

COMMISSIONING OF THE ALS TRANSVERSE COUPLED-BUNCH FEEDBACK SYSTEM*

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Commissioning results of the ALS transverse coupled-bunch feedback system are discussed. New test results concerning baseband quadrature processing, heterodyne/homodyne detection, and simultaneous operation of the transverse and longitudinal systems¹ are presented.

I. INTRODUCTION

The LBL Advanced Light Source is a third generation 1.5 GeV electron storage ring for producing synchrotron radiation in the .5-10000 eV range². The ring is designed to support a moderately high average beam current (400 mA) and a large number bunches, up to 328 in buckets separated by 2 nsec. As a result, a broad and dense spectrum of transverse coupled-bunch modes can be excited by higher-order RF cavity resonances and the transverse resistive wall impedance.

In order to control growth of this coupled-bunch motion, a 250 MHz bandwidth bunch-by-bunch feedback system has been designed and is presently undergoing testing and commissioning at ALS. The feedback system design and specifications as well as early test results are given in previous references^{3,4,5}. In this paper, recent results emphasizing the simultaneous operation of the transverse and longitudinal systems are addressed. In addition, a brief overview of the system is presented for orientation.

II. SYSTEM OVERVIEW

A block diagram of the ALS transverse feedback system is shown in figure 1. The system utilizes two sets of button pickups for detecting beam moment, $I\Delta x$. By summing the moment signals from the two sets of pickups in proper proportion, a correction signal that is 90 degrees out of phase with beam position at the kickers can be obtained. This quadrature condition results in optimal damping and can be adjusted to accommodate changes in tune.

The moment signals are detected at the sixth harmonic of the 1.5 GHz RF frequency (3 GHz) in order to exploit the good sensitivity of the button pickups at this frequency. The button signals are differenced and summed to produce true x and y moment signals that are subsequently demodulated to baseband (150 kHz - 250 MHz). As reported previously, the receiver electronics supports two types of detection, heterodyne and homodyne. The nominal detection mode, heterodyne, utilizes a 3 GHz local oscillator that is phase-locked to the storage ring RF to amplitude demodulate

the moment signals. In the absence of the longitudinal feedback system, the transverse system operated necessarily in the presence of large synchrotron oscillations. In this case, the oscillating arrival time of the bunches with respect to the fixed-phase local oscillator causes a reduction and a possible sign change in the average feedback gain⁶. For this operating scenario, homodyne demodulation which employs a local oscillator signal derived from the sum of the four button signals was used. The homodyne technique however is less desirable than heterodyne detection because it results in a feedback gain that is proportional to the square of the bunch current. Presently, with the prototype longitudinal feedback system running at ALS, heterodyne detection may be used exclusively for the transverse system.

The baseband moment signals are proportionally mixed with variable attenuators and a summing hybrid to produce the quadrature kick signal. Other baseband processing includes simple two-tap coaxial notch filters for rejecting orbit harmonic signals and simple coaxial timing delays. Finally, four 150 W, 10 kHz - 220 MHz, Class-A, commercial amplifiers are used to drive each electrode of each kicker separately (300 W per kicker). The amplifier/kicker combination provides per-turn kicks ranging from 2.3 kV at 100 kHz to 1.6 kV at 220 MHz. At the nominal betatron tunes, these voltages and frequency range are sufficient to control any expected transverse coupled-bunch motion.

III. RECENT COMMISSIONING RESULTS

Recent commissioning and test results have involved the simultaneous operation of the longitudinal and transverse feedback systems. As indicated above, with the reliable operation of the prototype longitudinal system, heterodyne detection for the transverse system has been tested and shown to be superior to homodyne detection. The successful demonstration and adoption of heterodyne detection for transverse feedback is a major milestone in the commissioning of the ALS system and the design of the PEP-II system⁷ which is modeled after the ALS system.

When transverse coupled-bunch modes are driven by resonant impedances such as higher-order modes in the RF cavities, large synchrotron oscillations can have a strong damping effect. Basically, this effect is the same as the gain dilution effect in the heterodyne demodulation technique. That is, the oscillating arrival time of a bunch at the impedance causes the phase of the excitation to be different on every turn resulting in a reduction in the average kick received by the

