LATTICE ANALYSIS OF THE KEKB COLLIDING RINGS

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Abstract

A low beta lattice with β_x^*/β_y^*=100/1 cm has been realized in the KEKB colliding rings. The basic optical parameters have been measured and compared with the model.

1 MODELING

KEKB[1]is an 8 GeV electron + 3.5 GeV positron double-ring collider (HER and LER) with a single interaction point (IP) for the Belle detector. The beta function at IP is designed to be 1 cm in the vertical plane (β_y^* = 1 cm) and a horizontal beam crossing angle of 22 mrad is adopted for collisions at a bunch spacing of 59 cm. Following counter solenoids which locally compensate the detector solenoid field, eight special quadrupole magnets, listed Table 1, are installed around IP. QCSR and QCSL are superconducting magnets which are common in both rings. The other normal magnets have special shapes with field free space for the counter-rotating beams. The modeling of those special magnets is one of the most important issues in the lattice design. The results of magnetic field measurements have been taken into account in the model as much as possible. Design and simulation works have been done by the code SAD[2] developed at KEK.

Magnet(Type)	r_b (mm)	B' (T/m)	x_m/y_m (mm)	Beam
QC2LE (N)	60	3.2	68/13	$e^- \downarrow$
QC2LP (N)	45	6.1	57/10	$e^+ \uparrow$
QC1LE (N)	38	-14.2	22/21	$e^- \downarrow$
QCSL (S)		-21	13/20	$e^- \downarrow e^+ \uparrow$
IP				
QCSR (S)		-21	14/24	$e^- \downarrow e^+ \uparrow$
QC1RE (N)	70	-13.2	29/27	$e^- \downarrow$
QC2RP (N)	42	2.9	69/12	$e^+ \uparrow$
QC2RE (N)	60	10.8	69/16	$e^- \downarrow$

Table 1: Special quadrupole magnets near IP. r_b is the bore radius, B' the field gradient, $x_m$andy_m the maximum amplitudes of the injected beams in the horizontal and vertical planes.

1.1 QCS and solenoid

The field distribution along the longitudinal direction in the solenoid area is given by 4 cm-thick slices with a constant field. Both QCSs are included in this area, and are also divided into slices with normal and skew multipoles up to the 32-th pole. The magnitude of multipole components were estimated from the results of field measurements[3]. Since the outgoing beams pass the QCSs at off-axis, it is necessary to express the transverse distribution with sufficient accuracy at $\sim$ 60 mm away from the center. To optimize the x-y coupling, the QCSR and QCSL are set to be rotated by 35.6 and -10.8 mrad, respectively.

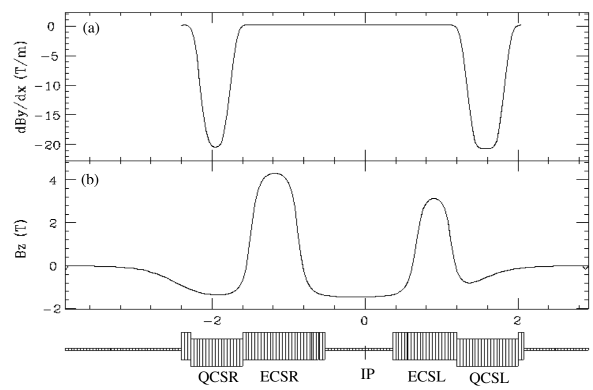

Figure 1: Model of QCS and compensation solenoid system.

1.2 QC1RE and Others

QC1RE is a half quadrupole for HER. The beam passes through 45 mm off-axis of the virtual center of QC1RE in the horizontal plane. The integrated dipole field obtained from the field measurement along the beam trajectory is consistent with 3-dimensional calculation and amounts to an additional kick of 1.1 mrad, which is incorporated as thin dipole magnets attached at both edges of QC1RE. The dynamic aperture with measured values of the higher multipoles was checked for some of the normal quadrupoles, which was found to be marginal compared with the requirements.

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1.3 Lattice for BEAST

The commissioning has commenced with β_x^*/β_y^*=100/2 cm, and the reduction of β_y^* to =1 cm has been succeeded in both rings[4]. The chromaticity correction has fully utilized 52-family noninterleaved sextupole pairs and vertical 2-family pairs for the local correction only in LER. The commissioning lattice has slightly modified for the BEAST detector, removing the detector solenoid. Because QCSs are already rotated, the x-y coupling should be corrected even without the detector solenoid. The rotations of normal IR quadrupoles have also been changed and the compensation solenoids have been excited to 10% of the nominal values to minimize strengths of skew quadrupoles. In order to adjust orbits and dispersions, local orbit bumps have been applied in the interaction region (IR) as shown in Fig. 2.

