Frascati Physics Series Vol. XXX (1997), pp. 000-000
CONFERENCE TITLE - Conference Town, Oct 3rd, 1996

FIRST BEAM-COMMISSIONING RESULTS FROM THE PEP-II *B*–FACTORY HIGH ENERGY RING: INTENSITY EFFECTS.*

U. Wienands, R. Assmann, V. Bharadwaj, Y. Cai, P. Corredoura, M. Donald,
P. Emma, J. Fox, T. Fieguth, A. Fisher, A. Hill, T. Himel, R. Iverson,
R. Johnson, J. Judkins, W. Kozanecki,† A. Kulikov, M. Lee, T. Mattison,
M. Minty, Y. Nosochkov, M. Placidi,‡ S. Prabhakar, J. Safranek, S. Smith,
V. Smith, H. Schwarz, J.T. Seeman, M. Sullivan, D. Teytelman, R. Tighe,
R. Traller, J. Turner, F. Zimmermann;
Stanford Linear Accelerator Center, Stanford, CA;
W. Barry, J. Corlett, M. Furman, R. Rimmer, A. Zholents, M. Zisman;
Lawrence Berkeley National Laboratory, Berkeley, CA

ABSTRACT

In two beam commissioning periods, clear evidence for intensity-related effects has been seen at the PEP-II High Energy Ring. In the presence of one unshielded bellows, beam currents appeared limited to about 60 mA and pronounced vertical beam motion was seen, which scraped parts of the beam out of the ring. With all bellows shielded, beam currents up to 300 mA were obtained, limited by a loss of longitudinal control at the highest beam current. Tune shift with intensity was observed, and there is evidence for an increase in bunch motion along an injected bunch train.

1 Introduction

The High Energy Ring (HER) of the PEP-II *B*–Factory is a 9 GeV electron storage ring designed for 1 A circulating beam current in 1656 bunches with the option of upgrading to 3 A in the future.

During the course of a first 4-week commissioning run in June, beam was stored and the life time was increased to roughly 10 h at low intensities. Two rf stations were used

*Supported by the U.S. DOE under contracts DE-AC03-76SF00515 and DE-AC03-76SF00098
†On leave from CEA-SACLAY, Gif-sur-Yvette, F
‡On leave from CERN, Geneva, CH

at that time. Both the transverse and the longitudinal feedback systems began commissioning. Towards the end of the run, maximum beam intensities of 60 mA were reached, limited by an unshielded bellows installed in the machine.

In a second, 6-week long run in September and October 1997 one more rf station was brought on line and commissioning of the various low-level rf loops was begun in earnest. Both transverse and longitudinal beam feedbacks were put in operation and the synchrotron light monitor (SLM) was commissioned. Towards the end of this run, maximum beam currents of 300 mA were achieved; at 250 mA, beams were stored controlled in all three planes by the feedback systems.

The Ring is described in more detail in Ref. [1] Beam-optics commissioning results and the performance of the HER systems are described in another contribution to this conference. [2]

2 Beam Feedbacks

2.1 Transverse feedback

The transverse feedback is a bunch-by-bunch analog/digital one-turn delay system designed to provide broadband damping of all transverse modes. [4] Two sets of designated standard BPM buttons are used to generate a pick-up signal at the required 90° phase offset to the kickers. The kickers are of strip line design; one each per plane. Figure 1 shows the beam response to a stimulus at various loop gains, verifying the damping capability of the system.

