BEAM ORBIT CONTROL SYSTEM FOR THE KEKB CRAB CAVITIES

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Abstract

KEKB is an electron-positron collider with an 8 GeV electron ring (HER) and a 3.5 GeV positron ring (LER). The two beams currently collide at one interaction point with a finite horizontal crossing angle of 11 mrad. The design luminosity of 10 /nb/sec was first reached in May 2003 and the peak luminosity exceeded 16 /nb/sec in December 2005. Simulations predict a luminosity boost if a crab crossing scheme is introduced. The installation of two superconducting crab cavities, one in each ring, is scheduled in 2006, in order to implement the crab crossing scheme [1]. For stable operation, the horizontal beam position in the crab cavity must be carefully controlled. This is needed to avoid loss of control of the crabbing mode field due to beam loading. A beam position feedback system at the crab cavity has been constructed and tested. Its performance will be discussed in this report.

INTRODUCTION

Two crab cavities are scheduled to be installed in the Nikko section shown in Fig. 1, one for the positron ring (LER) and the other for the electron ring (HER). The cavities will give a transverse kick to the beam bunches and the bunches will be "crabbed" all around the ring. The lattice design with the crab cavities is described elsewhere [2].

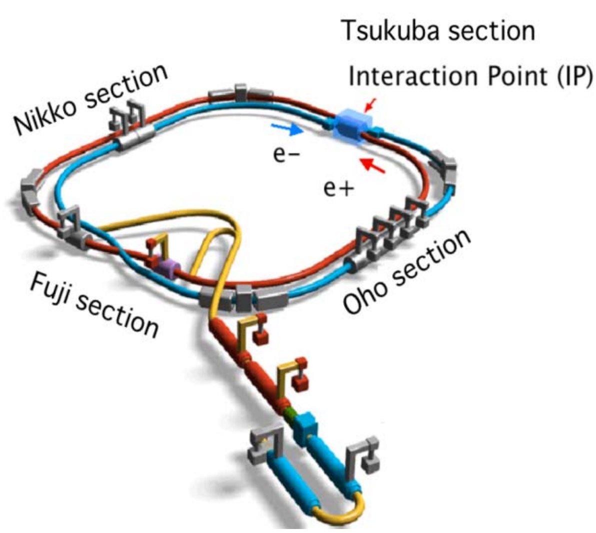

Figure 1: KEKB overview.

An orbit feedback system to control the local orbit at the crab cavities has been installed in both the LER and the HER. The system is designed to keep the horizontal orbit at the crab cavities stable since a large orbit change would increase the beam-induced voltage [3]. The required RF power is calculated and plotted as a function of loaded-Q value Q_L for various horizontal beam orbit change Δx in Fig.2[4]. Depending on the choice for Q_L, the tolerance for the orbit drift changes. With the current choice of Q_L=$1\sim3\times10^5$, the horizontal orbit is required to be kept constant within a few hundred microns. It should be noted that the tolerances of the orbit drift changes as a function of Q_L.

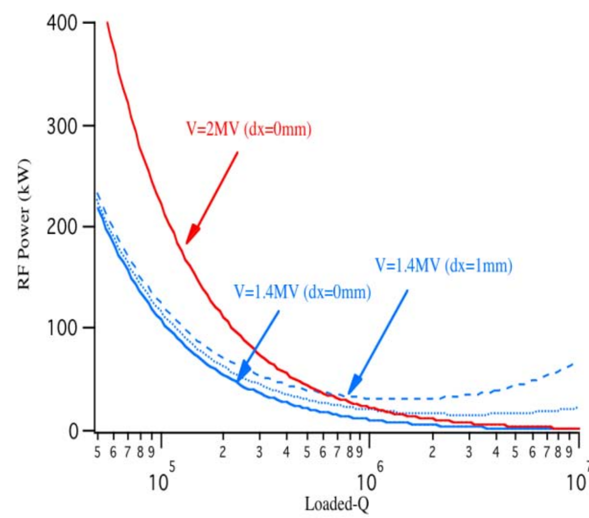

Figure 2: Required RF power vs. Loaded-Q.

BEAM ORBIT CONTROL SYSTEM AT CRAB CAVITY

In order to achieve stable operation of the crab cavities, two sets of orbit control systems, one for the LER and the other for the HER, were constructed. Each set consists of four horizontal steering magnets, which create a localized horizontal offset bump at the crab cavity. The steering magnets are controlled by PLC DAC (MELSEC Q68DAV) modules via EPICS. The EPICS/PLC software was developed by the KEKB control group. A feedback on beam position is considered now. The horizontal beam position at the crab cavity is calculated using two beam position monitors (BPMs) located upstream of the cavity and the transfer matrices from the beam position monitors to the cavity. The crab orbit feedback task cycles at 1 Hz, which is limited by the current BPM read-out time. Using the beam power at the cavity instead of the beam position at the cavity is also under consideration.

