RECENT PROGRESS OF THE OPERATION AT PF-RING AND PF-AR

Y. Kobayashi, T. Aoto, S. Asaoka, K. Haga, K. Harada, T. Honda, M. Izawa, T. Kasuga, H. Maezawa, A. Mishina, T. Mitsuhashi, T. Miyajima, H. Miyauchi, S. Nagahashi, T. Nogami, T. Obina, C.O. Pak, S. Sakanaka, H. Sasaki, Y. Sato, M. Shimada, T. Shioya, M. Tadano, T. Tahara, T. Takahashi, R. Takai, Y. Tanimoto, K. Tsuchiya, T. Uchiyama, A. Ueda, K. Umemori, S. Yamamoto
Photon Factory, High Energy Accelerator Research Organization (KEK)
K. Ebihara, T. Ieiri, T. Kageyama, M. Kikuchi, K. Kudo, K. Marutsuka, T. T. Nakamura, K. Oide, M. Ono, T. Ozaki, H. Sakai, Y. Sakamoto, S. Takasaki, M. Tejima, M. Yoshida, S. Yoshimoto
Accelerator Laboratory, High Energy Accelerator Research Organization (KEK)

Abstract

The present status of the Photon Factory storage ring (PF-ring) and the Photon Factory advanced ring (PF-AR) at High Energy Accelerator Research Organization (KEK), including recent progress for the machine developments, are reported. The operation times of both PF-ring and PF-AR were about 5000 hours and the failure time were about 50 hours in FY2008. Utilizing shutdown pariods of KEK B-factory (KEKB) from January to March 2009, a top-up operation with a continuous injection has been successfully carried out in multi-bunch mode at PF-ring.

INTRODUCTION

Two synchrotron light sources of PF-ring and PF-AR have been stably operated at KEK. PF-ring covers the photon-energy range from VUV to hard X-ray using a 2.5 GeV (sometimes 3.0 GeV) electron beam. PF-AR is mostly operated in a single-bunch mode of 6.5GeV to provide pulsed hard X-rays. Recently, the operation has progressed to realize a so-called top-up operation at PF-ring. In a single-bunch mode, the operation with a continuous injection to maintain a constant beam current of 51 mA has been carried out since February 2007. In addition, the injection with continuing the experiments has been successfully operated in a multi-bunch mode since January 2009. At PF-AR, sputter ion pumps have been extensively reinforced to prolong the beam lifetime and to reduce the frequency of sudden lifetime drops by substituting for distributed ion pumps, which are considered as one of the dust sources.

PF-RING

Top-up Operation

The KEK injector linac provides four kinds of beams with different modes sequentially to four storage rings: Low Energy Ring (LER) of KEKB (3.5 GeV/e^+), High Energy Ring (HER) of KEKB (8 GeV/e^-), PF-ring (2.5 GeV/e^-) and PF-AR (3 GeV/e^-). The beam injection is carried out at PF-ring and PF-AR twice daily, whereas the KEKB rings are operated under a continuous injection mode to maintain the stored current almost constant. The KEK Linac upgrade project has been in progress since 2004 so that a top-up operation for PF-ring and a continuous injection for KEKB can be conducted simultaneously. The final purpose of the upgrade project is the pulse-by-pulse switching of the linac parameters at 50 Hz using a multi-energy linac scheme, in which the common magnet settings for KEKB and PF-ring are required. The beam energy is pulse-by-pulse adjusted utilizing a fast control of a low-level RF phase. At present, a commissioning for the simultaneous beam injection to three rings (KEKB-LER, HER, and PF-ring) has been carried out to realize a top-up operation at PF-ring. The preparations for the top-up operation have been conducted in multi-bunch mode, and the test operation was attempted from January to March 2009. Figure 1 shows the stored beam current as a function of the elapsed time on 11th March 2009. The continuous injection was carried out at a repetition frequency of 2 Hz. The current stability of $\pm 1.1\times 10^{-4}$ was achieved as shown in Figure 2. In addition, we have developed new injection system using a pulsed sextupole magnet (PSM) without a pulsed bump. Through the evaluations of beamlines, we confirmed that the oscillations of the stored beam during beam injection were further suppressed compared with the conventional injection system. Consequently, the instantaneous fluctuation of the photon intensity at beamline #14 using the PSM was reduced one-tenth smaller than that of the conventional system [1].

