ORBIT STABILITY OF THE ALS STORAGE RING.*

R. Keller, H. Nishimura, and the Stability Task Force,† Advanced Light Source Center
E. O. Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720 USA

Abstract

The Advanced Light Source (ALS) storage ring [1], a synchrotron light source of the third generation, is specified to maintain its electron orbit stable within one tenth of the rms beam size. In the absence of a dedicated orbit feed-back system, several orbit-distorting effects were investigated, aided by a new interactive simulation tool, the code TRACY V. The effort has led to a better understanding of the behavior of a variety of accelerator subsystems and in consequnence produced a substantial improvement in day-to-day orbit stability.

1 INTRODUCTION

The ALS electron storage ring [1] is a third-generation light-source with very tight electron orbit tolerances. During user runs, the orbit should not vary by more than 1/10 the rms beam size in any of the straights, amounting to 20 μ horizontally and 2 μ vertically. Stability requirements this tight would normally require an orbit-feedback system, but over the nearly four years of storage-ring operation such a system has not yet been implemented at ALS, mostly because of Beam-Position Monitor (BPM) motion associated with the complex mechanical design of the ALS vacuum chambers and girders that each span an entire arc section, see Fig. 1. It is easy to imagine that the BPMs that are installed in the vacuum chamber and whose signals would be used for orbit feedback would follow the thermal distortions and mechanical vibrations of the vacuum chamber and therefore compromise the quality of the orbit correction.

On the other hand, the need for better control of the photon source-point locations increased with the degree of sophistication the users applied to their end stations, most notably with the increased spatial resolution required by microscopy experiments. For this reason a task force was established that had the mandate to improve the ALS orbit stability by about a factor of ten and thus meet the original specifications.

The diagnostics applied to the stabilization problem can be grouped into four classes: direct and indirect orbit monitors such as the electron BPMs and readout from a photon-beam feedback-system; precision dial indicators, linear potentiometers and inclinometers; temperature monitors for air, water, and storage-ring girders; and, last but not least, the simulation code TRACY V [2]. This code was upgraded and amended several times in the course of these investigations to better represent the influence of lattice magnet strengths and location variations of the electron orbit.

From the beginning, the task force concentrated on investigations of thermal effects for two reasons: thermally

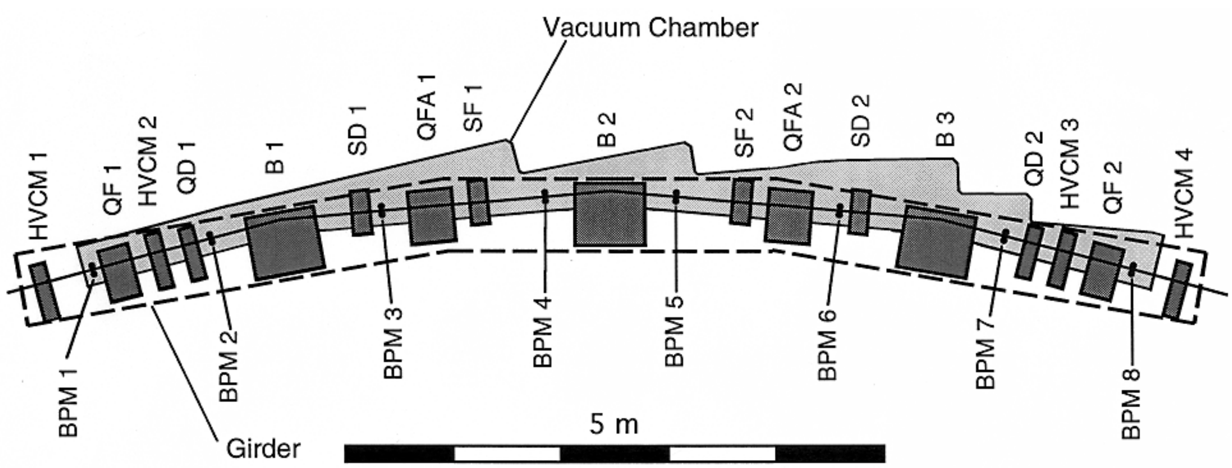

Figure 1. One out of twelve storage-ring arc sections showing outlines of girder, vacuum chamber, lattice and corrector magnets, and locations of the beam-position monitors (BPM).

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† A. Biocca, M. Chin, B. Feinberg, K. Fletcher, T. Henderson, J. Hinkson, M. Howells, Z. Hussain, A. Jackson, G. Krebs, D. Massoletti, R. Miller, E. Moler, A. Paterson, J. Pickrell, G. Portmann, W. Thur, T. Warwick, and J. Wunderlich.

induced deformations of the girders had caused poor convergence of the survey/alignment cycles [3] when the lattice magnets were put in place during the construction phase of the storage ring; and secondly, a vertical orbit oscillation with a 15-min. period had been completely eliminated by keeping the cooling water temperature of the ALS magnets constant within ±0.1°C [4]. On several occasions, however, other causes of orbit distortions were discovered and successfully eliminated.

