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Status of the Emittance Upgrade Program at the Photon Factory Storage Ring

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ABSTRACT

An emitttance upgrade program of the Photon Factory (PF) storage ring is in progress. The beam emittance will be reduced to 27 nm-rad by doubling the number of the quadrupoles and sextupoles in the normal cells. This will result in typically ten times higher brilliance of SR. Designs and developments of the accelerator components were finished and the fabrications are in progress. The reconstruction work of the ring will be started in Jan. '97 and will be finished in Sept..

1. INTRODUCTION

The performance of the Photon Factory (PF) storage ring has been steadily improved since the start of its operation in 1982 [1]. Now the ring stores 300 mA positron beam on average with a lifetime of more than 60 hours. The beam energy is normally 2.5 GeV and can be ramped up to 3 GeV.

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 1986 [2]. However, the emittance is still larger than those of the third generation synchrotron light sources by one order of magnitude [3] and the brilliance of the SR beam from insertion devices is smaller by one or two orders of magnitude.

To compete with the new generation machines in the next decade, a high brilliance (low emittance) lattice was designed [4]. Designs and developments of the accelerator components for the new configuration were finished and their fabrications are in progress. The present status of the emittance upgrade program is described.

2. LATTICE

The present FODO type normal cells which occupy one third of the ring will be modified for the high brilliance configuration, as shown in Figure 1. The quadrupoles and the sextupoles are doubled in number and are reinforced in field strength. No change is required for the bendings. The optics of the whole ring was designed for three cases of the horizontal betatron phase advance, 90, 105 and 135 degree per unit cell. The emittance is 44, 33 and 27 nm-rad, respectively. The natural beam sizes for the present optics and for the high brilliance optics (135 degree lattice) are shown in Figure 2. The smaller beam size of the new optics will results in higher brilliance of SR at all existing beam lines by factor of 5 to 10.

Because the sextupole fields become stronger for the lower emittance optics, the dynamic aperture becomes smaller and this may be a serious problem [5]. The commissioning of the new lattice will be started with the 90 degree optics which has relatively larger dynamic aperture. The lower emittance will be challenged step by step.

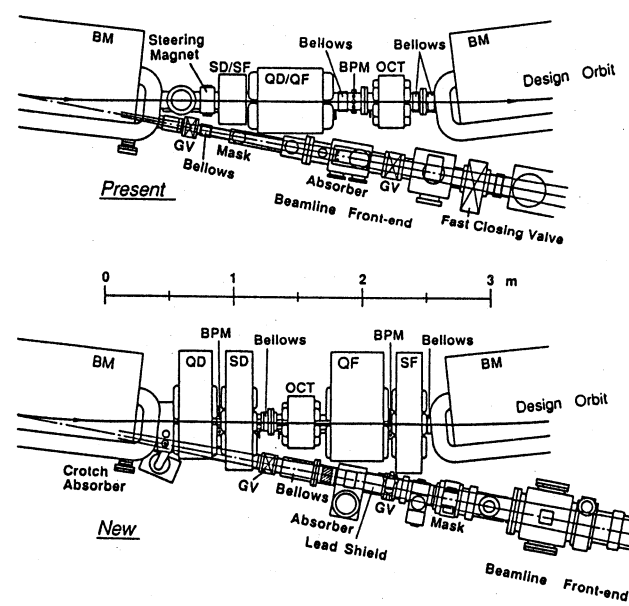

Figure 1. The present (upper) and the new (lower) configurations of the accelerator components in the normal cell section.

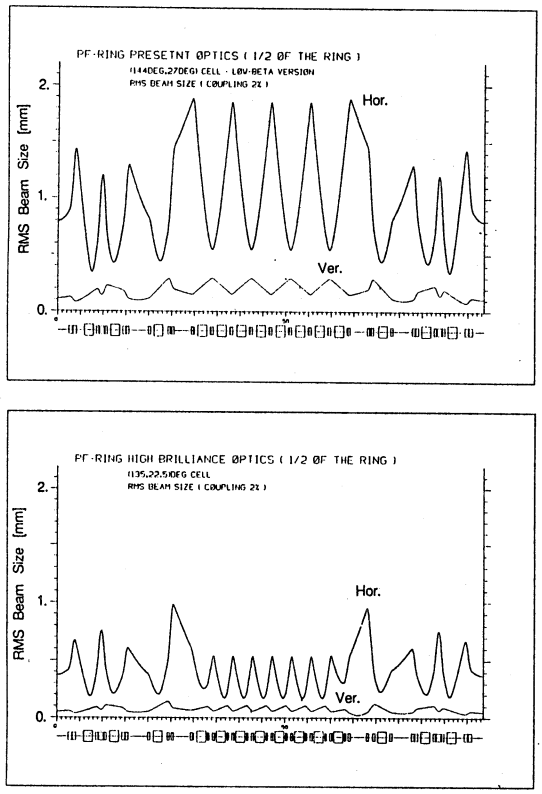

Figure 2. The natural rms beam sizes of the present lattice (upper) and new one (lower) with 135 degree cells. One half of the ring is shown.

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 [4]. This enables us to restart the operation quickly just after the reconstruction work with our familiar optics.

