STATUS OF PLSII OPERATION*

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Abstract

As the upgrade of PLS, PLSII is a 3 GeV light source in 12 super-periods (281.8 m circumference) with 5.8 nm design emittance and can store electron beam up to 400 mA with 3 superconducting RF cavities. Its most unique characteristic is that it has a short straight section and a long straight section for each cell (24 straight sections) and up to 20 insertion devices can be installed. But, as the installed insertion devices, particularly in-vacuum insertion devices, are sources of high impedance, these are quite challenging for high current operation. Current status of PLSII operation and future plans are described in this paper.

INTRODUCTION

PLSII is the upgrade machine of PLS which was a 2.5 GeV light source with a triple bend achromat lattice, and is a 3 GeV machine with a double bend lattice. Certainly, performance of PLSII has been upgraded from PLS, from 18.2 nm emittance to 5.8 nm emittance and PLSII can now store 400 mA compared to 180~190 mA storing of PLS [1]. But, the most special thing of the PLAII lattice is that it has 2 straight sections with different lengths per cell as can be seen in the PLSII lattice of Figure 1. The long straight section (LSS) is 6.88 m long and the short straight section is 3.69 m long. To make these many straight sections, gradient bending magnets were used and only 8 sets of quadrupoles were used in each cell. Parameters of PLSII are listed in Table 1.

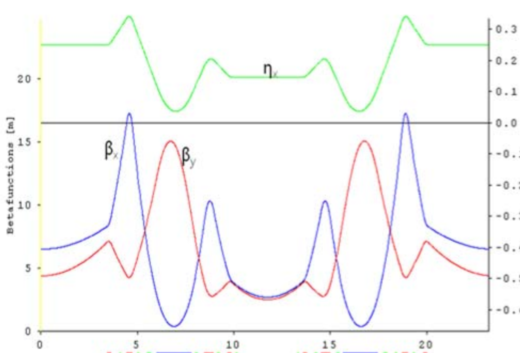

Figure 1: Magnet lattice of PLSII.

The purpose of reserving 2 straight sections per cell was to install as many insertion devices as possible. Hence, of the 24 straight sections of PLSII, 20 straight sections are already used or reserved for insertion devices. Particularly, many in-vacuum insertion devices have been installed to provide hard X-ray capacity to users. Currently, 12 in-vacuum insertion devices are installed. However, these many insertion devices and particularly in-vacuum insertion devices give difficulties to overcome for smooth operation. First of all, changing gap of the many insertion devices particularly the in-vacuum insertion devices by users is a severe source of orbit perturbation. Next, the insertion devices particularly the in-vacuum insertion devices generate resistive wall impedance high enough to cause transverse multi-bunch instability, when their gap is closed [2]. The instability is so severe that the highest beam current stable is only around 120 mA. The first problem was solved by global orbit feedback and local feed forward while the second problem was solved by a transverse feedback system. Details are explained below.

Table 1: Main Parameters of PLSII

Parameter	Value
Energy	3 GeV
Current	400 mA
Emittance	5.8 nm
Circumference	281.82 m
Tune (h/v)	15.24 / 9.17
Revolution freq.	1.0638 MHz
Harmonic No.	470
RF freq.	499.973 MHz
Cavity type	SC
No. of Cavities	3
Gap Voltage	4.5 MV

ORBIT STABILITY

Now, the PLSII orbit stability is assured by collaboration of the slow orbit feedback (SOFB) system and the fast orbit feedback (FOFB) system. Prior to January, 2016, SOFB was used alone and after January, 2016, SOFB + FOFB is used. Eight beam position monitors (BPM) are placed in a cell.

Slow Orbit Feedback System

SOFB makes use of the 8 correctors, which are actually trim windings on the same number of sextupoles, distributed over a cell. Prior to 2016, SOFB was operated in 1 Hz but is now operated in 2 Hz. With this speed, SOFB alone could not suppress faster orbit perturbations such as ground vibration or insertion device gap changing. Consequently, the unsuppressed orbit errors accumulated and the orbit difference from the reference orbit which is usually chosen twice a year could not maintained within the target value, 1 micron rms, over a long term (for example over the 10 day user service period). The orbit difference from the reference orbit made by SOFB alone over a 10 day period is shown in Fig. 2(a). In this figure, many orbit spikes appearing resulted from insertion device gap changing.

