OPTIMIZATION OF BEAM OPTICS IN THE KEKB RINGS

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Abstract

The lattice of the KEKB rings have a wide range of tunability. This paper represents various kinds of optics used for commissioning after the installation of the Belle detector.

1 OVERVIEW

The KEKB B-Factory[1] is an 8 GeV electron + 3.5 GeV positron double-ring collider (HER and LER). Each ring has four arcs and four 200 m-long straight sections. The arcs consist of 2.5 π unit cells with non-interleaved sextupoles connected by a pseudo $-I$ transformer[1,2]. Figure 1 shows a schematic view of the KEKB accelerator complex.

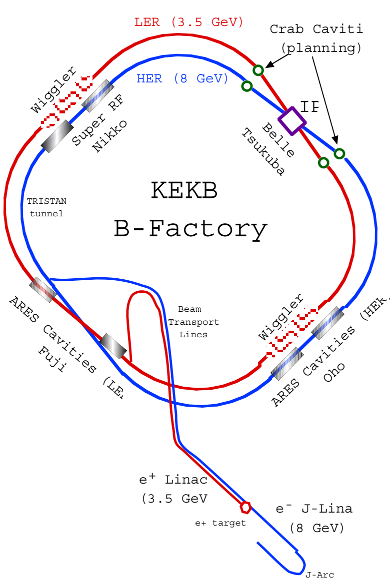

Figure 1: A schematic view of the KEKB B-Factory. The straight sections are functioned as: *Tsukuba* the interaction region for the Belle detector, *Fuji* for injection and RF cavities (LER), *Nikko* and *Oho* for RF (HER), wigglers(LER).

The main lattice parameters such as the emittance, the bunch length, the beta functions at the interaction point (IP) have been tuned flexibly according to the requirements from various operation status[3]. One big jump was switching to a high-emittance optics to increase the bunch current, since the number of bunches was almost limited to ~ 1000. To avoid instability and heating problems under high bunch-current operation, the bunch length was also increased as listed in Table 1. At present, the rings are operating with Optics HH2 and LH3. This paper describes

Table 1: Design parameters of nominal- and high-emittance optics.

HER	HM1	HH1	HH2
Emittance (10^{-8}m)	1.76	2.94	2.95
Momentum compaction (10^{-4})	1.89	2.48	3.39
Bunch length (mm)	4.79	4.90	6.43
RF voltage (MV)	9	11	9
Synchrotron tune	.0126	.0162	.0169
(measured)			.0162

LER	LM1	LH1	LH2	LH3
Emittance (10^{-8}m)	1.69	2.89	2.90	2.94
Momentum compaction (10^{-4})	1.05	1.11	2.42	3.13
Bunch length (mm)	3.41	3.50	5.16	5.86
RF voltage (MV)	5	5	5	5
Synchrotron tune	.0108	.0110	.0163	.0186
(measured)			.0161	.0184

how to adjust optics to meet requirements for higher luminosity. Almost all calculations related optics tuning done by the code SAD[4] developed KEK.

2 CONTROL OF EMITTANCE AND BUNCH LENGTH

2.1 2.5 π cell

There are 7 quadrupole families in the 2.5 π cells as shown in Fig. 2. By adjusting the horizontal dispersion at dipoles (*B2E*/*B2P*), the horizontal emittance and the momentum compaction factor can be optimized independently, keeping the pseudo $-I$ conditions between non-interleaved sextupoles (4 constraints in both horizontal and vertical planes, then totally 6 conditions are applied). One free parameter still remains, which is utilized usually to suppress the beta beat as small as possible. By adjusting the momentum compaction factor, the bunch length can be set to be a target value with a given RF voltage.

2.2 wiggler

In LER, 152 wiggler magnets are now placed in Oho and Nikko sections. After the Belle installation, those wigglers turned on to shorten the damping time to 1/2. The orbit difference due to the wiggler excitation (13.8 mm) was adjusted by chicanes. The bending radius of the wigglers is

