ORBIT FEEDBACK IN TAIWAN LIGHT SOURCE

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Abstract

The global orbit feedback system is indispensable for the Taiwan Light Source (TLS) operation. The existing orbit feedback system has been deployed for a decade to stabilize electron closed orbit. This orbit feedback system is used to suppress various perturbations include orbit excursion due to insertion device operation. To take advantages of advanced technologies in BPM and power supply, the feedback system is upgraded recently accompany with BPM electronic and corrector power supply upgrade; infrastructure of new system has also been modified and rebuilt. Orbit stability is improved drastically. Efforts of digital BPM (Libera Brillance), PWM power supply, orbit feedback system, on-line system modeling, diagnostic access, and control rules upgrade with reduced ill-conditioned response matrix will be presented in this report. Planning the global orbit feedback system based upon experiences accumulated form TLS project for the newly proposed Taiwan Photon Source (TPS) will be summarized also.

INTRODUCTION

Orbit stability is more and more emphasized for a modern synchrotron light source. Generally, beam motion should be less than 10 % of its beamsize or even smaller. There are many efforts make to improve orbit stability and reduce the ambient environment influence of Taiwan Light Source (TLS) such as, removing various mechanical vibration, feed-forward compensation of insertion devices, locate faulty power supply and etc. Besides these passive controls, the active orbit feedback system is also adopted. Nevertheless, the limited loop bandwidth of the system led incapability to suppress fast orbit perturbation above 5 Hz. The fast orbit feedback system was thus proposed. The commissioning of the new fast orbit feedback system will come to an end soon. In the report, the upgrade progress and performance of the BPM system will be presented. Measurement of the system response and latency are discussed next. Finally, the infrastructure and performance of fast orbit feedback are summarized.

INFRASTRUCTURE OF ORBIT FEEDBACK SYSTEM

The infrastructure of the new orbit feedback system is shown in Fig. 1. The orbit controls for the horizontal and vertical plane are separated from the old version to increase available computation power. The reflective memory is employed to shares fast orbit data without consuming extra CPU resource and support fast data for other subsystems. The Libera grouping which packs all of Liberas payload data into a single UDP packet to reduce the GbE communication jitter in CPU that will be discussed later. Beside, since there are no dedicated fast correctors at TLS, setting of the DC closed orbit control and the fast correction signal will be sum together by an in-house made interface card, which is mounted to the leftmost slot of power supply crate.

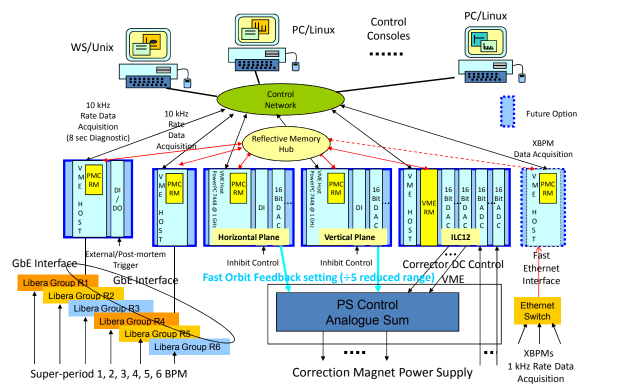


Figure 1: Infrastructure of the new FOFB and the related subsystems.

Power Supply Upgrade

The linear type corrector power supply has been replaced by MCOR 30 in January 2007 for the vertical plane and the horizontal plane in October 2008. Performance of the new MCOR3 power supply is 5 times better than the old one in noise level and has large small signal bandwidth. After upgrade, the bandwidth determined by a whole of power supply, corrector and the vacuum chamber is increased from a few Hz to around 80 Hz and 30 Hz in vertical and horizontal respectively. Figure 2 shows the measured overall response of the three vertical correctors in the feedback loop. The dynamics of these three correctors differ from each other.

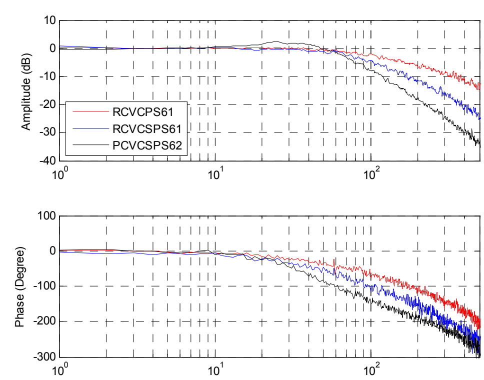


Figure 2: Three vertical correctors' (RCVCPS61, RCVCSPS61, RCVCSPS62) response functions.

