A NEW WORKING POINT FOR THE KEKB

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Abstract

In order to improve the beam-beam performance and to increase the luminosity of the KEKB [1,2], a new working point with a tune above the half integer in both planes has been proposed. The strong-strong beam-beam simulations with a code developed by K. Ohmi [3] are used for the luminosity scan. In this paper, we discuss the simulation results in the new tune space region, and suggest a new working point as a candidate for the operation of the KEKB machine.

1 INTRODUCTION

The performance of a collider and the luminosity depend sensitively on the working point. So choosing a good working point is very important for high luminosity operation. The KEKB B-factory has been well operated for more than two years since December 1998. At the early stage of the operation, the KEKB used the working points with the tunes above the integer in both planes, later on the horizontal tunes for both rings were moved to the values above the half integer, while keeping the vertical tunes above the integer [4].

The KEKB machine is now working with fractional tunes $\Delta\nu_x$ =0.52, just above half integer in horizontal, and $\Delta\nu_y$=0.08, just above integer in vertical (Jan. 2001). These tunes gave a good beam-beam performance and better luminosity, and there are still some potential to reach higher luminosity with them. But it seems that the tunes are very sensitive to the machine setting and could substantially effect the beam lifetime and luminosity, even their variations are small as 0.002~0.003. Also the beam-beam blowup has been observed even at the low beam currents [5].

For the present working point of the KEKB (Jan. 2001), the vertical tune is rather close to the integer, and its location in the tune plane is near the sextupole resonance $2\nu_x$-ν_y=47 (LER), these may cause the closed orbit and dynamic aperture more sensitive to the machine errors, therefore the luminosity and beam lifetime could be reduced.

Above considerations pushed us to perform a study aimed to find a new working point situated far from integer and from sextupole resonance, improving the beam–beam performance and increasing the luminosity.

2 BASIC CONSIDERATIONS FOR CHOICE OF A NEW TUNE

From the point of view of beam-beam dynamics, the fractional tunes between interaction points in a colliding beam storage ring would be better if they are close to, but above, an integer or half integer [6]. These tunes would give a good beam-beam performance, but result in the dynamic beta effect having a noticeable effect on the operation. Other effects to be considered for the choice include: the lower order resonance lines are less around it; the orbit distortion and dynamic aperture with the tunes should be less sensitive to the machine errors.

Comparing with the tune just above the integer, the tune above the half integer has some advantages. First, the closed orbit is not so sensitive to the machine errors as that with a tune just above the integer. This is due to the orbit distortion $\Delta x \propto \delta\theta/\sin\pi\nu$, where $\delta\theta$ is an error kick. Second, if we look at the tune plane and plot all the resonance lines up to fifth order, we could see that there is simply more space in the neighborhood of the half integer and coupling resonance than that with a tune just above integer. Third, Several existing colliders operate in the region of tune plane, just above the half integer. For the CESR machine, after switching to single interaction point operation with a crossing angle, it was found that the best working point is very close to the coupling resonance and just above the half integer [7]. These experiences are good examples.

Based on above considerations, we try to explore a new tune space region and find a more suitable working point for the KEKB machine.

3 STRONG-STRONG BEAM-BEAM SIMULATION IN A NEW TUNE REGION

We have used a strong-strong beam-beam simulation code developed by K. Ohmi [3] to perform luminosity scans in a new tune space region. The simulation is performed with 100,000 macro-particles divided into 5 slices in longitudinal, using a 64×128 mesh with horizontal and vertical sizes of 20μm×0.4μm. The particles are tracked for 45,000 turns. In the simulations, the horizontal tunes for both rings are kept almost same as present, i. e. ν_x=44.52 in the HER and ν_x=45.52 in the LER. For the vertical planes, we lower the integer tunes from 42 to 41 for the HER, and from 44 to 43 for the LER. This would decrease the nature chromaticity, and

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therefore reduce the sextupole strengths for the chromaticity correction.

The tune scans are mainly carried out for the LER. In order to determine the HER tunes quickly, a rough simulation is done by keeping a same fractional tune in each plane for both rings.

As the strong-strong beam-beam simulation quite costs computer time, so we only perform a rough scan in a limited tune space region which we are interested in.

The tune survey area covers fractional tunes in the range of $\Delta\nu_x$=0.510~0.550, and $\Delta\nu_y$=0.560~0.655. The tune scan step is 0.005 in both planes.