* Work supported by Korean Ministry of Science, ICT & Future Planning
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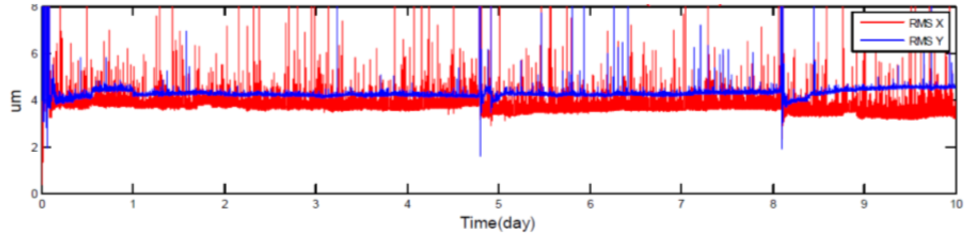
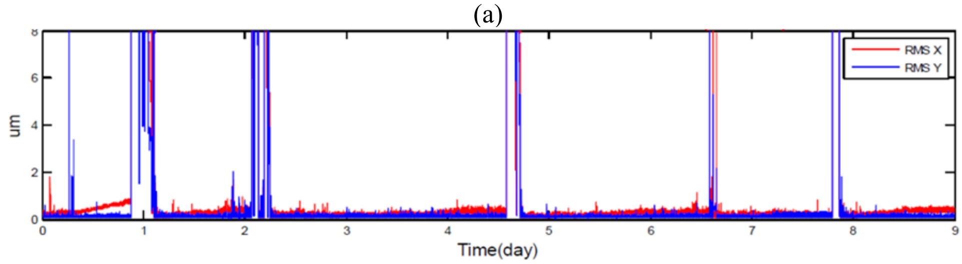


(a)



(b)

Figure 2: The orbit difference from the reference orbit made by SOFB alone over a 10 day period and the orbit difference from the reference orbit made by SOFB+FOFB over a 9 day period.

Fast Orbit Feedback System

FOFB makes use of 4 fast correctors located around the two straight sections of a cell. These corrector magnets are air-filled magnet without York core and placed on the stainless parts, to minimize the eddy current. Its maximum kick strength is limited to 20 micro-rad. Hence, the fast correctors would soon be saturated if these are used alone without slow correctors. In other words, fast correctors alone cannot make or maintain the electron beam orbit, and their role is limited to minimize the orbit deviation from the reference orbit.

SOFB+FOFB system

The SOFB+FOFB system has proved to be very effective for maintaining the long term orbit stability. As can be seen in Fig. 2(b), the orbit deviation from the reference orbit is kept far below 1 micron rms over a 9 day period. Actually, this orbit stability is maintained over months, which shows that the SOFB+FOFB combination can suppress all the major perturbation sources.

In this complementary combination, SOFB maintains the global orbit while suppressing the slow perturbations and FOFB concentrates on suppressing fast perturbations dumping any contribution to the orbit forming to SOFB. This dumping or downloading to SOFB occurs in 1 Hz.

Transient Orbit Distortion due to top-up injection

Currently, top-up injection is performed every 180 seconds. The problem of top-up injection is that the injection bump is not closed perfectly but generates transient orbit perturbations in both the horizontal and vertical directions after injection ends. The amount of distortion and duration in both directions is shown in Fig. 3.

To remove this transient orbit, we are making a plan to install a new and improved injection system with the following features:

1. An independent power supply for each of 4 injection kicker magnets.
2. New kicker magnets with smaller gap
3. New ceramic chamber
4. Magnet tilt adjusting system
5. New injection point. Decreased orbit bump from 15 mm 50 12 mm.
6. A set of digital BPM installed

Independent adjusting of each power supply and the magnet tilt adjusting will significantly reduce the transient orbit distortion. Reduced magnet gap and orbit bump ease the kicker magnet and power supply requirements, and will help to raise the injection efficiency.

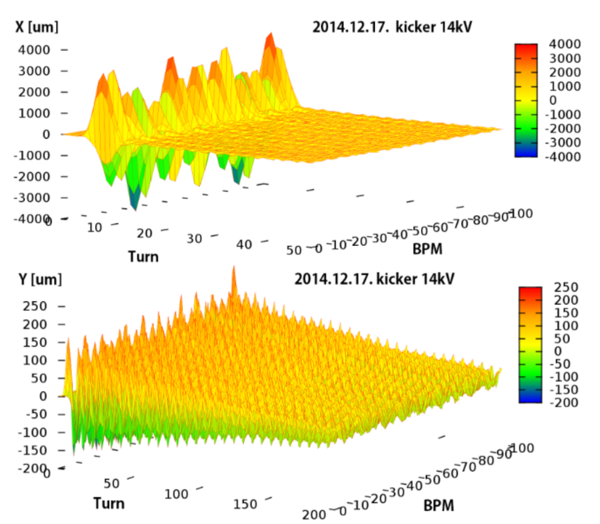


Figure 3: Transient orbit distortion generated by top-up.

