Status of KEKB Project

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Abstract

KEKB(B-Factory) is a 3.5 x 8 GeV, two-ring, asymmetric electron-positron collider in the existing TRISTAN tunnel. It aims at detecting the CP-violation effect at B-mesons. The final goal of the luminosity is 10^{34} $cm^{-2}s^{-1}$. The project has been approved by the Japanese government and the construction has started from April 1994. Progress of design work and the present status of R&D are reported.

I. INTRODUCTION

Two rings of the KEKB (3.5-GeV low-energy ring, LER, that store positrons, and 8-GeV high-energy ring, HER, that stores electrons) are to be installed side by side in the existing TRISTAN tunnel and the infrastructure of TRISTAN will be maximally utilized[1,2]. The 2.5 GeV electron linac will be upgraded to 8 GeV in order to inject 3.5 GeV positrons and 8 GeV electrons directly into KEKB.

We have elaborated a small-angle (± 2.8 mrad) crossing scheme, where we will fill every third to fifth bucket with beam. Bunch spacing in this case is long enough to install beam separation equipment, such as separation dipole magnets. If we start from this small-angle crossing scheme, later, we should move to a large-angle crossing scheme (~± 10 mrad) in order to fill every bucket with beam and reach the final luminosity. Crabbing scheme[3,4] might be required in order to suppress synchro-betatron resonances excited by beam-beam interactions.

The finite-angle crossing scheme has some advantages: (1) Even though we fill every bucket with beam, parasitic collision is not a concern. (2) We can remove separation dipole magnets and have no synchrotron light background coming from the separation dipole magnets. (3) Since the synchrotron lights emitted from the separation dipole magnets determine the minimum horizontal width of the beam pipe at the interaction point, we can make the diameter of the beam pipe smaller if there are no dipole magnets. (4) we can install a solenoid magnet at the place where the separation dipole is located. By producing a proper reverse solenoid field by this solenoid, we can make the integrated solenoidal field zero between the first quadrupole magnets. This cancellation is desirable for asymmetric colliders, where complete cancellation of the solenoidal field is necessary in order not to make the beams rotate by different angles between LER and HER.

Taking into account the above-mentioned advantages, we are studying whether we can employ a large-angle crossing scheme from the commissioning of KEKB. By computer simulation we found that synchro-betatron resonances due to beam-beam interactions are not strong if the synchrotron tune is not large and that we can find a good operating point even though we do not use a crabbing scheme. This strategy is advantageous because we can continuously increase the stored current without modifying the crossing scheme and we do not need to prepare sofisticated crab cavities at the start of the commissioning.

Figure 1 shows the layout of KEKB within the KEK site and Fig. 2 shows the scheme of KEKB. The interaction point, IP, will be located at Tsukuba Experimental Hall and BELLE detector will be installed at IP. Electrons and positrons are injected from the upgraded linac to KEKB at the Fuji straight section. RF cavities for LER will be installed at the Fuji straight section, whereas those for HER will be installed at Nikko and Oho straight sections.

II. LATTICE DESIGN

A. Beam Parameters

The main parameters of the KEKB accelerators are given in Table 1 for the finite-angle crossing scheme. The high-energy ring, HER, and the low-energy ring, LER, have the same circumferences, emittances, and the beta functions at IP. The large current, the large number of bunches and the small value of beta function at IP are the salient features of KEKB.

B. Chromaticity Correction

It is desirable if we can inject beams into KEKB without changing the optics at injection from that of collision; we have been studying a non-interleaved sextupole chromaticity

