RECENT PROGRESS AT KEKB

Y. Funakoshi, T. Agho, K. Akai, K. Ebihara, K. Egawa, A. Enomoto, J. Flanagan, H. Fukuma, K. Furukawa, T. Furuya, J. Haba, S. Hiramatsu, T. Ieiri, N. Iida, H. Ikeda, T. Kageyama, S. Kamada, T. Kamitani, S. Kato, M. Kikuchi, E. Kikutani, H. Koiso, M. Masuzawa, T. Mimashi, A. Morita, T. T. Nakamura, K. Nakanishi, H. Nakayama, Y. Ogawa, K. Ohmi, Y. Ohnishi, N. Ohuchi, K. Oide, M. Ono, M. Shimada, M. Suetake, Y. Suetsugu, T. Sugimura, T. Suwada, M. Tawada, M. Tejima, M. Tobiyama, N. Tokuda, S. Uehara, S. Uno, N. Yamamoto, Y. Yamamoto, Y. Yano, K. Yokoyama, Ma. Yoshida, Mi. Yoshida, S. Yoshimoto, F. Zimmermann*
KEK, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

Abstract

We summarize the machine operation of KEKB in past one year focusing on progress for this period.

INTRODUCTION

In this reports, we summarize the machine operation of KEKB mainly after the summer-shutdown in 2005. A status report before this was written elsewhere [1]. Fig. 1 shows 6-year's history of the KEKB luminosity and beam currents. Table 1 shows present machine parameters of KEKB compared with those of about one year ago. Both Fig. 1 and Table 1 show that progress in the KEKB performance in the past one year is not very remarkable compared with earlier years. In this paper, we describe causes of the present performance limitations of KEKB. After this, we discuss an issue of performance reproducibility after operation breaks where we made some progress very recently. Finally, we mention future plans on how to improve the KEKB luminosity against the present limitations.

Table 1: KEKB Machine Parameters.

	June 2006		**May 2005**		
	LER	HER	LER	HER	
Energy	3.5	8.0	3.5	8.0	GeV
Circumference	3016		3016		m
$I_{\rm beam}$	1616	1210	1730	1261	mA
# of bunches	1387		1387		
$I_{\rm bunch}$	1.16	0.871	1.25	0.909	mA
Ave. Spacing	2.1		2.1		m
Emittance	18	24	18	24	nm
β_x^*	59	56	59	56	cm
β_y^*	6.5	5.9	6.5	6.2	mm
Ver. Size@IP	1.7	1,7	2.1	2.1	μm
RF Voltege	8.0	15.0	8.0	15.0	MV
ν_x	.505	.511	.505	.511	
ν_y	.534	.568	.535	.577	
ξ_x	.106	.068	.110	.073	
ξ_y	.105	.060	.092	.056	
Lifetime	148	204	140	179	min.
Luminosity	16.52		15.62		/nb/s
Lum/day	1.232		1.178		/fb
Lum/7 days	7.81		7.36		/fb
Lum/30 days	30.21		29.02		/fb

PERFORMANCE LIMITATIONS

Effects of electron clouds

Since the beginning of KEKB, effects of electron clouds have been strictly limiting the KEKB performance. To mitigate their effects, we have installed lots of solenoid coils and permanent solenoid magnets in the drift space of LER. At present more than 95 % of the drift space in the ring is covered by solenoid fields with the field strength higher than 20 Gauss. Even with the solenoid coils, there are evidences that the KEKB luminosity is still limited by the electron clouds. The most direct evidence of the effects is vertical betatron sidebands appeared in the transverse beam spectra of the positron bunches[2]. The sidebands seems to be signals of the fast head-tail instability due to short-range wake fields within the electron clouds. Although the sidebands (usually upper sidebands) can be more clearly observed in the single beam, machine performance is affected by the effects both in the single beam and the two beam cases. In the single beam, a beam size enlargement is observed associated with the upper sidebands above a threshold beam current of the instability. In the two beam case, the luminosity saturation is observed as shown in Fig. 2. The figure shows the luminosity as function of the LER beam current. In the measurement, the HER beam current was fixed at around 1300mA. The red dots in the figure are data taken when the beam current decreased, while the blue dots are those when the beam current increased. The measurement shows that we can not get a higher luminosity with a higher beam current than about 1700mA. In the measurement, we used a bunch fill pattern of “3.5 bucket spacing” where 3 RF bucket and 4 RF bucket spacings were repeated alternately. With this fill pattern, the betatron sidebands started to appear at around 1400mA in a single beam measurement. It seems that the luminosity saturation comes from the electron cloud instability.