BPM Upgrade and Libera Grouping

The Libera Brilliance [1] is employed to replace the existing BPM electronics for the TLS (Fig. 3). This integration had start from 2007 and gradually was deployed not to interfere with the routine operation. All of Libera Brilliances in the storage ring are grouped together to produce a packed GbE UDP packet and reduce the number of IP packets receiving jitters for CPU. Figure 4 shows the structure of Libera grouping. All of Libera Brilliance units are connected to a ring by a redundant multi-gigabit links via the LC optical links and/or copper “Molex” cables. This link can exchange the data among the all units done by FPGA inside Libera and grouping all Libera together[2][3].

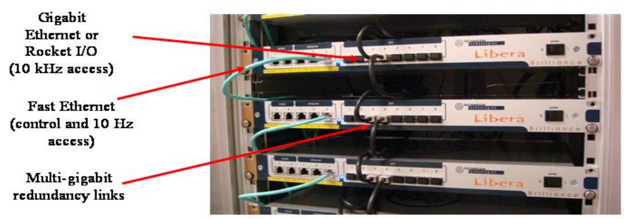


Figure 3: Photograph of Libera in the TLS.

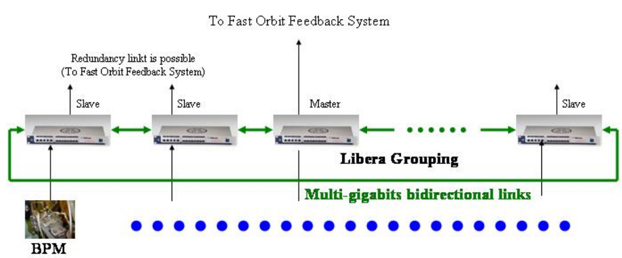


Figure 4: Structure of Libera grouping.

SINGULAR VALUE DECOMPOSITION AND MODE SPACE

SVD and Tikhonov Regularization

Singular value decomposition (SVD), as a most commonly used correction algorithm, is employed to invert the response matrix. Furthermore, to obtain a stable solution, Tikhonov regularization [4] is adopted. Figure 5 shows the scaling singular value versus different regularization parameter α of the TLS.

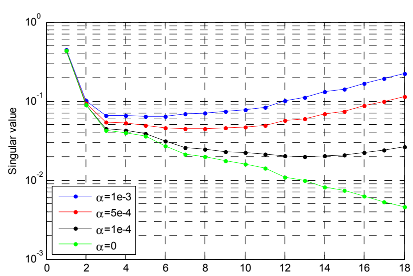


Figure 5: Singular values and Tikhonove regularization for different regularization parameter α.

This regularization method can solve ill-conditioned problems and less sensitive to measurement errors. After applying this method, the loop gain can be adjusted when the higher mode with less weightings and lower bandwidth.

BPM Data in Mode Space

Figure 6 shows BPM spectrum in mode space in the horizontal and vertical plane respectively. The higher mode has less weight for both of two planes and vice versa.

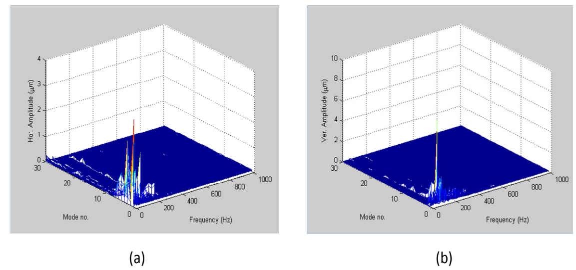


Figure 6: 3-D plot of BPM amplitude spectra. (a) is horizontal plane; (b) is vertical plane.

SYSTEM PERFORMANCE MEASUREMENT

Noise Sensitivity Function Measurement

The bandwidth of FOFB are measured and estimated as Fig. 7, which it can be seen that the new FOFB is promoted to suppress noise of bandwidth to 50Hz from old 5Hz system after system upgrade.

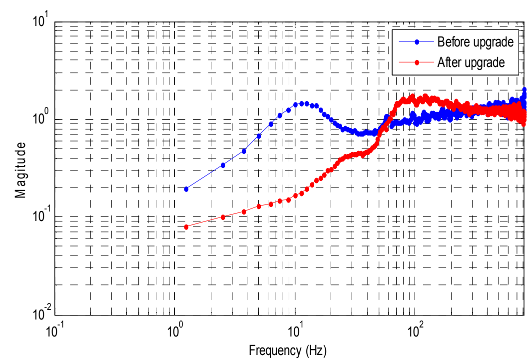


Figure 7: Noise sensitivity function comparison before and after FOFB upgrade.

Orbit Stability for User Operation

The feedback system can improve beam stability as shown in Fig. 8. The peak to peak displacement in the horizontal plane may be over 10 µm in some BPM position while it can be reduced less than 1 µm after applying the fast orbit feedback system. The stability could be even better when removing the perturbation source from quardpole power supply. Figure 9 also shows the standard deviation of all BPM reading in the vertical plane, which is suppressed to 0.2 um from 0.8 um between feedback on and off.