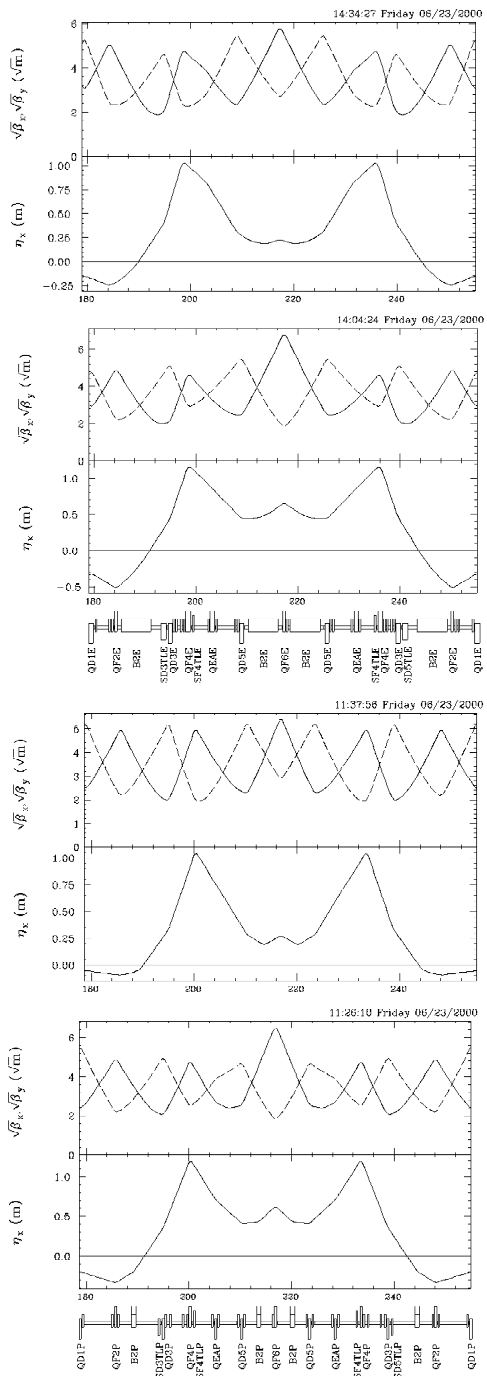

Figure 2: Optical functions in the unit cell in HER and LER: Optics HM1, HH2, LM1, and LH3, from top to bottom. One of the quadrupole family named *QEAE*/*QEAP* and a few quadrupoles in dispersion suppressers are fed by bipolar power supplies.

almost equal to that of the main dipoles, thus the momentum spread is kept unchanged. By adjusting the horizontal dispersion at the wigglers, the emittance can be controlled. However, the emittance and the momentum compaction factor are coupled to some extent in this kind of tuning. For example, the emittance in Optics LM1 is chosen to be equal to that in the case without wigglers, but the momentum compaction decreases by 30%. To keep the momentum compaction factor constant, the unit cells should be readjusted at the same time.

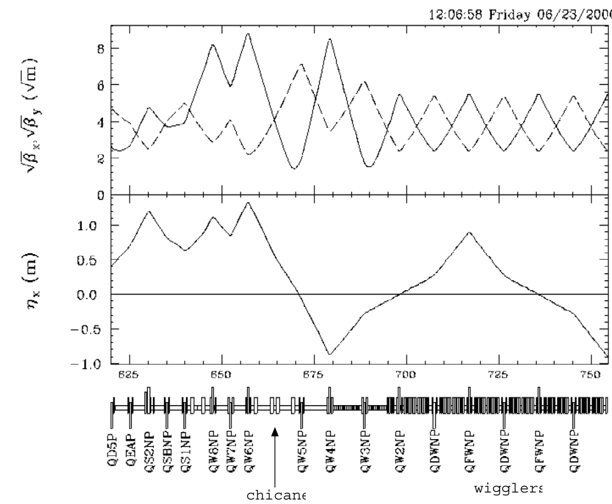

Figure 3: Optical functions in the wiggler section in LER.

3 CONTROL OF THE BETATRON TUNE

The betatron tunes are adjusted in the range $\leq\ 0.5$ by changing the quadrupoles in Fuji section, keeping various constraints. The required conditions are: the phase difference between injection kickers, the horizontal beta function at the injection point, and the phase relations between feedback elements.

4 CONTROL OF THE IP BETA FUNCTION

The beta functions at the IP can be tuned without changing the lattice in complicated area for collision, $x - y$ coupling correction, and the local chromaticity correction. For this purpose, quadrupoles named $QA*$ (6 quadrupoles in each side of the IR in each ring) are placed in the dispersion-free region just outside crab cavities. By adjusting only these quadrupole, the IP beta functions can be changed over the considerable range. It is difficult to keep the betatron tune exactly constant, thus The differences of the betatron tune are compensated in Fuji section. So far the IP beta functions β_x^*/β_y^* have been gradually squeezed to 63/0.7 cm as listed Table 2. The vertical beta function has been decreased smaller than the design value. For recovering from injection troubles and start-up after a shut down, high-beta optics are also prepared.

