INITIAL COMMISSIONING RESULTS FROM THE PEP-II TRANSVERSE COUPLED-BUNCH FEEDBACK SYSTEMS*

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Abstract

Initial commissioning results from the PEP-II transverse coupled-bunch feedback systems are discussed. In particular, the performance of key hardware and coupled-bunch damping results are described in some detail. Beam dynamics related measurements presented include beam transfer functions and selected modal growth and damping rates.

1 INTRODUCTION

The PEP-II B-Factory [1] is a high-luminosity, asymmetric electron-positron collider consisting of a 9 GeV, 1.0 A high-energy storage ring (HER), and a 3.1 GeV, 2.14 A low-energy storage ring (LER). Because of the high average beam currents in both rings, active feedback systems [2,3] are required to suppress the growth of transverse coupled-bunch instabilities.

At present, the HER has been commissioned to a current of 750 mA with the successful operation of the transverse feedback system [4]. Commissioning of the LER is scheduled to commence in July, 1998. Here, after a brief system and parameter review, we present commissioning results of the HER transverse feedback system. Transfer function measurements related to the system tuning process and modal growth and damping rate measurements are discussed. In particular, results thus far indicate that coupled-bunch mode growth rates are significantly greater than expected but still adequately controlled by the feedback system.

2 SYSTEM AND PARAMETER REVIEW

A brief list of accelerator and transverse feedback system parameters appears in Table 1. Nominally, PEP-II operates with every other bucket filled (238 MHz bunch rate). This sets the minimum bandwidth for the feedback system at 119 MHz. However, the electronics has been designed to have a bandwidth of 250 MHz to allow for possible operation with every bucket filled. The kickers cover DC-119 MHz for maximum shunt impedance in the every-other-bucket operating mode. They can be replaced with 238 MHz versions if an every-bucket fill becomes a likely operating mode. The feedback systems are designed to provide a damping rate that is approximately three times greater than the growth rate of the fastest expected (vertical resistive wall) coupled-bunch mode.

Table 1: Accelerator / feedback design parameters.

Parameter	Description	HER / LER Value
E	Beam energy	9.0 / 3.1 GeV
f_{rf}	RF frequency	476 MHz
–	Bucket space	2.1 ns
–	Bunch space	4.2 ns
I_{av}	Average current	1.0 / 2.14 A
f_0	Orbit frequency	136.3 kHz
ν_v	Vertical tune	23.64 / 34.64
ν_h	Horizontal tune	24.57 / 36.57
α_v	Vertical R-wall growth rate (calc)	0.26 / 1.09 ms^{-1}
α_h	Horizontal R-wall growth rate (calc)	0.18 / 0.71 ms^{-1}
α_f	Feedback design damping rate	3.2 ms^{-1}
Required feedback bandpass		13.6 kHz-119 MHz
Feedback electronic bandpass		10 kHz-250 MHz
Kicker bandpass		DC - 119 MHz

The feedback system diagram is shown in figure 1. Beam moment signals ($I\Delta x$) from two sets of pickups are detected with microwave receivers at $3f_{rf}$. After down-conversion to baseband, the signals are proportionately summed to produce a correction signal that is 90 degrees out of phase with beam position at the kickers. A digital delay provides the pickup-to-kicker timing and the kicker electrodes are individually driven differentially with 120 W class-A power amplifiers. Other system features include a provision for single-bunch kickout and pre-digitization orbit-offset-rejection electronics [2,3].

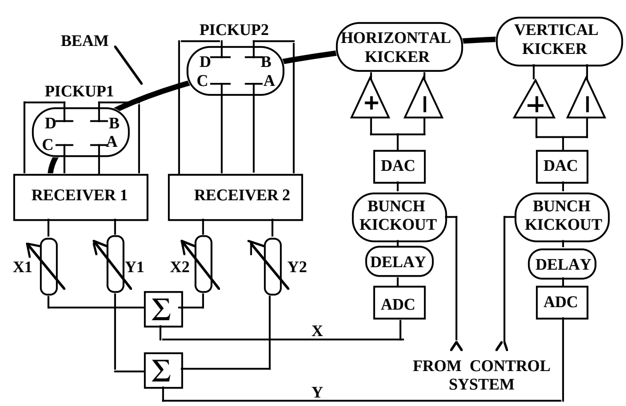

Figure 1: Transverse feedback system concept.