NEED FOR FASTER ORBIT CONTROL

The global beam orbit is adjusted to the desired orbit by a task called 'CCC', which stands for Continuous

COD Correction, every 10 seconds. This is not fast enough for the case where there is an abrupt orbit change. Fig.3 shows an example of such events during a physics run with the crab lattice. We have been operating the accelerator with the crab lattice since the fall of 2005. It should be noted that the horizontal beta function is much larger (~200 m) at the HER Crab cavity with these new optics. The collision condition became unstable due to an unexpected betatron tune change and a beam loss in the LER occurred. The HER beam current remained unchanged but a horizontal orbit change of ~0.2 mm was seen at the location where the crab cavity is scheduled to be installed. CCC brings the orbit back to where it was before within about 40 seconds. The new crab orbit feedback system is expected to correct the orbit faster than CCC.

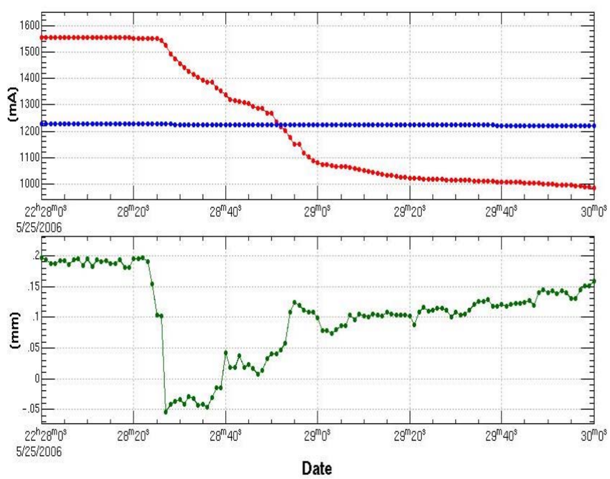

Figure 3: An example of a sudden horizontal orbit change observed at the crab cavity location in the HER (bottom). The LER and HER beam currents are plotted in the top figure.

TEST WITH THE HER BEAM

The software was modified for the BPMs which are used for the crab feedback. A faster read-out and localized data handling enabled faster orbit feedback. The read-out time of these BPMs is about 1 s which is about 4 times faster than the other BPMs in the ring used for CCC. A major modification would be needed if this read-out time limits the performance of the crab obit feedback. The maximum bump height that the crab feedback system can create is about 5 mm for the HER and 3 mm for the LER.

Bump test

First, the horizontal bump generated by the four horizontal steering magnets of the HER crab feedback system was checked with CCC off. Fig.4 shows the beam orbit when an offset bump of 2 mm height was set. The bump is well localized at the crab cavity section and there is no effect on the other parts of the ring. There is no big coupling to the vertical direction, either.

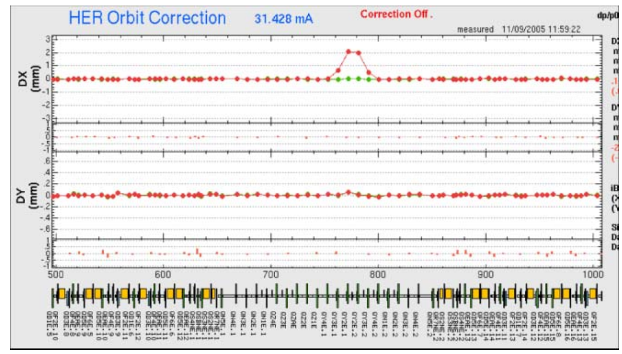

Figure 4: Horizontal bump at crab cavity in the HER

Feedback test

Secondly, the feedback performance was tested. The feedback system takes the BPM readings, translates them into the orbit change at the crab cavity location and sets a bump of the opposite sign with a specified height. The height of the bump set at each feedback cycle depends on the feedback parameters such as the damping factor. The feedback system should recognize the target orbit and steer the beam to the target. The target orbit was changed to see how quickly the system recognizes and follows the target with different damping factors. Fig. 5 shows the target orbit and the measured orbit. An overshoot was seen when the damping factor was larger. The damping factor might depend on the beam current and it should be adjusted later again for the actual operation.

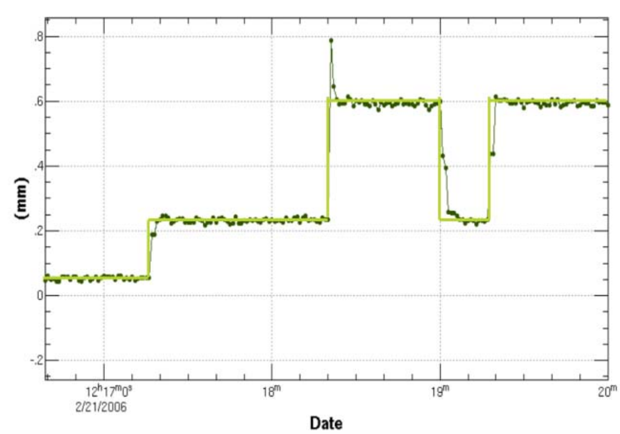

Figure 5: Feedback follows the target.