5 CHROMATICITY CORRECTION

Strengths of 52 sextupole pairs (+2 pairsfor the local chromaticity correction only in LER) are determined by optimizing chromatic behaviors of off-momentum optics di-

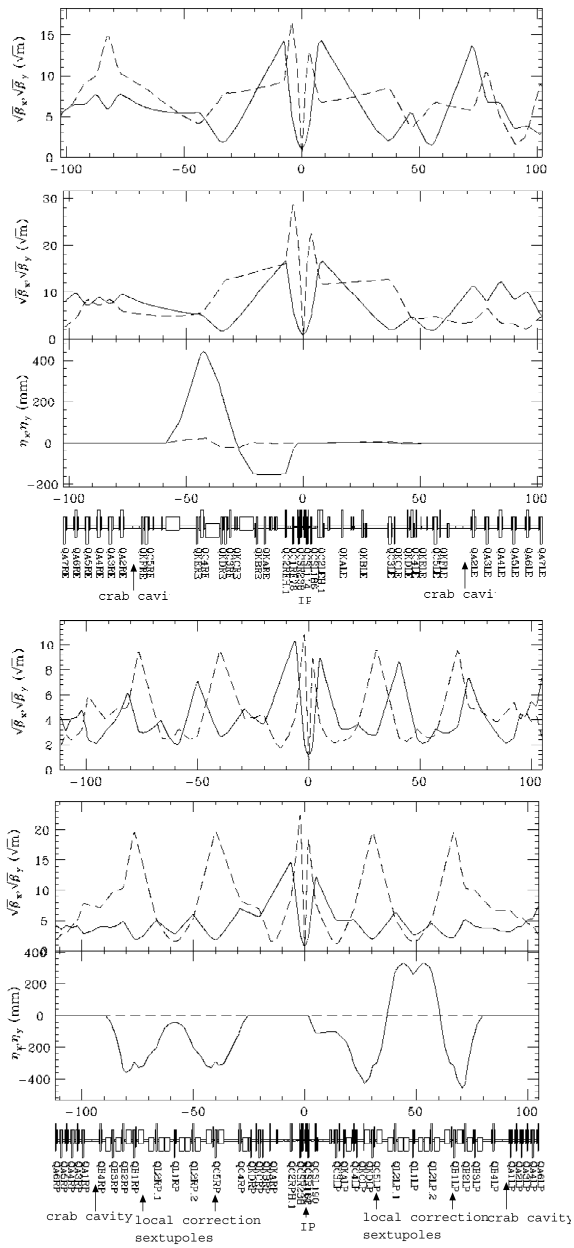

Figure 4: Optical functions in the IR: $\beta_x^*/\beta_y^*(\mathrm{cm}) = 150/3$ (HER), 63/0.7 (HER), 150/3 (LER), 63/0.7 (LER), from top to bottom.

rectly in a finite momentum band width, which is typically 1-2%[1,2]. In fine tuning, however, the linear chromaticities and the momentum dependence of the Twiss parameters at the IP are also adjusted according to conventional perturbation formulae so as to avoid a rapid change of sextupole strengths. A high vertical chromaticity of 10-12 is selected for stable high-current operation in LER.

The authors thank all the members of the KEKB accelerator group for helpful discussions and supporting the commissioning.

Table 2: IP beta functions and their luminosity performance. The "good" means to stand practical use for physics runs. (*) tried only for HER in a short period for machine studies.

β_x^* / β_y^* (cm)	1	0.7	0.6
100	good		
70		good	
63		good	
50		(*)	not good
33		(*)	

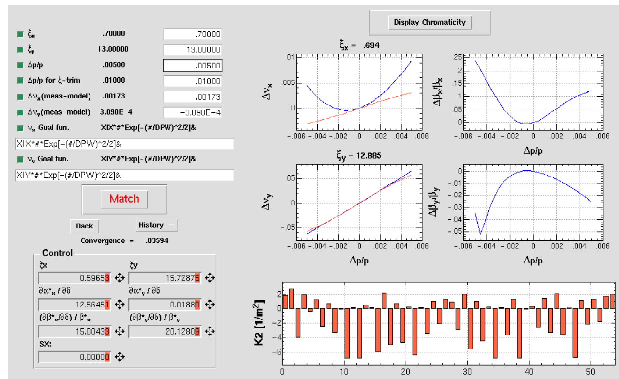

Figure 5: An example of chromaticity correction in LER.

6 REFERENCES

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