PRESENT STATUS OF PHOTON FACTORY ADVANCED RING

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Abstract

The upgrade project of the pulse X-ray source PF-AR was successfully completed by the end of 2001. The initial beam current and the lifetime were largely improved. The injection energy was raised from 2.5GeV to 3.0GeV, the maximum beam current of 65mA was achieved. With a new global orbit feedback system, orbit drifts were largely improved.

INTRODUCTION

The AR that was originally constructed as a booster of the TRISTAN electron-positron collider has been parasitically used as an X-ray source [1-2]. It was converted into a ring dedicated to pulse X-ray research and renamed PF-AR(Photon Factory Advanced Ring for pulse X-rays) after completion of the TRISTAN project, however, its performance as a light source was not satisfactory: low reliability due to overage machine components, a short beam lifetime due to insufficient vacuum system performance, deficiency of closed-orbit controllability caused by the unreliable beam position monitor(BPM) system, etc. In order to improve these problems, the PF-AR upgrading project[3] was started in 1999. Old vacuum ducts made of Al alloy were exchanged for ones made of OFHC copper with improved BPM electrodes and the pumping system was largely reinforced. The power supplies for the steering magnets were all changed and the control system were completely renewed. New beamlines and in-vacuum type insertion devices were installed. The upgrading project were completed in the end of 2001, and commissioning of the upgraded ring was successfully done in the beginning of January, 2002 [4-5]. After fine tuning of the machine, users' operation started in April. The typical lifetime of 15 hrs at the energy of 6.5GeV and the beam current of 50mA in a single bunch was achieved, and the closed orbit controllability was largely improved.

The present layout of the PF-AR is shown in Fig. 1. Both the ring and the experimental halls are housed underground. There are four SR beamlines from insertion devices (three in-vacuum-type undulators [6], one elliptically-polarized multipole wiggler [7]) and the other two from bending magnets. New north-west experimental hall, two beam lines(NW-2, NW12) and a new tapered undulator were constructed in the upgrade project.

OPERATION AND PERFORMANCE OF PF-AR

The PF-AR has been operated at beam energies of 6.5 and 5.0GeV, where the 5.0GeV operation is arranged for medical applications. The ring always stores a single-bunch beam of about 55mA, providing unique pulse X-rays for researches such as the time-resolved X-ray experi-

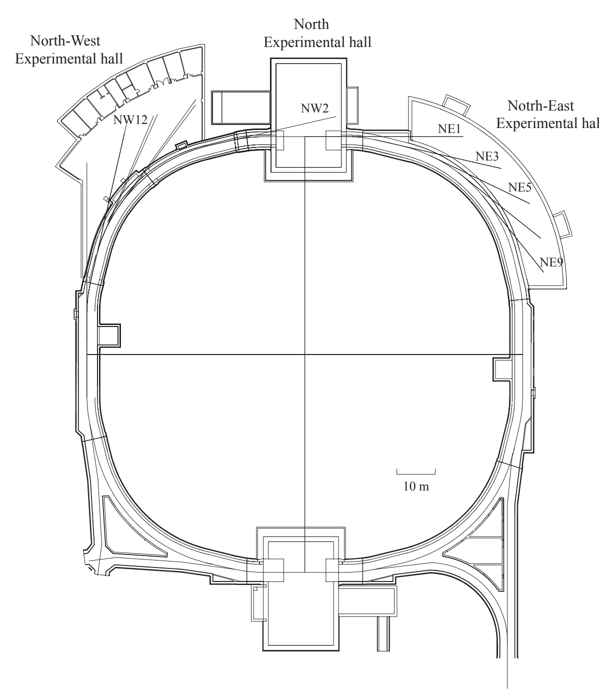

Figure 1: Layout of the PF-AR after the upgrade project.

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Table 1: Principal parameters of the PF-AR under the present optics.