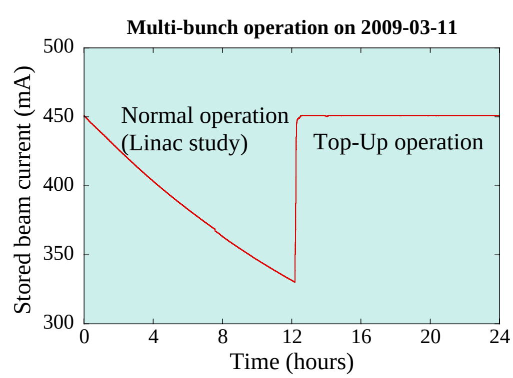

Figure 1: Stored beam current for one day when normal operation in the daytime and top-up operation in the night-time are carried out.

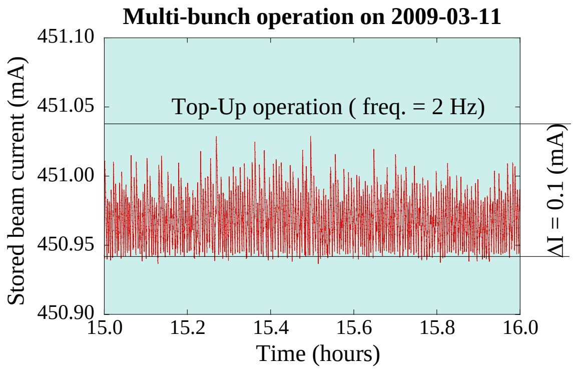

Figure 2: Stability of stored beam current for one hour.

Insertion Devices

We have developed a rapid polarization-switching source at a south long straight section of 8.9 m between the bending magnets B15 and B16. The source was originally planned to switch between left-handed and right-handed circular polarization at a rate as high as 10 Hz in the energy region of 200-1000 eV. Later the importance of switching linear polarization (horizontal and vertical and/or ± 45°) was also recognized. We decided to construct undulators in an APPLE (Advanced Planar Polarized Light Emitter)-II type magnetic configuration [2], which can be employed to produce all of these polarization states. Tandem polarizing-undulators will be installed along the straight section. Differently polarized synchrotron radiation (SR) from each undulator is introduced alternately to the beamline due to rapidly switching the horizontal bump-orbits of the electron beam using five kicker electromagnets. The undulator (U#16-1) is a polarizing undulator which has a period length of 56 mm and a periodicity of 44, designed to be a soft X-ray source covering the energy region from 200 eV to 1 keV. The specifications are listed in Table 1. This undulator was installed in March 2008 and has been providing the SR for users. In addition, a five fast bump system to switch the polarization at a frequency of more than 10 Hz. Bump switching frequency up to 50 Hz is almost successful, but the horizontal orbit leakage of the bump as a function of the frequency was observed. Figure 3 shows amplitudes of the horizontal and vertical leakage orbit oscillation measured by the fast position monitors as a function of the switching frequency. In the vertical direction, the amplitude was reduced to less than 10 μm. However, the amplitude at BPM013 increases as a function of the switching frequency. Thus, we have to further suppress the horizontal orbit leakage for the user operation.

Longitudinal Bunch-by-Bunch Feedback System

In multi-bunch operation, several longitudinal coupled-bunch mode instabilities are observed for stored beam currents above 50 mA, and many efforts have been made to suppress these instabilities [3, 4].

