1p-4

Present Status of the KEKB Project

Shin-ichi Kurokawa
National Laboratory for High Energy Physics, KEK
1-1 Oho, Tsukuba, Ibaraki, 305 Japan

ABSTRACT

KEKB (KEK B-Factory) is an 8 x 3.5 GeV, two-ring, electron-positron collider aiming at producing copious B-mesons for detecting CP-violation effect at bottom quarks. To achieve a luminosity of 10^{34} $cm^{-2}s^{-1}$ required by experiments, the rings should store 1.1-A electrons and 2.6-A positrons. These large currents are distributed into 5000 bunches. The large currents and the large number of bunches excite strong coupled-bunch instabilities, which should be avoided by adopting special accelerating cavities and strong bunch-by-bunch feedback systems. Electrons and positrons collide at a finite angle of ± 11 mrad at an interaction point, which BELLE detector surrounds. The construction of KEKB started in 1994 and it will be commissioned in JFY1998.

I. INTRODUCTION

Two rings of the KEKB (3.5 GeV low-energy ring, LER, for positrons, and 8 GeV high-energy ring, HER, for electrons) will be installed in the existing TRISTAN tunnel of 3 km circumference and the infrastructure of TRISTAN will be maximally utilized. Taking advantage of the large tunnel size of TRISTAN, two rings will be set side by side; unnecessary vertical bending of trajectories that may increase the vertical emittance of the beams is minimized.

Figure 1 illustrates the arrangement of two rings. KEKB has only one interaction point, IP, at Tsukuba experimental hall, where electron and positron beams collide at a finite angle of ± 11 mrad. BELLE detector will be installed at IP. The straight section at Fuji is used for injection from the linac and also for installing RF cavities of LER. Cavities of HER will be installed in straight sections at Nikko and Oho. These straight sections are also reserved for wigglers for LER, which reduce the longitudinal damping time of LER from 43 msec to the value of HER, 23 msec. In order to make the circumference of the two rings equal, a cross-over should be made at Fuji experimental hall where two rings pass each other.

To facilitate full-energy injection into the KEKB rings, the present 2.5-GeV electron linac will be upgraded to 8 GeV[1]. The upgrade is done by combining the main linac with the positron production linac, increasing the number of accelerating structures, replacing klystrons with high-power ones, and compressing RF pulses by SLEDs. We can also increase the energy of electrons impinging on the positron production target from 250 MeV to 4 GeV, thus multiplying positron intensity by 16. The injection time of positrons to LER is estimated to be 900 sec. A new bypass tunnel of 130 m for transport lines between the linac and KEKB rings will be constructed in JFY1996 and 1997.

II. BASIC DESIGN

The main parameters of the KEKB accelerators are given in Table 1. HER and LER have the same circumferences, emittances, and the ß functions at IP. The large current, the large number of bunches, small bunch spacing, the small value of ß function at IP and finite-angle crossing of beams are the salient features of KEKB.

We adopt a noninterleaved sextupole chromaticity correction scheme to increase transverse dynamic apertures necessary for injection and longitudinal dynamic aperture necessary for making Touschek lifetime sufficiently long[2].

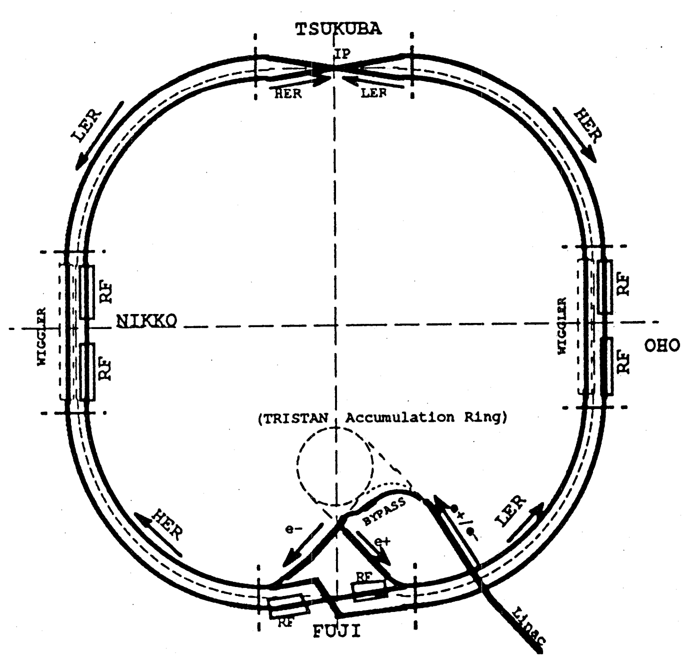

Fig. 1 Configuration of KEKB accelerator system.