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3 COMMISSIONING RESULTS

Much of the initial commissioning focused on basic hardware checkout with single-bunch operation. Beam signal measurements were taken and various hardware timing was done. In addition, the tune measurement system which uses the feedback amplifiers and kickers was set up during this initial commissioning period.

The next phase of commissioning involved timing and phasing the system for negative feedback. Rough timing of the system was accomplished in single-bunch mode by adjusting the digital delays and analog vernier delays to obtain damping-signal/bunch coincidence at the kickers. The upstream ports of the stripline kickers where both the bunch and kick signal could be seen served as diagnostic points for these adjustments.

After rough timing, the x and y loops were broken and open-loop transfer functions at betatron sidebands in the low-to-middle frequency part of the band were measured. The relative signal amplitudes from the pickups were then adjusted to produce loop phases of 180^o (negative feedback). Subsequently, the phases over the entire band were optimized by repeating the transfer function measurements at a few higher frequency sidebands and adjusting the fine timing (phase slope) of the system.

Example transfer functions of a tuned system for the horizontal plane are shown in figures 2, 3, and 4. The measurements have implicit 180^o phase offsets so that the 0^o references are actually 180^o. The transfer functions were measured at low current (12 equally spaced bunches with I_{av} = 12 mA) where the effective positive feedback gain due to beam impedance is much less than one. This eliminates beam impedance from the measurements of the feedback loop as desired and provides stable beam.

Figure 1 is the transfer function of the lower horizontal sideband of $10f_0$. This transfer phase was used to adjust the relative gains of the two pickups. The measurement in figure 3 of the lower sideband of $873f_0$ is at the upper edge of the band, 119 MHz. Here, the system time delay has been fine tuned to produce a 180^o phase shift. Figure 4 shows the transfer function for the lowest frequency sideband, the lower sideband of $1f_0$ (fractional tune = 0.72). In this case, the transfer phase is shifted by about $+45^o$ (seen by looking at the response far from resonance). This phase is consistent with the low-frequency phase response of the power amplifiers and other components with inductive coupling elements. The phase rolloff simply reduces the feedback gain by 3 dB for this sideband and causes no stability problems.

Figure 5 is an example of the damping effect of the feedback system on a stable driven sideband. Here the beam condition was 12 equally spaced bunches, I_{av} = 8.0 mA. The beam was driven at the kickers and detected at a pickup with a network analyzer. The reduction in the amplitude of beam motion as a function of feedback gain can be clearly seen. Similar results were obtained throughout the band under various beam conditions.

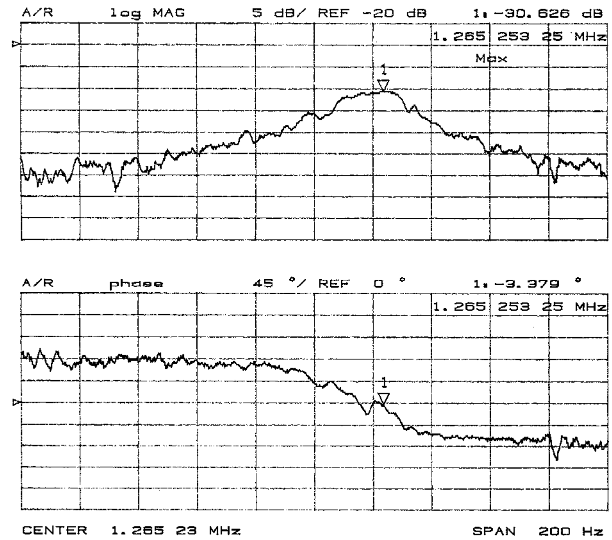

Figure 2: Lower horizontal sideband of $10f_0$.

