PF-RING AND PF-AR OPERATIONAL STATUS

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Abstract

The present operational status of the Photon Factory storage ring (PF-ring) and the Photon Factory advanced ring (PF-AR) in KEK is reported. The scheduled user times of them were more than 4000 hours in FY2006. In the last summer shutdown, new undulators were installed in both of the rings and have been stably operated. A top-up operation in a single-bunch mode was demonstrated for six days in February 2007 druring the shutdown of KEKB at the PF-ring.

INTRODUCTION

In KEK, we have two synchrotron light sources which were constructed in the early 1980s. One is the Photon Factory storage ring (PF-ring) and the other is the Photon Factory advanced ring (PF-AR). The PF-ring is usually operated at 2.5 GeV and sometimes ramped up to 3.0 GeV to provide photons with the energy from VUV to hard X-ray region [1]. The PF-AR is mostly operated in a single-bunch mode of 6.5 GeV to provide pulsed hard X-rays [1]. Main parameters of the PF-ring and the PF-AR are listed in Table 1. The injector for both of the ring is the KEKB linac. The operational performances of them have been upgraded through several reinforcements. After the reconstruction of the PF-ring straight sections from March to September 2005, two short-gap undulators were newly installed [2-3]. They allow us to produce higher brilliant hard X-rays even at the energy of 2.5 GeV. At present we are going to prepare a top-up operation for the PF-ring. In the PF-AR, new tandem undulators have been operated in one straight section since September 2006 to generate much stronger pulsed hard X-rays for the sub-ns resolved X-ray diffraction experiments. In this conference, we report operational status of the PF-ring and the PF-AR including other machine developments.

PF-RING

Operational Status

In the last fiscal year, since the beam lifetime was short due to the reconstruction of the straight sections, beam injections were conducted twice a day in a multi-bunch operation. When the lifetime was over 30 hours at a current of 450 mA, one-a-day injection was resumed from the operation of January 2007. In the single-bunch operation, the beam lifetime after the reconstruction was one-third shorter compared with previous lifetime. Thus, we increased the frequency of the beam injection to 8 times a day from this June. Figures 1 show typical status of beam current and lifetime in a day in a multi-bunch and a single-bunch operation.

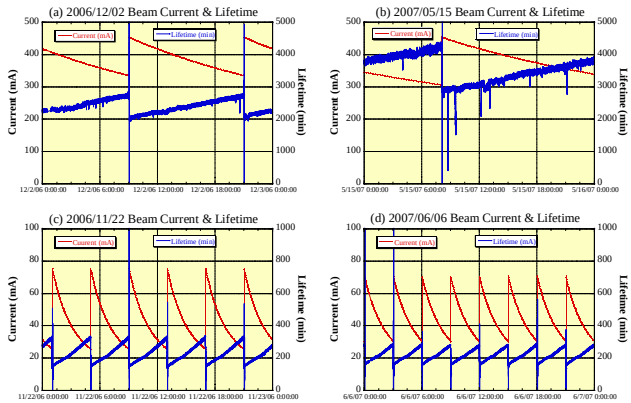

Figure 1: Typical statuses of beam current and lifetime in a day are shown in a multi-bunch operation: (a) 2006-12-02 and (b) 2007-5-15, and the statuses are displayed in the single-bunch operation: (c) 2006-11-22 and (d) 2007-06-06 at the PF-ring.

Table 1: Main Parameters of the PF-ring and the PF-AR.

Parameters	**PF-ring**	**PF-AR**
Beam energy	2.5 GeV	6.5 GeV
Circumference	187 m	377 m
Natural emittance	35 nm·rad	293 nm·rad
RF Frequency	500.1 MHz	508.6 MHz
Injection Energy	2.5 GeV	3.0 GeV
Typical number of bunches	280	1
Initial Stored Current	450 mA	60 mA
Beam lifetime (at init.cur.)	40-50 hours	15-20 hours
Number of insertion devices	9	6

Insertion Devices

Nine insertion devices are active, including new undulator (U#03) which was installed in the last summer shutdown. The principal parameters are listed in Table 2 and the brilliance spectra from these insertion devices are shown in Fig. 2. The U#03 and U#17 are short-gap undulators with a short period length of less than 20 mm and a minimum gap of 4.0 mm. They enable us to produce a higher brilliant hard X-ray than that of bending magnets at the PF-ring. We are now preparing a fast switching variable polarized undulator which will be installed in a long straight section of 8.9m with a fast magnetic bump system.