Table 1: Main Specifications of the Undulator (U#16-1)

Parameters	**Values**
Period length	56 mm
Number of periods	44
Minimum gap	21 mm
Magnet array phase	20 mm
Symmetric	± 28mm (p)
Asymmetric	± 28mm (p)
Magnetic field	
Symmetric vertical	6000 G
Symmetric horizontal	3800 G
Symmetric circular	3200 G
Asymmetric ± 45°	3250 G

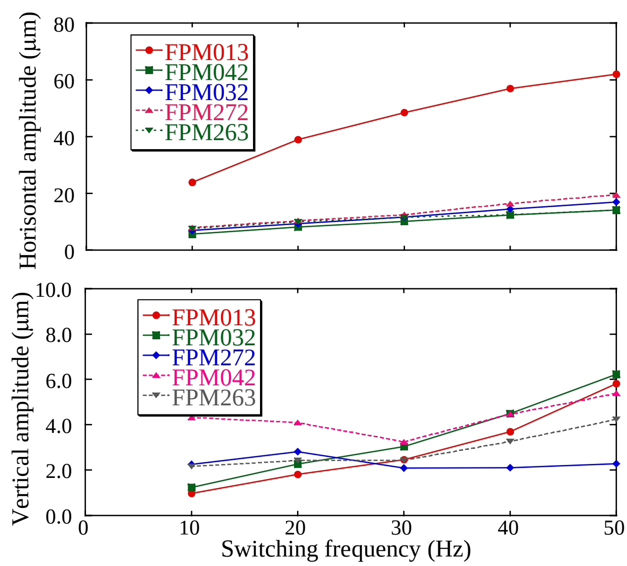

Figure 3: Amplitudes of the horizontal and vertical leakage orbit oscillation measured by the fast position monitors as a function of the switching frequency.

Under the situation, a full bunch-by-bunch feedback system, including a general purpose signal processor, the iGp, has been developed. The iGp provides real-time baseband signal processing at an RF frequency of 500 MHz for the 312 bunches. The longitudinal position of each bunch is digitized by an 8-bit ADC, processed by a 16-tap finite impulse response (FIR) filter, and transmitted to a DAC after the introduction of an appropriate delay. A digital filter is implemented using a field-programmable gate array (FPGA). At structural biology beamline (BL-5), an increase in intensity of approximately 50% was observed with feedback, with a decrease in fluctuations from 5% to 3%. The feedback system has thus been confirmed to be very effective as shown in Fig. 4. Regular multi-bunch SR operation starts with a stored current of 450 mA. In order to improve the highest beam current for dipole-mode suppression, two 500-W power amplifiers are ready to be installed in place of the present 100-W amplifiers. It is also important to suppress the quadrupole-mode instabilities to maximize the intensity at the insertion device beamlines with non-zero dispersion. At present, the instabilities are controlled using the feedback and the RF phase modulation. In addition, we are planning to develop another feedback system for the quadrupole-mode instabilities.

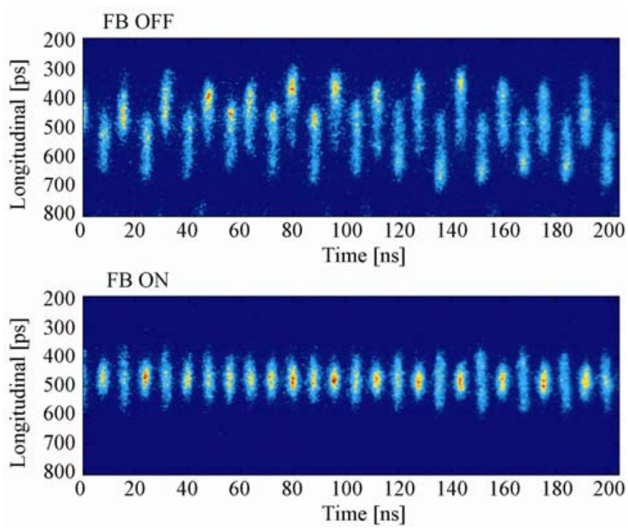

Figure 4: Longitudinal bunch oscillations without (FB OFF) and with (FB ON) feedback system measured by the streak camera.