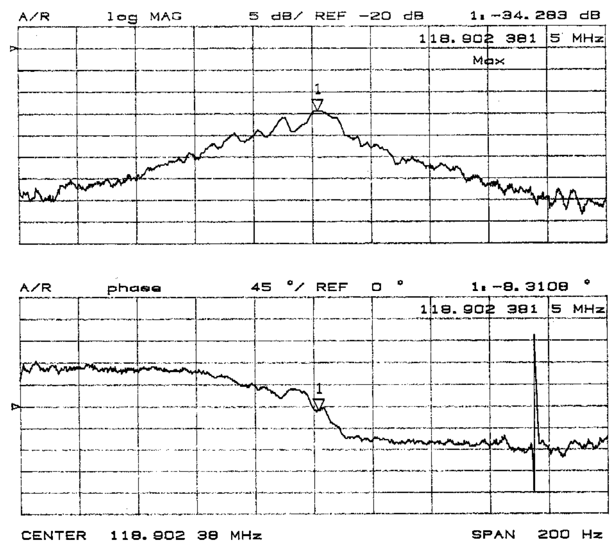

Figure 3: Lower horizontal sideband of $873f_0$.

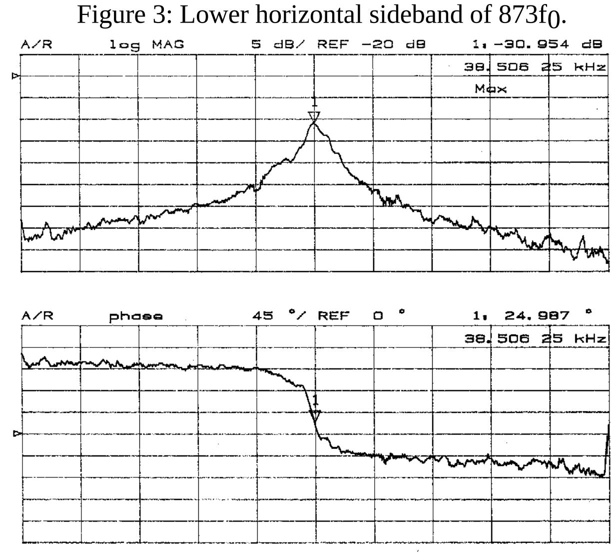

Figure 4: Lower horizontal sideband of $1f_0$.

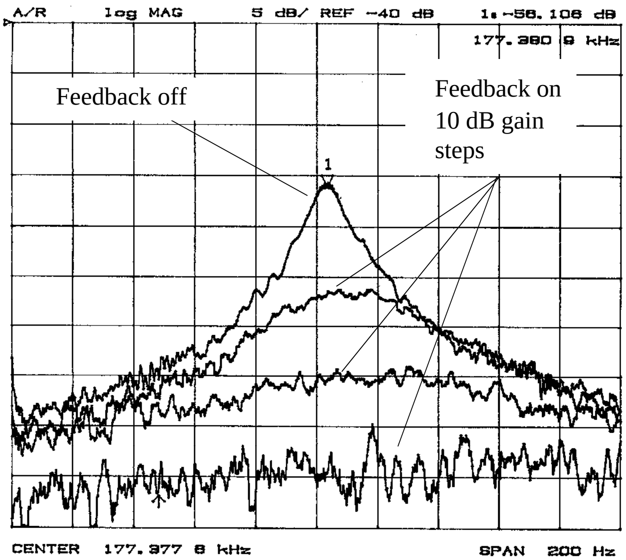

Figure 5: Feedback effect on driven sideband (lower horizontal of $2f_0$) for several different gains.

