STUDY OF BEAM SIZE BLOWUP DUE TO TRANSVERSE BUNCH FEEDBACK NOISE ON $e^+ e^-$ COLLIDER*

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Abstract

Vertical beam size blowups with the larger gain of the transverse bunch feedback systems have been observed in KEKB B-factory rings. With the numerical simulation, it has been shown that large beam-beam effect enhanced small oscillation induced by the broadband noise of the bunch feedback kick. To examine the simulation, the beam response, the effective beam size and the luminosity change with artificial external noise injected into the transverse feedback system have been measured in KEKB LER ring during collision. The result has been compared with the simulation including beam-beam effect and showed good agreement.

INTRODUCTION

On recent high luminosity colliders such as B-Factories, it is almost indispensable to use the powerful transverse bunch-by-bunch feedback systems to suppress fast coupled-bunch instabilities (CBI) coming from strong and wide-band impedance sources such as electron cloud instability or fast ion instability. The feedback gain of the systems tends to be rather larger at least to keep the beam with single beam condition. In the case of KEKB-LER, we have normally set the gain of the system to have the feedback damping time of around 0.2~0.5 ms, which corresponds to 20 to 50 turns of the revolution of the rings.

During the operation of the KEKB rings, we have unexpectedly observed a degradation of the luminosity related with the exceed feedback gain of the LER. With the systematic study of the relations between the transverse feedback gains and the luminosity, we have found only LER vertical feedback gain affected the luminosity and the vertical beam size; other transverse feedback gain, LER-H, HER-H and HER-V had no obvious relation to the luminosity. Figure 1 shows the obtained response of the luminosity with the LER vertical feedback gain.

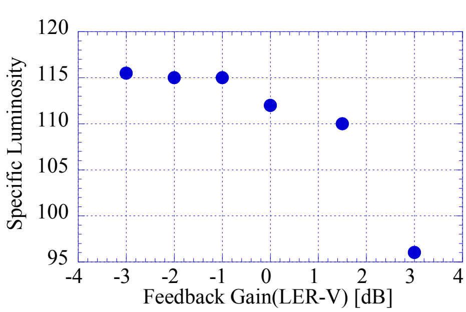

Figure 1: Luminosity reduction with the KEKB-LER vertical feedback gain.

We have also examined the effect of the vertical feedback gain on vertical beam size observed with the interferometer on both the collision and the single-beam condition of KEKB-LER. Though the vertical beam size slowly increased (~10%) with the feedback gain during single-beam condition, it jumped up more than 40% with small change of the feedback gain during collision. The resulting luminosity decreased around 10 to 20% with the blowup of the vertical beam size.

Since with lower vertical feedback gain which did not affect the luminosity we could inject and keep the beam with single-beam condition, and the coupling between the bunches could be smeared by the tune spread coming from strong beam-beam effect during collision, we could manage the effect realistically. It is however important to understand the effect, especially for the future low emittance storage rings with much lower x-y coupling such as SuperKEKB. With the numerical simulation, it has been shown that large beam-beam effect enhanced small oscillation induced by the broadband noise of the bunch feedback systems[2].

We have examined the simulation by measuring the beam response, the effective beam size and the luminosity change with artificial noise injected into the vertical feedback system in KEKB-LER during collision. Table 1 shows the main parameters of the KEKB rings during experiment.

Table 1: Main Parameters of KEKB Rings

	LER	HER	
Energy	3.5		GeV
Circumference	3016		m
f_{rev}	99.39		kHz
Crossing angle	22 (crab crossing)		mrad
Beam current	1.45	1.0	A
Harmonic number	5120		
Bunch number	1584	1584	
Betatron tune x	45.506	44.510	
y	43.558	41.620	
Total RF voltage	8.0	13.0	MV
IP beta $\beta x^*/\beta y^*$	120/0.59	120/0.59	cm

EXPERIMENTAL SETUP

The block diagram of the transverse feedback systems of KEKB-LER is shown in Figure 2[1]. Button signals are filtered with the cable-type BPF with center frequency of 2 GHz. The two facing button signals are subtracted with the 180-deg. hybrid and down-converted with 4 x RF signal to get amplitude (position) of the oscillation. The two horizontal or vertical positions are combined vectorially to make 90-deg phase shift and digitized with the