In this scheme sextupoles are arranged in pairs: two sextupoles in a pair are π phase-advance apart in both horizontal and vertical planes. Sextupole pairs are not interleaved. This scheme cancels out the geometric aberrations caused by the sextupoles effectively since the the transfer matrix between sextupoles is -I.

One unit cell of the adopted lattice has a phase advance of 2.5π and includes two pairs of sextupoles, SF and SD. The addition of extra $\pi/2$ phase advance over 2π cell enables effective correction of chromatic kicks and significantly improves the dynamic apertures. In the adopted lattice the momentum compaction factor can be changed from -1×10^{-4} to 4×10^{-4} and the emittance from 50% to 200% of the nominal value. This flexibility makes a strong tool to tune the machine.

In the IP straight section of LER, a local chromaticity correction scheme is adopted to correct the large vertical chromaticity produced by the final focus quadrupole magnets close to IP.

We adopt a finite-angle crossing scheme of ± 11 mrad. In this scheme, parasitic collision is not a concern even though every bucket is filled with beam; separation dipole magnets that would be necessary for a head-on collision are no longer necessary. The horizontal width of the beam pipe at IP is minimized in the finite-angle crossing where no synchrotron-light fans are produced by separation dipole magnets; smaller beam pipe improves the vertex point resolution and permits efficient use of the luminosity. We use superconducting final-focus quadrupole magnets in order to have a flexibility of tuning.

By computer simulation we found that although the finite-angle crossing somewhat reduces usable areas in the ν_x-ν_y plane due to synchro-betatron resonances, a fair amount of areas in the ν_x-ν_y plane is still free from reduction of luminosity, if we make the ν_s(synchrotron tune) smaller than 0.02[3]. We have also started an R&D work on superconducting crab cavities in order to prepare unpredictable beam-beam effects due to this finite-angle crossing. Crab cavities tilt the bunches and make them collide head-on at the interaction point.

Table 1 Main Parameters of KEKB

Ring		LER		HER	
Energy	E	3.5		8.0	GeV
Circumference	C		3016.26		m
Luminosity	L		1×10^{34}		$cm^{-2}s^{-1}$
Crossing angle	θ_x		± 11		mrad
Tune shifts	ξ_x/ξ_y		0.039/0.052		
Beta function at IP	β^*_x/β^*_y		0.33/0.01		m
Beam current	I	2.6		1.1	A
Natural bunch length	σ_z		0.4		cm
Energy spread	σ_δ	7.1×10^{-4}		6.7×10^{-4}	
Bunch spacing	s_B		0.59		m
Particles/bunch		3.3×10^{10}		1.4×10^{10}	
Emittance	$\varepsilon_x/\varepsilon_y$		$1.8 \times 10^{-8}/3.6 \times 10^{-10}$		m
Synchrotron tune	ν_s		$0.01 \sim 0.02$		
Betatron tune	ν_x/ν_y	45.52/45.08		47.52/43.08	
Momentum compaction factor	α_p		$1 \times 10^{-4} \sim 2 \times 10^{-4}$		
Energy loss/turn	U_o	0.81†/1.5††		3.5	MeV
RF voltage	V_c	$5 \sim 10$		$10 \sim 20$	MV
RF frequency	f_{RF}		508.887		MHz
Harmonic number	h		5120		
Longitudinal damping time	τ_E	43†/23††		23	ms
Total beam power	P_B	2.7†/4.5††		4.0	MW
Radiation power	P_R	2.1†/4.0††		3.8	MW
HOM power	P_{HOM}	0.57		0.15	MW
Bending radius	ρ	16.3		104.5	m
Length of bending magnet	l_B	0.915		5.86	m

† without wigglers
†† with wigglers

III. HARDWARE SYSTEM

The RF cavity for the KEKB should have a structure by which higher-order modes (HOMs) in the cavity are damped to the level where the growth times of the coupled-bunch instabilities excited by HOMs become comparable to or longer than the damping time. The fundamental mode of cavity also excites coupled-bunch instabilities if the detuning frequency of the cavity due to beam loading becomes comparable to or larger than the revolution frequency of the ring. The cavity should have enough stored energy in order to make the detuning frequency much smaller than the revolution frequency. We are now developing two types of cavities for the KEKB. One is a normalconducting cavity called ARES and the other is a superconducting, single-cell, single-mode cavity.