PF-AR

Sudden Drop of the Beam Lifetime

Since the first stage of the operation in 1980s, we have been suffering from sudden drops of the stored beam lifetime [5-6]. This is one of the most undesirable factors for the stable SR experiments not only by the rapid current decay but also by a burst of gamma-rays sometimes detected in the experimental area. Although such a phenomenon has been observed in many storage rings and is commonly attributed to the trapping of positively-charged dusts, its mechanism is still not fully understood.

Since a distributed ion pump (DIP) installed along the beam orbit is considered as the predominant candidate for the production source of the dust, 61 lumped sputter ion pumps (SIPs) were additionally installed from 2006 to 2008, and then the operation without DIPs has become available. As a result of the DIP-OFF operation, the frequency of the unrecoverable drops in the beam lifetime was reduced from 1.8 to 1.0 times/week (from 74times/6903h to 19times/3058h).

As for other dust sources, our operational experience has suggested that the lifetime drops can be triggered not only by the capture of originally residing dusts especially just after extensive vacuum chamber renewals, but also by electric discharges, supposedly due to wake fields from the beams, in the vacuum chambers such as in-vacuum undulators. Since both phenomena depend on the beam current, we have attempted the dust conditionings with 25% higher current than usual prior to the user operations. By the combination of the DIP-OFF operations and the high current conditionings, the lifetime drop frequency has been reduced to 0.5 times/week (3times/967h), though the statistical data is still being accumulated. The operational states before and after the cures are shown in Fig. 5.

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REFERENCES

[1] H. Takaki et al., in these Proceedings.
[2] S. Sasaki, Nucl. Instr. and Meth., **A 347** (1994) 83.
[3] S. Sakanaka, M. Izawa, T. Mitsuhashi and T. Takahashi, Phys. Rev. ST Accel. Beams, **3** (2000) 05701.
[4] W. X. Cheng, T. Obina, T. Honda, M. Izawa, M. Tadano, M. Tobiyama, T. Nakamura and K. Kobayashi, Proceedings of EPAC06, 3009
[5] H. Saeki, T. Momose, and H. Ishimaru, Review of Scientific Instruments **62** (1991) 874.
[6] Y. Tanimoto, T. Honda, T. Uchiyama, and T. Nogami,, Vacuum (2009) to be published.

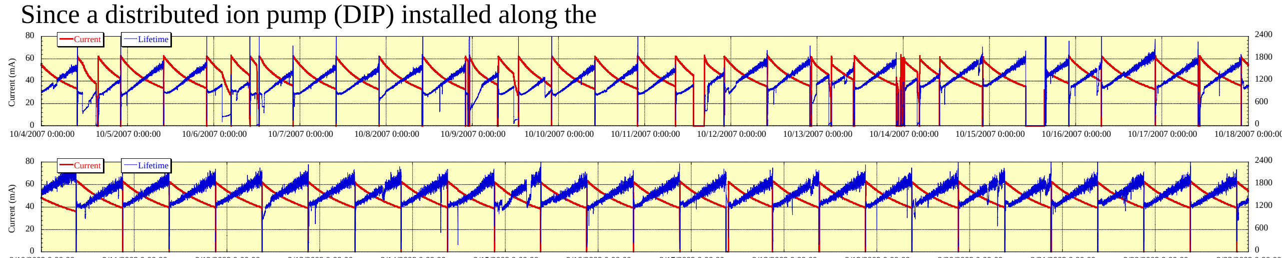

Figure 5: Comparison of the operational states before (upper part) and after (lower part) the cures for the lifetime drops. In each graph, the current in mA (left scale) and the lifetime in minutes (right scale) for typical two-week operation are shown.