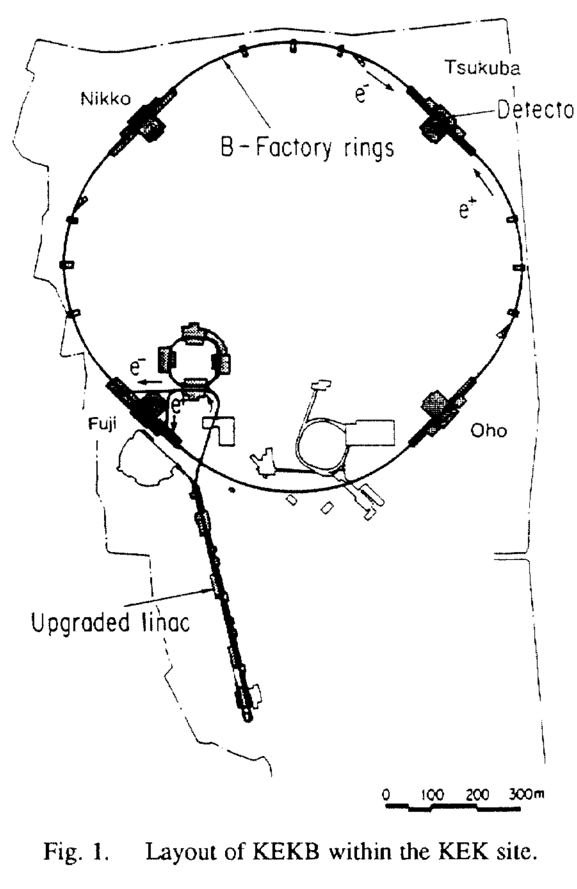

Fig. 1. Layout of KEKB within the KEK site.

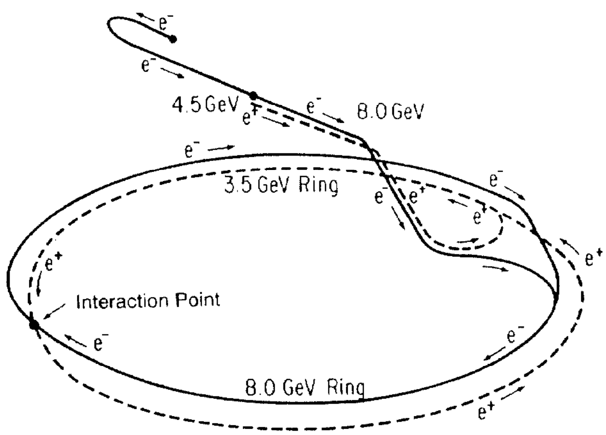

Fig. 2. Scheme of KEKB.

Table 1 Main parameters of KEKB

Energy	3.5	8.0	GeV
Circumference	3018		m
Luminosity	1×10^{34}		$cm^{-2}s^{-1}$
Crossing angle	$\pm$ 10		mrad
Tune shifts	0.038(x)/0.057(y)		
Beta function at IP	0.33/0.01		m
Beam current	2.6	1.1	A
Natural bunch length	0.4		cm
Energy spread	7.5×10^{-4}	7.9×10^{-4}	
Bunch spacing	0.6		m
Particles/bunch	3.3×10^{10}	1.4×10^{10}	
Emittance	1.8×10^{-8}(x)/3.6×10^{-10}(y)		m
Synchrotron tune	0.017	0.025	
Betatron tune	~ 43	~ 43	
Momentum compaction	1.7×10^{-4}	2.6×10^{-4}	
Energy loss/turn	0.91	4.1	MeV
RF voltage	8	24	MV
RF frequency	508		MHz
Harmonic number	5120		
Energy damping decrement	2.4×10^{-4}	5.7×10^{-4}	
Bending radius	15.9	75.4	m
Length of bending magnet	0.78	3.7	m

correction scheme expecting that this scheme enables us to have sufficient dynamic apertures at injection[5]. Between a pair of sextupoles no other sextupoles exist and the betatron phase advance is π in both horizontal and vertical planes. This scheme cancells the geometric aberrations of the sextupole by the -I transformation in a pair.

C. Low-α Lattice

In order to reduce the necessary accelerating RF voltage, V_c, we are studying lattice with small values of α (the momentum compaction factor). The α's of LER and HER are 1.7×10^{-4} and 2.5×10^{-4}, respectively, and corresponding V_c's are 8 and 24 MV for 4 mm bunch length. The small synchrotron tunes in this case (0.017 in LER and 0.025 in HER) might mitigate the synchro-betatron resonances.