Preliminary measurements of transverse growth and damping rates were made by gating the feedback loops open and closed with a broadband diode switch allowing all unstable modes to grow and damp. The time evolution of individual modes was measured with a spectrum analyzer in tuned-receiver mode. In general, at currents below 200 mA, unstable modes appeared only in the low frequency end of the band (below about 10 MHz) with thresholds of about 50 mA. Presumably, these modes are resistive-wall driven. At higher currents, the onset of higher frequency instabilities was noted.

Figure 6 is an example of a grow/damp measurement for the lowest frequency (vertical resistive wall) mode with I_{av} = 80 mA. The growth rate for the mode is 0.067 ms^{-1} and is typical of modes growing at this current. For this measurement, the feedback gain was adjusted to provide a damping constant of about 0.133 ms^{-1}. Scaling with current gives growth rates on the order of 0.84 ms^{-1} at I_{av} = 1.0 A which is over three times faster than expected (table 1).

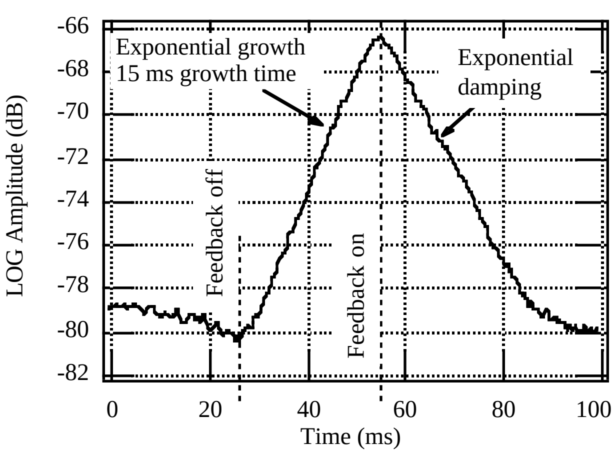

Figure 6: Typical growth/damping rate measurement (lower vertical sideband of $1f_0$, I_{av} = 80 mA).

A search for extremely fast growing modes at I_{av} = 200 mA yielded the example in figure 7. Here, the growth rate is 0.5 ms^{-1} which is ten times faster than expected at this current. Because of the frequency (7.16 MHz) and low saturation level, the growth mechanism is thought to be ion related. The mode is easily damped by the feedback system with electronic gain set within 10 dB of maximum. The feedback gain scales with current so that with this same setting, the mode should be stable at I_{av} = 1.0 A precluding any electronics saturation effects.

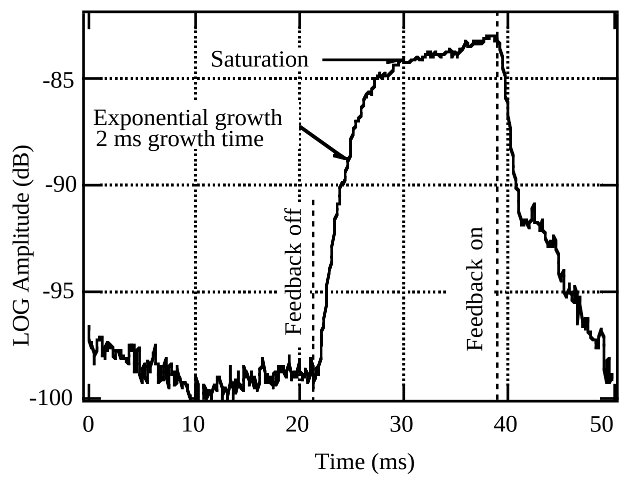

Figure: 7 Fast growing mode, upper vertical sideband of $52f_0$, I_{av} = 200 mA.

4 CONCLUSION

With the feedback system operational, the HER ran routinely with transversely stable beam currents of several hundred milliamps. Ultimately, at the end of the last (Jan '98) run, transversely stable currents of over 500 mA were common and the feedback system was necessary to contain beam at the highest current achieved (750 mA) to date. Future efforts will be directed towards further characterization of growth rates and the commissioning of the LER systems.

5 REFERENCES

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