3. DEVELOPMENTS OF ACCELERATOR COMPONENTS

3-1. Magnets

All the present quadrupoles and sextupoles in the normal cells will be replaced with the new ones of higher field gradients. 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 small bore diameters. The sextupoles have auxiliary windings for vertical steering. The fabrication of all the magnets were finished and the field measurements are under way [6].

3-2. Injection

The injection kickers will be reinforced to be compatible with the optical functions around the injection point of the new lattice. A traveling-wave type kickers are developed and under fabrication[7], whose short pulse length enables a single-turn injection scheme. No change will be made for the septum magnets

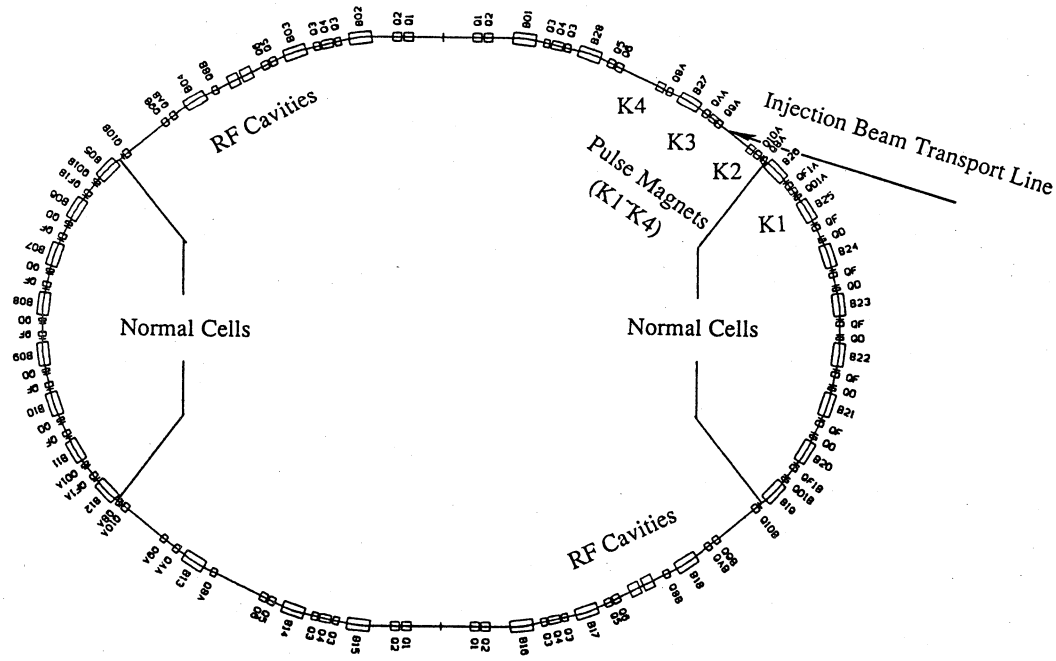

Figure 3. New configuration of the PF storage ring for higher brilliance. Mainly the normal cell sections will be reconstructed. There are also minor changes in the insertion sections.

3-3. Vacuum

About a half of vacuum chambers will be replaced with new ones, which are now under fabrication, to be compatible with new configuration of the magnets. The straight sections of the chambers are newly constructed. The bending sections are remained because there is no change on the bendings. A design consideration is taken to install all the components, such as pumping port, bellows and flange, in the narrow space limited by the doubled magnets. The smaller emittance and the shorter bunch length in the new lattice are expected to result in a shorter Touscheck lifetime and a higher sensitivity to irregularities of inner wall of the vacuum chambers. To guarantee a long beam lifetime, the new chambers are required to have effective pumping speeds equal to or higher than those of present chambers. The bellows and flanges are equipped with a shielding contact to cure the irregularities.

3-4. RF

For a low emittance beam, Landau damping produced by the octupoles cannot be effective to suppress the beam instabilities. The existing four RF Cavities will be replaced with damped cavities, in which dangerous higher order modes giving rise to beam instabilities are damped. A high power model is now under testing [8].

3-5. Beam Channels

The front-ends of the existing SR beam channels in the normal cells will be modified to fit with the new configuration of the magnets and vacuum components and also to cope with the increased power density of SR [9]. The reconstruction of the beam lines has already been started in advance to that of the storage ring. All the work will be finished in 1996.

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, a speed of data taking as fast as 2 kHz. A turn-by-turn beam position measurement scheme is under developing [10], which will be useful for commissioning of the new lattice.

For the orbit stabilization, which will be more important for a lower emittance light source, a fast and precise feedback system for fluctuations lower than 50 Hz is now under developing [11], which utilizes the new fast and precise BPM system mentioned above.

A transverse feedback system to suppress the beam instabilities is under developing, which consists of one deflector and two BPM's[12]. This will be a effective tool to suppress the beam instabilities due to 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[13]. Since the control of the magnets and the beam monitors are more important in the commissioning of the new lattice, their control system will be replaced, first during the shutdown in 1997.

4. SUMMARY

The developments and fabrications of the accelerator components for the emittance upgrade are in progress. All the preparations will be finished until the end of 1996. From Jan. to Sept. in 1997, the ring will be shut down. All the reconstruction work will be completed within this period. The operation of the ring will be restarted in Oct. 1997 with the present emittance optics, as mentioned in section 2. Commissioning of the new high brilliance optics will be tried in the machine study time, typically one day a week. The new optics will be introduced to users times as soon as possible.

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