III. COUPLED-BUNCH INSTABILITIES AND RF SYSTEM

A. Sources of Coupled-Bunch Instabilities

Large currents, many bunches and short distance between bunches cause strong coupled-bunch instabilities both in the transverse and longitudinal directions. Three sources of coupled-bunch instabilities are identified: (1) higher-order modes (HOM) of RF cavities (transverse and longitudinal); (2) accelerating mode of RF cavities (longitudinal); and (3) resistive wall of vacuum ducts (transverse).

B. Normalconducting RF cavity

A completely new type of RF cavity system called ARES (accelerator resonantly coupled with energy storage) has been proposed and extensive R&D works are under way[6,7,8].

If the amount of cavity detuning becomes comparable or larger than the revolution frequency of the ring, strong

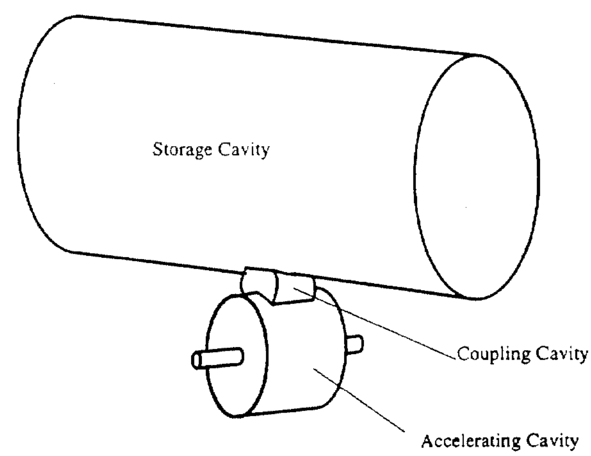

Fig. 3. A schematic view of ARES.

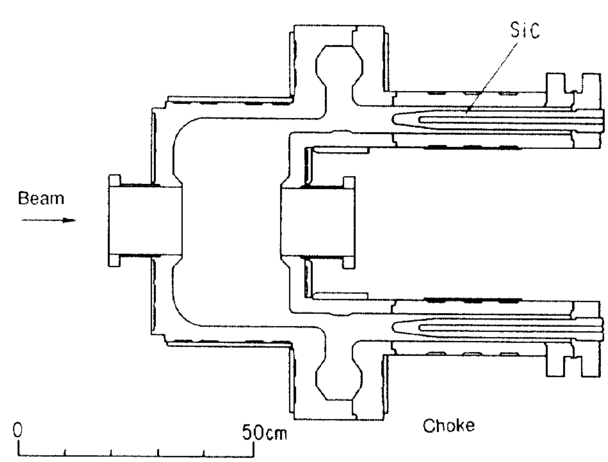

Fig. 4. Accelerating cell of ARES.

coupled-bunch instability is excited by the fundamental-mode impedance of the 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[9]. On the basis of this proposal, K. Akai, T. Kageyama and Y. Yamazaki proposed a 3-cell structure, where an accelerating cell and an energy-storage cell is connected to a coupling cell[10,11] (see Fig. 3). The system employs a $\pi/2$ mode where almost pure TM010 mode and almost pure TE015 mode are excited in the accelerating cell and the energy-storage cell, respectively, and very little field is excited in the coupling cell. Two parasitic modes (0 and π modes) have a field in the coupling cell and can be damped rather easily by a coupler attached to the coupling cell.

One-fifth aluminum model of ARES was constructed and its Q-value and frequency shift caused by a 6 mm diameter bead were measured. The Q-value was 3.27×10^4, which corresponds to 1.57×10^5 for a full-scale Cu cavity; this value is 87% of the calculation by MAFIA. The frequency shift was 1/13.5 of that of the case of the accelerating cell alone. This shows that ARES works as a system and can reduce the necessary detuning.

In order to suppress HOMs, a choke-mode cavity[12] is used as the accelerating cell. Figure 4 shows a cross-sectional view of the choke-mode type accelerating cell. The choke reflects back the fundamental mode only and HOMs propagate out and are absorbed by the SiC absorbers.