Table 2: Parameters of the insertion devices at the PF-ring is listed. The U, MPW, SCW, and EMPW denote an undulator, a multi-pole wiggler, a super-conducting wiggler, and an elliptical multi-pole wiggler, respectively. The revolver has magnetic configurations of four different periods. The λu, N, L, and G indicate a period length, a number of period, a total length of insertion devices and a minimum gap.

Name	λu (mm)	N	L (m)	Gy/Gx (mm)
U#02	60	60	3.60	28.0
U#03	18	26	0.50	4.0
MPW#05	120	21	2.52	26.4
U(MPW)#13	180	13	2.34	27.1
VW(SCW)#14			1.20	50.0
U#16	120	26	3.12	50.0
U#17	16	29	0.50	4.0
U#19 (Revolver)	50,72, 100,164	46,32, 23,14	2.30	30.0
U(EMPW)#28	160	12	1.92	30.0/ 110.0

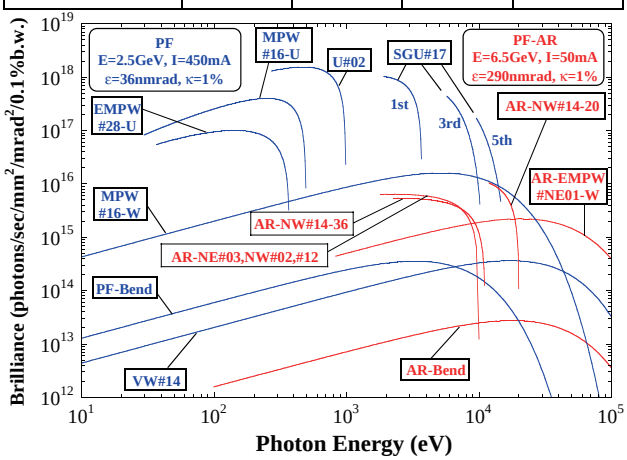

Figure 2: Brilliance spectra as a function of photon energy are shown. The blue lines are for the insertion devices at the PF-ring and the red lines are for the insertion devices at the PF-AR.

Top-up Operation

We are going to start a top-up operation from next autumn 2008 under the KEKB liniac upgrade [4]. In the phase I stage of the upgrade, new beam transport (PF-BT) line was constructed during the summer shutdown 2005 [5]. As the phase II stage, the pulsed bending magnet, which is the first bending magnet for the PF-BT, will be installed during this summer shutdown in the 3rd switch yard of the linac tunnel to realize the pulse-by-pulse switching between KEKB and PF injections. In the PF-ring, we are also preparing to allow us to conduct the experiment during the beam injection: for example, the MBS (Main Beam Shutter) open injection including a reinforcement of radiation protection and interlock system, a suppression of the coherent dipole oscillation of the stored beam, a reinforcement of the injection timing control, and a beam slit installation at the PF-BT line for the charge control, and so on. In February 2007, we conducted the top-up operation in the single-bunch mode in six days utilizing the KEKB shutdown for the installation of the crab cavities. Fig. 3(a) show the beam current in a day and (b) represents the variation of the beam current for five minutes. The beam current is controlled to maintain a stored current of 51 mA at an accuracy of 0.1 mA. The injection period is about 25 seconds at a repetition rate of 1 Hz. Beam current dips appear twice due to the interruptions of the PF-AR injection.

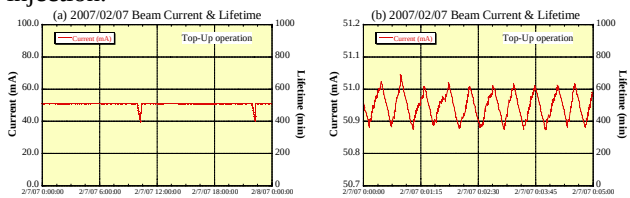

Figure 3: (a) Typical status of the beam current in a single-bunch mode of the top-up operation for one day, and (b) variation of the beam current during five minutes.