T. Shintake showed that the amount of the detuning frequency can be drastically decreased by attaching a large volume, low-loss, energy-storage cell to an accelerator cell[4]. On the basis of this proposal, a 3-cell structure, where an accelerating cell and an energy storage cell is connected via a coupling cell is proposed and called ARES[5]. In order to suppress HOMs, a choke-mode cavity [6] is used as the accelerating cell of ARES. The first prototype accelerating cell of ARES was delivered to KEK and successfully tested up to 110 kW of wall dissipation which corresponds to a gap voltage of 0.73 MV.

A superconducting cavity has a large stored energy due to its high field gradient and is immune to the beam-loading. The superconducting cavity for KEKB is a single-cell cavity with two large-aperture beam pipes attached to the cell[7]. HOMs propagate toward the beam pipes, since their frequencies are above the cut-off frequencies of the pipes. HOMs are absorbed by ferrite HOM absorbers.

A full-size Nb model was constructed and tested in a vertical cryostat. The maximum accelerating field obtained was 14.4 MV/m with a Q value of 10^9[8]. The prototype cavity for the AR beam study is under construction. Prototype HOM dampers made by HIP(hot isostatic press) method were successfully high-power tested [9].

Feedback systems that can damp the coupled-bunch oscillations of the beam with a bunch spacing of 2 ns are being developed[10]. A 2-tap FIR digital filter system works as the kernel of the signal processing unit. This kind of filter can be composed of memory chips and simple CMOS logic ICs without relying on DSP chips. By using 500 MHz ADC and DAC, two custom-made 4-bit GaAs 1:16 500-MHz demultiplexers and two 4-bit GaAs 16:1 500-MHz multiplexers, and having 16 parallel 2-tap FIR logic circuits, we can construct a signal processing unit on a single board. Kickers and wideband amplifiers are now being developed.

We have decided to use Cu as material for vacuum ducts by taking into account its low photodesorption coefficient, high thermal conductivity, and self shielding capability of X-rays. Cu ducts for LER are now under construction.

IV. SCHEDULE

Three-month long beam test is planned to be held in 1996 by the use of TRISTAN AR. We plan to store more than 500 mA electron beam in AR with a multibunch mode at 2.5 GeV. To accumulate this high current, the existing APS type RF cavities will be removed temporally from the ring and an ARES cavity and a single-cell superconducting cavity for KEKB will be installed. The transverse and longitudinal feedback systems will be also installed and tested.

Main components of LER such as magnets and vacuum equipment are procured in JFY1995 and 1996, whereas those for HER in JFY1996 and 1997. TRISTAN will be terminated by the end of 1995 and dismantling of TRISTAN main ring will start from January 1996. By the end of 1996 the TRISTAN tunnel will become ready for installation of magnets. We plan to commission the KEKB with Belle detector within JFY1998.

REFERENCES

[1] A. Enomoto, et al., Proceedings of the 1994 International Linac Conference, p.194.

[2] H. Koiso and K. Oide, Lattice Design in KEKB Colliding Rings, to be published in Proceedings of 1995 PAC, Dallas.

[3] K. Ohmi, K. Hirata, and N. Toge, A Study of Beam-Beam Interactions at Finite Crossing Angles for a B-Factory, to be published in Proceedings of 1995 PAC, Dallas.

[4] T. Shintake, Part. Accel. 44 (1994) 131.

[5] Y. Yamazaki and T. Kageyama, Part. Accel. 44 (1994) 107.

[6] T. Shintake, Jpn. J. Appl. Phys. Lett. 31 (1992) 1567.

[7] S. Mitsunobu, et al., A Prototype Superconducting Cavity for KEK B-Factory, to be published in Proceedings of 1995 PAC, Dallas.

[8] K. Asano, et al., Stable Performance of Superconducting Cavities for KEKB, to be published in Proceedings of 1995 PAC, Dallas.

[9] T. Tajima, et al., Development of HOM Damper for Superconducting Cavities for KEKB, to be published in Proceedings of 1995 PAC, Dallas.

[10] E. Kikutani, et al., Recent Progress in the Development of the Bunch Feedback Systems for the KEKB, to be published in Proceedings of 1995 PAC, Dallas.