3 PF-AR

3-1 Operation Summary

A scrap-and-build plan is being implemented in the northeast experimental hall of the PF-AR. In FY2008, two beamlines NE1 and NE3 were constructed according to the plan. A part of NE5 was decommissioned, and this experimental activity will be resumed at NE7 in the next year. The source for NE1 is an undulator that was originally designed to supply elliptically polarized synchrotron radiation and was installed in 1989. This undulator operates exclusively in a multipole wiggler mode for hard X-ray applications at NE1. The source of NE3 is the world's first in-vacuum undulator that covers the energy range of 5-25 keV using the primary, third, and fifth harmonics. This undulator was developed in 1990.

The pumping speed of the storage ring was continuously reinforced for three years from 2006 to 2008. During a full-scale reconstruction of the vacuum system in 2001, approximately 180 Ti sublimation pumps (TSPs) and 56 distributed ion pumps (DIPs) were installed in order to meet the vacuum specifications. However, the number of sputter ion pumps (SIPs) was insufficient, and many pumping ports remained unoccupied by SIP. Approximately 60 SIPs with a nominal pumping speed of 0.2 m^3/s have been added mainly to the arc sections. Then, the number of SIPs was doubled, and the total pumping speed for the storage ring improved considerably. Because of this improvement, it has become possible to maintain a sufficiently long beam lifetime without the DIP, which is considered a potential source of dust trapping that causes a sudden decrease in the beam lifetime. It was confirmed that the dust trappings could be reduced if all the DIPs were switched off during user operation.

With the achievement of a long beam lifetime and stable operation, the importance of the independent tuning of the undulators has gained considerable attention at the PF-AR. We have achieved independent tuning for the undulator NE1 by following the tuning procedure already established at the PF ring. There are five other undulators at the PF-AR; independent tuning for all the four will be performed one by one in FY2009.

As shown in Fig. 1, the total operation time was approximately 5000 h from FY2002 to FY2008 after the full-scale reconstruction in 2001. The operation statistics are listed in Table 1. In FY2007, we needed some time to adjust the new bending-magnet power supply, and the failure rate was exceptionally high (5.0%). In FY2008, the beam development time became considerably short, and the failure rate recovered to 1.0%, which is the best value obtained since 2002. The SR experiment time was almost 90% of the total operation time. We believe that the movable masks protecting the RF cavities from the SR irradiation installed in 2007 were also responsible for the stabilization of the operation.

Table 1
Operation statistics in FY2008.

Operation Time	4969.0 h	
SR Experiment	4414.6 h	88.8%
Beam Development	444.0 h	8.9%
Failure	50.7 h	1.0%
Miscellaneous	59.7 h	1.2%

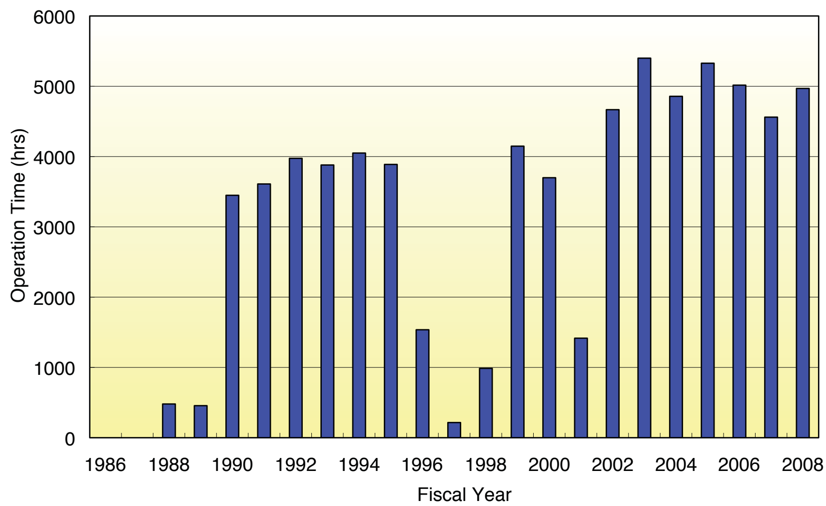

Figure 1
Operation time as a function of fiscal year.