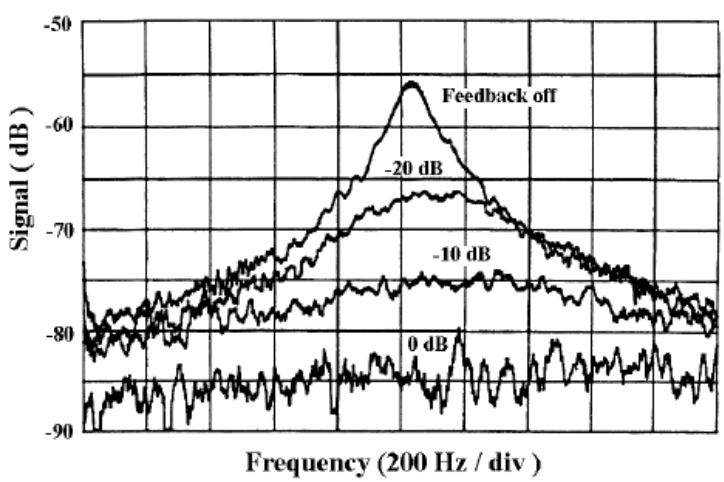

Figure 1: *Transverse beam response with feedback set at various gains*

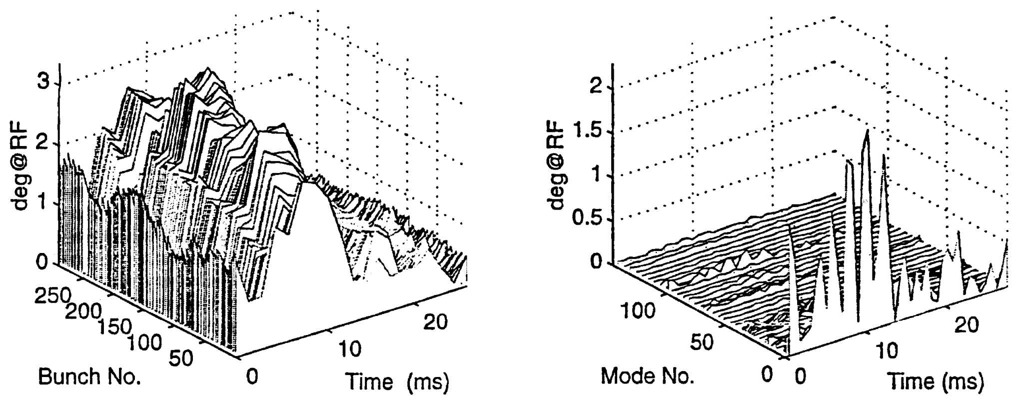

Figure 2: *Longitudinal grow-damp study; (a) time, (b) frequency domain.*

2.2 Longitudinal feedback

The longitudinal feedback system is a broadband fully digital system using a DSP farm to filter and process the beam signal. Besides its damping function it has extensive diagnostic capabilities and, together with accompanying Matlab routines, provides mode spectra and analysis of growth rates by mode number from grow-damp experiments. [5] A dedicated set of BPM buttons is used for pickup of the signal. A modular concentric longitudinal kicker is used to damp the beam. Figure 2 shows the result in the time and the frequency domain of a grow-damp study. Only low-order modes are apparent. Figure 3 shows a sequence of four images taken at various settings for the feedback systems. The effect on the beam size is evident.

3 Beam Dynamics

3.1 Single-bunch Operation

Single-bunch intensities beyond 15 mA/bunch were reached easily and with no detectable sign of instability. The nominal bunch current for 1 A in the machine is 0.6 mA. Tune *vs* intensity was measured, see Fig. 4. The slope measured, $\delta\nu = 2 \times 10^{-4}/mA$, is

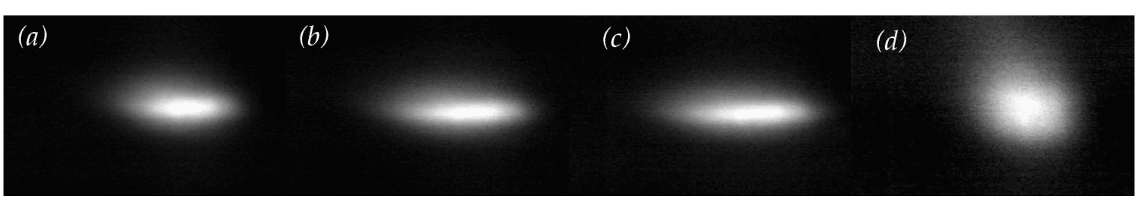

Figure 3: *SLM picture for (a) all feedbacks on; (b) longitudinal f/b off; (c) horizontal feedback off; (d) vertical feedback off.*