At first, the simulation is done based on a set of old operation parameters of the KEKB. With these parameters we have accumulated more simulation date for the vertical tunes above the integer [8], so we can compare them with that using new tunes. Second, the present operating parameters are used in the simulations.

3.1 Simulation with old parameters

Table 1 gives a set of parameters of KEKB earlier operation which are related to the simulation.

Table 1 Earlier operating parameters of the KEKB

	LER	**HER**
Horizontal emittance (nm)	**28.99**	**29.45**
Vertical emittance (nm)	**0.5973**	**0.6072**
β_x^*/β_y^* **(cm)**	**70/0.7**	**70/0.7**
Particales/bunch	**3.63395E10**	**2.34809E10**
Bunch length (mm@MV)	**5.9@5.0**	**6.4@9**

HER tune survey:

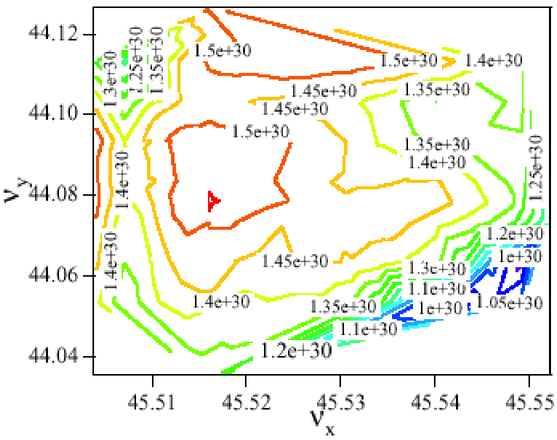
After a rough tune scan with same tune in each plane for both rings, it's found that a higher luminosity could be reached with fractional tunes of $\Delta\nu_x$=0.52, $\Delta\nu_y$=0.635. So we fixed the HER working point as ν_x=45.52, ν_y=41.635 when surveying the LER tunes.

LER tune survey:

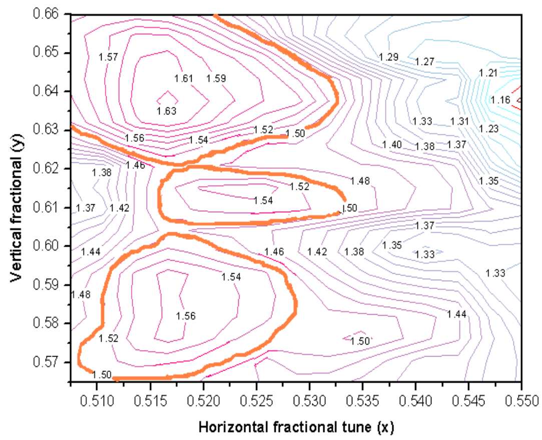
The simulation results show that the predicative luminosity in single bunch in the above tune space region is larger than that with present tunes. Fig. 1 shows the simulation results and compares them with that of vertical tunes above integer [8].

We can see that for the present tune region used for the KEKB, the best tunes are $\Delta\nu_x$=0.52, $\Delta\nu_y$=0.08, but the dimensions of the safe area around it are not so large. Also we could see that a luminosity reduction due to beam-beam driven resonance of ν_x-ν_y-ν_s=47. The simulation results with new tunes show that there are 3 tune space regions in which the luminosity is larger than $1.50\times10^{30}cm^{-2}s^{-1}$, and they are almost connected together in the vertical plane to form a safe area spreading from $\Delta\nu_y$=0.565 to 0.655. The largest safe region around the best tunes of $\Delta\nu_x$=0.515, $\Delta\nu_y$=0.635 covers the tune dimensions larger than 0.05 in both planes. The best luminosity in this set of simulations could reach $1.65\times10^{30}cm^{-2}s^{-1}$.

The results also show that in the three tune regions, the luminosity is very stable and is not sensitive to the variations of β_x^* in the LER, even it is changed from the value of 0.7 m to 0.33 m. But for the other regions, the luminosity could be improved while using a lower β_x^* value in the LER. For example, the luminosity could be increased about 10% by decreasing its value from 0.7m to 0.5m. With β_x^* of 0.33m in the LER, the luminosity could reach $1.50\times10^{30}cm^{-2}s^{-1}$ for almost the whole tune survey region, as showed in Fig. 2.



(a) Luminosity contour diagram for the vertical tunes above the integer (Tawada,EPAC'2000).



