

# STATUS OF THE EMITTANCE UPGRADE PROJECT AT THE PHOTON FACTORY STORAGE RING

Masahiro KATOH and Yoichiro HORI  
KEK-PF, Tsukuba, Japan

## Abstract

An emittance upgrade project is now in progress at the Photon Factory storage ring. The beam emittance, which is now 130 nm-rad, will be reduced to 27 nm-rad by doubling the number of the quadrupoles in the FODO cells. This small emittance will result in ten times brighter synchrotron radiation from the existing insertion devices. The fabrications of the accelerator components are almost finished. The reconstruction work will be started in Jan. '97 and be finished in Sept. '97. The commissioning of the new lattice will be started in Oct. '97.

## 1 INTRODUCTION

The Photon Factory storage ring has been working for about 15 years as a major synchrotron light source in Japan [1]. The beam emittance, which had been 460 nm-rad in the early stage of the operation, was reduced to 130 nm-rad by changing the quadrupole strengths in '86 [2]. However, the emittance is still larger than those of the third generation synchrotron light sources by one order of magnitude. This results in lower brilliance of SR by one or two orders of magnitude.

To compete with the new generation machines, a high brilliance ( low emittance ) lattice was designed [3, 4]. Soon after, this emittance upgrade was approved. The reconstruction work of the ring will be started in Jan. '97 and be finished in Sept. '97. The commissioning will be started in Oct. '97.

This reconstruction is not only for the emittance upgrade but also for the renewals of the accelerator components which are 15 years old now. Various parts of the machine are planned to be replaced.

The details of the reconstruction and the present status are described.

## 2 LATTICE

The present FODO type normal cells, which occupy one third of the ring as shown in Figure 1, will be modified to a high brilliance configuration. The quadrupoles and the sextupoles are doubled in number and are reinforced in field strength. There is no change for the bendings.

The beam optics before and after the emittance upgrade are shown in Figure 2. The optics was designed for three cases of the horizontal betatron phase advance of normal

cells, 90, 105 and 135 degree. The emittance is 44, 33 and 27 nm-rad, respectively. These low emittances will result in higher brilliance of SR at all existing beam lines by factor of 5 to 10.

After the reconstruction of the ring, operation for user's time should be restarted as soon as possible. By turning off some of the magnets and changing the polarities of some of others in the normal cells, an optics almost same as the present one can be reproduced[3, 4]. This enables us to restart user's time smoothly with the familiar optics.

Commissioning of the new optics will be done in machine study time, typically one day a week. It will be introduced to user's time as soon as possible. Because the sextupole fields get stronger for the lower emittance optics, the dynamic aperture gets smaller[4]. The commissioning will be started with the 90 degree optics which has relatively larger dynamic aperture. The lower emittance will be challenged step by step.

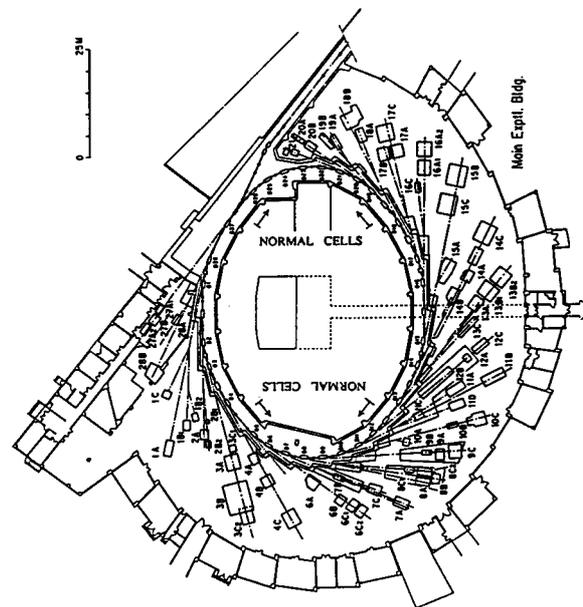


Figure 1. Layout of the Photon Factory. Two normal cell sections will be reconstructed.

### 3 ACCELERATOR COMPONENTS

#### 3.1 Magnets

All the quadrupoles and sextupoles in the normal cells will be replaced with the new ones of higher field gradients. Their maximum field strengths are compatible with 3 GeV operation with the lowest emittance optics. All of them are Collins type, not to disturb the synchrotron radiation extraction to the existing beam lines. Since the spaces are very limited, they have relatively short lengths and high field gradients (TABLE 2). The sextupoles have auxiliary windings for vertical steering. They can be used to produce skew quadrupole fields to control the coupling constant.

The fabrication and field measurements of the magnets were finished[5]. Alignment on the girders is under way.

Table 2. Parameters of the new magnets

	Field	Length
Defocus. Quadrupoles	24 T/m	0.25 m
Focus. Quadrupoles	24 T/m	0.40 m
Sextupoles	600 T/m <sup>2</sup>	0.20 m

#### 3.2 Injection

The injection kickers will be reinforced to be compatible with the new optical functions around the injection point. A traveling-wave type kickers are developed and under fabrication[6], whose short pulse length (600 nsec) enables a single-turn injection scheme. One-axis injection is also possible with a DC bump.

#### 3.3 Vacuum

About a half of vacuum chambers will be modified to be compatible with new configuration of the magnets, although the bending chambers are remained. A special consideration is given to the arrangements of all the components, such as pumping ports, bellows and flanges, in the limited spaces between the magnets. The new chambers have effective pumping speeds equal to or somewhat higher than those of present ones. Because the shorter bunches in the new lattice are expected to be sensitivite to irregularities of inner wall of the chambers, the bellows and flanges are equipped with shielding contacts.