More direct connection between the electron cloud ef-

* visiting from CERN, Switzerland

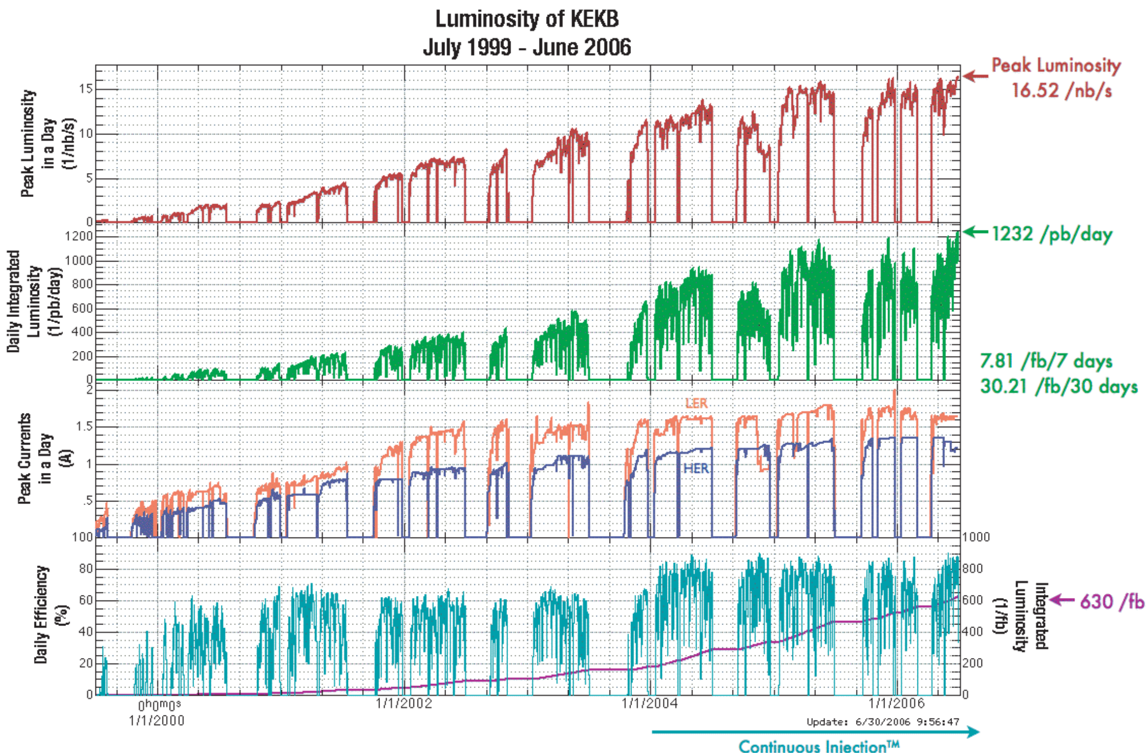

Figure 1: History of KEKB.

