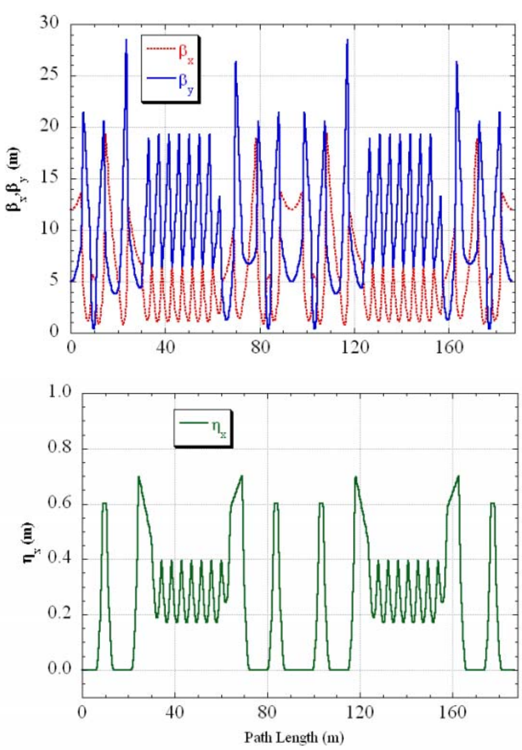

Figure 2: New optical functions for the upgrade project.

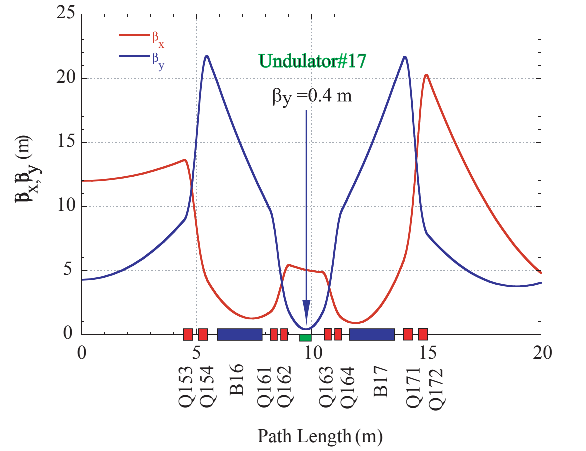

Figure 3: Low vertical beta function at the short straight section suitable for a narrow-gap undulator.

The horizontal emittance can be adjusted by changing the horizontal phase advance of the cells in arc sections. The minimum emittance on the calculation is less than 23 nm rad. But the achievable emittance is estimated as 27 $\text{nm}\cdot\text{rad}$ from a practical point of view, which is slightly lowered than the present value of 36 nm rad. The sufficient dynamic aperture is not expected for the operation point with a smaller emittance than 27 nm rad.

RECONSTRUCTION OF THE RING

The reconstruction work of the ring itself started in March, 2005. The shutdown period is planned to be about 7 months. The commissioning will start in the middle of September, 2005 and the user operation will resume after three weeks of vacuum scrubbing.

During the first month of the shutdown period, all quadrupoles and beam ducts to be replaced were completely removed from the ring tunnel. Figure 4 shows a photograph taken when only the bending magnets and the insertion devices were left around the straight sections, and all the other accelerator components were removed. First, the base plates to support the new girder of quadrupoles were fixed to the clear floor, and then new quadrupoles were carried into the tunnel with their girders. Figure 5 is a photograph when a doublet of quadrupoles on a common girder was just put on the base plate. The end of the multi-pole wiggler (MPW#13) is shown at the right side of the picture. The doublet was installed close to a nearby bending magnet, so the extra space was acquired at the downstream of the MPW. All quadrupoles have been installed in the ring tunnel by the end of April, 2005.

Following the quadrupoles, installation of the new beam ducts continues until the end of June, 2005. Figure 6 shows the drawing of the beam duct to be installed in the bending magnet. The main body of the beam duct is made of aluminium alloy. The intense power of the synchrotron radiation (SR) is turned down first by the crotch absorber and next by an SR mask, both made by a heat-resistant copper alloy. Twelve bend chambers have

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Figure 4: Old quadrupoles and beam ducts were completely removed from the straight sections.

Figure 5: Installation of the new quadrupoles.

been manufactured for the upgrade project. The experimental stations which utilize the SR from the bending magnets still remain after the reconstruction. At a few beamlines, alternation of the source to the insertion-device from the bending is necessary in future. The SR port of each bending chamber was carefully designed considering the situations of each beamlines.

Along with the reconstruction of the hardware, improvements of the control system are in progress. The power supplies for the quadrupoles will be reinforced and the number of the corrector magnets will increase. The control systems of magnets, RF and vacuum components [6] are being newly constructed in the EPICS environment. A transverse bunch by bunch feedback which has been confirmed its effectiveness to suppress the observed coupled bunch instabilities will be applied for the usual operation.

RECOVERY OF BEAM LIFETIME

During the three weeks of vacuum scrubbing at the commissioning, the integrated current will amount to 200 A h, if there is no unexpected delay about the beam storage. Figure 7 is the recovery of beam lifetime during half a year just after the low-emittance reconstruction in 1997. The beam ducts to be replaced are more than the previous reconstruction, but it is estimated that the recovery of lifetime trace a similar curve as that shown in the figure 7. The product of the beam current I and the lifetime τ will be retrieved to about 200 A min at the beginning of the user operation. $I\tau$ will be recovered over 500 A min with the integrated current 1000 A h after half a year operation. The RF phase modulation technique [7] to improve the lifetime will become effective when the integrated current exceeds 500 A h. The PF ring shares a full-energy injector LINAC with the KEKB factory and the PF-AR. Top-up injection is also scheduled by using a pulse bending for the beam switching [8].

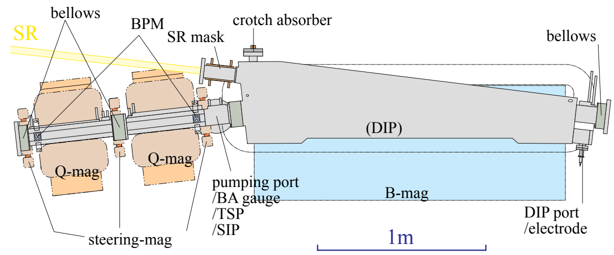

Figure 6: Drawing of the bending chamber.

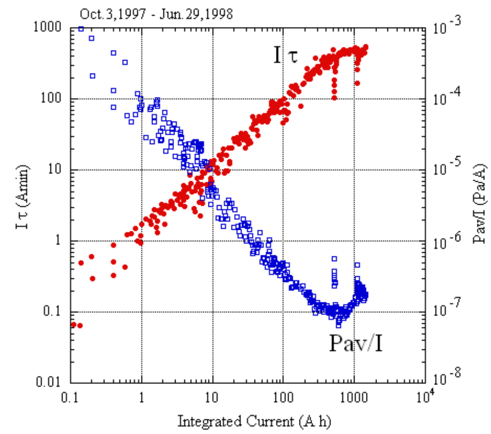

Figure 7: Record of the lifetime recovery after the previous reconstruction in 1997.

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