NEW FAST DITHER SYSTEM FOR PEP-II*

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Abstract

The PEP-II B-Factory uses multiple feedback systems to stabilize the orbits of its stored beams and to optimize their performance in collision [1]. This paper describes an upgrade to the feedback system responsible for optimizing the overlap of colliding beams at the interaction point (IP). The effort was motivated by a desire to shorten the response time of the feedback, particularly in the context of machine-tuning tasks. We describe the original feedback system, the design for the new one, and give a status report on the installation.

IP FEEDBACK SYSTEM

The IP feedback system uses corrector magnets and a luminosity signal to optimize the overlap of colliding beams at the interaction point. The luminosity signal comes from a zero-angle radiative-Bhabha detector situated about nine meters from the IP. One beam, the low-energy positron beam, is steered through the IP to maximize the signal from the detector. The other beam, the high-energy electron beam (HEB), is driven with small dither motions to allow luminosity detection of best beam overlap. The dither and applied corrections occur in three directions: horizontal, vertical, and vertical angle. The original system and new design differ in the following ways.

Discrete Dither, Sequential Correction

The original system uses discrete dither steps with synchronized luminosity measurements to characterize and correct the HEB trajectory. A correction cycle in a given direction consists of three dither steps and four luminosity measrements, two of which occur on the nominal trajectory, followed by a correction step derived from a fit to the dithered luminosity measurements. Both the dither and correction steps are implemented as closed-orbit bumps centered at the IP by a set of eight corrector magnets. A correction cycle requires about three seconds, based on the move and settle time of the magnets. Corrections are applied sequentially to the three HEB directions, thus a given direction is updated about every nine seconds.

Continuous Dither, Simultaneous Correction

The system described above has performed reliably and effectively since its introduction in the early days of PEP-II. It is essential for filling the storage rings, when beam currents and interactions are undergoing significant change. It is also essential in stabilizing slow drifts, and

in locking-in high-current collisions with little dither-induced luminosity loss. The response time is, however, somewhat slow when tuning the machine for better performance. Tuning activities often involve an experimental "knob" (linear combination of magnets) that might offset a beam at the IP, such that the utility of the knob remains in doubt until the feedback system reacts to IP errors. If the dither steps are small, as is the case for maximum integrated luminosity, then feedback corrections may take several cycles to manifest. Such delays tend to obfuscate or even discourage tuning experiments that might otherwise lead to improved machine performance. It is in this context that the new system was designed.

The new feedback system eliminates discrete dither steps in favor of continuous sine-wave dithers in the 100-Hz range. The drivers are four horizontal and four vertical pairs of low-power air-core coils, and the motions are again implemented as closed-orbit IP bumps. Since the IP region is highly coupled by the detector's solenoid, all eight coil pairs are needed for each bump, but with different strengths. The dithers in all three directions are simultaneous, but each occurs at a distinct frequency, and each has its own lock-in amplifier for a frequency-specific measurement of the luminosity signal. An HEB correction in each dither direction is calculated on each cycle of the feedback loop, and the orthogonal moves are summed and implemented as a single move by the existing corrector magnets. The new feedback system is expected to run at one Hz.

FAST DITHER DESIGN

The design allows for dither amplitudes of up to 40 microns horizontal, 5 microns vertical, and 0.1 mrad in vertical angle. Relative to the IP, the dither coils are at ±29 meters and ±48 meters, with a horizontal and vertical pair at each location. Simulations with MAD were used to estimate the angular kicks required to produce the closed and orthogonal IP bumps. Based on those results, the air-core coils have 48 turns and draw less than 20 Watts rms when driven at 100 Hz. The coils are installed on stainless-steel beam chambers for effective penetration of the time-dependent field. However, the chambers at 29 m are octagonal and the ones at 48 m round, so small phase delays are introduced to synchronize the dithers and close the bumps. An installation at 48 meters is depicted in Fig. 1.