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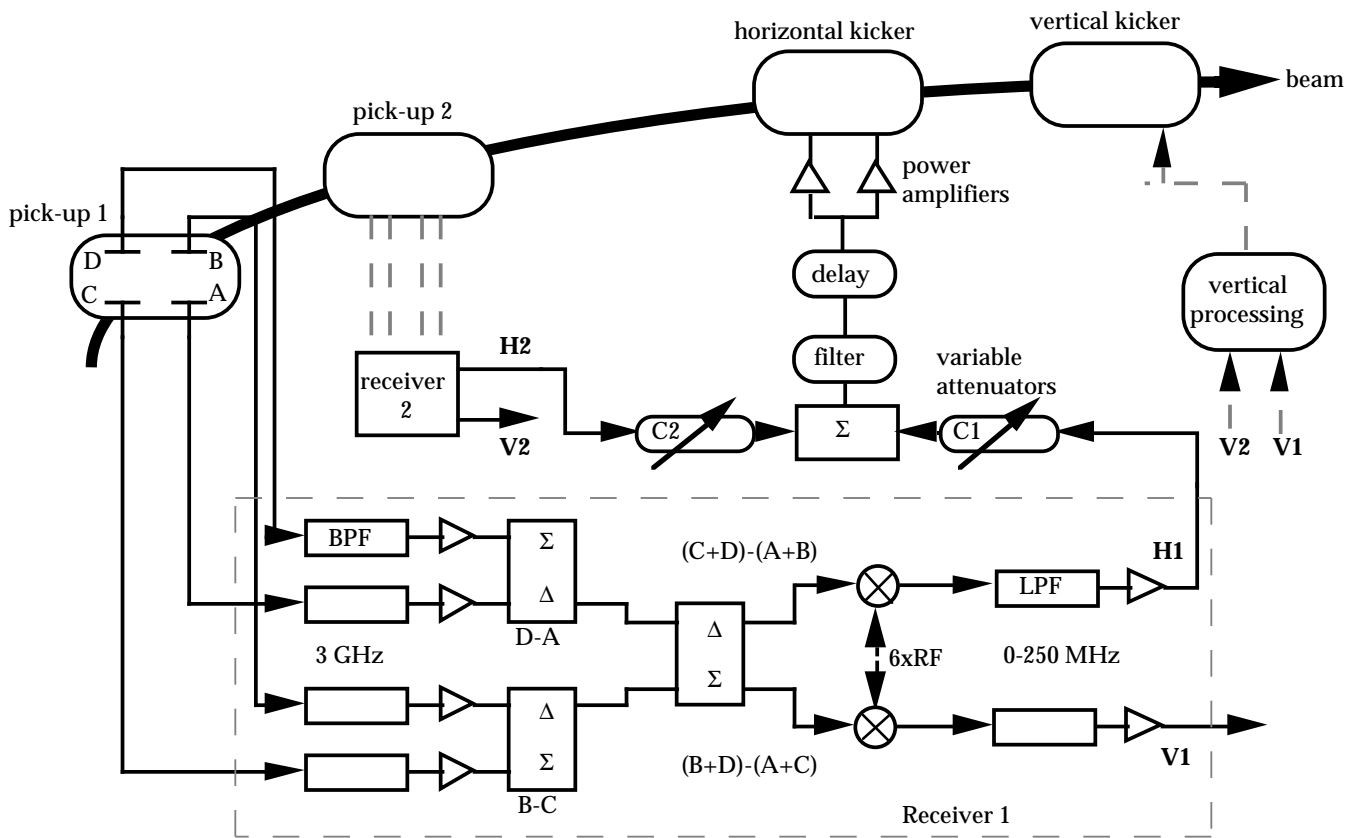


Figure 1. ALS transverse feedback system

bunch. In addition, with non-zero chromaticity, energy oscillations cause a bunch-by-bunch spread in tune which weakens bunch-to-bunch coupling in the transverse plane. If the synchrotron oscillations are large enough, these effects can cause a significant decrease in the growth rates of transverse modes and possibly prevent growth of modes which would otherwise be unstable.

These effects have been clearly seen at ALS during testing of the longitudinal feedback system. At moderate currents (> 70 mA), strong betatron sidebands are present when the longitudinal system has damped the longitudinal coupled-bunch motion. In the absence of longitudinal damping, these lines are weak or not present at all. Therefore, the ultimate test of the transverse system is its performance in conjunction with the longitudinal system.

Presently, efforts are under way to characterize the simultaneous performance of the longitudinal and transverse systems. Previously, as reported in reference [5], transverse coupled - bunch motion has been controlled in the presence of the longitudinal system as evidenced by the disappearance of betatron lines as detected by a spectrum analyzer. Recently, a synchrotron light monitor facility has been installed at beamline 3.1 at the ALS. With this facility, it is now possible to monitor the effects of the feedback systems on beam spot size.