2 TRACY V

The simulation code TRACY V is a “virtual machine” representing the ALS storage ring, written in Borland Delphi2 for Windows NT. The code calculates and displays many machine functions, such as linear optics functions and the closed orbit for a given set of magnet parameters; it also includes analysis tools for measured data. A Graphical User Interface provides flexibility in the modes of usage and display of results. With the exception of dynamic aperture calculations the response to user input is automatic and almost instantaneous.

In the context of orbit stability investigations, TRACY V furnished closed-orbit calculations for given sets of lattice-magnet strengths and misalignment values, and for combinations of corrector strengths. The computations are based on measured and adjusted sensitivity matrices that describe the response of the BPMs to changes in each individual corrector. For analysis of actual orbits, TRACY V can be linked to either archived data or to programs that capture BPM data on-line. Orbit correction can be performed using the local-bump, most-effective corrector, and singular-value decomposition methods. Misalignment values for lattice magnets can be set either individually or in a special ganged mode where the horizontal misalignment of all magnets on one girder progressively increases from the locations of the QFA magnets, see Fig. 1, to the QF magnets at the ends. An example of a closed-orbit distortion caused by this kind of girder deformation is given in Fig. 2.

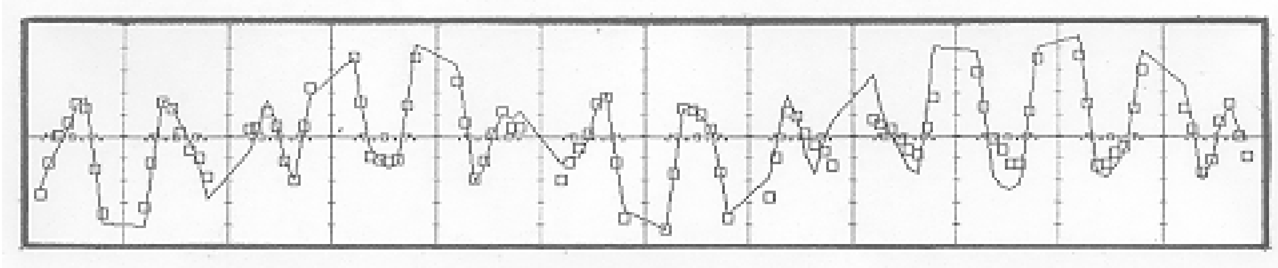

Figure 2. Horizontal closed-orbit distortion around the entire storage ring (±200μ full scale) as measured on 9/12/96 (open symbols) and simulated by TRACY V (continuous line), assuming a progressive girder deformation of up to 31 μ.

3 TYPICAL ORBIT DISTORTIONS

The storage-ring orbit is continuously being monitored by a set of new BPMs that are installed at both ends of most of the straights and termed ID-BPMs to distinguish them from the arc BPMs shown in Fig. 1. The ID-BPMs are inherently more sensitive and less beam-current dependent than the arc BPMs because they use one common amplifier chain only, in a multiplexing mode [5]. Archived ID-BPM data taken over a 12-hour period are displayed in the ALS control room [6] and give a very good indication of the orbit stability. An example of these signals, recorded at the end of summer 1996 before the work described here began, is given in Fig. 3.

Of the phenomena displayed in Fig. 3, the step change indicated by the asterisk is certainly the most intriguing. Its investigation stimulated the development of TRACY V to accommodate the effect of girder deformations, and in a dedicated experiment where a girder was locally heated by a hot-air gun, dial indicators mounted on the girder showed in fact several instantaneous position shifts of up to 16 μ. Later on, however, a step change was unambiguously correlated with the movement of one of the two building cranes. In another experiment it was shown that the perturbation of the magnetic field across a storage-ring straight, induced by the presence or absence of the crane, was associated with the orbit distortion and could be simulated by exciting two corrector magnets, one at the location from where the crane was leaving and one where it went. The second building crane showed similar effects, and once known they were eliminated administratively by regulating the use of the cranes.

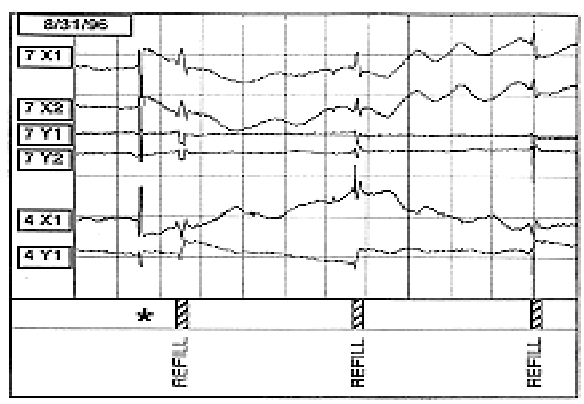

Fig. 3. Horizontal (X) and vertical (Y) ID-BPM signals from sectors 4 and 7, taken on 8/31/96. Grating units correspond to 150μ, vertically, and 1 hour, horizontally. The illustration shows 1-hour oscillations, long-term drift, and a 10-min. step change (marked by an asterisk at the bottom). Signals have no validity during refill times.