3-2 Improvement of Beam Lifetime

In the past three years, the vacuum system was reinforced by installing 61 sputter ion pumps (SIPs). The reinforcement resulted in a 13% increase in the total effective pumping speed, and consequently, the beam lifetime became 12% longer than before [1]. In particular, the improvement allowed us to mitigate the long-standing problem of a sudden decrease in the beam lifetime, which disturbs stable user experiments due to rapid current decay and burst of gamma rays, which are sometimes detected in the experimental area. The sudden decrease in the beam lifetime is attributed to the dust-trapping phenomenon, and the distributed ion pumps (DIPs) installed close to the beam orbit in all the 56 bending magnets are considered to be the major sources of dust particles. The reinforcement provided an option of substituting the DIPs with SIPs. As a result of the DIP-OFF operation, the frequency of the unrecoverable decreases in the beam lifetime was reduced from 1.8 to 1.0 times/week (from 74 times/6903 h to 19 times/3058 h).

Successive investigation to seek other sources of dust was carried out by checking vacuum data for signs of dust generation. We found that some of the sudden decreases in the beam lifetime were accompanied by a transient increase in the vacuum pressure at some discharge-prone vacuum chambers, such as in-vacuum undulators and an RF feedback kicker with strip-line electrodes. The transient changes in the vacuum pressure were supposedly caused by electric discharges due to wakefields from the beams. Therefore, we attempted dust conditionings with 25% higher current than usual, prior to user operations. Although statistical data is still being accumulated, we have observed that the lifetime drop frequency reduced to 0.5 times/week (3 times/967 h) when a combination of the DIP-OFF operations and the high current conditionings are adopted. The operational states before and after the cures are shown in Figs. 2 (a) and (b), respectively. The figures show that the stability of the routine operations has considerably improved.

REFERENCE

[1] Y. Tanimoto, T. Honda, T. Uchiyama and T. Nogami, *Vacuum,* **84** (2010) 760.

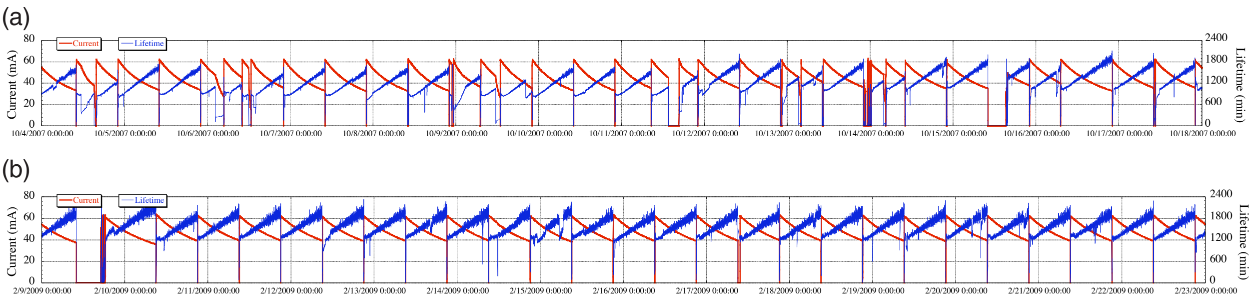

Figure 2
Typical operational states for two weeks are shown. The red line denotes the stored beam current, and the blue line denotes the beam lifetime. The upper part (a) shows the operational states before the cures in October 2007, and the lower part (b) shows the states after the cures in February 2009.

3-3 Independent Tuning for Insertion Devices

Six insertion devices (IDs) have been stably operated until now. Recently, the gap control system for the IDs has been renewed with EPICS. Independent tuning for every ID has been performed without applying any corrections for the orbit fluctuations since the beam sizes are relatively large and the influences are not serious in the case of the experiments. However, the effects of orbit fluctuations on the change in the gap are apparent at several beamlines with the increase in the number of IDs. Therefore, we suggested corrections for the orbit fluctuations on the change in the gap in order to realize independent tuning.