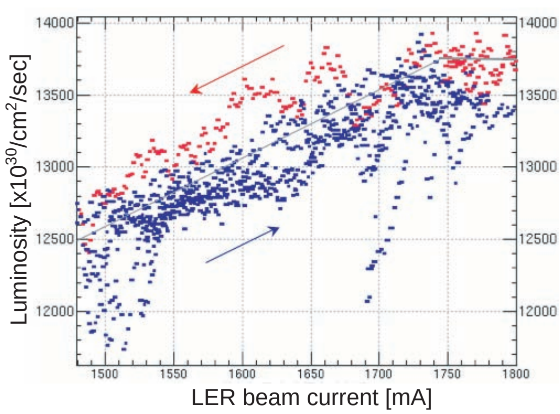

Figure 2: Luminosity as function of the LER beam current.

fects and the degradation of the luminosity was observed in a measurement of a bunch-by-bunch luminosity. This measurement was done for the purpose of investigating into the problem that a specific luminosity degrades with a shorter bunch spacing. The averaged bunch spacing is 3.5 RF buckets at present KEKB, while in the KEKB design we planed to fill all RF buckets with the beam except for some abort gap. From the viewpoint of hardware protection against the high beam currents, it is desirable to increase the number of bunches and decrease HOM power. To study the bunch spacing problem, which is thus important for KEKB, we prepared a special fill pattern. The base of this pattern is the usual 3.5 bucket spacing and about 1/10 of the pattern was changed into a 3.27 bucket spacing. From a constraint of the two bunch injection scheme, the fill pattern of KEKB must have a unit of 49 RF buckets and the same pattern must be repeated every 49 RF buckets. Both the 3.5 and 3.27 spacings are a mixture of 3 bucket and 4 bucket spacings. The base units of these pattern are (34343434343434) and (333433343334334), respectively. Fig. 3 shows a result of the measurement on the bunch-by-bunch specific luminosity. The red circles and the green triangles denote data of the 3.5 and 3.27 spacings, respectively. The abscissa shows a 49-folded bucket number of bunches in the fill patterns. Each data in the plot is the average value of many equivalent bunches. On the average, the specific luminosity with the 3.27 spacing is by about 5 % lower than that with the 3.5 spacing. In the case of the 3.27 spacing, the bunches after the 4 bucket spacing have relatively higher specific luminosity, while those after two or three successive 3 bucket spacings have lower specific luminosity. In another measurement with the single beam of LER, we confirmed that the bunches which have the lower specific luminosity have higher betatron sideband peaks. From these observations, we concluded that the degradation in the specific luminosity depending on the bunch spacing is originated from the effects of the electron clouds. The remaining problem is where in the ring do the electron clouds exist. In the summer shutdown 2005, we installed solenoid coils in the inside of 88 quadrupole magnets out of 461. However, we observed no effects of these additional solenoids on the luminosity.

Troubles with vacuum bellows in HER

A similar measurement to Fig. 2 was done concerning the HER beam current. Unlike the case of the LER beam current, we observed no saturation of the luminosity as for the HER beam current up to 1300mA. Therefore, the most

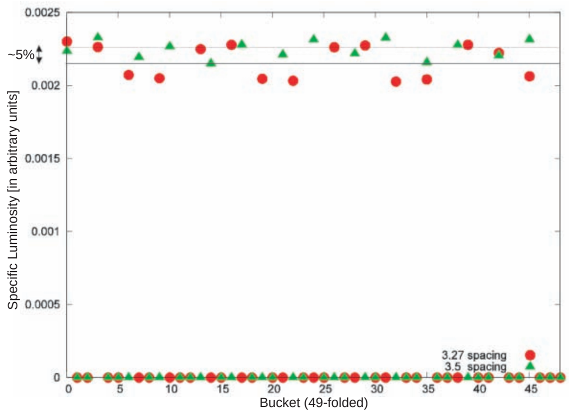

Figure 3: Measurement of bunch-by-bunch specific luminosity.