Each of the eight coil pairs must be excited by a sum of three sine waves at three dither frequencies, with individual dither amplitudes set by software. Accordingly, a control board for each coil pair attenuates or amplifies three reference sine waves to levels specified
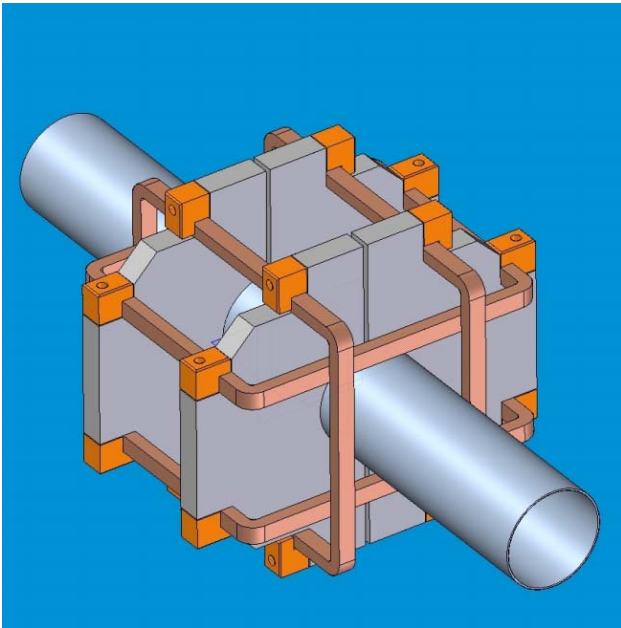
Figure 1: Low-power air-core coils for sine-wave dither, one of four installations.

amplifiers (Stanford Research Systems SR830) that measure the real (in-phase) and imaginary (out-of-phase) parts of the dithered luminosity signal. To avoid the variable network delays inherent to GPIB and ethernet communications, direct analog outputs from the lock-ins go to CAMAC digitizers and are read by the computer implementing the feedback.

When the dithered luminosity signal is in phase with the lock-in reference driving the dither, the lock-in luminosity measurement yields a real number (imaginary part goes to zero) proportional to the signed offset of the colliding beams. That is, the lock-in measurement is proportional to the derivative with respect to offset of the overlap integral, and it goes to zero when the beams are optimized. A control algorithm based on a Newton-method search for the zero of the luminosity signal is therefore a natural choice. The difference between two successive lock-in measurements divided by the intervening corrective move (a signed quantity in microns, say) provides the required slope information. Care must be taken with the small, noisy numbers. A simple routine based on small steps in the direction indicated by the lock-in signal is also being developed.

by computer controlled DACs, and the sum of weighted sines drives a bipolar voltage-controlled current source capable of delivering up to 20 A at 20 V (Kepco BOP 20-20M). A control board is sketched in Fig. 2. The reference sines are generated by the three lock-in

STATUS

Installation of the new IP feedback system is complete, and initial testing of system components has begun. A test of the new dither bumps with DC currents
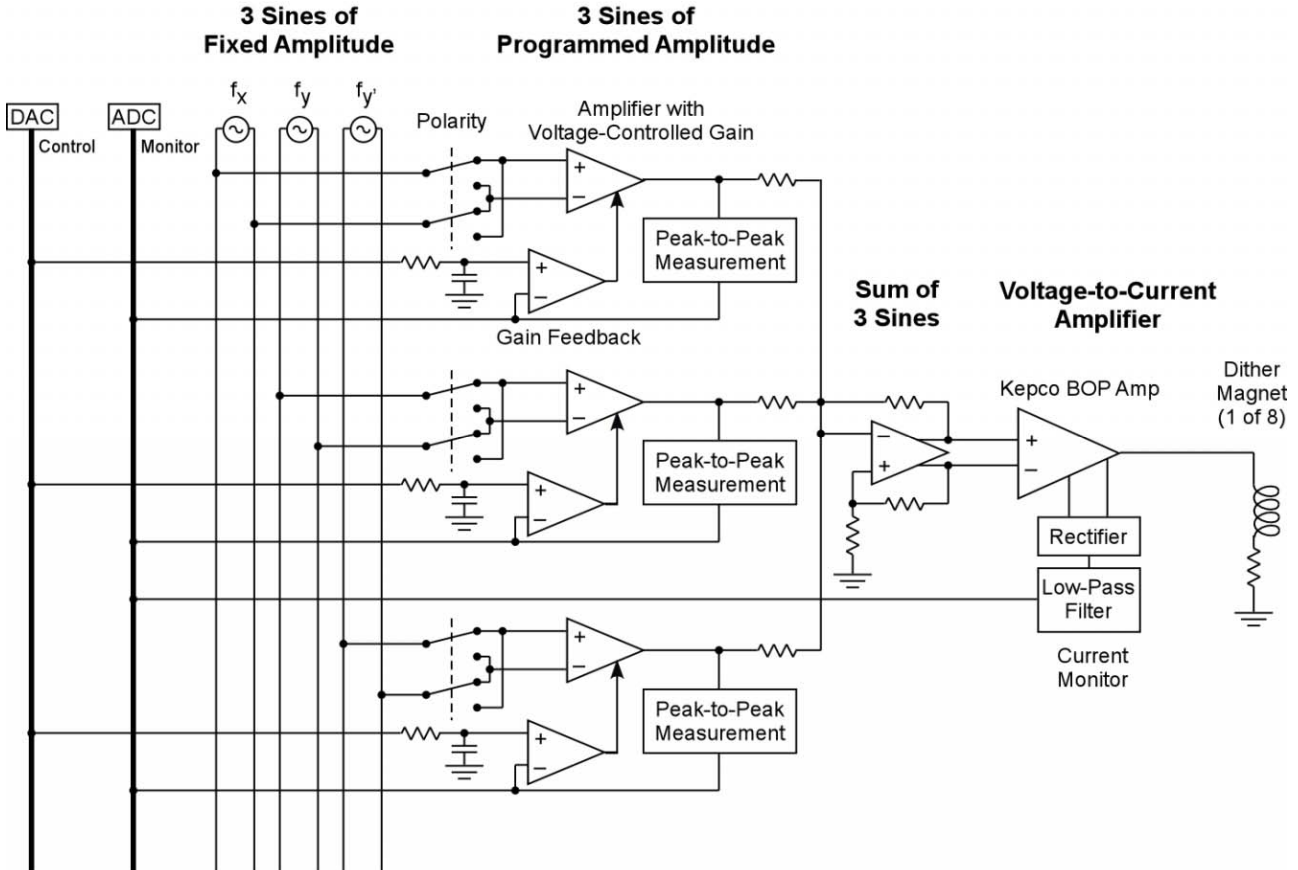