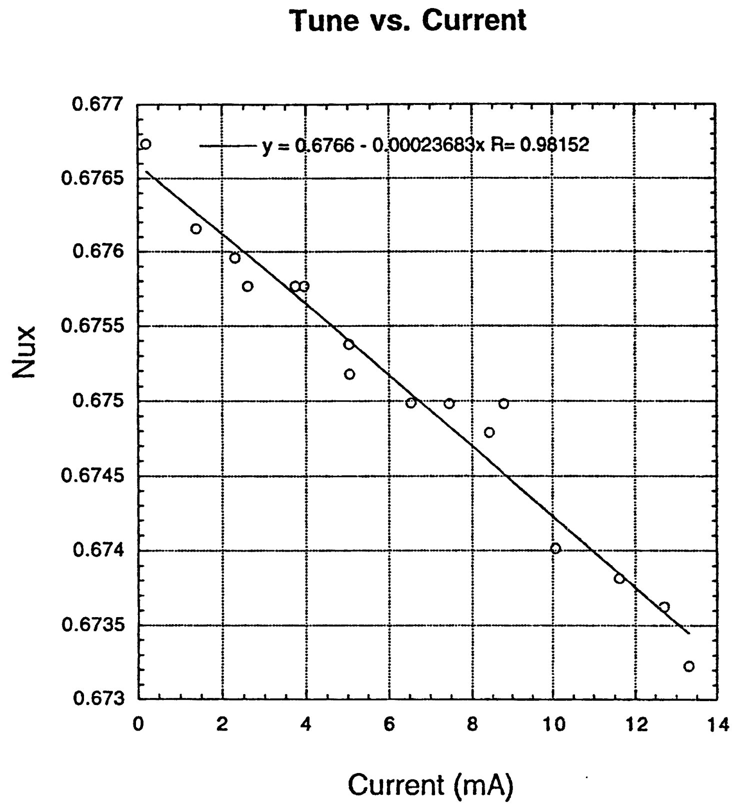

Figure 4: *Vertical tune vs bunch intensity*

consistent with an inductance of 50 nH, the predicted value. This measurement was taken with eight rf cavities installed. Tune shifts were also measured for a fixed bunch current and varying bunch pattern, and a small but discernable dependence of the tune on the number of bunches was seen, with the horizontal tune going *up* as the number of bunches increases. A possible explanation for this unexpected behaviour may be the presence of ions.

3.2 Multi-bunch Operation

Towards the end of the June run, beam currents up to 60 mA were achieved in 36 bunches. At these currents, the beam intensity along the bunch train would take on a characteristically sloped shape with the head of the train accumulating more and more charge as injection proceeded, while the tail would not accumulate anymore (Fig. 5). This behaviour was observed until the one non-shielded bellows in the machine was replaced by its final version with a proper rf shield, at which time this “saw-tooth effect” subsided and the intensity limit immediately went up beyond 100 mA.