direct way of increasing the luminosity is to increase the HER beam current. For this purpose, one more RF station for the ARES cavity in HER was installed during the summer shutdown in 2005, since the HER beam current was limited by available RF power. With this new RF station, the target HER beam current was 1500mA. However, we experienced a frequent troubles with vacuum bellows at the level of 1350mA. The troubles occurred not with special type bellows but with regular type bellows. The broken bellows have a race-track shape and had serious damages with their RF fingers on the top and bottom sides. It is believed that the troubles have a connection with transverse deformation of the bellows. We found that the bellows deformed in the horizontal direction when the beam current rapidly changes such as in beam aborts or during beam injections. We measured relative changes in the horizontal positions on both sides of flanges of the regular bellows at some locations. Bellows located in downstream of bending magnets had relatively large position changes, which indicates that the cause of the deformations are heating by SR. We confirmed that the bellows at the positions where the broken bellows were located had the largest relative position changes of about 3mm. A possible cause of the troubles is that the RF fingers and the spring fingers lost contact due to the horizontal deformations. Due to these troubles, we are operating the KEKB machine with a restriction of the HER beam current of 1300mA for the time being.

REPRODUCIBILITY OF LUMINOSITY

In the past one year, one of the most critical issues for the beam operation was a bad reproducibility of the luminosity after operation breaks. After the summer shutdown 2005, it took about 2.5 months to recover the performance before the shutdown. The most important change of the machine during the summer shutdown was to change the optics to meet conditions required for realizing the crab crossing scheme. The conditions are horizontal phase advances from the crab cavities and IP, large horizontal beta functions at the crab cavities and horizontal phase advances from SR monitors to IP. The last condition is needed to measure the crab angle with streak camera systems. Since the luminosity recovery was very slow with the crab optics, we made several modifications on the optics. For example, the original crab optics of HER had a different integer part of the horizontal tune. At the sacrifice of the 3rd condition to some extent, we could modify the crab optics so that it has the same integer part. Although we finally recovered the performance before summer with many trials and errors, we have not understood what were key problems. After recovering the luminosity before summer, reproducibility of the luminosity continued to be an issue. KEKB has regular 8-hour maintenance time which is usually taken every 2 weeks. Usually after the maintenance time, we do a magnet standardization and optics corrections. In some cases, the luminosity recovers quickly after these procedures. In many cases, however, it takes long time for recovery. When the luminosity do not recover, we tried to do the optics corrections or the magnet standardization again. In some cases these were effective but in other cases ineffective. Due to this problem of the luminosity reproducibility, we lost a lot of integrated luminosity. Also it deprived us of opportunities of other trials for a higher luminosity. After long-time investigations into this problem, recently we finally found the true reason for the bad luminosity reproducibility. The key parameter was the polarity of one of skew quadrupole magnets in LER. This skew quad is very weak and its polarity can be changed in the process of the optics correction. Since the magnet current between -2A and +2A could not be set due to a software problem, the actual magnet current was set either at around -2A or around +2A corresponding to $\sim \pm 1.5 \times 10^{-4} m^{-2}$ in K2 value, where K2 is $(B''L)/(B\rho)$. We found a strong correlation between its polarity and the achieved luminosity. It seems that the luminosity was affected by x-y coupling parameters at IP depending on the polarity of the skew quad. The precision of the optics correction seems to be insufficient to correct this error setting. After determining an optimum value of this skew by trials and errors, the luminosity reproducibility was drastically improved.

FUTURE PLANS

In the present plan, a crab cavity will be installed in each ring during the coming winter shutdown. We will replace power supplies of the solenoid coils in the straight sections with new ones. This will enable us to increase currents of solenoid coils from 3A to 5A. We expect that the effects of the electron clouds will be mitigated with higher solenoid fields. We are developing a new type of bellows as a countermeasure for the troubles in HER. We are also reconsidering methods of supports for the bellows and vacuum chambers near them.

REFERENCES

[1] Y. Funakoshi *et al.*, Proc. 2005 PAC, Knoxville, 707 (2005).

[2] J.W. Flanagan *et al.*, Phys. Rev. Lett. **94**, 054801 (2005).