COMMISSIONING RESULTS OF THE FAST ORBIT FEEDBACK AT THE ALS*

C. Steier†, A. Biocca, E. Domning, S. Jacobson,
G. Portmann, T. Scarvie, E. Williams, LBNL, Berkeley, CA 94720, USA

Abstract

A new fast global orbit feedback system has been designed at the ALS and is in commissioning since last September. The system has two main purposes. The first is to meet the demands of some users for even improved short term orbit stability. The second is to enable the use of more sophisticated insertion device compensation schemes (e.g. tune, beta-beating, coupling) for fast moving insertion devices like elliptically polarizing undulators, without deteriorating the orbit stability. One feature of the fast orbit feedback (with 1 kHz update rate) is the use of standard computer and networking equipment.

INTRODUCTION

The ALS is a third generation synchrotron light source and has been in operation since 1993. Many of the experiments carried out nowadays require very high resolution or measure very small asymmetries and therefore require extremely high orbit stability. On the other hand there are new sources of orbit distortions created with the installation of additional (fast moving) insertion devices [1] and the implementation of more and more feedback or feed-forward loops (e.g. optics and coupling compensation).

Over the years there have been continous upgrades of the orbit stability at the ALS, by improving the passive stability, using feed-forwards or slow (and most recently fast) feedbacks. One of the improvements in the last year was the installation of new chicane magnets. The second was the inclusion of additional stable, high-resolution beam position monitors around the center bend magnets, and the third were improvements in the slow orbit feedback algorithm. Last, there was the initial commissioning of a fast orbit feedback system.

New Chicane Magnets

The chicane magnets at the ALS are used to allow the use of two short (2 m) undulators in a long (5 m) straight section feeding two independent beamlines. The original set of chicane magnets in one straight section were iron core magnets and unfortunately they had larger than acceptable hysteresis and low bandwidth. To solve this problem a new low hysteresis chicane magnet was constructed based upon a novel design (see Fig. 1). The new chicane consists of permanent magnet cylinders and air core coils.

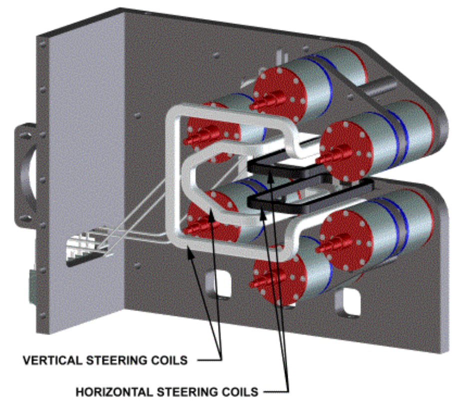

Figure 1: New permanent magnet/air coil chicane magnets.

Now the field integral errors of the fast moving APPLE-II type undulators can be corrected more locally, allowing them to shift from left to right circular polarization with significantly less than 1 μrad local angular distortion. Last year two of these new chicane magnets were installed in the ALS.

RF-Frequency Feedback

Starting in September 2001, RF frequency feedback was routinely included in the orbit feedback [2]. The orbit feedback now compensates changes in the ring circumference by adjusting the RF frequency once a second. Fig. 2 shows how the ring circumference changed since RF frequency feedback was implemented.

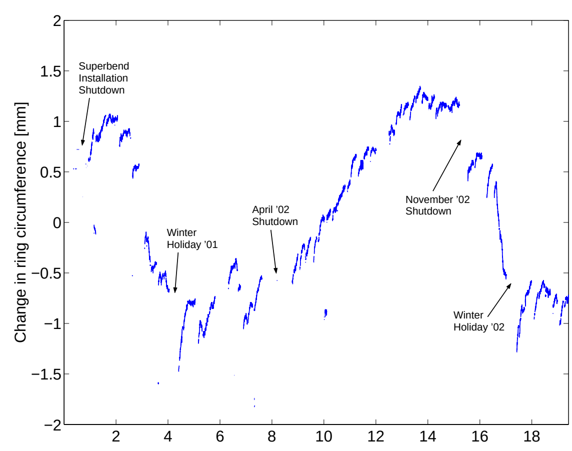

Figure 2: Change in circumference of the ALS over 1.5 years.