4 AIR TEMPERATURE STABILIZATION

After ascertaining in experiments that the hourly orbit oscillations were associated with air temperature changes of about 1°C and corresponding girder temperature changes of 0.2°C these distortions could substantially be reduced by a series of improvements to the system of 9 independent air-handling units that supply chilled air to the storage-ring tunnel. The changes included using temperature sensors with 0.1°C sensitivity, relocated to the outer perimeter of the storage ring; averaging their readout to regulate all air-handling units with identical set values; and forcing the tunnel air to move in a spiralling pattern upstream by directing the outlet heads of the air-handling units and deploying four additional fans on the tunnel floor. These improvements also cured most of the long-term drift problems seen before.

Another type of orbit distortions manifested itself as four-hour, 100-µ humps on the ID-BPM display. Two causes were identified to contribute to these phenomena, one associated with the switchover between two water chillers of different size that supply the air-handling units during nighttime and daytime, respectively, and the other one originating in the enhanced water flow of a building air-conditioning system that utilizes the same chillers. These effects were eliminated by using the larger of the chillers as a default and reducing the water flow through a bypass in the air-conditioning unit.

The striking improvement in orbit stability obtained after resolving all these issues is shown in Figs. 4 and 5.

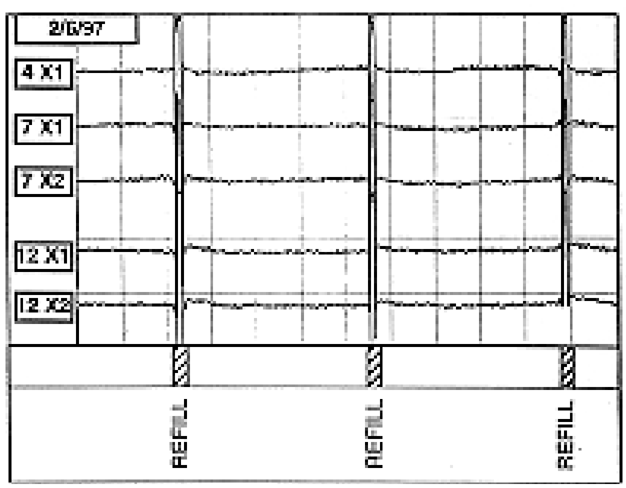

Figure 4. Horizontal ID-BPM signals observed on 2/6/97 after substantially improving the temperature-stabilization. Grating units 150µ, vertically, and 1 hour, horizontally.

5 ADDITIONAL EFFECTS AND OUTLOOK

One other flavor of orbit distortion, a step change without apparent return, used to occur about 30 minutes before a refill of the storage ring was planned. It turned out that this effect was caused by the excitation of the last two of the four dipole magnets in the booster-to-storage-ring (BTS) injection line. Even though these magnets are located about 1.5 m away from the storage ring, their fringe fields are strong enough to perturb the stored electron beam. This problem can again be solved administratively.

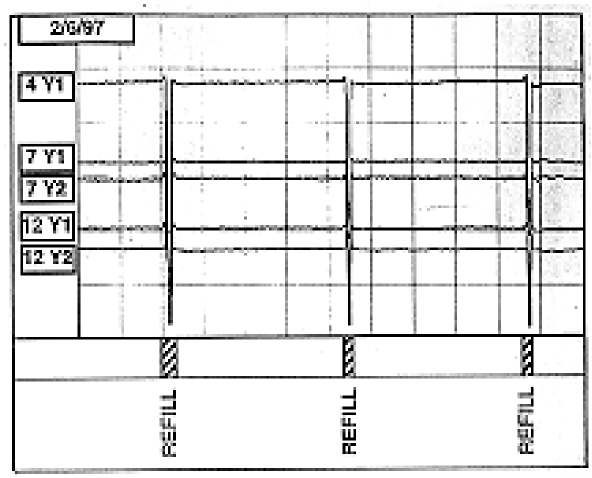

Figure 5. Vertical ID-BPM signals observed on 2/6/97 after substantially improving the temperature-stabilization. Grating units 150µ, vertically, and 1 hour, horizontally.

Last, but certainly not least, it should be mentioned that the ALS orbit is heavily affected by the changing magnet fields when insertion-device gaps are opened or closed. This effect is suppressed by applying corretive set values to the steerer magnets in a feed-forward mode [7].

With all these measures, ALS has reached an impressive level of orbit stability, even exceeding the tight specifications mentioned at the beginning. The reduction of temperature variations in the tunnel to ±0.1°C also largely reduces the arc vacuum-chamber deformations and in this way leads to much more stable arc-BPM positions. This eliminates one of the major obstacles for the implementation of an orbit feedback system, and such a system could now be developed to reach even better orbit stability, below ±1 µ vertically.

6 ACKNOWLEDGMENTS

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