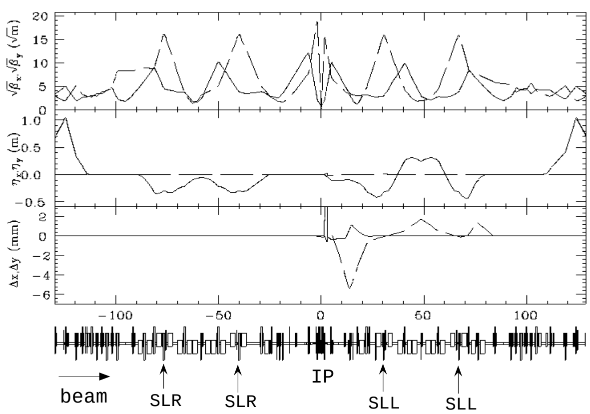

Figure 2: LER optical functions in IR. SLL and SLR are sextupoles for the local chromaticity correction.

2 MEASUREMENT OF BASIC PARAMETERS

2.1 Closed Orbit

The global closed orbit has been successfully corrected with conventional methods (SVD and MICADO) better than 0.6 mm rms. The local bumps has also been used for fine tuning and for diagnostics of machine errors.

2.2 Transverse tune

Even a few steps of improvements of the model lattice as listed Tables 2 and 3, the measured tunes still have some difference from the model in both rings. It is necessary to precise calibration between various magnets (superconducting, normal, IR quadrupoles with special shapes) to identify error sources.

2.3 Dispersion

The measured values of horizontal dispersions agree with the model within 16% in LER and 6% in HER. Sometimes a large vertical dispersion has been observed, which depends on the vertical orbit. The vertical dispersion has been decreased to a reasonable level by adequate tuning of the vertical orbit, in particular, at sextupoles.

Source	$\Delta\nu_x$	$\Delta\nu_y$
(a) Flat rectangular dipole	0	0
(b) Edge angle	0	0.40
(c) Slope of B_y, $B_y = B_y(s)$	0	-0.037
(d) Integrated quadrupole	0.057	-0.056
(e)Integrated sextupole, $\int B_y''(s)x(s)ds$	0.114	-0.112

Table 2: Model of LER dipole magnet. The quadrupole and sextupole components are estimated from the results of field measurements[5]. ModelB and A are with and without Source(e).

	LER $\Delta\nu_x$,$\Delta\nu_y$	HER $\Delta\nu_x$,$\Delta\nu_y$
β_y^*=2 cm Adjust energy, QCS	-0.01, -0.30	0.12, -0.08
LER dipole modelA with fudge factors (*)	+0.04, -0.10	
LER dipole modelB (no fudge factors)	-0.14, -0.20	
Adjust QCS β_y^*=1 cm	-0.13, -0.19	0.12, -0.09
Adjust tunes, orbits, chromaticity, etc.	-0.07, -0.22	+0.07, -0.06

Table 3: History of tune deviations from the model lattice. (*)Fudge factors of -0.4% and -0.8% were applied for tow families of quadrupole magnets in unit cells, QD3P(40) and QD5P(48), respectively.

2.4 Chromaticity

The examples of the chromaticity measurement are shown Fig.4. The differences from the model are not so big, but amount to 5 in the vertical direction in the β_y^*=1cm case. It is necessary to adjust tunes of the model lattice to the measured ones in finding solution of strengths of sextupoles.

2.5 β Function

Big mismatch of LER optics in the vertical direction was observed both in the response of single kick orbits [6] and in measurements with trim coils of normal quadrupoles as shown in Fig.6. The matching was greatly recovered by adjusting field strengths of QCSs by +0.8%, which was determined by analyzing the leakage orbit of the local bump at QCSs. After recent refinements of the QCS model by subtracting effects of the return yoke of the Belle detector, QCSs still look stronger by 0.37% than other quadrupole magnets in LER. In HER, β_y at QCSs and QC1s are consistent with the model in 10%. Further measurements and analysis are now being in progress.

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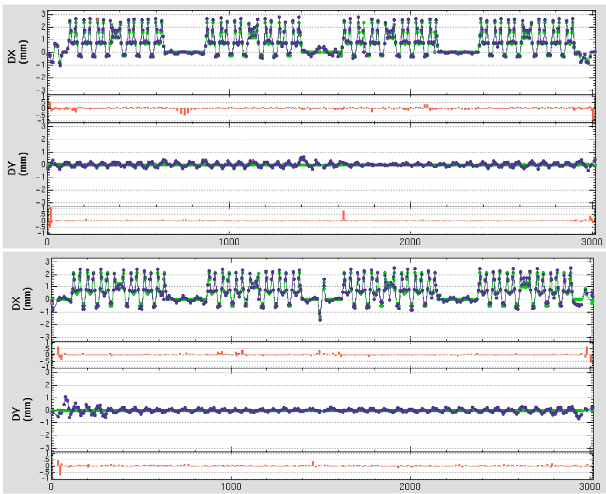

Figure 3: Measured and calculated dispersions (above:LER, below:HER).