A modal analysis of the beam motion at higher intensities using the longitudinal

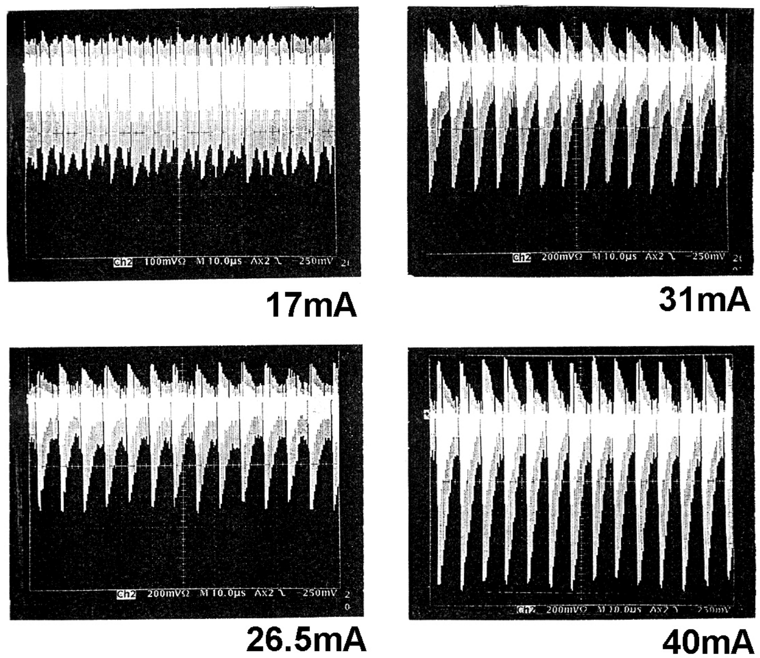

Figure 5: *Intensity distribution at various beam currents*

feedback system indicated the presence of significant $m = \pm 3$ motion on the beam. The impedance responsible for this motion was attributed to the “parked” rf cavities (inactive cavities, nominally set to a frequency between the 2^{nd} and 3^{rd} revolution harmonic). [6] This was later confirmed by being able to suppress the $m = 3$ motion by changing the tune of one set of parked cavities.

Various bunch-train experiments were performed in which the beam motion amplitude and frequency along a bunch train was measured. A plot of the vertical amplitude along a train with 700 bunches is shown in Fig. 6. Although the measurement was difficult due to beating of the oscillations there is evidence of an increase in motion along the train. Possible explanations again include the presence of ions, [7] although in this case the transient induced by the large gap in the beam is also likely to play a significant role.

4 Summary

In two beam-commissioning runs the HER has reached almost one-third of the nominal beam current of 1 A. Beam feedbacks have been proven to work and be able to damp the oscillations seen. The intensity-dependent tune shift is consistent with the predicted inductive impedance. Beam behaviour seen at the highest intensities is consistent with the presence of ion effects, but positive evidence for ions has not been seen.

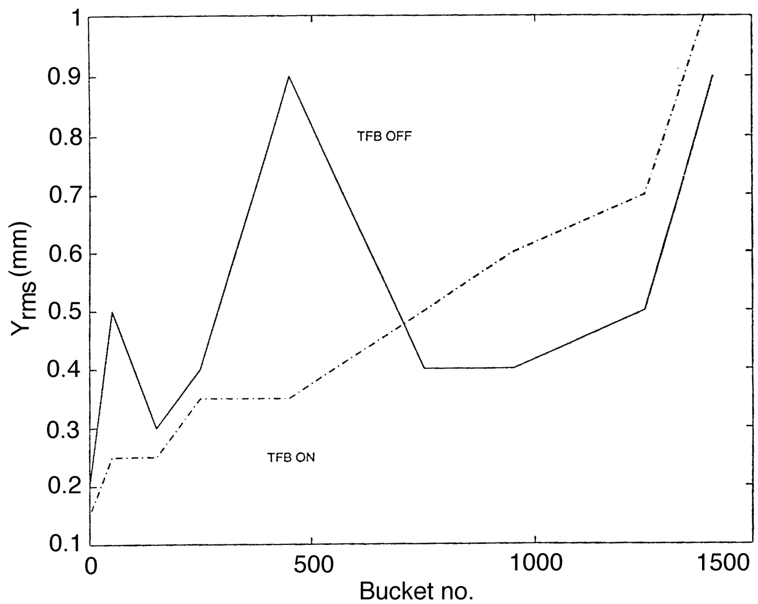

Figure 6: *Vertical motion amplitude along a bunch train (* TFB=*trans. feedback)*

Acknowledgments

Successfull beam commissioning of the HER would have been impossible without the participation of the enthusiastic and capable operations staff and support staff of SLAC.

References

1. J.T. Seeman, *these proceedings*.
2. U. Wienands, *these proceedings*
3. PEP-II Conceptual Design Report, SLAC Report SLAC-418, June 1993.
4. W. Barry *et al.* Proc. IEEE PAC 1997, Vancouver, BC (*in press*).
5. D.Teytelman *et al.* Proc. IEEE PAC 1997, Vancouver, BC (*in press*).
6. S. Prabhakar *et al.*, SLAC, PEP-II AP NOTE 98-04, Feb. 1998.
7. F. Zimmermann *et al., these proceedings*