Thirdly, a single kick was given to the HER beam intentionally to create a COD of about 0.5 mm at the crab cavity location as in Fig.6. The beam position is measured every second and plotted along with the target value. The feedback system brings the orbit back to the target orbit within several seconds, which is 10 times faster than CCC. The crab feedback was turned off at the end of the test. The orbit started drifting away from the target orbit as soon as the feedback was turned off.

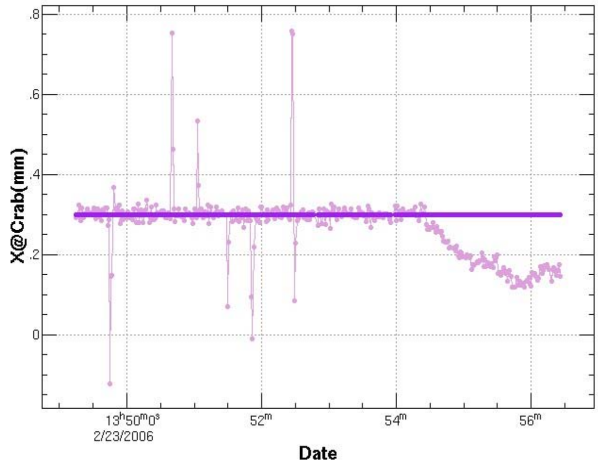

Figure 6: Beam orbit at the crab cavity in the HER. Dots are the measured orbit and the solid line is the target orbit. Spikes indicate the COD generated by an intentional single kick.

In order to evaluate the feedback convergence, the difference between the target position and the measured orbit, Δx, is plotted in Fig. 7. The Δx distribution is fitted by a Gaussian with a mean value of zero and a sigma of ~7 μm. The feedback convergence rate is sufficient.

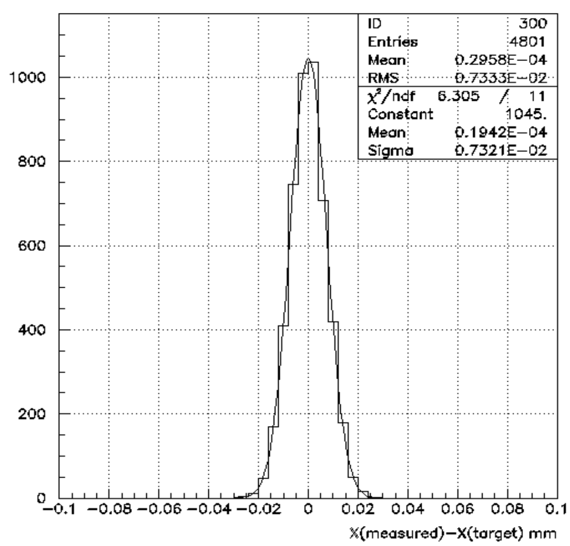

Figure 7: Δx distribution when the crab feedback was on.

Lastly, the performance of the crab feedback system was tested with CCC on. The crab feedback and CCC should not interfere with each other. The shape of the bump used for the crab feedback system is fixed. Only the bump height changes depending on the orbit change. The crab feedback system tells CCC its bump height so that CCC does not change the bump intentionally created by the crab feedback system. Fig. 8 shows the difference between the measured orbit and the 'gold' orbit when both CCC and crab orbit feedback were on. The gold orbit is the target orbit of the CCC system. Since the crab bump information is included in the gold orbit, CCC did not correct the bump at the crab. The local bump by the crab feedback system can coexist with the CCC task.

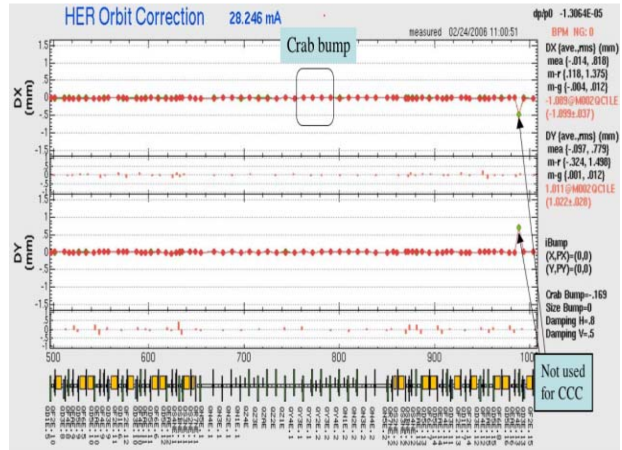

Figure 8: Deviation from the gold orbit in the Nikko crab section is shown when both CCC and crab feedback were on.

SUMMARY

An orbit feedback system to control the horizontal beam position at the crab cavity has been constructed for both the LER and the HER. The feedback controls the beam orbit faster than the global orbit correction. The beam orbit can be maintained and/or moved to a desired place by the feedback system. There was no serious interference with the global orbit correction system. A feedback performance test with higher current is underway. Using the beam loading as the input to the feedback system is also considered for the future.

ACKNOWLEDGEMETS

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