First, the correction of the orbit fluctuations for ID-NE#01 was carried out using steering magnets located at both ends of the ID. Steering magnets can generate an integral magnetic field of up to 2000 gauss·cm when driven with a 12-bit DC power supply (HP6633B) in both the horizontal and the vertical directions. Since a permalloy was used as the core material of the magnet in order to reduce the remnant magnetic field, reliable reproducibility was obtained for the orbit correction. The orbit fluctuations were measured by using the BPM system for both vertical and horizontal directions. Eighty-three BPMs were used, and the relative accuracy of the fluctuations was less than 20 μm. The acquisition time for changing the gap and reading the BPM data was approximately 5 min.

Figures 3 (a) and (b) show the results of the orbit fluctuations as a function of the BPM number for gap differences between 30 mm (minimum) and 100 mm (maximum) with and without the corrections. The orbit fluctuations after the correction were reduced to less than 20 μm around the ring in both directions. The operation with the independent tuning for ID-NE#01 was begun in April 2009 and will be accomplished step-by-step for the other IDs.

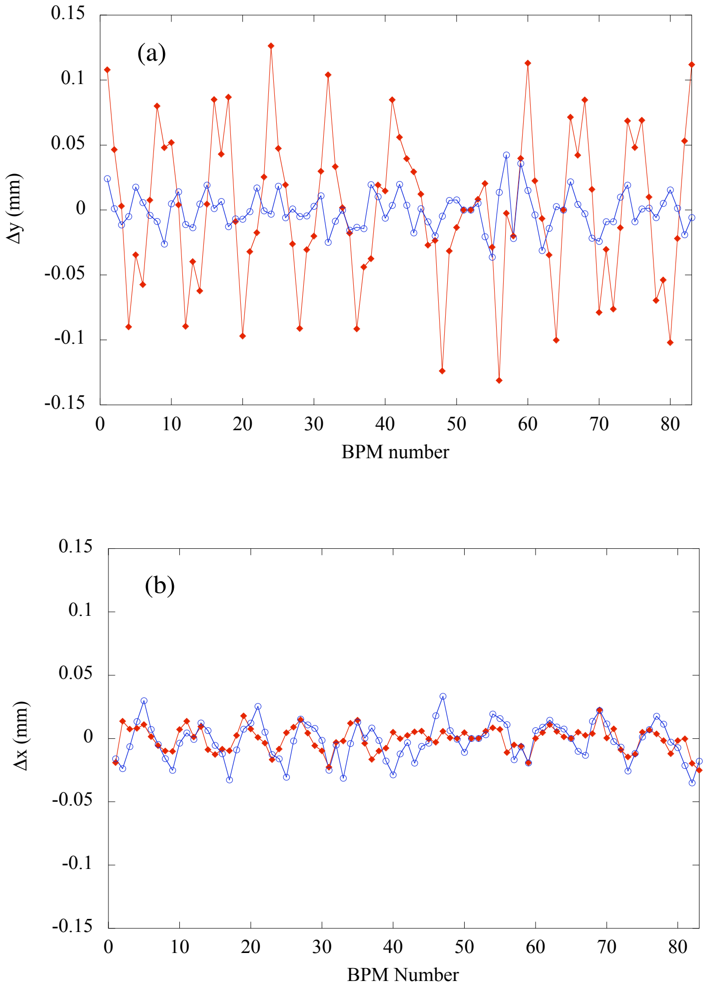

Figure 3
Orbit fluctuations of the gap (between 30 mm and 100 mm) for ID-NE#01 as a function of the BPM number. Red diamonds and blue open circles represent the fluctuations before and after corrections, respectively. The upper part (a) shows the vertical orbit fluctuation, and the lower part (b) shows the horizontal orbit fluctuation.