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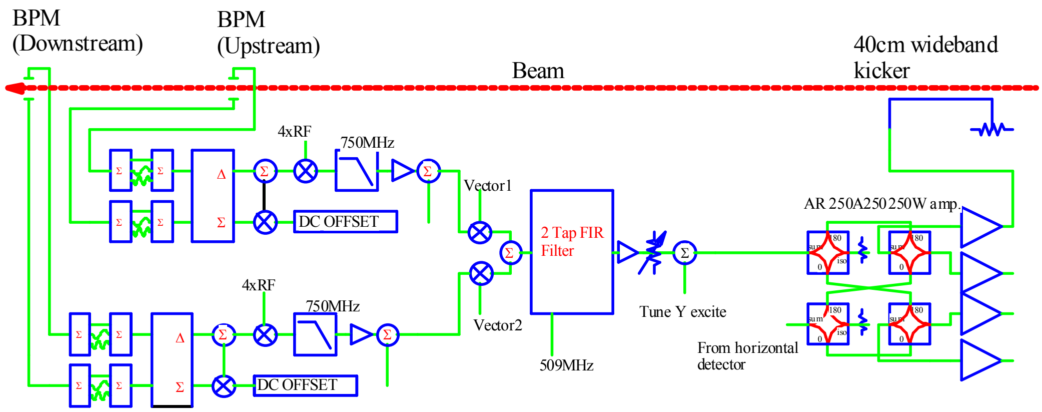

Figure 2: Block diagram of KEKB-LER transverse (vertical) feedback systems.

fast 8-bit ADC. The hardware two-tap FIR digital filter is used to cancel the DC component and to adjust the one-turn delay. The resulting feedback signals (horizontal and vertical) are combined using hybrids and amplified with high power final amplifiers (AR250A250) to kick the beam back.

In the system, there are external injection ports (horizontal and vertical) to excite transverse oscillation just after the 2-tap FIR filter. We have injected pure sinusoidal signals or band-limited white noises from Agilent 81150A function generator using 5 MHz low pass filter. The peak-to-peak amplitude of the excitation was confirmed by switching the output of the function generator to an oscilloscope. The amplitudes of the excited oscillation of the LER beam were detected with the bunch oscillation recorders (BOR) [1] which store all the transverse bunch positions in 4096 turns of revolution. BPMs at the same downstream port of the feedback detector were used as the input of the BOR. The data of the BOR are calibrated using local bumps around the BPMs. We have made the FFT on the recorded bunch-by-bunch oscillation data to get the mean amplitude of the oscillation corresponding to the excitation. The effective beam size was measured using interferometer with the repetition of around 1 Hz. The luminosity data was delivered by the Belle detector. Since the update of the luminosity data was slow, typically around 0.1 Hz, and had huge latency due to online data processing, and the change of the effective beam size due to beam-beam effect was also slow, we have waited the settling the measured data such as luminosity and beam size long time after the change of the excitation parameters. During the experiment, we have kept the beam current both HER and LER constant with the continuous injection as much as possible, and also used the normal collision feedback used on physics running.

RESULTS AND DISCUSSIONS

At first, we have injected pure sinusoidal signal into the vertical excitation port of LER with several frequencies (0.55, 0.56, 0.58, 0.6, 0.62, 0.65, 0.68, 0.72 and 0.75 in vertical tune) and amplitudes (from 0.05 Vp-p to 2 Vp-p). Figure 3 shows the measured vertical amplitudes of the beam with supplied amplitude of the excitation in peak-to peak value. As clearly see, the responses of the beam on

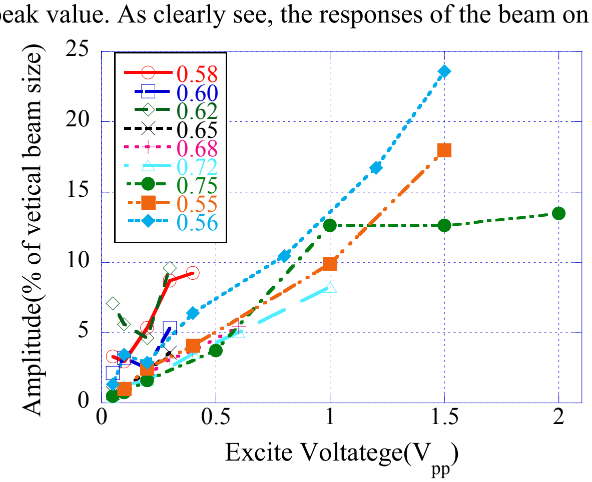

Figure 3: Measured vertical oscillation with externally supplied excitation amplitude.

the excitation frequencies are not the same. In the beam-beam region starting from 0.58 (vertical tune) to 0.63 (vertical tune + beam-beam tune shift) seems to have larger response than other frequency. Figure 4 shows excited beam amplitudes with fixed excitation voltage by the excitation tune. It also shows that though the beam-beam region around 0.6 is more sensitive from small external signal to large one, other region far from the betatron tune responses is not negligible.