R/Q of the ARES is 13.6 Ω and the amount of of the cavity detuning is of the order of 10 kHz for LER. This detuning is small compared to the revolution frequency of the ring and the growth rate of the coupled-bunch instability due to the fundamental mode is about 50 msec.

C. Superconducting RF Cavity

The superconducting cavity for KEKB is a single-cell cavity with two large-aperture beam pipes attached to the cell. HOMs propagate toward the beam pipes, since their frequencies are above the cut-off frequencies of the beam pipes. The diameter of the one pipe is made larger than that of the other in order to make a few transverse modes otherwise trapped propagate. The iris between the cell and the larger beam pipe prevents the fundamental mode from propagating toward the beam pipe.

After having determined the optimized shape of the cavity by computer calculation, a full-size aluminum model was manufactured and resonance spectra of the cavity were measured with and without ferrite absorbers. The loaded Q values of HOMs were ~ 100 or less with absorbers, except two harmless quadrupole modes, TM210 and TE211.

A full-size Nb model with this optimized shape was constructed and tested in a vertical cryostat. The maximum accelerating field obtained was 11.7 MV/m with a Q value of 8×10^8.

Bonding ferrite on inner surface of a Cu beam pipe by HIP (hot isostatic press) has been tried: by HIP the powder of ferrite is sintered and bonded simultaneously on the Cu surface under high temperature and high pressure. A reduced-scale model (15 cm long and 10 cm in diameter) was successfully made and S-band RF power was applied. 2.6 kW of RF power was absorbed by the ferrite and the maximum power density amounted to 10.7 W/cm^2. No crack was found. Full-scale model production is under way.

D. Bunch-by-Bunch Feedback System

Feedback systems that can damp the coupled-bunch oscillations of the beam with a bunch spacing of 2 ns are being developed[13]. Since the number of bunch is large (5000) and the bunch spacing is short (2 ns) at KEKB, the signal processing part of the system needs a lot of R&D. We are trying to develop a 2-tap FIR digital filter system as a kernel of the signal processing unit. The 2-tap FIR filter of the peak-gain mode does not require any multiplication but a substraction of two signals half oscillation period apart from each other. This kind of filter can be composed of memory chips and simple CMOS logic ICs[14]. By using a 500 MHz ADC and a DAC, making a custom-made GaAs 1:16 500-MHz demultiplexer and a 16:1 500-MHz multiplexer, and by having 16 parallel 2-tap FIR logics, we can construct a signal processing unit on a single board. Development of prototype unit is under way.

IV. MACHINE STUDY

A. Beam Test of RF Cavities and Feedback Systems at the TRISTAN AR

Three-month long beam test is planned to be held in 1996 by the use of TRISTAN Accumulation Ring (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 will be installed. The transverse and longitudinal feedback systems will be also installed.

B. Dynamic Aperture Study

Since the non-interleaved sextupole scheme has never been adopted in real machines, we must be very careful introducing this scheme. In autumn of 1993 a machine study of one month was done by the use of TRISTAN MR in order to check the viability of the scheme. The result is reported elsewhere[15].

V. REFERENCES

1. B-Physics Task Force, Accelerator Design of the KEK B-Factory, KEK Report 90-24 (1991).
2. S. Kurokawa, Proceedings of 1993 Particle Accelerator Conference, p.2004.
3. K. Oide and K. Yokoya, Phys. Rev. A40, p.315 (1989).
4. K. Akai et al., Proceedings of B Factories, the State of the Art in Accelerators, Detectors and Physics, SLAC-400, p.181 (1992).
5. H. Koiso, ibid. p.86.
6. N. Akasaka, et al., in these Proceedings.
7. T. Kageyama, et al., in these Proceedings.
8. K. Akai, et al., in these Proceedings.
9. T. Shintake, KEK Preprint 92-191 (1993).
10. Y. Yamazaki et al., Particle Accelerators, 44 p.107 (1994).
11. K. Akai et al., KEK Preprint 93-167.
12. T. Shintake, Jpn. J. Appl. Phys. 31 p.1567 (1992).
13. E. Kikutani, et al., in these Proceedings.
14. F. Pedersen, private communication.
15. Y. Funakoshi, et al., in these Proceedings.