Parameter	Value
Beam energy	5.0 - 6.5 GeV
Injection energy	3.0GeV (2.5GeV)
Circumference	377.26 m
Harmonic number	640
Horizontal betatron tune	10.15
Vertical betatron tune	10.21
rf frequency	508.58 MHz
Emittance (at 6.5GeV)	294nm·rad
Initial stored current	55mA (single bunch)

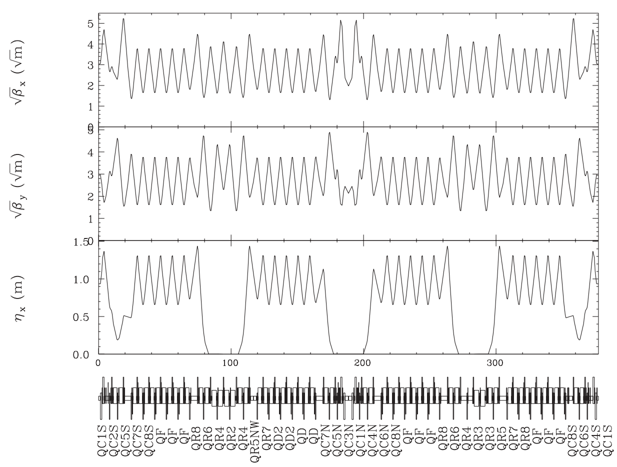

Figure 2: Optical functions in the PF-AR under 90-degree optics.

ments. High beam energy and full-time single-bunch operation characterizes the PF-AR. The principal parameters of the ring are given in Table. 1

The PF-AR is made up of normal FODO-cells, four long straight sections and eight short straight sections. The ring is operated at 90-degree[1] optics for user operation, the emittance is 294nm·rad and the dynamic aperture is sufficiently large. Fig. 2 shows the optical functions of the PF-AR 90-degree optics.

Beam Lifetime

Before the PF-AR upgrade project, the beam lifetime was rather short; about 3 hours at a beam current of 40mA, to maintain an average current, injections more than ten times a day were necessary. After the upgrade project, the beam lifetime became longer (about 15 hours at a beam current of 50mA) and injections are reduced to 3 times a day. Fig. 3 shows the typical beam current and beam lifetime in one-day.

The history of the vacuum conditioning after the upgrade project are shown in Fig. 4, where I and τ are the beam current and the beam lifetime, respectively. The value $I \cdot \tau$ have increased gradually with the integrated beam current.

[1]Phase advance per normal FODO cell.

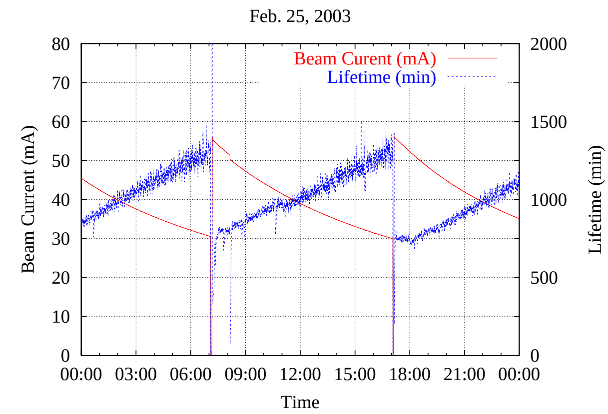

Figure 3: Typical one-day operation of the PF-AR after the upgrade project.

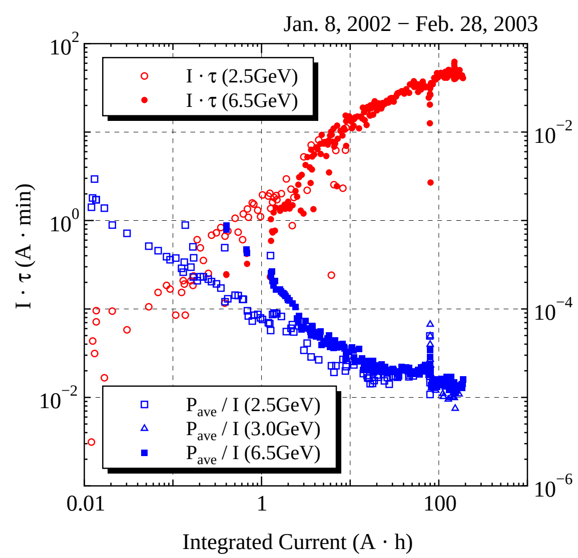

Figure 4: History of the vacuum conditioning after the upgrade project, where I and τ are the beam current and the beam lifetime, respectively.

3.0GeV Injection

Before the upgrade project, the injection energy was 2.5GeV. However, beam instabilities that limited the maximum stored beam current at about 47mA, were observed during the injection [8]. In order to improve the situation, the injection energy was raised from 2.5GeV to 3.0GeV. As a result of the 3.0GeV injection, a higher beam current over 65mA was achieved, however, instabilities still have been appeared during injection. Since 3.0GeV injection started from October, 2002 for user operation, the typical initial stored current is about 55mA.