The luminosity and the effective vertical beam size measured by the interferometer on both HER and LER and luminosity change with the excited amplitude are also compared in the beam-beam region and out of the beam-beam region. At the beam-beam region the LER beam size has increased fairly quickly and the luminosity gradually decreased with the excitation amplitude. On the other hand, at out of the beam-beam region, though the

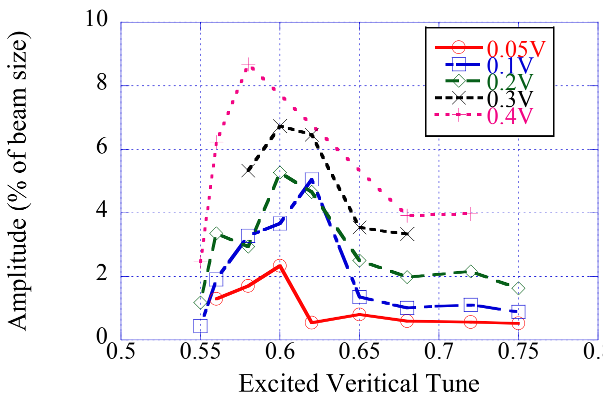

Figure 4: Beam response with the exited tune.

increase of the LER beam size was much slower than that of in the beam-beam region, the drop of the luminosity with the excited amplitude was rather milder. The drop of the luminosity by excited vertical amplitude with several excitation frequencies are shown in Figure 5.

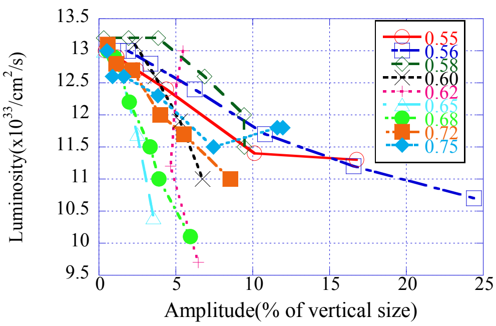

Figure 5: Luminosity degradation due to oscillation applied externally in the feedback system.

In the case of white noise excitation, we have estimated the amplitude of the oscillation corresponding to each tune used the single frequency excitation from the FFT amplitude of the BOR. The shape of the beam response

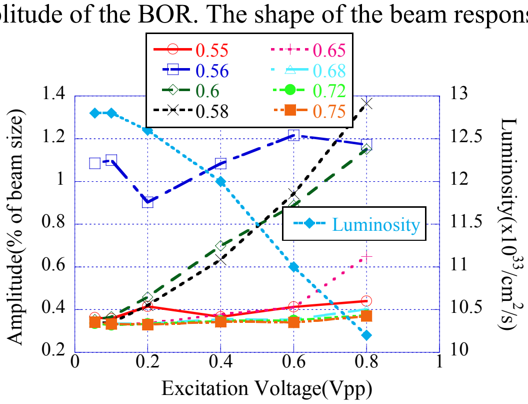

Figure 6: Luminosity response with band-limited white noise excitation. The luminosity had dropped 5% with the noise of 0.4Vpp level.

was roughly similar to the case of single frequency excitation shown in Figure 4. The luminosity response is shown in Figure 6. The luminosity has dropped about 5% with the noise amplitude of 0.4 Vpp. Apparently, this huge level of the noise is completely senseless for the normal operation of the feedback systems.

After the observation of the luminosity degradation due to excess feedback gain, simulation work has been carried out and has shown that small amount of external oscillation in vertical plane might increase the vertical beam size and degrade the luminosity[2]. The simulation work with the same accelerator conditions as the excitation experiment are also in progress. Figure 7 shows an example of the result of the simulation which shows the luminosity degradation with the externally excited sinusoidal noise. Roughly, the simulation reproduces the

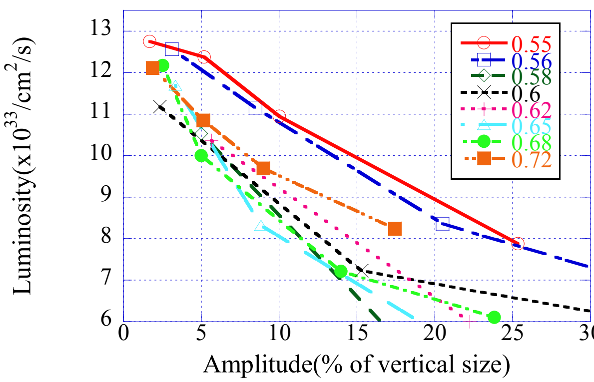

Figure 7: Luminosity degradation by the externally applied sinusoidal noise by the beam-beam simulation. The results are scaled to fit the experimental data.

amplitude dependences of the experimental results. Detailed simulations are in progress. In the experimental wok, we plan to make more detailed experiment on DAFNE accelerators.

SUMMARY

We have studied the effect of the vertical beam size blowups and the luminosity degradation due to externally supplied noise in the feedback systems. The simulation reproduces the amplitude dependences of the effect well. Also the study of the blowup mechanism is in progress with the beam-beam simulation. It is, however, to reproduce the vertical oscillation with white noise, huge noise level which never exist in normal feedback systems is needed.

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