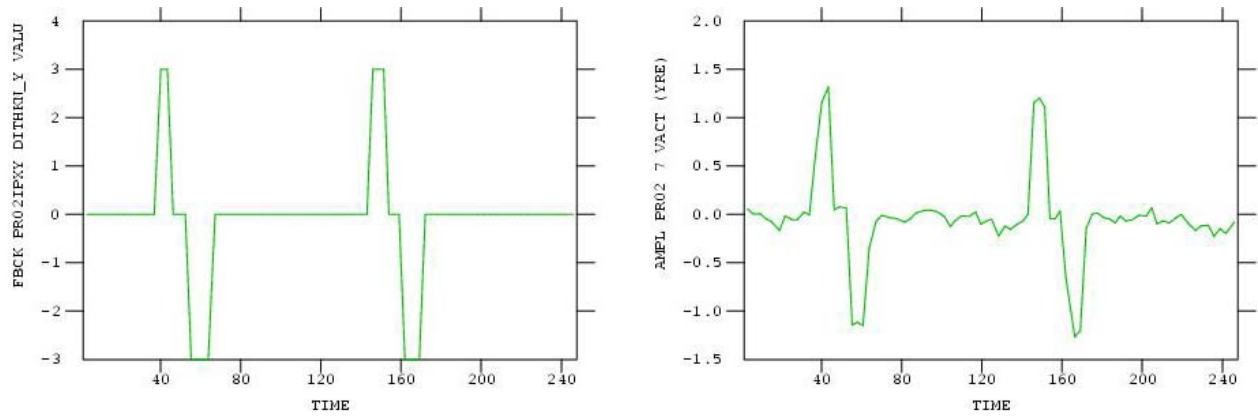Figure 2: Sketch of control board for driving a dither magnet, one of eight.

Figure 3: Measured response of lock-in amplifier (right) to discrete dither steps (left). For this test, the large ±3 micron vertical-dither steps were applied to the HEB at a slow rate (horizontal axis is in seconds) while, at the same time, the beam was driven with a vertical sine-wave dither amplitude of 0.6 microns at 73 Hz. Shown is the real part of the lock-in response (Volts) to the 3 micron jumps. Note the null response when beams are overlapped.

demonstrated that the MAD-designed vertical and horizontal bumps are nearly closed; the vertical-angle bump requires further effort. Small AC dither amplitudes have been applied to the HEB, and their effect clearly observed on a spectrum analyzer and in the lock-in luminosity signal. Figure 3 shows lock-in response to discrete dither steps applied by the existing (but hopefully soon retired) dither system. The control algorithm developed in simulations will be gradually brought online and refined as we configure the system and learn its control parameters.

REFERENCES

[1] L. Hendrickson, et. al., "Slow Feedback Systems for PEP-II", EPAC, Vienna, Austria, SLAC-PUB-8480 (2000).