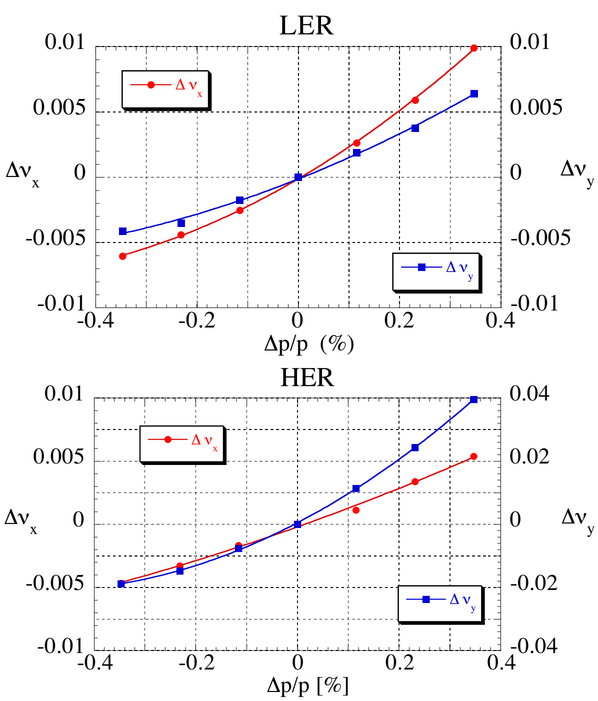

Figure 4: Measured chromaticities (above:LER, below:HER) in the case of β_x^*/β_y^*=100/1 cm.

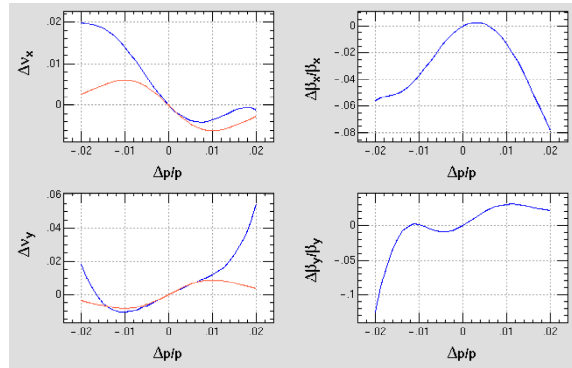

Figure 5: Calculated chromaticities of LER in the case of β_x^*/β_y^*=100/1 cm.

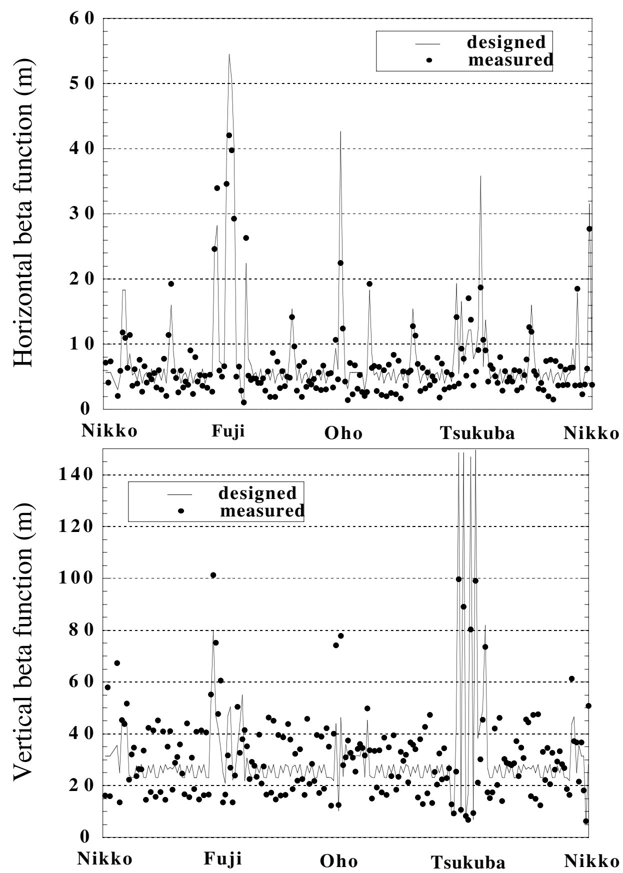

Figure 6: Measurement of β-function with trim coils of quadrupole magnets in the case of β_x^*/β_y^*=100/2 cm. The field strength of each quadrupole was changed typically 1.5% by the trim coil.

3 REFERENCES

[1] KEKB B-Factory Design Report, KEK-Report 95-7, (1995).

[2] http://www-acc-theory.kek.jp/SAD/sad.html

[3] N. Ohuchi *et al.*, Proc. of EPAC98 (1998).

[4] K. Oide *et al*