IMPEDANCE

Small gap of the many in-vacuum insertion devices installed over the PLSII storage ring cause electron bunches passing the insertion devices to be influenced heavily by the impedance and consequently execute transverse multi-bunch instability. This transverse instability is effectively and perfectly suppressed by a transverse feedback system developed and made by Spring8, Japan.

On the other hand, the narrow gap insertion device chamber also provides high resistive wall impedance to electron bunches and this high impedance sometimes raises thermal capacity issue. In 2015, during a 400 mA operation, a bellow finger located on a short straight section was melted perhaps by the resistive wall impedance caused heating. This is one of the reasons why 400 mA top-up operation is not provided every day.

To mitigate the peak impedance and so prevent this kind of accident, installation of a third harmonic cavity is considered. Bunch lengthening through a third harmonic cavity will reduce the peak current and thus the peak impedance experienced by an electron bunch.

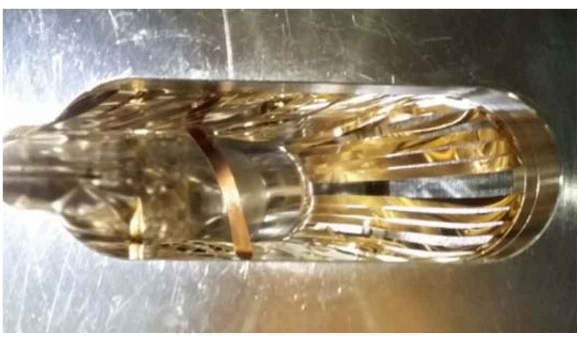


Figure 4: A melted bellow finger.

HYBRID MODE

A 300 mA hybrid mode is serviced routinely in the 300+1 filling pattern. Its oscilloscope image is shown in Fig. 5.

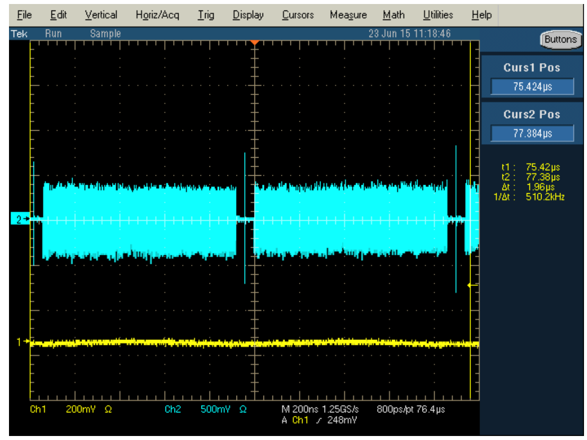


Figure 5: Oscilloscope image of the PLSII hybrid fill pattern.

SUMMARY

PLSII has achieved orbit stability through the SOFB + FOFB combination which maintains the rms orbit deviation from the reference orbit far below 1 micron. The transient orbit distortion is generated by injection kicker at the time of top-up and will be removed by installing a new injection system in the next few years.

PLSII has also achieved 400 mA top-up operation by using the transverse feedback system to suppress the transverse multi-bunch instability caused by high impedance of insertion devices. But, 400 mA top-up operation is not routinely serviced because of the insufficient thermal capacity of the vacuum chamber components. To solve this problem, a third harmonic cavity may be installed in the future.

REFERENCES

[1] I. Hwang, M. Kim, T.-Y. Lee and C. D. Park, “Operation improvement by tuning of storage ring at PLS-II”, in *Proc. IPAC2016,* Busan, Korea, May 2016, paper THPMB030, pp. 3297-3298.

[2] T. Nakamura, K. Soutome, M. Takao, M. Masaki and T. Hara, “Resistive-wall coupled-bunch instability driven by in vacuum insertion devices in the spring-s storage ring”, in *Proc. PAC 2001*, Chicago, USA, Jun. 2001, pp. 1969-1971.