Figure 2 shows the beam spot for a 175 mA beam consisting of 10 groups of 4 bunches (bunches separated by 4 nsec) equally spaced around the ring. In this case the

longitudinal system is controlling the synchrotron oscillations. As shown, strong vertical betatron oscillations cause a blowup in the vertical spot size. With the vertical

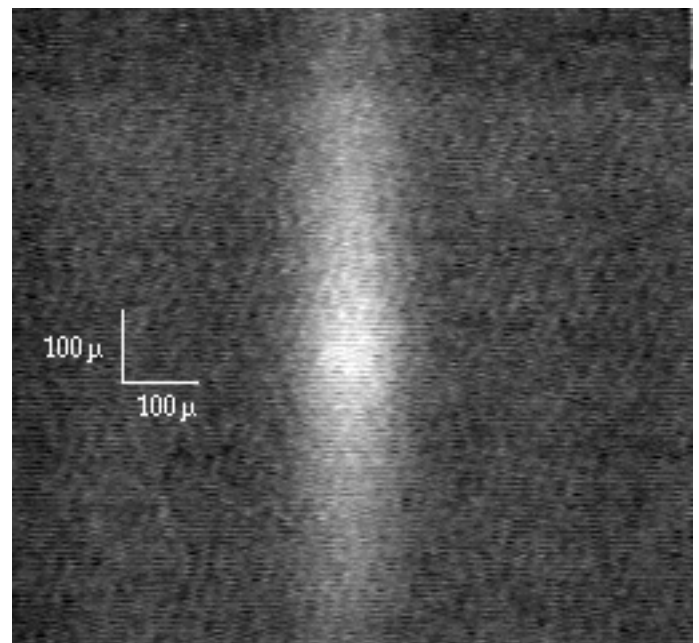


Figure 2. Beam spot with vertical feedback off.

feedback turned on, betatron oscillations are suppressed and the spot size is dramatically reduced as shown in figure 3. In both

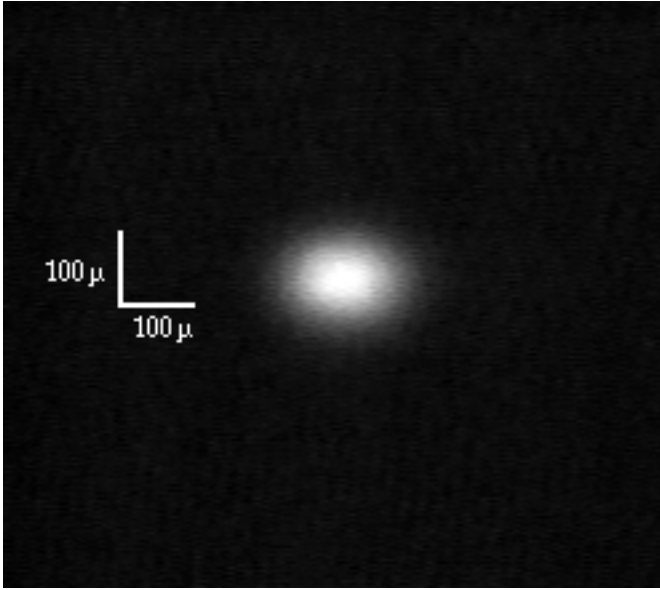


Figure 3. Beam spot size with vertical feedback on.

cases, the horizontal feedback was controlling a significantly smaller amount of horizontal betatron motion.

It should be noted that the prototype longitudinal system can control only specific bunch patterns with a minimum bunch spacing of 4 nsec (every other bucket). In this case, only half the bandwidth of the feedback systems is exercised. With the arrival of the final longitudinal system in the near future, the ability of both systems to damp coupled - bunch modes with every bucket full can be evaluated.

Finally, initial tests of the two - pickup quadrature system indicate that the transverse system can be operated in modes ranging from resistive to reactive as evidenced by amplitude reduction or frequency shift, respectively, of driven betatron lines on a spectrum analyzer. The remaining task is to determine the amplitude settings of each of the two pickups that minimize the deviation from linear phase of the feedback path over the entire baseband. This adjustment is expected to become critical when operating with every bucket full.

IV. CONCLUSION

A broadband feedback system for controlling transverse coupled-bunch instabilities in the LBL ALS is presently undergoing testing and commissioning. Most recently, the system has been tested in conjunction with the longitudinal system with excellent results. In particular, large vertical coupled - bunch motion has been controlled resulting in a dramatic decrease in beam spot size. Present efforts are being directed towards the optimum phasing of the two - pickup quadrature system. In addition, when the final longitudinal system is installed and operating, the full

bandwidth capabilities of the transverse system (operation with every bucket full) will be addressed.

V. ACKNOWLEDGMENTS

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