#### 3.4 RF

The existing four RF Cavities will be replaced with damped cavities, in which dangerous higher order modes giving rise to beam instabilities are extracted and absorbed. A high power model was successfully tested[7]. One cavity was replaced in summer '96, prior to the

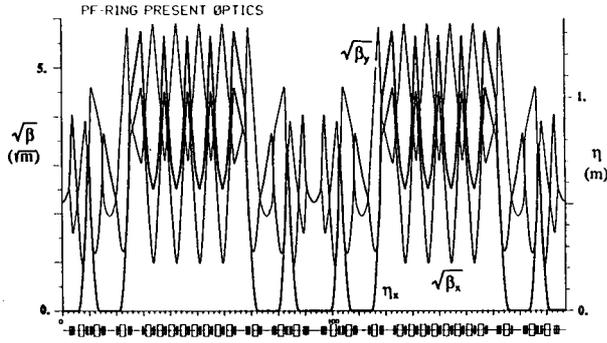


Figure 2-a. Optical functions of the present lattice. The whole ring is shown.

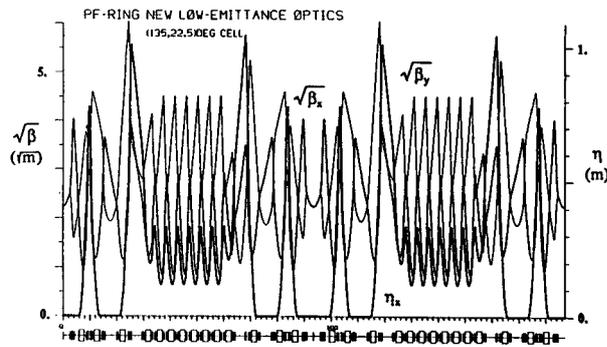


Figure 2-b. Optical functions of the new lattice of the lowest emittance (27 nm-rad). The whole ring is shown.

Table 1. Beam Parameters

	Present	Low-ε
Emittance	130 nm-rad	27 nm-rad
Energy Spread	7.3x10 <sup>-4</sup>	7.3x10 <sup>-4</sup>
Mom. Compaction	0.016	0.0043
Betatron Tunes	(8.44,3.30)	(10.85,4.20)
Chromatisity	(-13.5,-9.0)	(-16.1,-13.3)
RF Voltage	1.7 MV	1.7 MV
Synchrotron Tunes	0.023	0.011
Bunch Length	1.52 cm	0.84 cm

Note: Low-ε optics is for 135 degree horizontal phase advance of a FODO cell.

reconstruction of the ring. The remainder will be replaced subsequently.

### 3.5 Beam Channels

The front-ends of the existing SR beam channels in the normal cells will be modified to be compatible with the new configuration of the magnets and the vacuum components, as shown in Figure 3. They are also compatible with the increased power density of SR [8]. The reconstruction of the beam lines has already been started. All the works will be finished in '96, prior to the reconstruction of the ring.

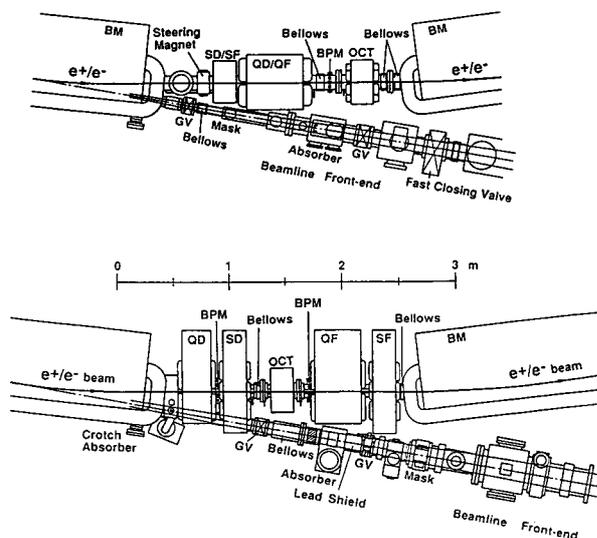


Figure 3. Configuration of present (upper) and new (lower) lattice at a normal cell.

### 3.6 Beam Monitors and Handlings

The present beam position monitors in the normal cells, each of which consists of six electrodes, are replaced with new ones with four electrodes to fit with the new vacuum chambers. The signal processing will be improved to achieve an accuracy as good as a few micron and a speed of data taking as fast as 2 kHz. A turn-by-turn beam position measurement scheme is under developing [9], which will be an effective tool for commissioning of the new lattice.

Orbit stabilization will be more important for a lower emittance light source. A fast and precise feedback system for fluctuations lower than 50 Hz is under construction [10], utilizing the orbit data from the new BPM system.

A transverse feedback system is under developing, which consists of one deflector and two BPM's[11]. This will be an effective tool to suppress the beam instabilities

due to higher order modes of the RF cavities, beam-ion interactions or beam-electron interactions.

### 3.7 Control

The control system will be replaced with a new one which consists of UNIX work stations and VME systems[12]. Since the control of the magnets and the beam monitors are more important for the commissioning, their control system will be replaced prior to the others, during the shutdown in 1997. The remainder will be replaced subsequently.

## 4 SUMMARY

The developments and fabrications of the accelerator components for the emittance upgrade are almost finished. Their tests and calibrations are in progress. Some components were and will be installed prior to the reconstruction of the ring. All those works will be finished until the end of 1996. From Jan. to Sept. in 1997, the ring will be shut down for 9 months. All the reconstruction work will be completed within this period. The operation of the ring will be restarted in Oct. 1997 with the present optics. Commissioning of the new high brilliance optics will be tried in machine study time. The new optics will be introduced to user's times as soon as possible.

## ACKNOWLEDGMENT

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