(b) Luminosity contour diagram for the tunes above half integer in both planes, the unit of luminosity in the figure is $10^{30}cm^{-2}s^{-1}$.

Fig. 1 Simulation results comparison for the two tune space regions.

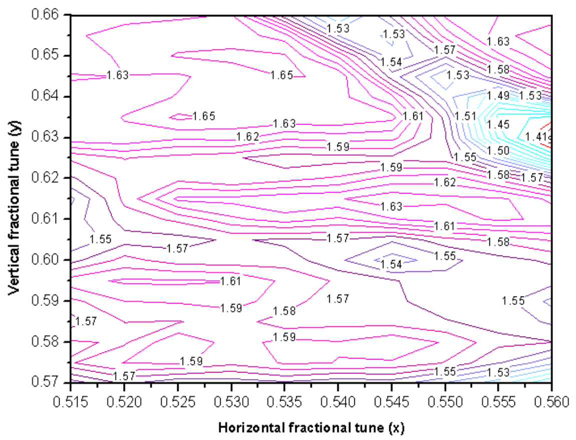


Fig. 2 Luminosity contour diagram with β_x* of 0.33 m in the LER.

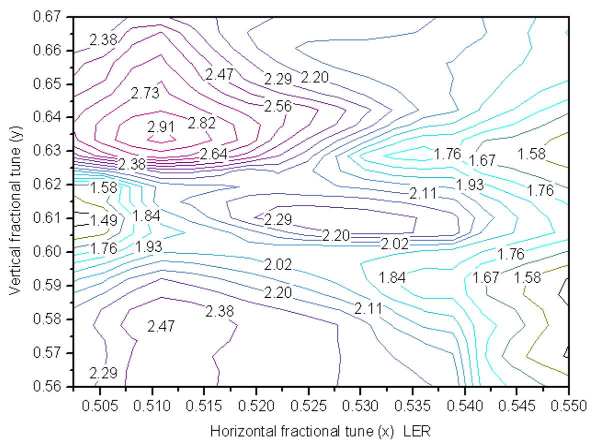


Fig.3 Luminosity contour diagram for the present operation parameters of KEKB (Jan., 2001).

3.2 Simulation with present operation parameters (Jan. 2001)

Table 2 shows the parameters of KEKB at present. Compared them with the parameters in the table 1, the beam currents have been increased obviously.

Table 2 Operating parameters of KEKB at present

	LER	HER
Horizontal emittance (nm)	**18**	**24**
β_x^* / β_y^* (cm)	**63/0.7**	**80/0.7**
Emittance ratio ϵ_y / ϵ_x (%)	**2**	**1**
Beam current (mA)	**760**	**580**
Particales/bunch	**4.15E10**	**3.16E10**
Bunch length (mm@MV)	**5.5@6.0**	**5.7@11**

In this set of simulations, the HER working point is fixed as ν_x=44.52, ν_y=41.625, and the tune space region of $\Delta\nu_x$=0.505~0.550, $\Delta\nu_y$=0.560~0.665 is covered for the LER tune scans. The simulation results with above parameters are presented in the Fig. 3, which shows that the behavior of the luminosity contour is similar as that in the (b) of the Fig.1. One can see that the expected luminosity is larger than 2.0×10^{30}cm^{-2}s^{-1} in quite a large area of $\Delta\nu_x$=0.513~0.530, and $\Delta\nu_y$=0.560~0.665. The best tune space region is around the tune pint (0.510, 0.635), where they are the horizontal and vertical tunes, respectively, having a single bunch luminosity of 2.94×10^{30}cm^{-2}s^{-1} which corresponds a peak luminosity of 3.4×10^{33}cm^{-2}s^{-1} with 1153 bunches. Another better tune space region is around the tune point (0.510, 0.575), and the predictive luminosity per bunch at this point is 2.47×10^{30}cm^{-2}s^{-1}.

4 SUMMARY

It's reasonable to explore a new working point with a tune above the half integer in both planes for the KEKB. The simulation studies demonstrate that a larger safe tune space area could be found, and a higher luminosity could be reached in the new tune space region which we chose. The fractional tune points ($\Delta\nu_x$=0.505~0.530, $\Delta\nu_y$= 0.560~0.660) for both beams could be tested in the KEKB machine.

5 ACKNOWLEDGEMENTS

The authors would like to thank S. Kurokawa, K. Oide, H. Koiso, H. Fukuma for the very helpful discussions and support.

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