What can be seen is that there are substantial circumference variations. Some of the variations are seasonal and are due to temperature and ground water levels. These changes

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† CSteier@lbl.gov

correspond to a variation of about 3 mm over the year and the variation appears to be cyclic. The ALS circumference changes for example rapidly when the rainy season begins in November (months 3 and 15) which is the dominating external factor influencing the circumference. There are also changes that occur on faster time scales such as changes in the thermal load corresponding to the three daily fills. Frequency analysis shows even smaller effects due to the tides and the daily outside air temperature variations. Using resonant depolarization it was verfied that the RF-frequency feedback keeps the beam energy very stable.

There was also continous further development of the slow orbit feedback system. Of particular note was the inclusion of more stable, high resolution beam position monitors in several arcs. The result was a marked improvement in the orbit stability at some especially sensitive bending magnet beamlines.

FAST GLOBAL ORBIT FEEDBACK

Employing a combination of good passive measures and careful engineering of noise sources like power supplies and the cooling system, the short term closed orbit stability in the ALS fulfills the user requirements up to now. In the range between 0.1 and 500 Hz the integrated closed orbit motion in the insertion device straights is below 2 μm in the vertical plane and about 3 μm in the horizontal plane (one sigma beam sizes at 1.9 GeV at that position are about 23 μm vertical and 300 μm horizontal).

The constant expansion of the ALS creates new sources of closed orbit noise. Elliptically Polarizing Undulators [1] for example require fast focusing and coupling compensation, to minimize their influence on the beamsize, which in turn creates fast distortions of the orbit. Other noise sources are active tune/chromaticity compensation schemes, the cryogenics of superconducting magnets or beamlines, etc. To prevent a deterioration of the current orbit stability due to those upgrade projects and ultimately provide a short term submicron orbit stability a fast, global orbit feedback system was designed similar to the approach at several other light sources [3, 4, 5]. The initial goal was to operate at an update rate of up to 1 kHz.

Transfer Function Measurements

In preparation for the commissioning of the fast orbit feedback, many transfer function measurements were carried out. The transfer functions of all power supplies, magnets, vacuum chambers, and BPMs were measured (compare Fig. 3) and the results were put into a Matlab Simulink model of the feedback system.

In addition the noise performance of all components (BPMs, ADCs, DACs, power supplies) was measured. To improve the resolution of the system, the DACs were upgraded to a higher resolution dual DAC system with effectively about 20 Bit of resolution.

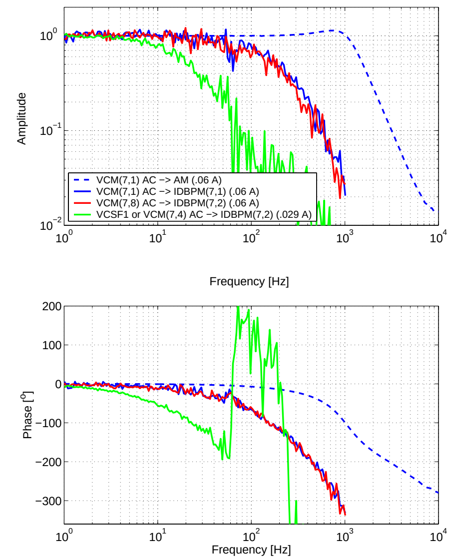

Figure 3: Transfer function of an ALS corrector magnet power supply and combined transfer function of power supply, magnet, vacuum chamber and beam.

Feedback System Layout

With the advent of higher performance networking it is practical to use it directly for medium performance distributed control systems. This system consists of 12 Compact PCI chassis distributed around the ring on a private, switched 100 Mbit/s network. Each chassis handles four BPM inputs and four corrector magnet outputs. Each crate has a timing board to provide the interrupt synchronizing the inputs and outputs of the control algorithm. Initially network packets are used to synchronize these timers. If necessary, there is a backup plan to distribute a precision timing signal to the cards via hardware. More details can be found in [6].

Commissioning Results

The commissioning of the fast orbit feedback started late last year. Initially the system was configured as a single channel local feedback to simplify the optimization. Later it was tested in its full configuration with 24-40 BPMs in each plane and 22 corrector magnets in each plane distributed at 12 distinct locations.

After solving many software and hardware problems a reasonable performance of the system could be achieved, correcting all orbit noise below 15 Hz down to the BPM noise floor (compare Fig 4), without exciting higher frequencies in a significant way (compare Fig 5).

The performance is limited by the fact that it is currently impossible to operate the system reliably with update rates above 700 Hz. At higher rate, the communication becomes unreliable. This effect did not occurr in our network benchmarks with a test setup, so we are currently investigating the exact cause. A possible reason is a priority inversion problem with the other EPICS functions running on the same local computers.