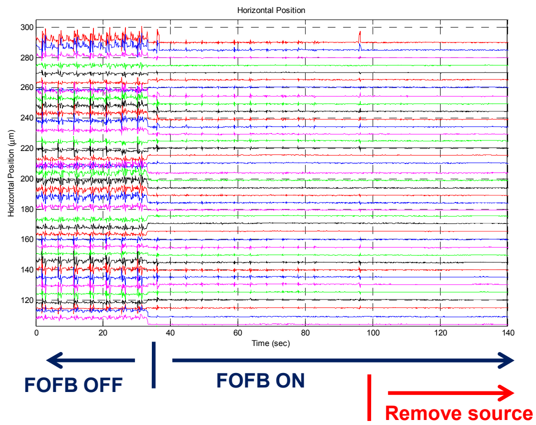


Figure 8: SA data for FOFB ON/OFF. FOFB OFF before 32 sec and ON after 32 sec.

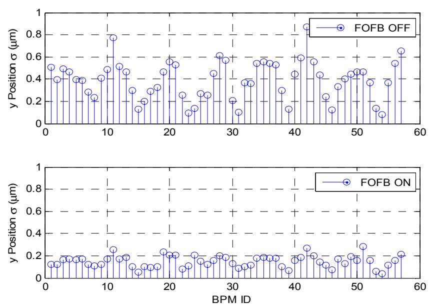


Figure 9: The standard deviation of vertical orbit displacement between FOFB on/off.

Figure 10 shows the R6BPM7 FA data spectrum comparison when FOFB on and off. The orbit stability can be suppressed to one micron at this location with larger β function therefore the overall RMS orbit stability should be submicron from DC to 50 Hz.

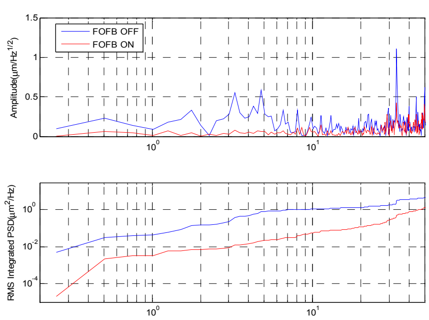


Figure 10: The spectrum and integrated PSD of R6BPM7 for FOFB on/off.

We also plot the modal spectra for feedback on/off in the vertical plane as Fig. 11. It shows the same result as Fig. 10.

Effects of FOFB for Insertion Device Operation

The wider bandwidth of the new orbit feedback loop can promote the motion speed of insertion device. Fig. 12(a) shows the 1 mm/sec phase move of the EPU5.6. The orbit displacement is shown in Fig. 12(b). It is clearly observed that the feedback loop can eliminate the orbit excursion.

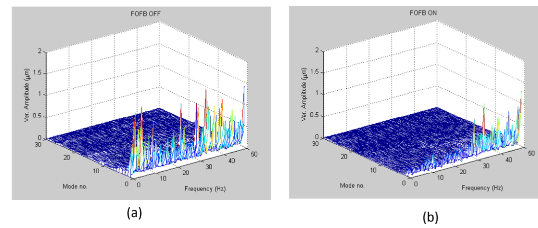
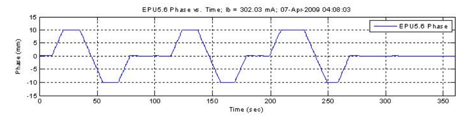
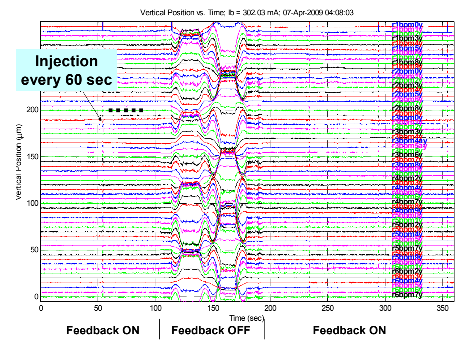


Figure 11: 3-D plot of BPM amplitude spectra in the vertical plane. (a) is feedback off; (b) is feedback on.



(a)



(b)

Figure 12: Effectiveness of the new orbit feedback system to suppress orbit excursion of 1 mm/sec phase change of EPU5.6: (a) history of the EPU5.6 phase motion at speed of 1 mm/sec and (b) beam position reading of all BPMs.

SUMMARY

Infrastructure of the FOFB for TLS has been revisited. Various R&D including modelling, measurement, control rules, and etc. are going on. Various results and exercises confirmed that the FOFB system effectively improves orbit stability.

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[2] C. H. Kuo, et al., "Fast Orbit Feedback System Upgrade with New Digital BPM and Power Supply in the TLS", DIPAC'07.
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