Other Machine Developments

The transverse bunch-by-bunch feedback system was introduced to suppress the beam instabilities in 2005, and it has been working well [6]. At the PF-ring, the transverse beam instabilities have been suppressed using the octupole magnets. However, the magnets reduced the dynamic aperture, and then deteriorated the injection efficiency. Thus, we turned off the octupole magnets during the injection time. This was the reason why we introduced the bunch-by-bunch feedback system in stead of the octupole magnets since it was impossible to turn off the magnet in the top-up operation. The other machine developments are carried out as follows:

- Beam based alignment of the beam position monitors
- Beam position and angle monitor for the insertion device beam lines using a synchrotron radiation monitor technique
- Pulsed sextupole magnet system for the top-up operation [7]

- Bump system for the fast switching variable polarized undulator, and so on.

PF-AR

Operational Status

In the last November, we unexpectedly found the orbit to lengthen the beam lifetime during the machine tuning. Though the reason is not understood yet, we have operated using the orbit. Then, the product of beam current multiplied by lifetime increases from 50 A·min to 65 A·min. Figs. 4 show the beam currents and lifetimes in the day of 2006-11-29 (65 A·min) compared with the day of 2006-11-18 (50 A·min).

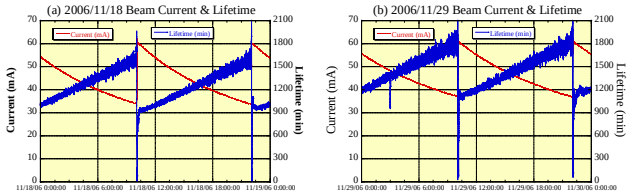

Figure 4: Beam current (red line) and lifetime (blue line) at the PF-AR in the day of (b) 2006-11-29 (65 A·min) compared with the day of (a) 2006-11-18 (50 A·min).

Insertion Devices

Six insertion devices are active at the PF-AR, including new undulator (U#NW14-2) which was installed in the last summer shutdown. The principal parameters are listed in Table 3 and the brilliance spectra from these insertion devices are also represented in Fig. 2. The U#NW14-36 and U#NW14-20 are tandem undulators located in the same straight section NW14, but one quadrupole exists between them. The U#NW14-20 with a shorter period enables us to produce a higher brilliant hard X-ray than other undulators.

Table 3: Same as Table 2, but the parameters at the PF-AR. The U and EMPW denote an undulator and an elliptical multi-pole wiggler, respectively.

Name	**λu (mm)**	**N**	**L (m)**	**Gy/Gx (mm)**
EMPW#NE1	16	21	3.36	30.0/110.0
U#NE03	40	90	3.60	10.0
U#NW02	40	90	3.60	10.0
U#NW12	40	95	3.80	10.0
U#NW14-36	36	79	2.84	10.0
U#NW14-20	20	75	1.50	8.0

Other Machine Developments

In this March, renewal of the bending power supply was carried out. The power supply consists of two converter parts with IEGT (injection enhanced gate transistor) switches, a direct reactor part, a filter part with IGBT (insulated gate bipolar transistor) switches, an over voltage protection part and a control circuit. This was produced by Toshiba Co., Ltd. The special characteristic of the power supply is unity of power factor. Table 4 shows the principal specifications. Though some troubles happened during the period of the initial tuning, it has been operated since the middle of this May.

The other machine developments are carried out as follows:

- Development of the fast switching polarized undulator and test experiment using the device
- Development of the bunch feedback system for the multi-bunch operation
- Development of the movable mask to protect rf cavities from irradiation of synchroton radiation, and so on.

Table 4: Principal specifications of the renewal bending power supply.

Max output current	I	1500 A
Max output voltage	V	1200 V
Max power	P	1.8 MW
Input voltage	Vac	6.6 kV
Current ripple		$< \pm 1 \times 10^{-5}$
Current stability		$< \pm 1 \times 10^{-5}$ /12 hours
Power factor		1

SUMMARY

Both of the PF-ring and the PF-AR have been stably operated with a trouble rate of less than 1% in spite of the old machine. The machine maintenances and developments are continued to supply the stable synchrotron radiation for users. A top-up operation will be carried out from the autumn 2008 at the PF-ring.

ACKNOWLEDGMENT

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