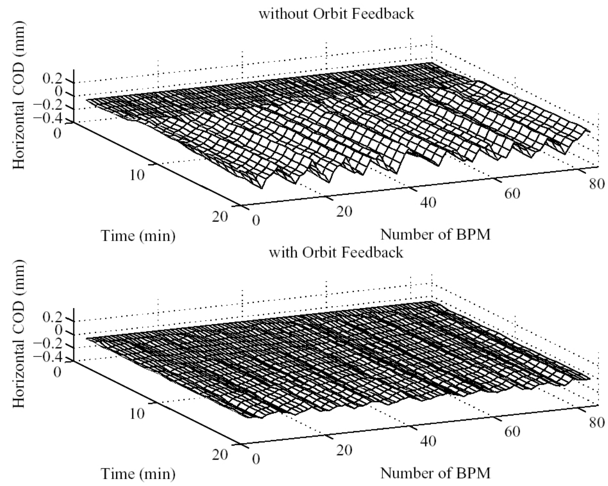

Figure 5: Horizontal orbit fluctuation with and without global orbit feedback. The fluctuation is reduced to 16μm from 85μm for orbit feedback.

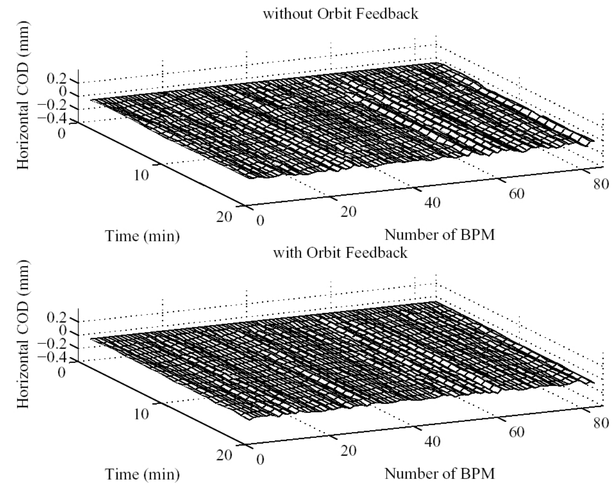

Figure 6: Vertical orbit fluctuation with and without global orbit feedback. The fluctuation is reduced to 63μm from 29μm for orbit feedback.

Orbit Stabilization

A slow orbit drift is observed in proportion to decrease in the beam current in the user operation mode. The typical initial stored current is about 55mA as mentioned above, the current decreases down to 30mA in one operation shift of 8 hours. Thermal deformation of the magnet poles and the vacuum chambers generates the reproducing COD, and r.m.s values of the orbit drift in the horizontal and vertical planes are 85μm and 63μm, respectively.

To suppress this orbit drift, we have improved the global orbit feedback system and make COD correction every 20sec. With the new global orbit feedback system, the r.m.s value of the horizontal and vertical orbit drift are reduced to 16μm and 29μm, respectively. 3D plots of the horizontal and vertical orbit drift with and without global orbit feedback are shown in Fig. 5 and Fig. 6.

Low Emittance Optics

The PF-AR is currently operated at an emittance of 294nm·rad under 90-degrees optics in user operation. For the present lattice the emittance can be reduced to 160 nm·rad using 140-degree optics. In order to reduce the emittance for user operation, studies of low emittance optics have been started April, 2003. After adjusting the machine parameters, electrons could be stored at the low emittance optics. However the beam current was limited to 30mA. It seems that the current limit is caused by the beam instabilities that was observed in 2.5GeV injection. We will survey operating points free from beam instabilities and try to tune the acceleration to 6.5GeV.

SUMMARY

The PF-AR upgrade project was successfully completed. The beam lifetime became longer (about 15 hours at a beam current of 50mA) and injections are reduced to 3 times a day. As a result of the 3.0GeV injection, a higher beam current over 60mA was achieved without beam instabilities. With the new global orbit feedback system, the orbit drift is suppressed. In order to reduce the beam emittance, we will survey operating points free from beam instabilities at the low emittance optics. We will also study beam stability for user operation. For example, sudden decrease of beam lifetime, stabilization of temperature in the ring tunnel and so on.

ACKNOWLEDGMENTS

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