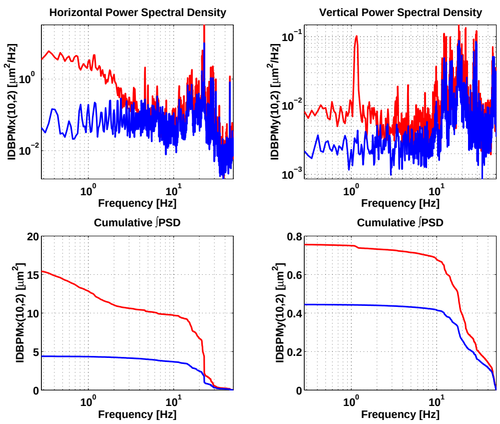

Figure 4: Power spectral density of the closed orbit motion between 0.1 and 50 Hz with the fast orbit feedback in open and closed loop. The measurements were taken with an independent acquisition system connected to a BPM which is not included in the feedback system. At low frequencies the orbit motion is corrected close to the noise floor of the BPMs.

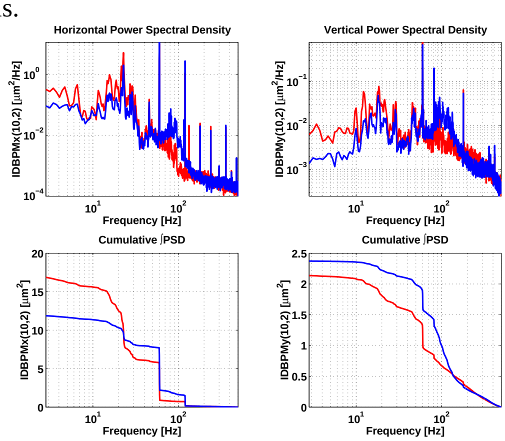

Figure 5: Power spectral density measurement between 1 and 500 Hz. The gain of the feedback changes sign at about 50 Hz and some measurable excitation of orbit oscillallations is observed above 100 Hz.

Once the feedback system was operating, we measured closed loop transfer functions, step responses, and disturbance rejection and compared the results with predictions of the Simulink model. The agreement of the measurements and the model predictions is very good (see Fig. 6).

Future Plans

Further work in the commissiong will include improving the controller algorithm, including a notch filter to directly target steady 60 Hz noise, debugging and resolving the communication problems at higher update rate, improving the timing system (which is currently completely network based) and making the slow and the fast feedback system work together.

Planned upgrades for the next year include the switch to faster network (gigabit), use of ADCs with higher speed (which will allow digital filtering to improve the BPM resolution and noise), use of DACs with shorter access times and further improvements to the timing system. There are

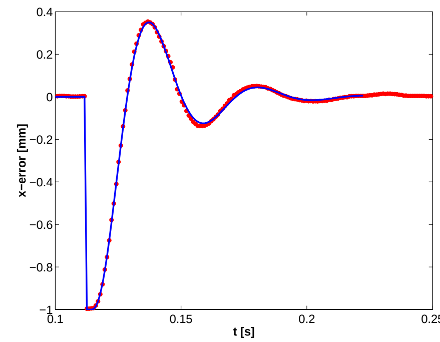

Figure 6: Comparison of the error signal of a measured closed loop stepresponse of the feedback system (dots) with the predictions of the Simulink model (solid line) for the same settings of the PID controller. The PID settings for this example were intentionally chosen to exhibit some oscillatory behaviour.

plans to integrate the slow and fast orbit feedback systems into one system in the long term.

To improve the slow orbit stability it is planned to install monitors to measure the physical location of BPM buttons (pickups placed on invar rods).

SUMMARY AND OUTLOOK

The orbit stability at the ALS has been continually improved. Recent improvements included new chicane magnets for the EPU straights, installation of additional high precision BPMs in several arc sectors, improvements to the slow orbit feedback algorithm and the initial commissioning of the fast feedback system. Even without the fast orbit feedback system, the orbit stability is comparable to the best other light sources. The commissioning of the fast feedback encountered several problems and the performance of the system so far is satisfactory up to about 15 Hz. The current work focuses on solving the communication problems to allow higher update rates. In addition work is spent to make the slow and fast orbit feedbacks cooperate. Once that challenge is solved, the fast feedback in its current state will already provide a significant improvement in orbit stability especially for transient effects of insertion device motion.

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